Book of Proceedings

February 16-18, 2022

Abstracts, Papers and Proceedings - The 51st Annual Meeting of the Southeast Decision Sciences Institute 2022 Jacksonville, FL.

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Student Papers (Undergraduate, Master and Ph.D. Students)

Elizabeth Rasnick.....Georgia Southern University

Sustainability, SCM, Quality Management, Logistics, Hospitality, Recreation and Sports

Hadi Farhangi.....Savannah State University

Suman Niranjan.....University of North Texas

Best Undergraduate Paper Award

Qualitative Benefits of Language Capable Individuals

Hunter Cushing
College of Business, Anderson University
316 Boulevard, Anderson, SC 29621
Email: hcushing104@andersonuniversity.edu

Best Graduate Student (Doctorial – Level) Paper Award

Analysis of Legalized Sports Gambling in the U.S.

Ryan Hartquist, Andrew Kuchel, Jeffrey Bridges, Michael Alberts
Oklahoma State University

Best Undergraduate Student Paper Presentation

Impact of COVID-19 on Supply Chain Internships

Hannah Cunningham
Anderson University

Best Doctoral - Student Paper Presentation

The Relationship between Environmental Performance of Firms and Profitability: Exploring the Effect of Operational Productivity

Senali Amarasuriya
Georgia Southern University

An Integrative Framework of Antecedents and Consequences of Transactive Memory Systems

Irita Mishra
Georgia Southern University

Best Paper Award

Employment and Prescription Drug Utilization in the U.S.

Xiaohui You
College of Health and Applied Sciences, Metropolitan State University of Denver
890 Auraria Pkwy, Denver, CO 80204
Email: xyou@msudenver.edu

Cyril Chang
Fogelman College of Business and Economics, The University of Memphis
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Table of Contents

Analytics, Big Data Applications, Business Intelligence, Data Mining, Statistics and Expert Systems - Abstracts

Analytics, Big Data Applications, Business Intelligence, Data Mining, Statistics and Expert Systems - Papers

Data Analytics and Statistics Instruction (DASI) - Abstracts

Healthcare, Public Sector and Not for Profit Management - Abstracts

Healthcare, Public Sector and Not for Profit Management - Papers

IS, IT, Blockchain Technology and Social Media - Abstracts

IS, IT, Blockchain Technology and Social Media - Papers

Information Privacy, Security and System Resilience, Business Ethics, Business Law - Abstracts

Information Privacy, Security and System Resilience, Business Ethics, Business Law - Papers

Innovative Education, Assessment, Engaged Learning Curriculum, Teaching and Pedagogy - Abstracts

Innovative Education, Assessment, Engaged Learning Curriculum, Teaching and Pedagogy - Papers

Management, Marketing, Accounting, Economics and Finance, Strategy, Organizational Behavior Organizational Theory, Human Resource Management, Consumer Behavior, International Business - Abstracts

Management, Marketing, Accounting, Economics and Finance, Strategy, Organizational Behavior Organizational Theory, Human Resource Management, Consumer Behavior, International Business - Papers

Online Education, Online Teaching and Online Assessment - Abstracts

Production and Service Operations Management - Abstracts

Production and Service Operations Management - Papers

Special Topic on Research and Teaching related to COVID-19 - Abstract

Special Topic on Research and Teaching related to COVID-19 - Papers

Student Papers (Undergraduate, Master and Ph.D Students) - Abstracts

Student Papers (Undergraduate, Master and Ph.D Students) - Papers

Sustainability, SCM, Quality Management, Logistics, Hospitality, Recreation and Sports - Abstracts

Sustainability, SCM, Quality Management, Logistics, Hospitality, Recreation and Sports - Papers

Scholarly Journal Editors' Panel - Abstracts

Deans' Panel - Abstracts

Analytics, Big Data Applications, Business Intelligence, Data Mining, Statistics and Expert Systems - Abstracts

A Comparison of Machine Learning Models to Predict Customers' Cross-buying Decisions

Oral Presentation

Dr. Mehmet Kilinc [1], ***Mr. Robert Rohrhirsch*** [1]

1. *Le Moyne College*

Cross-buying, which refers to the purchase of additional products or services from the same firm, provides higher customer lifetime value. Predicting a customer's cross-buying decision correctly helps companies to identify and target the right customers for marketing efforts. In this study, we compare different machine learning algorithms to predict existing customers' cross-buying decisions in the financial industry (i.e., opening a checking account). Our dataset includes 100,000 customers and their demographics, transactions, payments, and the bank's marketing efforts. We handle the imbalanced classes and the missing values in the data pre-processing phase. Then, we perform hyper-parameter optimization with cross-validation in the training phase and evaluate the models with different performance metrics.

A DATA ENVELOPMENT ANALYSIS FOR PERFORMANCE EVALUATION OF COMMUNITY BANKS

Oral Presentation

Dr. Jun Huang [1]***, Dr. Wei Wang*** [2]***, Dr. Haibo Wang*** [3]

1. *Angelo State University,* ***2.*** *Chang'an University,* ***3.*** *Texas A&M International University*

Data Envelopment Analysis (DEA) is an analytical method for evaluating relative efficiency within a group of homogeneous decision-making units (DMS). This paper concerns with the operational efficiency and productivity of community banks in USA. After analyzing the characteristics of community banks, we present a slacks-based measure (SBM) model for DEA to analyze 3171 community banks. The model uses an additive structure with inputs, outputs, and links to reveal a comprehensive structural measure of bank development. There are undesirable inputs and outputs as well as desirable inputs and outputs with links connecting between inputs and outputs. Indicators in different dimensions are allocated across this system after being assigned to either inputs or outputs in the structure. Besides comparing the differences between community banks and non-community banks, we also investigate the black box of relative efficiency. We assess the internal effects such as bank size and business lines on the relative efficiency of community banks. Using the Census regions and divisions data, we assess the external effects of geographic regions at county level including unemployment, household income and house market value. The result shows that there are significant effects of these internal and external factors on community bank efficiency. This article sheds new light on the exploration of models attempting to integrate a clear structure into the bank development process to reflect the internal and external interactions among the different stages of operation.

A NETWORK SCIENCE APPROACH FOR STOCK PERFORMANCE

Oral Presentation

Dr. Elie Alhajjar [1], ***Mr. Oscar Morales*** [1]

1. *United States Military Academy*

Stock markets generate huge amounts of data, which can be used to construct the network reflecting the market's behavior. The dynamics of the stock market are of great importance to research from different fields of study. In this paper, we apply network science techniques to the stock market to find insights about a stock's performance. Based on data of stocks over one year captured as daily time series, combined with network centrality measures, our analysis reveals a correlation between the position of a stock in the network and its performance over a period of time.

AN INTEGRATED RECOMMENDER MODEL: RECOMMENDING FUNDRAISERS TO DONORS IN ONLINE DONATION-BASED CROWDFUNDING

Oral Presentation

Ms. Mingyan Xu [1], ***Dr. Yuanfeng Cai*** [1]

1. *Baruch College, CUNY*

Donation-based online crowdfunding success has attracted extensive research attentions given its societal importance. In each donation-based crowdfunding platform, there is enormous number of fundraisers and donors. Intuitively, it is important for the fundraisers to understand how to get funded. But for each donor, it is also critical to know how to locate a fundraiser. However, limited research has been conducted to help donors locate fundraisers from a large number of candidates. In light of the recommender systems studies in e-commerce literature, this study aims to understand the recommendation feasibility for donors in donation-based online crowdfunding platform to cope with the information overload challenge in the digital context. In this research, we propose an integrated recommender model which focuses on the donation traces as well as the platform-accessible information. Although a few prior studies have adopted social information to assist in recommendation performance in online crowdfunding context, we are novel in measuring the participants' similarity from the platform-based homophily features rather than relying on any third-party social login information. We aim to effectively recommend fundraisers to donors so as to increase the fundraising success in donation-based crowdfunding platforms.

AUTOMATED FRAUD DETECTION OF ONLINE TRANSACTIONS USING MACHINE LEARNING

Oral Presentation

Dr. Bahram Alidaee [1], ***Dr. Haibo Wang*** [2], ***Dr. Wendy Wang*** [3], ***Dr. Yi Liu*** [4]

1. *University of Mississippi,* ***2.*** *Texas A&M,* ***3.*** *Trident University International,* ***4.*** *University of Massachusetts, Dartmouth*

E-commerce requires credit card companies to detect fraudulent online transactions in real time. However, most spurious activities are uncovered afterwards. Such delay occurs since the existing fraud detection methods mostly rely on static data instead of real time data, so the prediction models that these methods based on can only analyze data after transactions are complete. The existing systems encounter highly unbalanced data because most transactions in real life are authentic, and the fraudulent ones are rare. With each attribute of fraudulent transactions often falling within the confidence interval of normal distribution, the fraudulent transactions (anomaly data point) are difficult to detect. This study proposes a new data structure and solution framework to address such detection delay - using quantum annealing solvers to identify online fraudulent transactions. The integration of quantum computing capabilities and machine learning on data analytics will assist credit card companies to achieve the much-desired real time fraud detection. The two key components in our study are data processing and solution framework using machine learning methods such as SVM. The results of applying this novel approach, along with the benchmarking of using a traditional approach on very large online transaction data are reported in this study.

BIG DATA & BUSINESS ANALYTICS-ENABLED DYNAMIC CAPABILITIES TO LEVERAGE INNOVATION: AN EMPIRICAL STUDY OF DEVELOPING AND VALIDATING SCALE MEASURE

Oral Presentation

Dr. Adilson Yoshikuni [1], ***Dr. Rajeev Dwivedi*** [2]

1. *Mackenzie Presbyterian University,* ***2.*** *Eastern Washington University*

This study shows a scale developed and validated based on the Dynamic Capabilities Theory (DCT) of the organization which emphasizes a firm's ability to sense, seize and transform capabilities to leverage innovation to attend business environmental challenges enabled by big data and business analytics (BDA). The BDA-enabled dynamic capabilities are defined as second-order ordinary capabilities combined with IT resources and strategic management practices, to leverage innovation. The statistic test of convergent and divergent validity through PLS-SEM was realized at 191 U.S. firms with 12 attributes related to sensing, seizing, and transforming dimensions. The findings demonstrated that BDA-enabled dynamic capabilities can be a viable alternative to measure the IT-business value to leverage innovation, contributing to filling novel knowledge of IS and strategic management literature.

Binary Programming for Student Semester Scheduling

Oral Presentation

Dr. Hadi Farhangi [1]

1. *Savannah State University*

Program map is a semester-by-semester coursework of students and this work evaluates the program map of the Global Logistics program at Savannah State University. Furthermore, it schedules the semesters of students in the program. Accounting for restrictions such as prerequisites, semester offering, maximum number of courses per semester, etc., a binary programming model is developed to evaluate the program map and schedule students' semesters. The model can also be used for advising, in which, the rest of students' semesters will be planned given the courses they already passed. The analysis of solving the resulting model shows that it can evaluate the program map and successfully schedule the students' semesters.

Class Imbalance with CKD data

Oral Presentation

Mr. Rashawn Edwards [1], ***Dr. Kaye McKinzie*** [1], ***Dr. Mike Ellis*** [1]

1. *University of Central Arkansas*

Data sets used for binary classification are often imbalanced with respect to the classes to be predicted. This is a concern when working with medical data since most serious conditions occur in a small portion of the population. If care is not taken, the majority class, which dominates the data, can overwhelm the less frequently occurring minority class in the resulting model. For example, a model that always predicts “no condition” leads to a prediction accuracy of over 99% when the minority class represents less than 1% of the data. While 99% accuracy seems impressive, it is a model that is a dismal failure since the goal of the model is to classify the minority class successfully. One such medical data set where we see these imbalance issues deal with chronic kidney disease (CKD). This study applies four sampling methods to address the class imbalance issue while building a model to predict the minority class of patients with CKD. The sampling methods used are under-sampling, over-sampling, Synthetic Minority Oversampling Technique (SMOTE), and Adaptive Synthetic Sampling (ADASYN).

Under-sampling, a common method used for class imbalance, involves the reduction of the majority class to the same amount of data as the minority class. However, one concern with under-sampling is that the method is data inefficient since it may delete data containing class boundary information. Over-sampling is another method commonly used with imbalanced datasets to avoid the loss of important data. With over-sampling, the minority class will be copied until its size is more in line with that of the majority class. A potential issue with over-sampling is that it may result in a predictive model that overfits the minority class since the same data points will appear repeatedly. Rather than simply copying data, SMOTE generates new synthetic examples in the minority class that are similar to the existing data. The ADASYN technique also creates new synthetic examples but adds an adjustment for the homogeneity of the neighborhood surrounding existing minority data points.

The results obtained applying these four methods will be analyzed using descriptive statistics, scatterplots for the numerical variables, and bar plots for the categorical variables. The goal is to determine which method (or methods) better represent the data without introducing bias and maximizing the use of the data set.

Conjecturing for Discovery of Patterns for Multi-class Classification

Oral Presentation

Prof. Paul Brooks [1], ***Prof. David Edwards*** [1], ***Prof. Craig Larson*** [1], ***Dr. Nico Van Cleemput*** [2]

1. *Virginia Commonwealth University,* ***2.*** *Ghent University*

Modern machine learning methods are designed to exploit complex patterns in data regardless of their form, while not necessarily revealing them to the investigator. Here we demonstrate situations where modern machine learning methods are ill-equipped to reveal feature interaction effects and other nonlinear relationships. We propose the use of a conjecturing machine that generates and presents feature relationships in the form of bounds for numerical features and boolean expressions for nominal features. We discuss how the method can be adapted for use in a multi-class classification setting.

Development of a Regular Expression Method to Facilitate Reading of Financial Disclosures during the COVID-19 Pandemic

Oral Presentation

Dr. Kevin Pan [1], ***Mr. John Brody Cantrell*** [1], ***Mr. Eli Breece*** [1]

1. *Samford University*

Public companies in the United States companies can file voluntary financial disclosures throughout the year. There can be many financial disclosures in a short period of time, such as during the onset of the COVID-19 pandemic, and it can take many hours for humans to read the disclosures accurately. In this study, we develop a computer program using a regular expression method to facilitate the reading of financial disclosures more automatically. Specifically, the program identifies financial filings that disclose stock dividend suspension. Measured against human readings of 1,414 financial disclosures, we found that the program can achieve accuracy of 98.4%, with a tremendous time saving: the deciphering of these 1,1414 disclosures takes human reading more than 100 hours while takes the program only about 10 minutes.

DISPARITY OF WORK-LIFE BALANCE AND COMPENSATION SATISFACTION AMONG DIFFERENT GENERATIONS AND GENDER

Oral Presentation

Ms. Seungyeon Lee [1]***, Dr. Sameh Shamroukh*** [1]

1. *Harrisburg University*

This paper explores the differences in the work-life balance and compensation satisfaction levels of millennial men and women and compares those levels to prior generations (Baby Boomers and Generation X). In order to conduct this analysis, two K-mode clusters were created to predict the overall satisfaction levels of employees with regards to compensation and work-life balance at the point of resignation. Additionally, four ordinal logistic regression models were run in order to evaluation this paper's hypotheses. All four ordinal regression models showed significant evidence to reject the null hypotheses that gender and generation had no impact on income or work-life balance satisfaction. The data showed that age and gender are correlated with compensation and work-life balance satisfaction. The research question was whether there were shifting attitudes in work-life balance and income satisfaction for men and women over time, which the data suggests can be answered affirmatively. The data suggests that the disparities in compensation satisfaction between men and women in the workforce is shrinking while the gap in work-life satisfaction is increasing. It also suggests that the shifting make-up of the workforce may drive changes in compensation/work-life balance structure as employers compete to match the changing needs of their employees.

DOES MATCH MATTER? THE DYNAMICS OF LEAD DONOR MATCH OFFER EFFECTS ON DONATION-BASED CROWDFUNDING SUCCESS

Oral Presentation

Ms. Mingyan Xu [1], ***Dr. Yuanfeng Cai*** [1]

1. *Baruch College, CUNY*

Online crowdfunding serves as an effective avenue for the fundraisers to raise money from the crowds. Match offer is a conditional commitment made by lead donors to match the contributions of individuals in online crowdfunding platforms. While a few prior studies suggest that match offer may contribute to the matched project's success given signaling effect argument, the understanding to match offer effects is still far from certain. Firstly, diffusion of responsibility literature suggests that the existence of match offer can generate bystander effect on the individual donor's donation decision thus impede the matched project's fundraising success. Secondly, the effects of varied match offer schemes, like real-time conditional match and top-up challenge match, are unclear. Further, it is also intriguing to answer when match offer would kick in to affect the crowdfunding performance. To understand the effects of match offer both in individual and project perspectives, this study empirically examines a donation-based online crowdfunding platform. We find 1). donors own match experiences matter in their following donation decisions. 2). the varied match offer schemes do affect the individual donations and the fundraising outcome differently. 3). the effects of match offer on the project fundraising performance vary across the project's life cycle.

Examining Topics in Business Analytics Teaching Journals 2003-2020

Oral Presentation

Dr. Kellie Keeling [1]

1. *University of Denver*

Text Analytics allows researchers to gain insight and understanding about unstructured data in documents. In this paper I am examining the years 2003 to 2020 to explore the titles, keywords, and abstracts for the *Decision Sciences Journal of Innovative Education*, the *Journal of Statistics Education* (currently *Journal of Statistics and Data Science Education*), *INFORMS Transactions on Education*, and *Teaching Statistics*. The goal is to determine the topics that have been reported on over the past 18 years in the statistics and business analytics education literature. In particular, I am examining the words and phrases that appear most often. In addition, I am breaking down the articles over time into 6-year time periods to focus on the changes over time. Finally, topic modeling will be used to explore over-arching themes in order to place articles into an educational research taxonomy.

FEDERATED DEEP LEARNING FOR HETEROGENEOUS MOBILE ROBOTS

Oral Presentation

Mr. Khandaker Mamun Ahmed [1]***, Mr. Ahmed Imteaj*** [1]***, Dr. M. Hadi Amini*** [1]

1. *Florida International University*

Data privacy assurance is essential due to the massive amount of data collection, rapid training, and scaling the learning process in heterogeneous data distributions that guide
towards more robust and generalizable machine learning (ML) systems. Traditional deep learning models do not work in different data distributions. Moreover, data is being collected beforehand, which hampers data privacy, especially, when the data is sensitive. Differing from traditional deep learning, federated deep learning (FDL) enables participants to train a model locally and share the training results subsequently, and thus, ensures efficiency and security. In FDL, participants are considered to have similar computing resources and a subset of clients are selected at each training round which is unrealistic as clients are heterogeneous. For a given task clients with sufficient computing resources take significantly less computation time comparing clients with low computational resources. Motivated by this observation, we propose an FDL model that considers distributed clients' resource heterogeneity, where the clients are mobile robots. In this study, we train multiple global models where each of the models is trained on a different cluster of mobile robots. We demonstrate the effectiveness of our proposed model in terms of model accuracy and model convergence time.

How does market respond to latent investor sentiment jumps? A reinforcement learning with a Hawkes cross-excitation modeling approach

Oral Presentation

Prof. Steve Yang [1], ***Dr. Yangyang Yu*** [2]

1. *Stevens Institute of Technology,* ***2.*** *Stevens Institute of Technolo*

News sentiment is different from the true investor sentiment, and there is a conductive process of information flow from news sentiment to the latent investor sentiment and vise versa. The aim of this study is to develop a methodology to estimate the latent effect between the investor sentiment jumps and the market return jumps using a multivariate Hawkes process along with a deep reinforcement learning algorithm. We achieve this goal through a three-step process: (i)identify the baseline intensity among the events of news sentiment and market return by a multivariate Hawkes process; (ii) estimate the hidden effect that drives the movement of events of news sentiment and market return from the baseline intensity via deep reinforcement learning; (iii) reveal the interaction mechanism among the true investor sentiment and the market return that is responsible to the latent investor sentiment. This approach can be broadly applied to analyzing many phenomena in finance and economics where latent events are non-stationary and can not be observed directly.

Impacts of Tax Regulation Compliance for Virtual Products

Oral Presentation

Mr. Jonah Ji [1], ***Ms. Hannah Ji*** [2], ***Dr. June Wei*** [1]

1. *University of West Florida,* ***2.*** *Cornell University*

This paper first develops a conceptual model to investigate the impacts of tax regulation compliance for virtual products from the customers' point of views. Then, a set of propositions are developed by deriving the impacts and relationships from this conceptual model. A survey is adopted to collect data for further statistical data analysis. Finally, the theoretical, managerial and practical implications are also presented.

INTEGRATING SUPER EFFICIENCY AND CROSS EFFICIENCY DEA METHODS FOR RANKING EFFICIENT DECISION-MAKING UNITS

Oral Presentation

Prof. Hong Jae-Dong [1]***, Dr. Jeong Kiyoung*** [2]

1. *South Carolina State University,* ***2.*** *University of Houston Clear Lake*

Data envelopment analysis (DEA) method was developed to effectively identify the frontier decision-making units (DMUs). But the conventional DEA (C-DEA) shows several intrinsic weaknesses. To overcome these weaknesses, several methods extending the C-DEA are proposed. Among them, the cross-evaluation DEA (CE-DEA) and super-efficiency DEA (SE-DEA) are considered good alternatives to the C-DEA. Each of these two methods also reveals its own weaknesses, so a few methods based on the CE-DEA are proposed to complement the shortcomings of these two methods. This paper integrates these two methods to improve ranking efficient DMUs beyond the original methods.

L1-norm Matrix Completion in Recommendation Systems

Oral Presentation

Prof. Paul Brooks [1], ***Ms. Fatemeh Valizadeh Gamchi*** [2]

1. *Virginia Commonwealth University,* ***2.*** *Virginia*

Today, customers are confronted with several overwhelming choices as a result of the vast amount of information available on the internet. Recommendation Systems (RS) can help with the information overload problem by proposing new, not-yet-experienced options to users based on user-specific activities. The goal of a recommender system is to provide users with appropriate options to choose from. Collaborative filtering is one approach for RS. Matrix completion is a technique for collaborative filtering that produces latent factors. User-item interactions are recorded as inner products in matrix completion models. In order to breakdown the interaction between the item and the user into a lower-dimensional space, one can fit a subspace similar to principal component analysis (PCA) so that the variance-covariance structure of the existing ratings is captured. We propose a new method for RS using subspaces that are fit based on the L1 norm in an effort to increase outlier insensitivity. We will present results on examples with outliers.

Method Developments to Identify Digital Resources Clusters in a Software Ecosystem

Oral Presentation

Dr. Martin Kang [1], ***Dr. Gary Templeton*** [2], ***Dr. Ted Lee*** [3], ***Dr. Andrew Miller*** [4]

1. *Mississippi State University,* ***2.*** *West Virginia University,* ***3.*** *University of Memphis,* ***4.*** *Fort Lewis College*

A popular form of software development is the use of digital resources (e.g., API and SDK) that are co-created and shared by software developers in software ecosystems. In doing so, digital resources, software development projects, and software organizations are closely or loosely networked together and form digital resource clusters (DRC). Management science research has focused on how business organizations can use DRC to innovate their software products and services. However, the existing research in management science is methodologically limited to identifying DRC because of spatiotemporal complexities of a network structure of a software ecosystem which are attributed to transitively, heterogeneously, and temporally networked digital resources, software development projects, and software organizations. In this research, we devise a method framework that comprises two methods to identify DRC using machine learning approaches. Specifically, we devise a spatiotemporal network embedding method that produces a node feature matrix that can represent temporal, transitive, and heterogeneous networks of software ecosystems. Then, we devise a spatiotemporal clustering method that identifies DRC based on the node feature matrix from our devised spatiotemporal network embedding method. We conduct empirical experiments to test the performance of our devised methods to identify DRC. The experiments show that our devised methods are superior to the conventional methods to identify DRC.

Modeling Climate Change Through DNN and LSTM

Oral

Mr. Ray Jennings [1]***, Ms. Kaleemunnisa Lnu*** [1]

1. *Pace University*

Reputable data sources have shown that multiple factors are increasing both the air and the ocean temperatures which are contributing to significant climate change. Many of these factors are attributed to population- specifically overall population size, urban population size, educational level, life expectancy, poverty rate and population density. Additional attributes for which there are data include land usage types such as agriculture, farming, and forestry as well as energy consumption of both renewable and non-renewable sources. Furthermore, greenhouse gas emissions, which may contain CO2, methane, and nitrous oxide are also contributing factors. These factors are all believed to play a significant role in climate change. Through this analysis, we demonstrate how all these attributes have direct correlation to the increase in the global
temperature which is a primary contributing factor to climate change. The data sources are Our World In Data (https://ourworldindata.org) and The World Bank Group (https://www.worldbank.org). The datasets are labeled by year, attribute, and country. Deep Neural Network (DNN) and Long Short-Term Memory Network (LSTM) models were built using Tensorflow and Keras to model the dataset features.

Multi-Period Set Covering Problems, Application, and Solution

Oral Presentation

Dr. Hadi Farhangi [1]

1. *Savannah State University*

Set covering problem is one of core combinatorial optimization problems with a variety of applications in Operations Research such as scheduling, planning, and systems design. This problem selects sets to cover the entire elements of a universal set. This paper extends the set covering problem to multiple periods of planning. It is shown that the extensions are not unique and several models are explored mathematically. One application for these extensions in systems design is discussed. To gain insight on the complexity of extensions and solution times, Cplex solver is utilized to solve one of the resulting multiple periods set covering problems.

On the nature of complexity in supply chain network structure: A longitudinal study

Oral Presentation

Dr. Natalie Simpson [1], ***Dr. James Minas*** [2]

1. *University at Buffalo,* ***2.*** *St. John's University*

While few would disagree that modern supply chains are complex networks, there is surprisingly little consensus on how network complexity should be measured. In this study, we identify competing definitions of complexity from the network science literature, to create a suite of measures to evaluate twenty years of time series data. This data set describes the major supply chain relationships of 34 global brands, as annual networks which ultimately connect 2,376 additional firms through major supply relationships. The purpose of the study is two-fold: first, to observe which definitions of network complexity appear most relevant to the context of authentic supply chain structures; second, to detect what structural conditions have changed among these supply chains in recent years. Surprises include the fact that these 34 different supply networks have long been connected through co-dependencies, forming one large network throughout the two decades of data. Some popular complexity measures such as entropy appear to communicate little about the sample under study, while those based on network evolution (churn) indicate a lessening of complexity over time. In contrast, measures such as those expressing connectivity within the sample increase throughout the same time period. We argue the connectivity measures, which capture direct and indirect co-dependency and exposure between firms, are among the most salient to managing supply chain risk.

PRIVACY-ENHANCED FORECASTING OF BEHIND-THE-METER SOLAR PVS USING FEDERATED LEARNING

Oral Presentation

Mr. Saman Taheri [1], ***Dr. Ali Razban*** [1]

1. *Indiana University Purdue University at Indianapolis*

With the widespread use of distributed renewable energy sources (DRESs) in modern energy systems, accurate estimation of aggregated DRESs is of great importance to keep the grid stability. Currently, the majority of distributed photovoltaic (PV) systems are located behind-the-meter (BTM), rendering them undetectable to utilities. To obtain an accurate aggregated BTM PV electricity forecast, prediction models need a vast number of data from small sites. However, collecting and accessing the data of all on-site PVs scattered in different places is very difficult, if not impossible, due to data security and privacy concerns, availability of measurement devices, and time-consuming administrative processes. This paper introduces federated learning (FL)-based PV energy forecasting as an unique decentralized collaborative modeling technique capable of training a super model on data from a large number of BTM sites. Specifically, a multi-layered perceptron (MLP) is designed as the BTM PV forecasting model without endangering the data's privacy or security. A comparison of the proposed private distributed model to non-private centralized and completely private localized models demonstrates that the proposed FL forecasting has a high degree of accuracy (18.17 % lower RMSE than localized and only 9.9 higher RMSE than centralized model).

Replacement Methodologies: Chronic Kidney Disease

Oral Presentation

Mr. Rashawn Edwards [1], ***Dr. Kaye McKinzie*** [1], ***Dr. Mike Ellis*** [1]

1. *University of Central Arkansas*

The continuing rise of chronic kidney disease (CKD) as a leading cause of death is a worldwide major public health concern. The diagnosis of CKD is given to individuals with abnormal kidney function and individual markers of kidney damage. But to be able to predict and model CKD, the data must be accurate and representative. Many studies delete rows of data containing missing values, thus significantly reducing the sample size and potentially biasing the data. This study uses Python to compare the MICE, KNN, and delete methods to assess which methods result in the least bias to the data.

STACKING ENSEMBLE WITH TRANSFORMER NETWORK AND TRANSFER LEARNING FOR STOCK VOLATILITY FORECASTING

Oral Presentation

Dr. Subhajit Chakrabarty [1], ***Mr. Prabhat Dhungana*** [1], ***Mr. Shiv Sarada*** [1]

1. *Louisiana State University Shreveport*

Transformers are currently the best performing models in natural language processing. They convert a given sequence to another sequence with attention layer (weighting according to a learned measure of relevancy). Transformers can perform well on time series, too. Our first objective was to improve volatility forecasting for S&P 500 and Russell 1000. Our second objective was to implement transfer learning. Previous work has performed ensemble techniques for volatility forecasting of some stock exchange indices; bagging has been performed for application of transformer network to stock volatility forecasting on S&P 500. Our hypothesis was that stacked generalization and boosting techniques will perform better on our data. We performed a comparative evaluation of bagging, boosting and stacking ensembles. Our ensembles included Decision Trees, Support Vector Machine, LSTM, Transformer and GARCH. We fit the models on data across 650 trading days for Russell 1000. We used Accuracy and Mean Absolute Error for our performance metrics. We performed transfer learning and fine-tuned for S&P 500. Results indicated that our ensemble models of stacked generalization outperformed baseline models. The study also suggests best practices for performing transfer learning in this domain.

STUDENT RETENTION IN INSTITUTIONS OF HIGHER LEARNING: A Case Study With Big Data

Oral Presentation

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1. *The university of Tennessee at Chattanooga*

STUDENT RETENTION IN INSTITUTIONS OF HIGHER LEARNING:
A Case Study With Big Data

Abstract

Many institutions of higher education are faced with the problem of student retention. Thus, it is imperative to determine the main factors that cause students to drop out or move to other universities. Some studies have suggested that student engagement in their first year of college is an important factor but have concluded that any additional research should go beyond how to keep students engaged. Other studies have suggested introducing factors or treatments that might affect the behavior of students and decrease attrition. Yet, there are others that believe that student retention is determined by creativity, emotional intelligence, and learner self-sufficiency.

Our study will evaluate demographics, student performances, as well as several other variables for the fall of 2011 through the fall of 2020 and will determine the factors that influenced retention. Furthermore, we intend to determine the effect of the pandemic on the learning environment of the institution. Data consisting of information on 209,463 students and 40,581courses for a period of 10 years were provided by the institutional research department of the University of Tennessee at Chattanooga.

The following charts show graphs of the several variables in our study.

Once we complete analyzing the data, we will be able to answer the following questions.

1. What are the major determinants of staying at the institution?
2. Explain the characteristics of those students who stay versus those that leave the institution.
3. Did the pandemic affect retention?
4. Does the institution need to change methods of delivery of instructions?

UNDERSTANDING HOW FOOD BANK OPERATIONS ARE IMPACTED DURING DISASTER (COVID-19 PANDEMIC)

Oral Presentation

Mr. Simachew Ashebir [1]***, Dr. Lauern Davis*** [2]***, Dr. Seong-Tae Kim*** [3]

1. *North Carolina A&T State University,* ***2.*** *North Carolina A & T State University,* ***3.*** *North Carolina A&T State Univ.*

Food insecurity is one of the world's significant issues, including the U.S. Millions of children and families living in America face hunger and food insecurity every day. North Carolina is the 10th hungriest State in the U.S. In North Carolina, more than 600, 000 households regularly suffer from insufficient food, and 1 in 5 children face hunger. The Government and many non-profit organizations are working to solve food insecurity problems. Food banks are non-profit hunger relief organizations that collect food and monetary donations from donors and distribute food to local agencies that serve people in need. Contributions come from local retail, food manufacturers, individuals, groups, federal, and Feeding America. The uncertainty of supply and demand is a significant challenge for food banks in fighting against food insecurity. This study investigates how external shocks such as government policy or pandemics impact food donation and distribution using the data obtained from the Food Bank of Central and Eastern North Carolina. Using Exploratory Data Analysis techniques, we show that from March 2020 to May 2020, most of the contribution comes from Government policies, but food banks' supply from donors decreases, whereas demand increases. We further investigate a relationship between food distribution and county-level demographic and socioeconomic factors. Our study is expected to help non-profit organizations exercise more effective and efficient operations.

Using AI on the Ontology for Intelligent Big Data Visualization: A Case Study on Crop Future Price Prediction

Oral Presentation

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1. *Department of Statistics & Actuarial Science, The University of Hong Kong,* ***2.*** *The School of Molecular and Cellular Biology, The University of Illinois, Urbana-Champaign,* ***3.*** *Department of Statistics and Actuarial Science, The University of Hong Kong,* ***4.*** *Data Science Lab, Department of Statistics & Actuarial Science, The University of Hong Kong,* ***5.*** *ImpactInvest Limited*

There are many financial predictive models with good performance for predicting the price trends. However, those models did not link the related information for explaining the data. Financial analysts require to search the related information to explain the predictions and market phenomenon. Therefore, the aim of this research is to propose an intelligent big data visualization tool to relate and visualize the related information. Since ontology defines the attributes of the objects and can set rules in the ontology to link the related information for reasoning, this research used a novel approach of applying AI to an ontology for relating the textual and numerical information to explain the relationships of the price trends and predictions. A dashboard including maps, bar charts, line charts, and news was designed. A case study on predicting crops future price was used to demonstrate the application of ontology onto the big data visualization tool for financial analysis and decision making. A review on how trading activities and weather influencing the crops future price was done. A prototype demo was implemented for illustrating how to relate the relevant information for intelligent visualization, and to support financial analysts in investment decision making.

Analytics, Big Data Applications, Business Intelligence, Data Mining, Statistics and Expert Systems - Papers

A NETWORK SCIENCE APPROACH FOR STOCK PERFORMANCE

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ABSTRACT

Stock markets generate huge amounts of data, which can be used to construct the network reflecting the market's behavior. The dynamics of the stock market are of great importance to research from different fields of study. In this paper, we apply network science techniques to the stock market to find insights about a stock's performance. Based on data of stocks over one year captured as daily time series, combined with network centrality measures, our analysis reveals a correlation between the position of a stock in the network and its performance over a period of time.

INTRODUCTION

Complex and large systems such as the internet, social connections, telephone networks, and international economies can be modeled by networks. The networks capable of describing these complicated systems are composed of two key elements: vertices and edges. Networks are built on top of one another. Consider social networks as a common example: they are built on information networks, which in turn are built on communications networks that operate using physical networks for connectivity. More broadly, they are interactive and mutually interdependent systems that together constitute a much larger system.

As the modeling of networks employs a variety of techniques and is used in a vast array of applications, network science is considered an interdisciplinary field that combines ideas from areas like mathematics, physics, biology, computer science, statistics, and social sciences to name a few. The field has benefited enormously from the wide range of viewpoints brought to it by practitioners from different disciplines, but it has also suffered from the dispersion of human knowledge about networks across the scientific community.

The modern economy is a complex system consisting of an enormous number of companies that interact with each other to achieve their own goals. Modeling the aggregate as well as the local behavior of such systems is an extremely important, albeit complex problem. One of the modern approaches to building models of economic or financial systems is graph models that are based on transforming empirical data into a network representation using additional reasonable assumptions. A financial market is a complex system composed of many interacting units. Network science can tackle the complexity of the systemic study of stock markets by predicting market dynamics. This is usually accomplished by identifying the key

players in the market: the importance of a player is not only determined by its association to a large number of players but also its association to highly connected players. Within this context, different types of networks can be constructed by giving different definitions to nodes and links.

The concept of the market graph was first examined in the paper [8] in which a market network is defined as a complete weighted graph where the nodes represent stocks and weights of edges reflect similarity between stocks behavior, i.e., correlation. An edge between two vertices is inserted in the market graph, if and only if the corresponding value of correlation coefficient is above a given threshold. Further properties of the market graph have been investigated such as maximum cliques, maximum independent sets, degree distribution, and clustering in Pearson correlation.

In this work, we study the performance of a stock using network science techniques. In particular, we focus on centrality measures and network characteristics. The current paper is organized as follows. After a brief introduction, we give an overview of the field of network science in section 2. Section 3 summarizes some of the related work previously done in the existing literature. Section 4 describes the methodology used to analyze the dataset and to calculate the centrality measures. We explain the intuition as well as the technical details of our chosen methods. In Section 5, we record the results and discuss our findings to highlight the level of impact a given stock ought to have. We conclude our work in Section 6 and pose some open questions and future research directions.

PREREQUISITES

In this section, we give a brief introduction to the field of network science as discussed in [2]. For more technical details, the reader is encouraged to consult [2] and the references therein.

The terms *graphs* and *networks* are used indistinctly in the literature. The only nuance is that the term graph usually refers to the abstract mathematical concept of nodes and edges, while the term network refers to real-world objects in which nodes represent entities of some system and edges represent the relationships between them. We adopt a natural framework for the rigorous mathematical description of networks, namely *graph theory*. Graph theory is a vast field of mathematics that can be traced back to the seminal work of Leonhard Euler in solving the Konigsberg bridges problem in 1736 [1]. We give some formal definitions below.

Let $V = \{v_1, v_2, \ldots, v_n\}$ be a finite set of elements and $V \times V$ the set of all ordered pairs $\{v_i,v_j\}$ of elements of V. A relation on the set V is any subset E of $V \times V$. A *simple graph* is a pair $G = (V, E)$, where V is a finite set of *nodes* (or *vertices*) and E is a relation on V such that $\{v_i,v_j\}$ is in E implies that $\{v_j,v_i\}$ is in E and $v_i \neq v_j$, that is G has no loops. The elements of E are called *edges* or *links*, we shall denote them as $E = \{e_1, e_2, \ldots, e_m\}$.

If an edge e joins two nodes v_i and v_j, then we say that v_i and v_j are *adjacent* and they are *incident* to e. The simplest characteristic of a node is its *degree*, which is defined as the number of nodes adjacent to it. The *adjacency matrix* $A = (a_{ij})$ of a graph G is an $n \times n$ array (n being the number of vertices) defined as: $a_{ij} = 1$, if $\{v_i,v_j\}$ is in E; and 0 otherwise. Note that for a simple

undirected graph, the adjacency matrix is symmetric and the entries on the main diagonal are all equal to zero.

In a graph G = (V, E), a *path* from a node v_i to a node v_j is a collection of ordered vertices $\{v_i, v_{i+1}, \ldots, v_{j-1}, v_j\}$ in V and a collection of ordered edges $\{(v_i,v_{i+1}), (v_{i+1},v_{i+2}), \ldots, (v_{j-1},v_j)\}$ in E. The *length* of a path is the number of edges traversed along the path. A *shortest path*, or a *geodesic path*, from node a v_i to a node v_j is a path of shortest length. A *cycle* is a closed path, i.e., a path in which $v_i = v_j$. We say that a graph is *connected* if there is a path between any pair of nodes in the graph. A *component* of a graph is a connected subgraph. A *tree* is a connected graph that has no cycles. One can easily derive that for a tree, there is a unique path between any two given nodes. Equivalently, the deletion of any edge breaks a tree into disconnected components. In the case there is a parent node, or *root*, from which the whole tree arises, then it is called a *rooted tree*. The nodes at the bottom that are connected to only one other node are called *leaves*.

The simplest characteristic of a node is its *degree*, which is defined as the number of nodes adjacent to it. For directed graphs, the distinction is made between the *in-degree* and the *out-degree* of a node. The former is the number of edges pointing in the direction of the node, while the latter is the number of edges going out of the node. The *average degree* of an undirected/directed graph is simply the arithmetic mean of the degrees of all nodes. The *clustering coefficient* of a node measures the likelihood that the adjacent vertices to this node are connected to each other.

Let G = (V, E) be an undirected graph. The *degree distribution* p_k is the probability that a randomly chosen node has degree k. Such a distribution plays an important role in the characterization of a network since it provides information about the connectivity and the topology of the underlying graph. Two network models are of great importance: random networks and scale-free networks. A random network is a network model in which the values of certain features are fixed, but the network is otherwise random. The degree distribution of a random network follows the Binomial distribution, which can be approximated by the Poisson distribution. On the other hand, a scale-free network is a network whose degree distribution follows a power law that can be determined via the normalization condition. The key difference between a random network and a scale-free network is rooted in the different shape of the Poisson and the power-law functions: in a random network most nodes have comparable degrees, and hence hubs are forbidden, while hubs are expected in scale-free networks. Moreover, the more nodes a scale-free network has, the larger are its hubs.

RELATED WORK

Stock markets generate huge amounts of data, which can be used for constructing the network reflecting the market's behavior. In [10], the authors use a threshold method to construct China’s stock correlation network and then study the network’s structural properties and topological stability. They conduct a statistical analysis of this network and show that it follows a power law model. They also detect components, cliques, and independent sets in this network,

which allows a new data mining technique of classifying financial instruments based on stock price data and provides a deeper insight into the internal structure of the stock market. Moreover, they test the topological stability of this network and find that it displays a topological robustness against random vertex failures, but it is also fragile to intentional attacks.

In the paper [7], Androsov et al. study a complex network formed as a directed graph in which nodes represent the companies traded on the NYSE or NASDAQ, while directed edges represent a connectedness measure between the financial assets, using the notion of conditional value at risk (CoVaR). The difference in CoVaR measures the relationship between any two assets and is based not only on the yields of the assets but considers the mutual effect of its performance. They examine the intrinsic properties and regularities of the stock market by analyzing the directed complex network with more than 3700 stocks as nodes which have been traded on the NYSE and NASDAQ in recent years. This analysis leads them to finding influential spreaders, i.e., companies which are more likely to spread negative shocks in a large part of the network.

The authors of the paper [9] use the concept of the market graph in parallel with constructing a company co-mention network in which any two companies are connected by an edge if a news item mentioning both companies has been published in a certain period of time. Topological changes of the networks over the period 2005-2010 are investigated using the sliding window of six-month duration. They use graph similarity metrics and QAP (Quadratic Assignment Procedure) to estimate how the networks evolve over time.

Finally, Memon et al. [11] consider the cross-correlation coefficients of daily stock returns belonging to the blue-chip Karachi stock exchange (KSE-100) index in an attempt to examine the interdependency and evolution of Pakistan's stock market. By examining the topological properties of the network and generating six minimum spanning trees around three general elections in Pakistan, their results reveal a star-like structure after the general elections of 2018 and before those in 2008, and a tree-like structure otherwise. The main takeaway is that a structural change in the stock market network took place due to general elections.

More generally, outside the scope of the stock market, applications of network science abound in the literature. More recently, the analysis of terrorist and criminal cells using network science techniques has garnered a lot of attention. Methods like centrality measures, network characteristics, and other indicators have been extensively used to better understand the operational nature of such networks (see [3,5,6] for example).

METHODOLOGY

Centrality is arguably the most popular operational concept used by social network analysts. Node centrality measures tell us how the nodes within a network are positioned. This section is divided into two parts: first, we give an overview of the main centrality measures used in the literature, then we elaborate on the data sets we employ for our validation process.

By definition, centrality aims to capture the notion of "importance" of a node in a network. There are plenty of centrality measures in the literature and efficient algorithms to compute them for large networks. Perhaps the most natural centrality measure for a node in a network is simply its degree or *degree centrality*, i.e., the number of nodes adjacent to it. Nodes with high degree centrality are those that attract a high concentration of direct connectivity within a network. It is a local indicator of a node's importance and does not take into consideration the global characteristics of the graph.

The *betweenness centrality* measures the extent to which a node lies on paths between other nodes. It introduces the concept that it is not the quantity but the quality of connections that matters more. Said differently, betweenness centrality measures the extent to which a node mediates relationships between other nodes by its position along paths within the network: the greater a node is located along the paths in the network, the higher its betweenness centrality is.

The *eigenvector centrality* measures the influence a node has in the network. It relies on the assumption that some nodes are central because they have a high degree of direct contacts and because these direct contacts are themselves in direct contact with high degree nodes in the same network. In other words, eigenvector centrality measures the extent to which a node is connected to other nodes that are high in degree centrality in the network.

We obtain our dataset as follows. First, we start by web scraping daily close prices for 3200 stocks during the period from March 2017 through March 2018. Then we collect the data in a DataFrame in the software Python, where the index is the date and each column contains the stock prices. In order to speed up computations, we convert this DataFrame into a numpy matrix which gives rise to a directed graph where each edge is the correlation coefficient between the two nodes. Finally, network measures for every node are computed and inserted into a new DataFrame where every row is a different stock and each respective column is a different characteristic of either the stock performance or measures of the node within the network.

RESULTS

Multiple graphs are created with different correlation thresholds ranging from 0.2 to 0.9: 0.2, 0.4, 0.7, and 0.9. In other words, the correlation threshold determines the minimum correlation between two stocks for the edge to be included in the network. For example, if stock A and stock B have a correlation of 0.5, but the correlation threshold is 0.7, then there would be no edge or connection between these two nodes in the graph. After the graphs are initiated, a logarithmic plot of the degree distribution is created to determine if the network is a scale-free network: a log-plot of a scale-free network is a negative linear line.

Based upon the 3200-node network, a correlation threshold above 0.9 yields a scale-free network. Networks with a threshold of 0.2 and 0.4 have no indication of being scale-free networks, as the plots have no semblance to the fitted power law line. A hint of such a property starts appearing at the 0.7 threshold, see Figures 1 and 2 below for illustration.

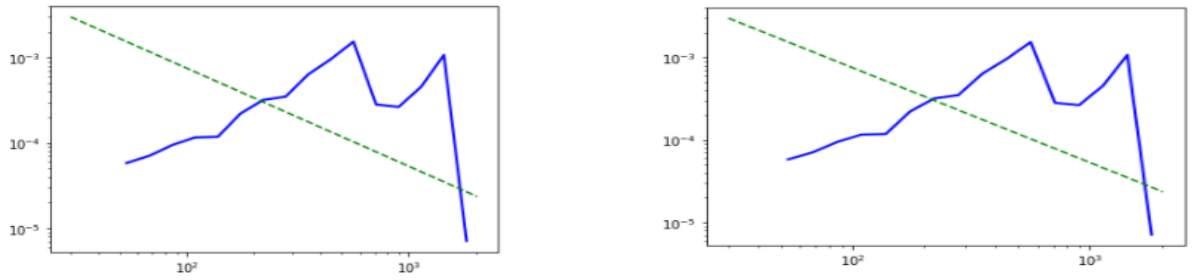

Figure 1: Networks with Correlation Thresholds 0.2 and 0.4

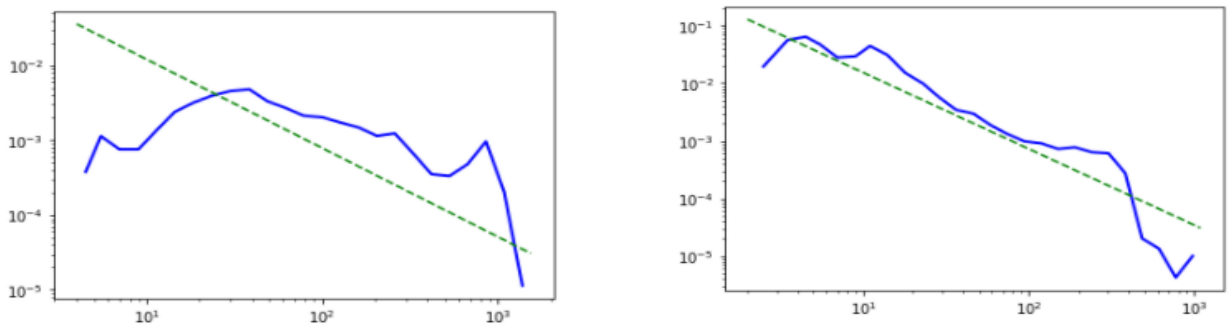

Figure 2: Networks with Correlation Thresholds 0.7 and 0.9

Figure 3: Return vs Betweenness Centrality Normalized Plot (Color = Degree).

Next, we focus on the network with threshold of 0.9, and compute some centrality measures on it while contrasting them with stock returns. Figure 3 shows a weak relationship

between stock returns and betweenness centrality, with a slight positive correlation. However, it is easily seen from Figure 4 the subtle positive correlation between stock returns and eigenvector centrality. This allows analysts to find stocks with negative returns, which the individual investor can avoid or short. Shorting a stock means betting the stock will go down by selling the stock at the current price and buying it back at a lower price. Moreover, the eigenvector centrality helps finding stocks that are yielding positive returns: this can be noted by the diminishing of negative returning stocks as you move right in the graph.

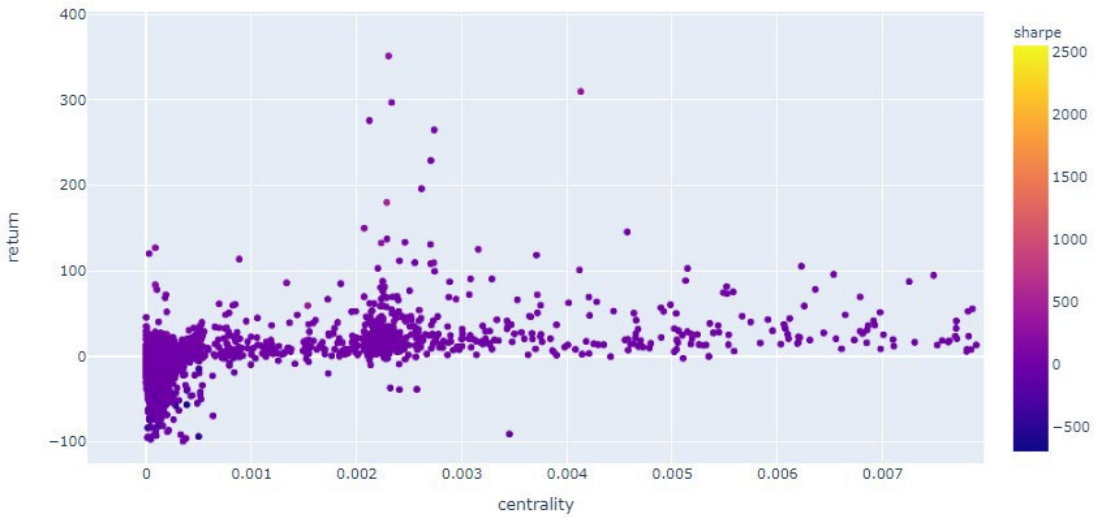

Figure 4: Return vs Eigenvector Centrality Normalized Plot (Color = Sharpe Ratio).

Additionally, we analyze the performance of a stock based on its risk adjusted returns. A stock's risk adjusted return or Sharpe Ratio considers a stock's return as well as the amount of risk taken to get that return. The general statement is that the more volatile a stock is, the riskier it is; the goal then becomes to maximize a portfolio's return in terms of risk. By examining Figure 4, one can tell that stocks with small eigenvector centrality values indicate negative returns, and as the eigenvector centrality increases the return increases as well up to a certain ceiling.

Finally, Figure 5 shows the degrees of the nodes in the network. A node's degree is simply the amount of links or connections it has with other nodes. There is no linear relationship here, but there are clear degree thresholds that are indicative of positive returns and negative returns. Stocks with degrees above 100 overwhelmingly showed positive returns. Stocks with degrees below 100 showed a much more varied distribution of returns, although a clear bias towards negative stock returns. This simply implies that stocks with low correlation to the overall market will move in a less predictable manner.

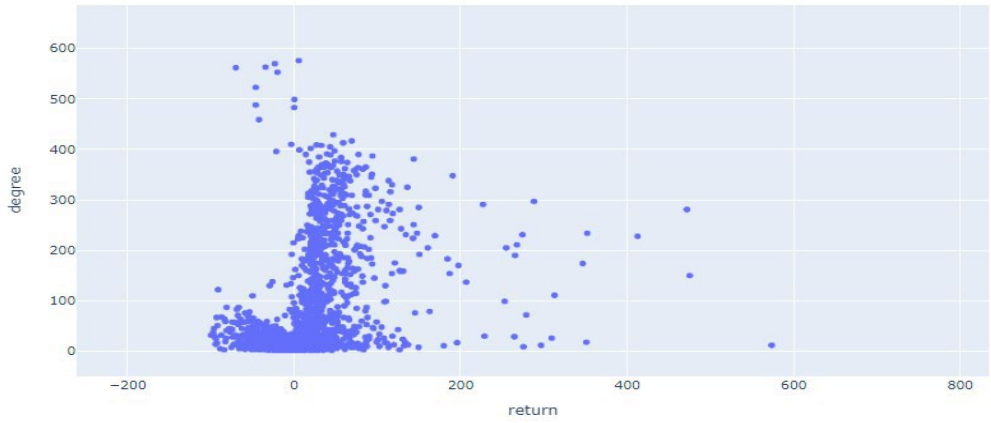

Figure 5: Degree vs Stock Return

CONCLUSION

Combining the research results of this paper, we conclude that a stock's return is linked to its location in the network. If a stock lies on outer edges, then it is more likely to perform well independently of the general economy and stock market. Investors looking for above average returns need to focus on stocks with low betweenness centrality. Stocks with low eigenvalue centrality values indicate that a stock is likely to have negative returns, while a higher such value indicates higher returns. This positive correlation to returns is true for both eigenvalue and betweenness centrality measures.

Possible future improvements or extensions of this research could be creating a cointegrating network as opposed to a correlation network. Cointegrating measures are much better indicators of a stock's relative movement than simple pairwise correlation. This could unlock new insights not possible with pairwise correlation. Another future direction is to investigate shorter time frames and see how the network changes over time, especially before and after major events such as elections or federal reserve announcements.

Lastly, hypernetwork science is an emerging field of research based on the study of hypergraphs to highlight the multi-way relationships involving interactions among more than two entities, dependencies between more than two variables, or properties of collections of more than two objects. Many recent papers have used techniques from this new field to study different topics (see [4] for example). Modeling the stock market as a hypergraph instead of a simple graph has the potential of depicting relationships between stocks characteristics that are not so clear using market graphs.

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REFERENCES

[1] Agnarsson, G., & Greenlaw, R. (2007). Graph Theory: Modeling, Applications, and Algorithms. *Upper Saddle River, NJ: Pearson Prentice Hall*.

[2] Alhajjar, E. (2022). Network Science. In Daniel Bennett, Paul Goethals and Natalie Scala (Ed.), *Mathematics in Cyber Research* (pp. XX-XX). Boca Raton, FL: CRC Press. To appear.

[3] Alhajjar, E., Fameli, R. & Warren, S. (2021). Are Terrorist Networks Just Glorified Criminal Cells? *Northeast Journal of Complex Systems*, 3(1): 1-16.

[4] Alhajjar, E. & Friar, R. (2022). A Historical Perspective On International Treaties Via Hypernetwork Science. *Proceedings of the International Conference on Network Science (NetSciX)*, Porto, Portugal.

[5] Alhajjar, E. & Morse, S. (2020). A Layered Network Collapse Method in Cyber Terrorism. *Proceedings of the 15th International Conference on Cyber Warfare and Security*, Norfolk, VA, pages 18-22, XII.

[6] Alhajjar, E., & Russell, T. (2019). A Case Study Of The Noordin Network. In *Proceedings of the International Conference on Social Computing, Behavioral-Cultural Modeling, & Prediction and Behavior Representation in Modeling and Simulation*.

[7] Androsov, I., Faizliev, A., Korotkovskaya, E., Lunkov, A., Mironov, S., Petrov, V., Sidorov, S. & Smolov, F. (2019). *Shock Diffusion Analysis for a Directed Market Network Constructed with Use of the Risk Measure CoVaR*. In Journal of Physics: Conference Series (Vol. 1334, No. 1, p. 012003). IOP Publishing.

[8] Boginsky, V., Butenko, S. & Pardalos, P. M. (2003). Innovations in Financial and economic networks. *Northampton: Edward Elgar Publishing Inc.* 29-45.

[9] Faizliev, A., Balash, V., Petrov, V., Grigoriev, A., Melnichuk, D., & Sidorov, S. (2019). *Stability analysis of company co-mention network and market graph over time using graph similarity measures*. Journal of Open Innovation: Technology, Market, and Complexity, 5(3), 55.

[10] Huang, W. Q., Zhuang, X. T., & Yao, S. (2009). *A network analysis of the Chinese stock market*. Physica A: Statistical Mechanics and its Applications, 388(14), 2956-2964.

[11] Memon, B. A., Yao, H., & Tahir, R. (2020). *General election effect on the network topology of Pakistan's stock market: network-based study of a political event*. Financial Innovation, 6(1), 1-14.

BIG DATA & BUSINESS ANALYTICS-ENABLED DYNAMIC CAPABILITIES TO LEVERAGE INNOVATION: AN EMPIRICAL STUDY OF DEVELOPING AND VALIDATING SCALE MEASURE

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ABSTRACT

This study shows a scale developed and validated based on the Dynamic Capabilities Theory (DCT) of the organization which emphasizes a firm's ability to sense, seize and transform capabilities to leverage innovation to attend business environmental challenges enabled by big data and business analytics (BDA). The BDA-enabled dynamic capabilities are defined as second-order ordinary capabilities combined with IT resources and strategic management practices, to leverage innovation. The statistic test of convergent and divergent validity through PLS-SEM was realized at 191 U.S. firms with 12 attributes related to sensing, seizing, and transforming dimensions. The findings demonstrated that BDA-enabled dynamic capabilities can be a viable alternative to measure the IT-business value to leverage innovation, contributing to filling novel knowledge of IS and strategic management literature.

Keywords: Big data, Business analytics, Construct development, Dynamic capabilities, Innovation.

1. INTRODUCTION

Previous studies have been investigating how information systems in terms of IT resources and capabilities influence proximate and distal outcomes through resource-based theory (RBT) [1]–[4]. These studies by RBT often develop IT capabilities as the set of IT assets that an organization has adopted under its control, and their mere existence will be associated to gain outcomes performances [5], [6].

There is a notion in the IS literature that these kinds of IT-business value studies of RBT had been moving from its inception to maturity [7], and growing research examining the organizational impact of IT capabilities on competitive advantage by dynamic capability theory (DCT) as extending of RBT [8]–[12]. The dynamic capabilities span a very broad and complex construct by first-order and second-order capabilities in the domains of managerial decision processes, to business processes, and competitive actions, as mentioned by Helfat and colleagues [13], [14] and Teece [15].

According to Li and Chan [7], zero-order capabilities are related to ordinary capabilities by the adoption of IT assets, and first-order dynamic capabilities represent routines and processes that extend, modify, or create enabled by IT ordinary capabilities. The previous studies demonstrated that first-order dynamic capabilities can be insufficient, and second-order dynamic capabilities are needed to support firms to adapt to novel situations [13], [16].

Therefore, there is limited IS studies examining the second-order dynamic capabilities enabled through information systems, even more, activating overall firm-wide sensing, seizing, and reconfiguring capabilities through big data & analytics [7], [17], [18]. Teece and colleagues [19, p. 18] define dynamic capabilities as the organization's capacity through "sensing, seizing and transforming to innovate, adapt to change, and create change that is favorable to customers and unfavorable to competitors".

Once based on the perspective of RBT studies can be restrictive to explanatory power related by how IT resources are harnessed as zero-order and first-order capabilities to leverage dynamic capabilities to competitive performance gains [20], [21]. Furthermore, there is little attention to how firms build their big data and business analytics capabilities, and this issue can be an important research question for future research [22]. Moreover, recent studies of dynamic capabilities [15] and dynamic IT capabilities [7] have mentioned that can be necessary to explore the relationship between IS application and higher-order dynamic capabilities through new analytical approaches to investigate different dynamic capabilities configurations, even more by emergence technologies, as big data & analytics, mentioned by Conboy and colleagues [23].

Thus, on the dynamic capability's theory, this study proposes to develop a measure of IT resources and strategic management practices are capable of explaining the core areas in which big data & business analytics should be infused to enable dynamic capabilities to leverage innovation under constantly changing of uncertainty conditions. Hence, big data & business analytics capabilities (BDA) as dynamic capabilities were conceptualization and measurement, hereafter defined as BDA-enabled dynamic capabilities to leverage innovation, develop on the argument that BDA is only creating IT-business value if BDA is harnessed appropriately to enable or strengthen the firm capability.

The dynamic capabilities theory provides the theoretical foundation on which the dimensions of sense, seize, and transform capabilities through delineating limits and conditions under which innovation can be created [19]. Despite recent articles developing on the dynamic

capabilities theory to support associations among constructs that dynamic capabilities were enabled by IT capabilities [18], [21], [24]. The reliable and valid scale to measure the effectiveness of the dynamic capabilities to leverage innovation through big data and business analytics has not been developed and reported in the literature. Thus, this study aims to answer how the dynamic capabilities through BDA systems can be used to explain the development of novel measurement instruments that contribute to is relevant to IS and dynamic capabilities literature.

2. THEORY BACKGROUND

Previous studies of IT capabilities have demonstrated the influence of IT resources, IT competencies, and IT-enabled capabilities [5], [25]. IT resources are widely available in the firm as commodity-like assets, such as IT infrastructure, human skills and knowledge, which can be purchased from the IT suppliers [6], [7]. However, the adoption of IT resources can not guarantee the outcomes performances by themselves, they need to use strategically by the organization [9], [26]. Otherwise, previous studies have demonstrated that IT competencies are related to managing and developing to use and deploy IT assets to enable organizational capabilities by orchestrating IT resources within the IS function. [2], [3]. On the order hand, IT-enabled capabilities are referred to as the strategic purpose application of IT competencies to build organizational, and recent empirical studies defined through higher-order latent variables [18], [21], [24].

The dynamic capabilities as an extension of resource-based theory (RBT), and growing interest among scholars to examine how firms adapt and change to leverage innovation under the environmental requirement [14]. According to Teece and colleagues [19] organizations must be more than survive, they need to prosper under the turbulent market conditions, so, they need to develop dynamic capabilities to sense, seize, and transform to sustain themselves in the longer term to customers, technologies change and competitors. Hence, this study is based on the theoretical foundation that effective deploying of dynamic capabilities leverage innovation should be when firms enable operational capabilities to recognize and respond to opportunities and threats through changing, extending, modifying or creating resource configurations [15].

Therefore this study focuses that dynamic capabilities to leverage innovation through enabling firms to sense [identification, development, co-development, and assessment of technological opportunities (and threats) in relation to customer needs], seizing (by the mobilization of resources to address needs and opportunities and capture value from doing so), and continued renewal by transforming organizational capability [19, p. 18]. Thus, the study developed the idea of the novel construct by BDA-enabled dynamic capabilities to leverage innovation can be built on these requirements. Consequently, this study contributes to dynamic IT capabilities literature [7], when understanding how operationalized this concept by latent variable as defined as second-order dynamic capabilities embedded in the processes of sensing, seizing, and transforming.

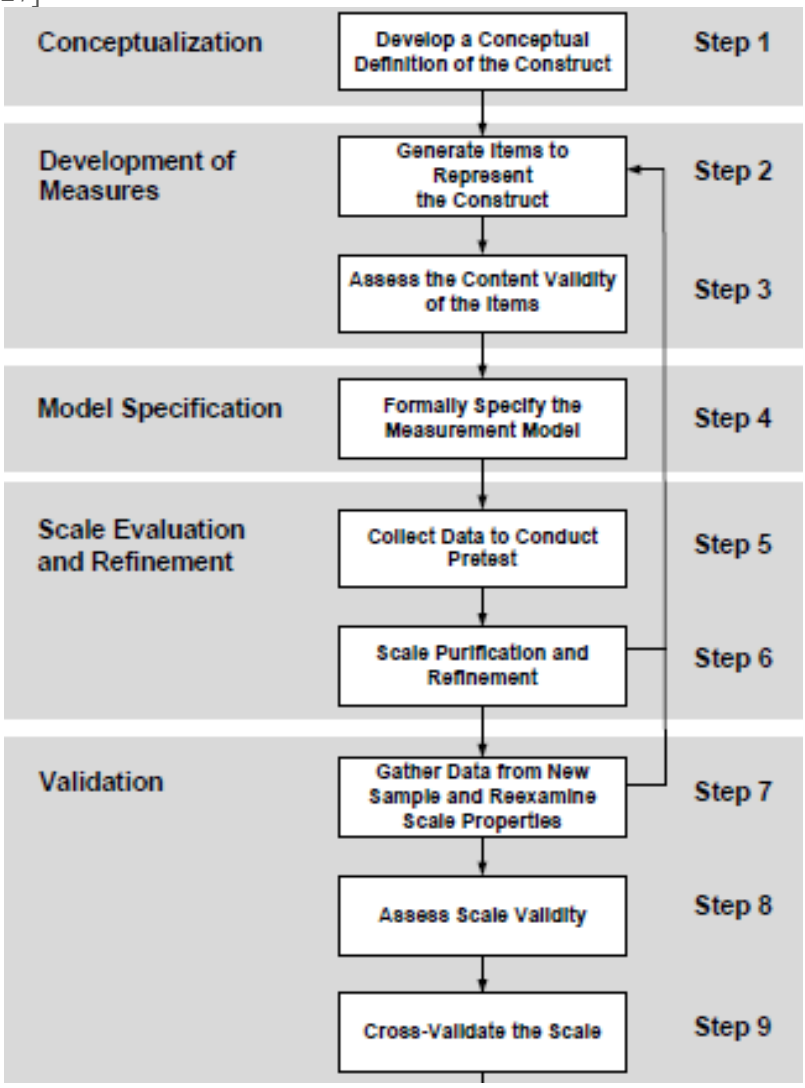
3. SCALE DEVELOPMENT

In the information systems research, the scale development and validation of measurement instruments can be a critical challenge, and important studies to build and contribute to fill gaps in knowledge and create cumulative knowledge should be developed [27]–[29].

Previous studies have presented the steps of the scale development process [29]–[31]. This study followed the guidelines of information systems research suggested by Mackenzie and colleagues [27]. They authors divided the scale development process into five phases: (a)

conceptualization, (b) development of measures, (c) model specification, (d) scale evaluation and refinement, and (e) validation see Figure 1.

Figure 1. Overview of Scale Development Procedure adapted by Mackenzie and colleagues [27]



3.1 Scale conceptualization

The theoretical propositions to explain and predict phenomena of interest are the first step to developing measurement instruments for the domain of the novel construct [29]. The conceptual definition of the novel construct relates to establishment of theoretical propositions, as well as the dimensions that comprise it [31]. As stated in this paper was presented an adequate theoretical view of dynamic capabilities to leverage innovation [19] and dynamic IT capabilities [7], which conceptualizations and measurements of the novel construct BDA-enabled dynamic capabilities to leverage innovation could be based. Researchers recommended developing a precise and detailed conception of its theoretical context and the target construct through writing out a brief and formal description of the novel construct [27]. Hence, the concise definition of the novel construct is synthesized below:

BDA-enabled dynamic capabilities are defined as a firm's abilities to sense, seize and transform capabilities enabled through big data and business analytics, in orchestration with other organizational resources and capabilities, to leverage innovation and respond to business environmental challenges.

Hence, dynamic capabilities as an extension of BDA-enabled dynamic capabilities focus on the set of organizational capabilities that underpin them to leverage innovation, which was described by capabilities/dimensions including (i) sensing, (ii) seizing, and (iii) transforming.

Sensing capabilities are the ability to sense and shape opportunities and threats by organizational ability to spot, scan, interpret and learn activities [32]. Seizing capabilities refer to the firm ability to mobilize resources to respond to opportunities and threats [23]. Transforming capabilities is the firm ability to continue renewal through strategic moves to create and change existing modes of operations [19].

Therefore, in this study BDA-enabled dynamic capabilities are measured as the capacity of the firms to leverage their sensing, seizing and transforming through big data and business analytics, in combination with other enterprise resources and capabilities.

3.2 Development of measures

The next step consist of the development of measures by a draft measurement instrument of the novel construct.

3.2.1 Generate Items to Represent the Construct

It is produced and improved by multiple iterations with the specialist the conceptual domain of the novel construct by dimensions of which it is comprised [30]. Hence, based on the previous studies of the scale development process [27], [28], this research adopted current literature of conceptual and empirical studies, suggestions from specialists in the IS and strategic management field by examining existing construct measures to develop the items on the instrument in the dimensions of sensing, seizing and transforming capabilities enabled by BDA.

Hence, it was created a set of items that gather the essential aspects of the domain of the construct dimension. The novel construct of BDA-enabled dynamic capabilities to leverage innovation was generated by conceptual studies and adapting existing items from empirical in the domains of IS [9], [21], [33], [34] and strategic management [15], [19], [35]–[37]. The set of items is presented by the dimension of the novel construct in Table 1. Thus, the assertive sentence for each item is asked respondents to assess "how effective your company is in using information systems through big data & business analytics (BDA) applications to support the organization for the following purposes: (1-Not effective at all, 7-Highly effective)"

Table 1. Assertive Items for the DBA-enabled dynamic capabilities construct

Dimensions	Assertive items	Source	References
Sensing	SENS1. Scanning trends in the external environment (such as social-cultural, the federal government, demographic, political, energy, technology, etc.) and identifying new business opportunities	Adapted	[9], [21], [36], [37]

	SENS2.Identifying changes in the organization's target market	Adapted	[33], [36]
	SENS3.Identifying changes in people's behavior and attitudes (values and lifestyles)	Adapted	[35]
	SENS4.Identifying new business opportunities in the micro-sector environment (such as suppliers, intermediary customers, state and municipal government, regulatory agency, etc.)	Created	[35], [36]
	SENS5.Identifying new business practices to create unique customer experiences.	Created	[35], [36]
	SENS6.Identifying changes in customer needs	Adapted	[21]
Seizing	SENZ1. Developing potential business solutions to meet changes in the micro-operating environment to deal with opportunities and threats detected	Created	[35], [36]
	SENZ2. Developing effective routines for creating potential business solutions to deal with opportunities or threats detected	Adapted	[34]
	SENZ3.Developing potential business solutions to meet trends in the external environment to deal with opportunities and threats detected	Adapted	[34]
	SENZ4. Developing potential business solutions to actively influence the direction of the sector in which it belongs.	Adapted	[35], [36]
	SENZ5. Developing potential business solutions to meet the organization's target market	Adapted	[35], [36])
	SENZ6. Develop new ways of doing business to meet customer needs	Created	[35], [36]
Transforming	TRA1. Adjust your business processes in response to changes in your business priorities	Adapted	[21]
	TRA2. Reconfigure your business processes to generate new productive assets (resources)	Adapted	[9], [21]
	TRA3. Optimize the use of existing productive resources in new areas with new purposes	Adapted	[35], [36]
	TRA4. Optimize the use of existing knowledge in new areas for new purposes	Adapted	[35], [36]
	TRA5. Integrate new know-how with the company's existing knowledge	Adapted	[35], [36]

	TRA6. Develop new business processes to achieve the organization's goals and objectives	Created	[36], [37]

3.2.2 Assess the content validity of the items

The next step consisted of evaluating the content validity. According to Boateng and colleagues [29], content validity concerns evaluating each of the items in an instrument reflect the domain for content relevance, representativeness, and technical quality. Thus, by the guideline of Mackenzie and colleagues [27], it was made assessing content validity to check, (1) whether each item is representative of the content domain by the construct dimension, and (2) if the construct dimension was collectively represented by the items set. The validation method of content validity is employed through an empirical assessment of content validity by qualitative and quantitative assessment [30]. Qualitative assessment was made by judgmental and subjective assessment by experts. They selected the items to dimensions and comment difficulties and offer suggestions for improvement (including, modifying, and deleting items). Quantitative assessment was made by a combination of the q-sort methodology and the Content Validity Ratio (CVR) techniques. The test was performed by six academics, and five senior executives in the field of IS and strategic management.

The experts' group assessed content validity by an excel file with three columns and 18 assertive items. The dimensions of the BDA-enabled dynamic capabilities to leverage innovation represented each column, and 18 assertive items (Table 1) were in random order. The experts were asked to choose the assertive item to a better dimension of the construct. Thus, when the excel file was completed, it was calculated the item placement ratio ("Hit Ratio") indicated how many assertive items were correctly placed in the right dimension. To calculate the ratio of item placement to the total number of items was dividing the number of items correctly assigned to its respective constructs. Table 2 indicates in the diagonal elements the number of correctly chosen assertive items by all experts. The results demonstrated that three dimensions of the novel construct can be measured by a specific set of assertive items.

Table 2. The ratio of item placement

Dimension	Sensing	Seizing	Transforming	**Total**	**Item Placement Ratio**
Sensing	68	4	0	72	94%
Seizing	1	61	10	72	85%
Transforming	0	7	65	72	90%

After the Hit Ratio, the experts received another excel file with a list of the assertive items from the updated instrument, and they are asked to evaluate the relevance of each to the construct, using the scale 1 – Essential, 2 – Important, and 3 – Not relevant [30]. Thus, a content validity ratio (CVR) was calculated for each assertive item by the following formula: CVR = (n-N/2)/(N/2), where "N" is the total number of respondents and "n" is the number of experts indicating an item as essential rating the assertive item as appropriate. According to the minimum values of CVR and one-tailed test, p = .05, the CVR score is 0.59 for a group of 11 experts [38].

Table 3. Results of content validity ratio

Dimension	Item	Essential	Important	Irrelevant	Content Validity Indices (CVR) (N = 11, CVR thresh. = 0.59)	Status
Sensing CVIs=0.82	SENS1	11.00	-	-	1.00	Accepted
	SENS2	9.00	2.00	-	0.64	Accepted
	SENS3	7.00	4.00	-	0.27	Rejected
	SENS4	9.00	2.00	-	0.64	Accepted
	SENS5	8.00	2.00	1.00	0.45	Rejected
	SENS6	11.00	-	-	1.00	Accepted
Seizing CVIs=0.73	SEIZ1	5.00	5.00	1.00	- 0.91	Rejected
	SEIZ2	10.00	1.00	-	0.81	Accepted
	SEIZ3	9.00	2.00	-	0.64	Accepted
	SEIZ4	5.00	2.00	4.00	- 0.91	Rejected
	SEIZ5	10.00	1.00	-	0.81	Accepted
	SEIZ6	9.00	2.00	-	0.64	Accepted
Transforming CVIs=0.68	TRA1	9.00	2.00	-	0.64	Accepted
	TRA2	7.00	3.00	1.00	0.27	Rejected
	TRA3	9.00	2.00	-	0.64	Accepted
	TRA4	9.00	3.00	-	0.45	Rejected
	TRA5	10.00	1.00	-	0.81	Accepted
	TRA6	9.00	2.00	-	0.64	Accepted

3.3 Model specification

Once the measurement model has been developed of measures, it is necessary to focal construct through dimensions and the best captures of the assertive items [30]. it was guided by the recommendation of Mackenzie et. al. [27] and the novel construct of BDA-enabled dynamic capabilities was defined as a Type II second-order factor modeled by a formative model with three (sensing, seizing, and transforming) first-order reflective measurement models. Thus, the three dimensions were modeled by reflective assertive items, thus, they were used to capture and quantify each of the first-order dimensions, as a reflective-formative construct [39]. Because the first-order dimensions are theoretically distinct and contribute as a unique element to the BDA-enabled dynamic capabilities as a higher-order latent variable.

3.4 Scale Evaluation and Refinement

The next step, the pretest was conducted to get empirical feedback about the measurement properties of the scale through the controlled sample to assess the appropriateness of examining the convergent, discriminant, and nomological validity [29]. Based on the guidelines set was assessed criteria for scale purification for Type II second-order latent variable, and used the elimination criteria: problematic indicators have low validity, low reliability, strong and significant measurement error covariances, and/or non-hypothesized cross-loadings that are strong and significant, as recommended by Mackenzie and colleagues [27, p. 316]. The outcomes demonstrate that all criteria were accepted of pretest with 50 firms.

The next step calculated the Variance Inflation Factor (VIF) to examine multicollinearity between three first-order dimensions to analyze whether first-order dimensions have a significant association with the BDA-enabled dynamic capabilities variable. The tests show

that all VIF's through path weights are well, by SmartPLS software 3, below the threshold of 10, indicating no problem with multicollinearity Hair et al. [39], see Table 4.

Table 4. Multicollinearity analysis and path weights

Dimension	Weight	VIF
Sensing	0.357***	3.287
Seizing	0.373***	4.486
Transforming	0.351***	2.872

3.5 Validation

The sample data by convenience sampling was collected with U.S. firms. The authors contacted the respondents in each firm using different sources and networks, such as personal contacts, professional association contacts, forums, mailing lists, and directories, in line with current research on empirical IS and management studies. The key informants know the BDA-enabled dynamic capabilities properties, including C-level executives and senior executives of business and IT units. The instrument instructions recommended that the respondents who didn't have high knowledge of specific information should consult other executives, thus, the collecting process was approximately 90 days (May 2021 to July 2021).

The final sample size (50 first and 141 late responses) is 191 cases, which is considered a good sample size by confirmatory factor analysis in structural equation model through the association network of theoretical concepts [30], and even more when the commonalities are high and the factors are strongly determined [27], as demonstrated in this study. The sample characteristics by firms' sector; agribusiness (5%), commerce (5%), financial (16%), manufacturing (27%), services (28%), and government (7%).

Thus, the next step was to re-examine by final the final sample the convergent validity, internal consistency of reliability, and discriminant validity [39]. Convergent validity was assessed by loadings of items, confirming loadings above 0,70 and indicator reliability above 0.50, and Average Variance Extracted (AVE) exceeded the threshold of 0.50. Composite Reliability (CR) and Cronbach Alpha (CA) values were examined, and all values are among 0.60 to 0.90, indicating internal consistency reliability. The outcomes were in favor of the discriminant validity, indicating that square roots of AVE`s against each latent constructs cross-correlations were greater than its highest correlation with any other construct (Fornell-Larcker criterion), and HTMT confidence interval does not include 1. Table 5 demonstrates the results summary for reflective measurement for the three dimensions of BDA-enabled dynamic capabilities are presented.

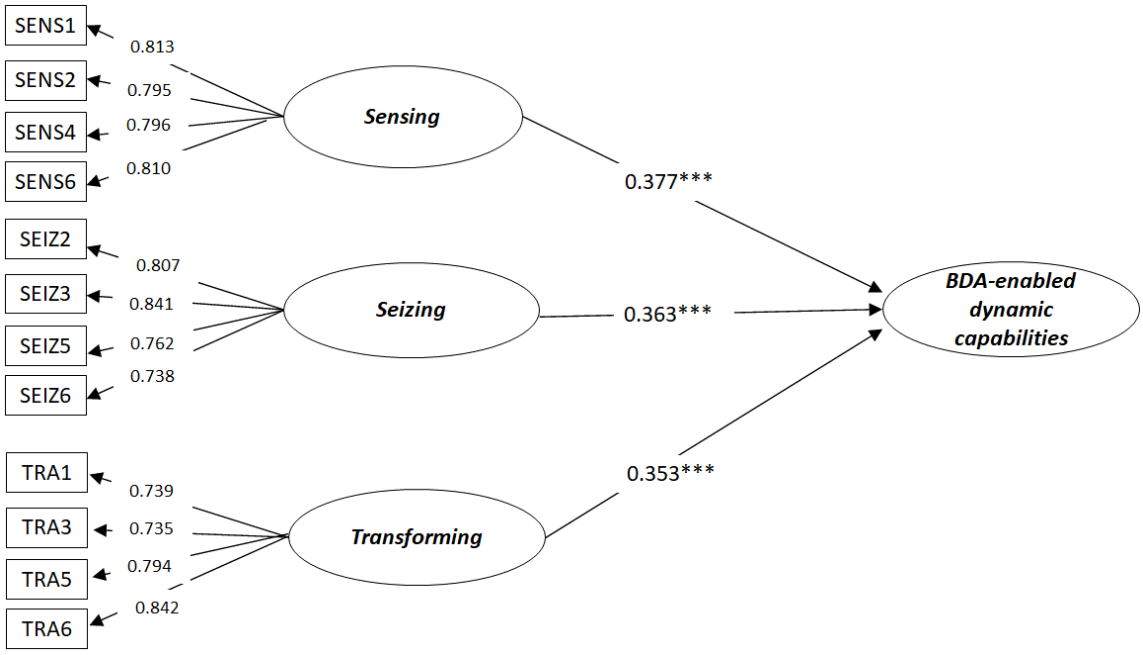
Table 5. Results summary for reflective measurement models

Dimensions	**Indicators**	**Loadings**	**Indicator Reliability**	**VIF**	**AVE**	**Composite Reliability**	**Cronbach's Alpha**	**Discriminant Validity**	
		>0.70	**>0.50**	**>10**	**>0.50**	**0.60-0.90**	**0.60-0.90**	**HTMT does not include 1**	**Square AVE of Fornell-Larcker criterion**
Sensing	SENS1	0.813	0.660	2.775	0.646	0.879	0,817	Yes	Yes
	SENS2	0.795	0.632						
	SENS4	0.796	0.633						

	SENS6	0.810	0.656						
Seizing	SEIZ2	0.807	0.651	2.901	0.621	0.867	0.795	Yes	Yes
	SEIZ3	0.841	0.707						
	SEIZ5	0.762	0.580						
	SEIZ6	0.738	0.544						
Transforming	TRA1	0.739	0.546	2.862	0.606	0.860	0.782	Yes	Yes
	TRA3	0.735	0.540						
	TRA5	0.794	0.630						
	TRA6	0.842	0.708						

The study used PLS-SEM to validate the measurement models [39], in line with previous empirical studies of IS and strategic management [9], [18], [21], [24]. The results demonstrated that the set of assertive items match their specific dimension by distinct item and dimension level. Figure 2 shows the path weights of the first-order construct on the second-order construct and the items loading.

Figure 2. Measurement Model



Note: *** $p < 0.001$

4. DISCUSSION, CONCLUSION, AND FUTURE RESEARCH

To the best of the authors' knowledge, based on the dynamic capabilities theory, this is the first study that conceptualized, developed, validated, and large-scale empirical testing the construct of big data and business analytics (BDA)-enabled dynamic capabilities scale, exploring how sensing, seizing and transforming dynamic capabilities leverage innovation dynamic as second-order capabilities.

The recent studies of dynamic capabilities and big data & business analytics asked to develop future studies to understand how sensing, seizing, and transforming capabilities by dynamic capabilities view [19] can be enabled by big data and business analytics [23], thus, this empirical research contribute to novel knowledge of dynamic capabilities and IT capabilities literature.

This study investigated how dynamic capabilities to leverage innovation, once the deploying first-order dynamic capabilities can be insufficient to capture IT-business value by IT resources and strategic management practices, as mentioned by Li and Chan [7]. Thus, this empirical research demonstrated that second-order dynamic capabilities enabled by BDA can be a viable alternative to support firms to build and execute changes to leverage innovation to face business environmental challenges.

Future studies can examine big data and business analytics-enabled dynamic capabilities as a dependent variable when the resources orchestration among IT resources and strategic management practices can be variables antecedent. Hence, proximate and distal outcomes can be influenced by BDA-enabled dynamic capabilities, and open a large avenue to investigate how novel construct can influence the outcome performance, such as decision-making performance, strategic flexibility, organizational agility, exploration and exploitation innovation, and corporate performance, as suggested the research agenda for realizing business value by big data and big analytics [22].

Moreover, the effects of BDA-enabled dynamic capability to leverage innovation through sensing, seizing, and transforming capabilities can be different by specific characteristics, such as sector, firm-age, firm-size, and competitive pressures from the business environmental challenge, and further studies can be conducted to address this phenomenon.

REFERENCES

[1] N. Melville, K. Kraemer, and V. Gurbaxani, ‘Review: Information Technology and Organizational Performance: An Integrative Model of IT Business Value’, *MIS Q.*, vol. 28, no. 2, pp. 283–322, 2004.

[2] R. Kohli and V. Grover, ‘Business Value of IT: An Essay on Expanding Research Directions to Keep Up with the Times’, *J. Assoc. Inf. Syst.*, vol. 9, no. 1, pp. 23–29, 2008.

[3] G. Kim, B. Shin, K. K. Kim, and H. G. Lee, ‘IT Capabilities, Process-Oriented Dynamic Capabilities, and Firm Financial Performance’, *J. Assoc. Inf. Syst.*, vol. 12, no. 7, pp. 487–517, 2011.

[4] Y. Lu and K. Ramamurthy, ‘Understanding the Link Between Information Technology Capability and Organizational Agility: An Empirical Examination’, *MIS Q.*, vol. 35, no. 4, pp. 931–954, 2011.

[5] P. Mikalef and A. Pateli, ‘Developing and validating a measurement instrument of IT-enabled dynamic capabilities’, *24th Eur. Conf. Inf. Syst. ECIS 2016*, no. June 2016, 2016.

[6] A. Bharadwaj, ‘A Resource-Based Perspective on Information Technology Capability and Firm Performance’, *MIS Q.*, vol. 24, no. 1, pp. 169–196, 2000.

[7] T. (Carol) Li and Y. E. Chan, ‘Dynamic information technology capability: Concept

definition and framework development', *J. Strateg. Inf. Syst.*, vol. 28, no. 4, pp. 1–20, 2019.

[8] Y. E. Chan, J. S. Denford, and J. Wang, *The Co-Evolution of IT, Knowledge, and Agility in Micro and Small Enterprises*, vol. 18, no. 3. 2019.

[9] A. C. Yoshikuni, F. R. Galvão, and A. L. Albertin, 'Knowledge strategy planning and information system strategies enable dynamic capabilities innovation capabilities impacting fi rm performance', *VINE J. Inf. Knowl. Manag. Syst.*, vol. ahead of p, 2021.

[10] M. Taher, 'Resource-Based View Theory', in *Information Systems Theory: Explaining and Predictin Our Digital Society. Vol. 1. Integrated Series in Information Systems 28*, Y. K. Dwivedi, M. R. Wade, and S. L. Schneberger, Eds. New York, NY: Spring New York Dordrecht Heidelberg London, 2012, pp. 151–163.

[11] N. Levallet and Y. E. Chan, 'Role of Digital Capabilities in Unleashing the Power of Managerial Improvisation', *MIS Q. Exec.*, vol. 17, no. 1, pp. 1–21, 2018.

[12] Y. E. Chan, J. S. Denford, and J. Y. Jin, 'Competing Through Knowledge and Information Systems Strategies: A Study of Small and Medium-Sized Firms', *J. Inf. Knowl. Manag.*, 2016.

[13] C. E. Helfat and S. G. Winter, 'Research prospectives untangling dynamic and operational capabilities: strategy for (n)ever-changing world', *Strateg. Manag. J.*, vol. 32, pp. 1243–1250, 2011.

[14] C. E. Helfat and R. S. Raubitschek, 'Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems', *Res. Policy*, vol. 47, no. 8, pp. 1391–1399, 2018.

[15] D. J. Teece, 'Dynamic capabilities as (workable) management systems theory', *J. Manag. Organ.*, no. May, pp. 1–10, 2018.

[16] E. M. Daniel, J. M. Ward, and A. Franken, 'A dynamic capabilities perspective of IS project portfolio management', *J. Strateg. Inf. Syst.*, vol. 23, no. 2, pp. 95–111, 2014.

[17] R. Wilden and S. P. Gudergan, 'The impact of dynamic capabilities on operational marketing and technological capabilities: investigating the role of environmental turbulence', *J. Acad. Mark. Sci.*, vol. 43, no. 2, pp. 181–199, 2015.

[18] P. Mikalef, A. Pateli, and R. Van de Wetering, 'IT architecture flexibility and IT governance decentralisation as drivers of IT-enabled dynamic capabilities and competitive performance: The moderating effect of the external environment', *Eur. J. Inf. Syst.*, vol. 27, pp. 1–29, 2020.

[19] D. J. Teece, M. Peteraf, and S. Leih, 'Dynamic capabilities and organizational agility: Risk, uncertainty, and strategy in the innovation economy', *Calif. Manage. Rev.*, vol. 58, no. 4, pp. 13–35, 2016.

[20] M. Wade and J. Hulland, 'Review: the Resource-Based View and Information Systems Research: Review, Extension, and Suggestions for Future Research1', *MIS Q.*, vol. 28, no. 1, pp. 107–142, 2004.

[21] P. Mikalef and A. Pateli, 'Information technology-enabled dynamic capabilities and their indirect effect on competitive performance: Findings from PLS-SEM and fsQCA', *J. Bus. Res.*, vol. 70, pp. 1–16, 2017.

[22] P. Mikalef, I. O. Pappas, J. Krogstie, and P. A. Pavlou, 'Big data and business analytics: A research agenda for realizing business value', *Inf. Manag.*, vol. 57, no. 1, 2020.

[23] K. Conboy, P. Mikalef, D. Dennehy, and J. Krogstie, 'Using business analytics to enhance dynamic capabilities in operations research: A case analysis and research agenda', *Eur. J. Oper. Res.*, vol. 281, no. 3, pp. 656–672, 2020.

[24] A. C. Yoshikuni and L. A. Albertin, 'IT-Enabled Dynamic Capability on Performance: an Empirical Study of BSC Model', *J. Bus. Manag.*, vol. 57, no. maio-jun, pp. 215–231, 2017.

[25] J. Peppard and J. Ward, 'Beyond strategic information systems: towards an IS capability', *J. Strateg. Inf. Syst.*, vol. Volume 13, no. Issue 2, p. Pages 167-194, 2004.

[26] A. Bharadwaj, O. A. El Sawy, P. A. Pavlou, and N. Venkatraman, 'Visions and Voices on Emerging Challenges in Digital Business Strategy', *MIS Q.*, vol. 37, no. 2, pp. 633–661, 2013.

[27] S. B. MacKenzie, P. M. Podsakoff, and N. P. Podsakoff, 'Construct measurement and validation procedures in MIS and behavioral research: Integrating new and existing techniques', *MIS Q. Manag. Inf. Syst.*, vol. 35, no. 2, pp. 293–334, 2011.

[28] C. B. Jarvis, S. B. Mackenzie, P. M. Podsakoff, N. Giliatt, and J. F. Mee, 'A Critical Review of Construct Indicators and Measurement Model Misspecification in Marketing and Consumer Research', *J. Consum. Res.*, vol. 30, no. 2, pp. 199–218, 2003.

[29] G. O. Boateng, T. B. Neilands, E. A. Frongillo, H. R. Melgar-Quiñonez, and S. L. Young, 'Best Practices for Developing and Validating Scales for Health, Social, and Behavioral Research: A Primer', *Front. Public Heal.*, vol. 6, no. June, pp. 1–18, 2018.

[30] B. R. Lewis, G. F. Templeton, and T. A. Byrd, 'A methodology for construct development in MIS research', *Eur. J. Inf. Syst.*, vol. 14, no. 4, pp. 388–400, 2005.

[31] R. F. Devellis and C. T. Thorpe, *Scale Development: Theory and Applications*, 5th ed. Sage Publications, Inc, 2021.

[32] D. J. Teece, 'Explicating Dynamic Capabilities: The Nature and Microfoundations of (Suvstainabile) Enterprise Performance', *Strateg. Manag. J.*, vol. 28, no. 13, pp. 1319–1350, 2007.

[33] S. F. Wamba, R. Dubey, A. Gunasekaran, and S. Akter, 'The performance effects of big data analytics and supply chain ambidexterity: The moderating effect of environmental dynamism', *Int. J. Prod. Econ.*, vol. 222, no. September 2019, 2020.

[34] P. Mikalef and J. Krogstie, 'Big data analytics as an enabler of process innovation capabilities: A configurational approach', *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 11080 LNCS, no. January, pp. 426–441, 2018.

[35] A. Jantunen, A. Tarkiainen, S. Chari, and P. Oghazi, 'Dynamic capabilities, operational changes, and performance outcomes in the media industry', *J. Bus. Res.*, vol. 89, no. June 2017, pp. 251–257, 2018.

[36] M. E. Porter, *Competitive advantage: Creating and sustaining superior performance:*

with a introduction, Free press. New York, NY: Simon and Schuster, 1998.

[37] H. Mintzberg, B. W. Ahlstrand, and J. Lampel, *Strategy safari: The complete guide through the wilds of strategic management*, 2nd ed. Harlow:UK: Financial Times Prentice Hall, 2009.

[38] C. H. Lawshe, 'A quantitative approach to content validity', *Pers. Psychol.*, vol. 28, no. 4, pp. 563–575, 1975.

[39] J. F. Hair, G. Hult, C. Ringle, and M. Sarstedt, *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 2° Ed. Thousand Oaks: Sage Publications, Inc., 2017.

DEVELOPMENT OF A REGULAR EXPRESSION METHOD TO FACILITATE READING OF FINANCIAL DISCLOSURES DURING THE COVID-19 PANDEMIC

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ABSTRACT

Public companies in the United States companies can file voluntary financial disclosures throughout the year. There can be many financial disclosures in a short period of time, such as during the onset of the COVID-19 pandemic, and it can take many hours for humans to read the disclosures accurately. In this study, we develop a computer program using a regular expression method to facilitate the reading of financial disclosures more automatically. Specifically, the program identifies financial filings that disclose stock dividend suspension. Measured against human readings of 1,414 financial disclosures, we found that the program can achieve accuracy of 98.4%, with a tremendous time saving: the deciphering of these 1,1414 disclosures takes human reading more than 100 hours while takes the program only about 10 minutes.

INTRODUCTION

To facilitate investment decisions, public companies provide financial disclosures to investors and analysts. Some filings are required by the SEC (Securities Exchange Commission), such as the yearly report (10-K) and quarterly report (10-Q). In addition to the yearly and quarterly reports, companies can also file additional disclosures, known as 8-Ks, to provide updates on a more ad-hoc basis as events occur [13].

To make informed decisions, investors and analysts read these financial disclosures to glean information that will facilitate their decision making. For example, one important announcement is news about stock dividends and share repurchases. Stock dividends and share repurchases are not only an important mechanism of rewarding investors, but also a critical element in the valuation of a company [5]. When a company increases stock dividends, investors have more incentives to purchase the stock. On the other hand, when a company suspends or reduces dividends, investors may need to reconsider investing in this company.

One way to glean information from a financial disclosure is simply for an investor to read the disclosure manually. While the suspension of dividends may seem a rather straightforward disclosure to read, the disclosures can in fact be long or complicated:

companies can bundle multiple pieces of information in one financial disclosure [6] [21], and a financial disclosure can include lengthy legal disclaimers regarding risk factors that are not the actual news but statements that discuss risk factors.

Further, during a crisis, such as the onset of the COVID-19 pandemic, many companies can file financial disclosures in the same period. In the United States, COVID-19 was declared a national emergency by the United States Secretary of the Department of Health and Human Services on January 31, 2020 [1]. The United States stock market crashed in March of 2020 [16]. During this time, many companies filed 8-K financial disclosures. To understand these disclosures, we downloaded all the 8-Ks from the SEC website in the first three months of calendar year 2020. We used the same definition of voluntary 8-K financial disclosure as He and Plumlee [11]. We found 1,414 voluntary 8-K financial disclosures that mention coronavirus or COVID-19.

However, as we read these financial disclosures that mention coronavirus or COVID-19, we realized that not all of these filings disclose a suspension of dividend. Some filings are about the move of shareholders' meeting to a virtual format; some filings are about how the company is prioritizing the health and safety protocols; some companies even disclosed corporate good news such as a technology to diagnose or treat COVID-19. To discern whether each filing discloses the withdrawal of stock dividends, it took each author more than 100 hours of human reading to decipher these 1,414 disclosures.

To improve the efficiency and potentially accuracy of reading financial disclosures, in this study we developed a regular expression approach to read the financial disclosures based on rules of text phrases. Specifically, this algorithm identifies disclosures of suspension of stock dividends or share repurchase. Measured against human readings of 1,414 financial disclosures, we found that this program is able to achieve 98.4% accuracy, with a tremendous time saving. The initial success of this pilot system suggests for broader use of expert system in facilitating the reading of financial disclosures.

The rest of this manuscript is organized as follows: Literature Review, Hypothesis Development, Methods, Sample Selection, Results, and Discussion.

LITERATURE REVIEW

Financial Disclosures

Public companies offer stocks that the public can buy and sell over open stock exchanges. In the United States, these companies are regulated by the Securities Exchange Commission (SEC). To help public investors make informed decisions about stock investment, the SEC requires each public company to provide disclosures to the public. Such disclosures are submitted to the SEC, and the SEC will post these disclosures on the public SEC website for the public to view [24].

One mandatory financial disclosure is the yearly financial report, known as the 10-K, and quarterly financial statements, known as the 10-Q. A public company

files a detailed, audited 10-K every year. For the quarters when there is not a 10-K, each company will file a 10-Q, which provides quarterly update, though often unaudited and not as detailed as the 10-K. Since material events that affect a company's financial standing can happen more often than every 3 months, i.e., quarterly, the SEC also has another financial disclosure form, 8-K, which can be filed on an ad-hoc basis [13]. Some of these events are mandated by the SEC; the SEC has a list of events that a company has to file an 8-K disclosure [21]. For example, item 1.01 is Entry into a Material Definitive Agreement. A company has 4 days to file an 8-K when a mandatory event occurs.

Meanwhile, there are also voluntary events that a company can choose to disclose before the quarterly reports. For example, when a global catastrophe occurs, a company may, before its quarterly earnings conference, decide to withdraw stock dividend for the rest of the year, and provides an 8-K to disclose such information.

Various papers in the literature examined determinants for companies' 8-Ks filings, such as Bird and Karolyi [2], Gleason et al. [10] and He and Plumlee [11]. The scope of this paper is not to understand the determinants of filing 8-Ks, but to develop an intelligent computer program that can facilitate the reading of financial disclosures.

COVID-19 Pandemic

COVID-19 not only a tremendous public health hazard, but also a major economic and financial crisis. Following the onset of the pandemic, the Dow Jones Industrial Index declined by 40% starting in February of 2020 and bottomed in March of 2020. Many companies responded to the pandemic in various ways: moving meetings online, asking employees to work from home, closing stores and in-person dining rooms, and, importantly, postponing or withdrawing the distribution of stock dividends. In the first three months of year 2020, where the business environment was rapidly changing, companies file 8-Ks to disclose these actions before their scheduled quarterly filings.

Needless to say, there are many important questions related to COVID-19 that require much research. Those studies are beyond the scope of this manuscript.

Text Analysis of Financial Disclosures

As financial disclosures are intended for humans, the gold standard is human reading of financial disclosures. While it provides a standard of practice, it is not the most robust or efficient. For example, at the onset of the COVID, many companies filed 8-Ks. As there are more and more data, it is desirable to have a more automated approach that is more efficient than human reading. Human reading is not only time consuming, but also less systematic and can therefore result in errors.

Loughran and McDonald [15] provided a detailed review of text analysis for finance and accounting. While more papers have been published since this review, many the more recent papers still applied the same categories of approaches outlined in Loughran and McDonald [15]. A detailed review of text analysis is beyond the scope of this manuscript; please refer to reviews such as Loughran and McDonald [15].

The following categories of approaches were reviewed by Loughran and McDonald [15]. One approach is to evaluate the information content of a financial disclosure, e.g., word counts, file size. Another approach is to evaluate the readability of a financial disclosure [4][8]. One of the most popular approaches is Bag-of-Words methods, which count the relative frequencies of words in a document. Advantages of this approach include its highly quantitative nature, efficiency, and many readily usable algorithms. Meanwhile, bag-of-words methods do not consider the context of words. One type of bag-of-words approaches is word-list approach, i.e., the development of a dictionary of words that have different sentiments, e.g., positive, negative, based on financial disclosures [14][19].

Another bag-of-words approach is to classify financial disclosures by machine learning algorithms such as Naïve Bayes methods [15]. Still another bag-of-words approach is machine learning of thematic structures such as latent Dirichlet Allocation [15]. Frankel et al. [9] found that machine learning methods are more powerful and reliable than dictionary-based methods. While these machine learning approaches can help provide classification of documents, they suffer from the same drawback of bag-of-words approaches as they do not consider the context of each word in the document.

To consider the context of words, one approach is to examine the collocation of words [15]. While a complete collocation analysis is a computationally daunting task, there may be ways to perform specific collocation analysis for specific purposes. Iwatsuki et al. [12] demonstrated the use of formulaic expressions and shows that they can help to extract information from scholarly papers. Steinbart [23] showed that it is possible to develop a rule-based system to analyze financial disclosures. In this study, we examine rules for one particular type of collocation analysis for financial documents, which is suspension of dividends or stock repurchase. We will discuss further in the next section.

HYPOTHESIS DEVELOPMENT AND METHODS

While it is computationally infeasible to extract all possible collocations of words, we take a different approach in this study by taking advantage of the specific context of financial disclosures and the specific purpose of our analysis.

Hypothesis: *It is computationally feasible to use regular expression to correctly detect most of the companies making a disclosure of suspending dividends or stock repurchases.*

Regular expression is a special programming language used to match specific patterns of text [7]. It provides flexibility in terms of the text patterns that can be matched. For example, while “withdraw dividend” may be what a company discloses in its document, another company may use “withdrawing dividend;” yet another company may say “withdraw our quarterly dividend.” Instead of having to code each of these patterns individually, regular expression allows its user to capture all of these variations by the following regular expression pattern:

withdraw.*dividend

, where .(dot) matches any character except a newline, and * causes the regular expression to match 0 or more repetitions. In other words, any number of non-newline characters can appear between “withdraw” and “dividend” and be matched.

However, it may not always be desirable to match an unlimited number of characters as false positives can be introduced. Regular expression allows one to specify that characters can be matched up to a certain number.

withdraw.{1,50}dividend

, where .{1,50} means that any non-newline character can appear between 1 and 50 times and be considered a match; if more than 50 characters occur between “withdraw” and “dividend,” then it is not considered a match.

Further, regular expression allows the incorporation of logical statements to allow for even more flexibility. For example, this regular expression includes logical statements:

(?i)((withdraw|suspen|cancel|postpone|defer|reduc|delay).{1,50}?((share|stock) repurchase|(share|stock) buyback|dividend))

, where ?i means case insensitive. The vertical line | designates an ***or*** logic, i.e., any of the items separated by | can be matched by the regular expression.

We implemented our program of matching regular expression using Python on Google Colaboratory (Bisong, 2019).

The results are evaluated by positive predictive value, negative predictive value, and accuracy as follows:

True Positive = text determined by computer program to be positive and human to be positive

False Positive = text determined by computer program to be positive and human to be negative

True Negative = text determined by computer program to be negative and human to be negative

False Negative = text determined by computer program to be negative and human to be positive

$$False\ Positive\ Rate = \frac{False\ Positives}{False\ Positives + True\ Negatives} \quad (1)$$

$$False\ Negative\ Rate = \frac{False\ Negatives}{False\ Negatives + True\ Positives} \quad (2)$$

$$Positive\ Predictive\ Value = \frac{True\ Positives}{True\ Positives + False\ Positives} \quad (3)$$

$$Negaive\ Predictive\ Value = \frac{True\ Negatives}{True\ Negatives + False\ Negatives} \quad (4)$$

$$Accuracy = \frac{True\ Positives + True\ Negatives}{True\ Positives + False\ Positives + True\ Negatives + False\ Negatives} \quad (5)$$

SAMPLE SELECTION AND DESCRIPTIVE STATISTICS

As COVID-19 started to affect businesses in the United States in January 2020, and the stock market bottomed at the end of March 2020, we used publicly available data on the SEC EDGAR Website for the month of January, February, and March of 2020. As the pandemic progresses, it would become less a voluntary choice for a firm to disclose information about it since the public would likely desire information about COVID-19's impact on a company in its 8-K and in its earnings call conference. Therefore, we focus our study on the early stage of COVID-19 where there was much uncertainty and companies made voluntary decisions to file 8-Ks to discuss about COVID-19.

In the same period of January through March of 2020, there are 17,631 total 8-Ks on the SEC website filed by all companies (See Table 1). Among these 17,631 8-Ks, 2,481 are press releases of quarterly or annual earnings reports, i.e., 10-Q or 10-K. As the purpose of this study is to examine voluntary 8-K in response to an event, these 2,481 were excluded from further analysis; we use the remaining 15,150 non-earning 8-Ks for further analysis. Of the remaining 15,150 non-earning 8-Ks, 1,414 are voluntary 8-Ks, i.e., items 2.02, 7.01, and 8.01 (the same definition of voluntary as He and Plumlee, 2020), that mention coronavirus or COVID-19 (See Table 1). This sample of 1,414 voluntary 8-K is where we tested our regression expression matching method for suspending dividends or stock repurchase.

Table 1
Sample Selection

During 2020 Q1 (January through March)	Number of observations
Total 8-Ks	17,631
8-Ks that are not quarterly earnings press release	15,150
Non-earning voluntary 8-Ks that mention COVID-19 or coronavirus	1,414

Before we applied regular expression, we applied the same procedures to clean financial disclosures established by McDonald [17], including removing XML tags, special characters, and tables. Please see McDonald [17] for a detailed description of the data parsing and cleaning procedure.

Table 2 shows the number of 8-K filings that contain the phrases we designed the Python program to match. Up to 50 characters are allowed between the phrases suspend and dividend. For phrases related to withdrawal of dividends, the most common phrase

was suspend or suspension…dividend, which occurred in 50 files (3.54% of 1,414 files). The next most common phrase was reduce or reduction… dividend, which occurred in 19 files (1.34% of 1,414 files). For phrases related to withdrawal of stock repurchase, the most common phrase was reduce or reduction… stock|share repurchase|buyback, which occurred in 69 files (4.9% of 1,414 files). The next most common phrase was reduce or reduction…stock|share repurchase|buyback, which occurred in 12 files (0.85% of 1,414 files). The other phrases did not occur as often, as shown in Table 2.

Table 2
Descriptive Statistics

Phrase	**Number of 8-K files (% of 1414 8-K files)***
Dividend related:	
suspend/suspension…dividend	50 (3.5%)
reduce/reduction…dividend	19 (1.34%)
defer…dividend	9 (0.64%)
delay…dividend	3 (0.21%)
withdraw…dividend	2 (0.14%)
cancel… dividend	1 (0.07%)
postpone…dividend	1 (0.07%)
Stock repurchase related:	
suspend/suspension…stock|share repurchase|buyback	69 (4.9%)
reduce/reduction… stock|share repurchase|buyback	12 (0.85%)
defer… stock|share repurchase|buyback	2 (0.14%)
delay… stock|share repurchase|buyback	1 (0.07%)
withdraw… stock|share repurchase|buyback	1 (0.07%)
cancel…stock|share repurchase|buyback	0 (0.0%)
postpone…stock|share repurchase|buyback	0 (0.0%)

*The list is not mutually exclusive, i.e., a file can use multiple phrases.

ANALYSIS RESULTS

We apply the following regular expression:

(?i)((withdraw|suspen|cancel|postpone|defer|reduc|delay).{1,k}?((share|stock)

repurchase|(share|stock) buyback|dividend))

, where (?i) means it is case insensitive, and *k* is the maximum number of characters allowed between the first word (withdraw, etc.) and the second word (dividend, etc.) Then, we calculate false positive rates, false negative rates, positive predictive value, negative value, and accuracy according to equations (1) through (5).

Table 3 shows the results of false positive rates, false negative rates, positive predictive value, negative value, and accuracy. With increasing k, the false positive rate increases while the false negative rate decreases. With *k* of 10, the false positive rate is 0.1%, while the false negative rate is as high as 36.9%. With increasing *k*, the false negative rate decreases. This is because that more matches are made with increasing k, and these additional matches can be true positives or false positives. The positive predictive value decreases with increasing *k*; the negative predictive value increases with increasing k. The accuracy increases at first from 96.5% to 98.4% with *k* increasing from 10 to 60. The accuracy peaks at *k* = 60. With additional *k*, the accuracy decreases to 97.6%. This is because additional false positives are included. Therefore, 60 seems to be the optimal choice of *k*.

Table 3
Accuracy of regular expression pattern matching

k	False positive rate	False negative rate	Positive predictive value	Negative predictive value	Accuracy
10	0.1%	36.9%	98.8%	96.4%	96.5%
20	0.3%	27.7%	95.9%	97.3%	97.2%
30	0.5%	18.5%	93.8%	98.2%	97.8%
40	0.9%	10.8%	90.6%	98.9%	98.2%
50	1.3%	8.5%	87.5%	99.1%	98.0%
60	1.4%	3.8%	87.4%	99.6%	98.4%
70	1.6%	3.8%	86.2%	99.6%	98.2%
80	1.6%	3.8%	85.6%	99.6%	98.2%
90	1.9%	3.8%	83.3%	99.6%	97.9%
100	2.3%	3.8%	81.2%	99.6%	97.6%

*k is the maximum number of characters allowed between the two words in the regular expression
(?i)((withdraw|suspen|cancel|postpone|defer|reduc|delay).{1,k}?((share|stock) repurchase|(share|stock) buyback|divide

With $k = 60$, we next examine the specific causes of false positives and false negatives. Table 4 lists the causes of positives and false negatives. There are 18 false positives for $k = 60$. Table 4 Panel A lists the causes of false positives: the matched sentence is not stating a suspension or reduction of dividend (8 false positives); the regular expression matched two sentences that happened to have suspension in the first sentence and dividend in the second sentence (8 false positives); the match is in a forward-looking statement (2 false positives). Table 4 also lists a few examples. For example, a matched sentence that is not stating a reduction of dividend is "Reduction Date (and, for the avoidance of doubt, the related dividend" which is not stating that the firm is reducing its dividend. An example of two sentences that happened to have reduction in the first sentence and dividend in the second sentence is "reductions negotiated with clients Capital: Current stock repurchase."

With k=60, there are 5 instances of false negatives. Table 4 Panel B lists the causes of false negatives. Most of the false negatives are due to special characters such as in one instance the text says "Suspension of the Company's discretionary open-market shar'b'e repurchase" with the extra special characters 'b' in share. Another instance says "share repurchase" with multiple space characters between "share" and "repurchase." One other cause of false negative is passive voice, though this occurred in only one instance: "Stock buyback and dividend activity will also be suspended."

Table 4

Causes of false positives and false negatives

Panel A. Causes of False Positives

Cause of false positive	Number of documents (% of 1414 documents)	Example
The matched sentence is not stating a suspension or reduction of dividend.	8 (0.6%)	"Reduction Date (and, for the avoidance of doubt, the related dividend"
The expression matches two sentences that happened to have suspension in the first sentence and dividend in the second sentence.	8 (0.6%)	"reductions negotiated with clients Capital: Current stock repurchase."
The match is in a forward-looking statement, i.e., a legal disclaimer.	2 (0.1%)	"A number of important risk factors could cause actual results to differ materially from the results described, implied or projected in any forward-looking statements. These factors include, without

		limitation:… (25) reduction or elimination of dividends on our common stock;…"

Panel B. Causes of False Negatives

Cause of false negative	Number of documents (% of 1414 documents)	Example
Special character in the text prevents regular expression matching.	4 (0.3%)	"Suspension of the Company's discretionary open-market shar'b'e repurchase"
The statement is in passive voice.	1 (0.1%)	"Stock buyback and dividend activity will also be suspended."

DISCUSSION

Interpreting of financial disclosures is an important task with many applications. Previous studies applied readability approach as well as bag-of-words approaches. Bag-of-words approaches can include dictionary-based methods and machine-learning methods. While bag-of-words methods can examine large amounts of documents, collocation of words is usually not considered due to the computational complexity; without collocation of words, specific meanings, such as the suspension of dividend, is not extracted by bag-of-words methods.

This paper presents a novel approach to identify specific phrases in a financial disclosure that conveys special meanings to financial analysts and investors. Rather than a bag-of-words approach where words are counted without collocation, this approach uses expert knowledge of how important messages are conveyed in a financial document. Specifically, when a crisis such as COVID-19 pandemic occurs, firms may have to suspend or withdraw dividends or stock repurchase programs. These disclosures often use phrases such as "suspend dividend" or "cancel stock repurchase."

This study helps to evaluate the effectiveness of the approach on a sample of 1,414 8-K filing documents of U.S. companies in the first three months of 2020, when the COVID-19 pandemic started to cause a financial impact to these public companies. The study evaluated the accuracy with different numbers of characters allowed in the regular expression pattern. The results show that this approach is able to achieve 98.4% of accuracy.

There are limitations to this study and future studies should address these limitations. One limitation is that the sample came from 8-Ks discussing COVID-19 in the first

three months of 2020. While this is an extremely important event, future studies should evaluate whether this approach can be effectively applied to other samples. Another limitation is that a financial disclosure's legal disclaimers can cause false positives; a future study can incorporate a filter to remove text in the legal disclaimer section. Yet another limitation is that the study only examined the phrase "suspend…dividend" or "suspend…purchase." There are other important messages that can lead to changes in decision making by an investor or analyst. For example, resume of dividend or even increase in dividend. Future studies should examine the applicability of the regular expression method to other phrases.

REFERENCES

[1] Azar, A. M. Determination that a Public Health Emergency Exists. January 31, 2020. Retrieved from https://www.phe.gov/emergency/news/healthactions/phe/Pages/2019-nCoV.aspx

[2] Bird, A., & Karolyi, S. A. (2016). Do institutional investors demand public disclosure?. *The Review of Financial Studies*, *29*(12), 3245-3277.

[3] Bisong E. (2019) Google Colaboratory. In: *Building Machine Learning and Deep Learning Models on Google Cloud Platform*. Apress, Berkeley, CA. https://doi.org/10.1007/978-1-4842-4470-8_7

[4] Bonsall IV, S. B., Leone, A. J., Miller, B. P., & Rennekamp, K. (2017). A plain English measure of financial reporting readability. *Journal of Accounting and Economics*, 63(2-3), 329-357.

[5] Brigham, E. F., & Houston, J. F. (2021). *Fundamentals of financial management*. Cengage Learning.

[6] Chapman, K. L., Reiter, N., White, H. D., & Williams, C. D. (2019). Information overload and disclosure smoothing. *Review of Accounting Studies*, 24(4), 1486-1522.

[7] Cui, M., Bai, R., Lu, Z., Li, X., Aickelin, U., & Ge, P. (2019). Regular expression based medical text classification using constructive heuristic approach. *IEEE Access*, 7, 147892-147904.

[8] de Souza, J. A. S., Rissatti, J. C., Rover, S., & Borba, J. A. (2019). The linguistic complexities of narrative accounting disclosure on financial statements: An analysis based on readability characteristics. *Research in International Business and Finance*, 48, 59-74.

[9] Frankel, R. M., Jennings, J. N., & Lee, J. A. (2021). Disclosure Sentiment: Machine Learning vs Dictionary Methods. *Management Science*, forthcoming.

[10] Gleason, C., Ling, Z., & Zhao, R. (2020). Selective disclosure and the role of Form 8-K in the post-Reg FD era. *Journal of Business Finance & Accounting*, *47*(3-4), 365-396.

[11] He, J., & Plumlee, M. A. (2020). Measuring disclosure using 8-K filings. *Review of Accounting Studies*, 25(3), 903-962.

[12] Iwatsuki, K., Boudin, F., & Aizawa, A. (2021). Extraction and evaluation of formulaic expressions used in scholarly papers. *Expert Systems with Applications*, 115840.

[13] Lerman, A., & Livnat, J. (2010). The new Form 8-K disclosures. *Review of Accounting Studies*, *15*(4), 752-778.

[14] Loughran, T., & McDonald, B. (2011). When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks. *The Journal of Finance*, 66(1), 35-65.
[15] Loughran, T., & McDonald, B. (2016). Textual analysis in accounting and finance: A survey. *Journal of Accounting Research*, 54(4), 1187-1230.
[16] Mazur, M., Dang, M., & Vega, M. (2021). COVID-19 and the march 2020 stock market crash. Evidence from S&P1500. Finance Research Letters, 38, 101690.
[17] McDonald, B. (2019, January). *Stage One 10-X Parse Data.* University of Notre Dame Software Repository for Accounting and Finance. https://sraf.nd.edu/data/stage-one-10-x-parse-data/
[18] McMullin, J. L., Miller, B. P., & Twedt, B. J. (2019). Increased mandated disclosure frequency and price formation: evidence from the 8-K expansion regulation. *Review of Accounting Studies*, *24*(1), 1-33.
[19] Nguyen, B. H., & Huynh, V. N. (2020). Textual analysis and corporate bankruptcy: A financial dictionary-based sentiment approach. *Journal of the Operational Research Society*, 1-20.
[20] Rubin, A., Segal, B., & Segal, D. (2017). The interpretation of unanticipated news arrival and analysts' skill. *Journal of Financial and Quantitative Analysis*, *52*(4), 1491-1518.
[21] Securities and Exchange Commission (SEC) (2012). Investor Bulletin: How to Read an 8-K. Accessed December 31, 2021. Available at https://www.sec.gov/investor/pubs/readan8k.pdf
[22] Segal, B., & Segal, D. (2016). Are managers strategic in reporting non-earnings news? Evidence on timing and news bundling. *Review of Accounting Studies*, *21*(4), 1203-1244.
[23] Steinbart, P. J. (1987). The construction of a rule-based expert system as a method for studying materiality judgments. *Accounting Review*, 97-116.
[24] Zhao, X. (2017). Does information intensity matter for stock returns? Evidence from Form 8-K filings. *Management Science*, *63*(5), 1382-1404.

Impacts of Tax Regulation Compliance for Virtual Products

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ABSTRACT

This paper aims at investigating the moderation effects that influencing users' intention to comply with international e-commerce taxation regulations for digital products. Specifically, it first develops a research model to investigate the moderation effects of tax regulation compliance for virtual products at both macro level and micro level from the customers' point of views. Then, a set of propositions are developed by deriving the impacts and relationships from this research model. A survey is adopted to collect data for further statistical data analysis. Finally, the theoretical, managerial and practical implications are also presented.

Keywords: Virtual Products, Tax Regulation Compliance, Propositions

INTRODUCTION

With the Internet facilitating global businesses, organizations across world have taken advantages of the information and communication technologies to access new customers and open new global markets. Meanwhile, taxation regulations for the international e-business are important to organizations when there are transactions across countries. The compliance of tax regulations trade agreements, payment methods, exchange rates play very important role.

In the United States, trade policies for international e-business transactions are free trade agreements, which was first developed in 2000. However, there are issues that have not been addressed in these agreements in regard to digital goods and digital services. Due to the nature of digital goods and services across boards transactions, international electronic business transactions need to be protected by the tax regulations. Current tax regulations for digital products rely on narrow interpretations of intellectual property laws.

Some literatures indicated the importance of develop the tax regulations for new digital goods and services [4][7]; however, little focus is on the compliance of these tax regulations. In this research, we try to bridge the gap by investigating the intentions of compliance on tax regulations for digital products in international electronic transactions.

THEORETICAL MODEL

Figure 1 illustrates the conceptual model to reflect the factors that influencing the intention to comply with international e-commerce taxation regulations for digital products. The impact factors include seller locations, types, prices, exchange rates and payment methods of digital products, as well as existing e-commerce taxation regulations for brick-and-mortar. The

moderate factors including macro factors (such as economy, culture and policy) and micro factors (such as age, gender and education level) are also analyzed.

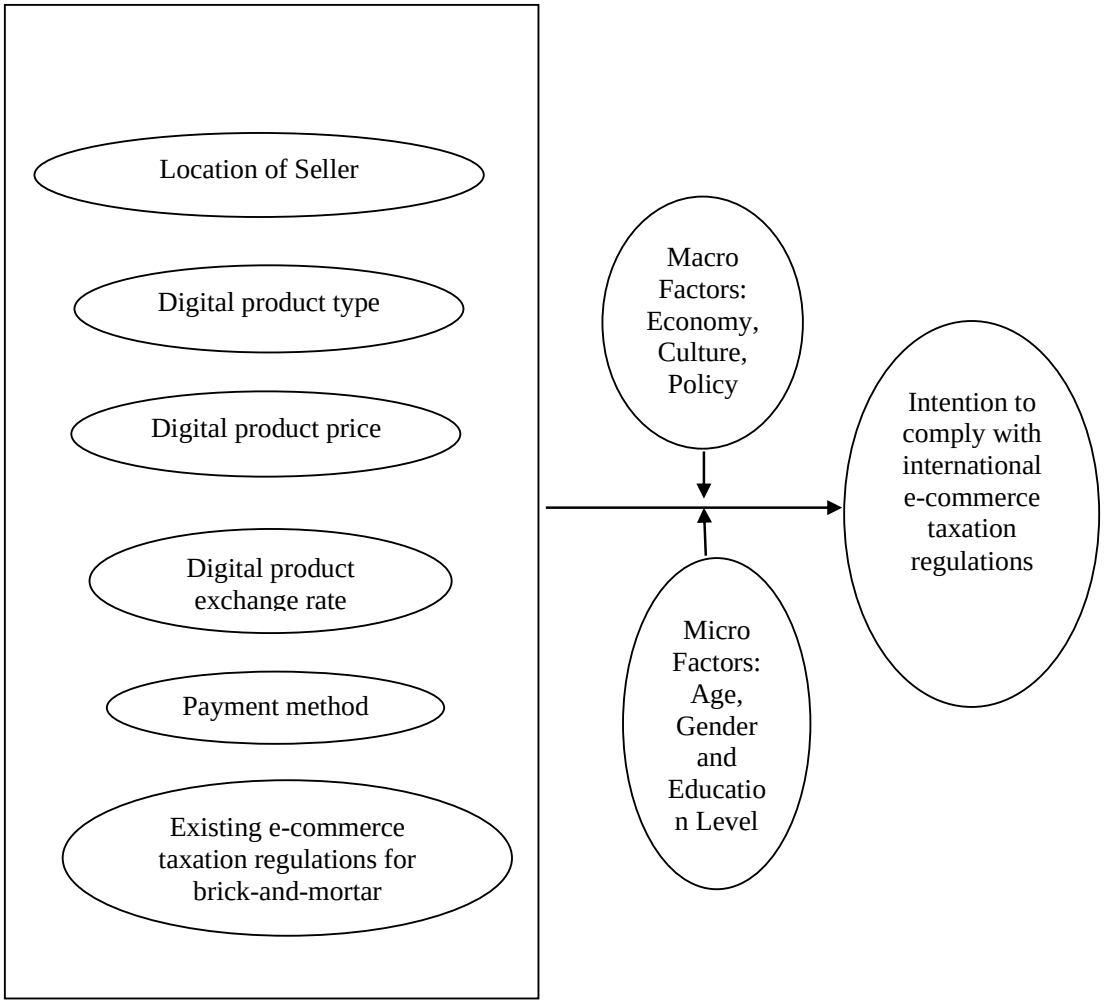

Figure 1. Research Model to Assess Tax Regulation Compliances

Social factor indicates how a company engages in the digital product commerce. This factor also relates to cultural and policies in the export and import countries. The policies and cultural in these countries would have impact on the users' intention to comply international e-commerce taxation regulations via existing e-commerce regulation, digital product types, prices, exchange rates and payment methods [11][12]. As a result, we propose the following propositions:

Proposition 1a: Social factor has moderation effect on the relationship between seller's location and human's intention to comply with the e-commerce tax regulation.

Proposition 1b: Social factor has moderation effect on the relationship between product types and human's intention to comply with the e-commerce tax regulation.

Proposition 1c: Social factor has moderation effect on the relationship between product prices and human's intention to comply with the e-commerce tax regulation.

Proposition 1d: Social factor has moderation effect on the relationship between exchange rates and human's intention to comply with the e-commerce tax regulation.

Proposition 1e: Social factor has moderation effect on the relationship between payment methods and human's intention to comply with the e-commerce tax regulation.

Proposition 1f: Social factor has moderation effect on the relationship between existing international e-commerce taxation regulations that brick-and-mortar commerce engages and human's intention to comply with the e-commerce tax regulation.

Economic Factor: To maximize profit is one of the most important objectives for most organizations. However, in most countries, market economy is influenced by their governmental regulations [5]. The location, product price, exchange rate and payment method are influenced by economic factor. Due to the nature of digital products, the businesses would need to have different tax regulations than their standard brick-and-mortar businesses. However, existing companies still comply with existing international commercial regulations for both digital and brick-and-mortar businesses [4]. Therefore, we propose the following propositions that:

Proposition 1a: Economic factor has moderation effect on the relationship between seller's location and human's intention to comply with the e-commerce tax regulation.

Proposition 1b: Economic factor has moderation effect on the relationship between product types and human's intention to comply with the e-commerce tax regulation.

Proposition 1c: Economic factor has moderation effect on the relationship between product prices and human's intention to comply with the e-commerce tax regulation.

Proposition 1d: Economic factor has moderation effect on the relationship between exchange rates and human's intention to comply with the e-commerce tax regulation.

Proposition 1e: Economic factor has moderation effect on the relationship between payment methods and human's intention to comply with the e-commerce tax regulation.

Proposition 1f: Economic factor has moderation effect on the relationship between existing international e-commerce taxation regulations that brick-and-mortar commerce engages and human's intention to comply with the e-commerce tax regulation.

Location of the seller business influences firms' intention to comply with taxation regulations. Some countries are in favor of trading agreements, while others may not abide with any tax regulations which make their products expensive [10].

Product type is influenced by economic and political factors. It also impacts on firms' intention to comply with taxation regulations. Some products might receive tax treatments while others might not. Some importing companies might not be able to meet the tax requirements demands due to lack of information technologies for the digital products. Some governments might also change tax regulations to protect domestic companies against foreign competitive [8][9].

Price of products is influenced by economic and political also impact on firms' intentions to comply with taxation regulations in the digital international business. Some countries might increase tax rates for foreign products to make their domestic products more competitive [2].

Payment method is influenced by economic, political and cultural factors. It also impacts firms' intention to comply international tax regulations in the digital products. Payment methods involve credit cards, checks, and/or cash etc. For medium to large size companies, they will accept credit cards rather than checks and cash. The current economic system can determine payment agreements. For example, medium to large companies can negotiate with transaction fees, interest rates etc. [1].

Exchange rate plays an important role in the international e-commerce tax regulation, and is influenced by economic, political and cultural factors [3]. It also impacts firms' intentions to comply with the international tax regulations for digital products. A favorable exchange rate can make the export digital products more affordable [6].

Therefore, we propose the following propositions:

Proposition 3a: Seller's location has positive impact on organizations' intention to comply with the e-commerce tax regulations for digital products.
Proposition 3b: Product type has positive impact on organizations' intention to comply with the e-commerce tax regulations for digital product types.

Proposition 3c: Product price. has positive impact on organizations' intention to comply with the e-commerce tax regulations for digital product prices.

Proposition 3d: Product exchange rate has positive impact on organizations' intention to comply with the e-commerce tax regulations for digital product exchange rates.

Proposition 3e: Product payment method has positive impact on organizations' intention to comply with the e-commerce tax regulations for digital product payment methods.

Proposition 3a: Existing international e-commerce taxation regulations that brick-and-mortar commerce engages has positive impact on organizations' intention to comply with the e-commerce tax regulations for digital products.

METHODOLOGY

A questionnaire was developed to assess these factors shown in Figure 1. There are twenty questions were adopted and modified based on previous validated research. Specifically, the social factor is assessed via Sweidan [12], economic factor from Frenkel [4], existing international e-commerce tax regulation for brick-and-mortar engagement from Khadem [8], price of digital products from Brown [2], payment method from Birkner [1], exchange rate from Dabrowski [3]. A five-point likerly scale is used with five (Strongly agree) to one (Strongly disagree). Four (Agree), three (neutral), and two (Disagree) are in between.

CONCLUSIONS

This research aims at investigating the impact factors on firms' intention to abide with international e-commerce tax regulations when importing and exporting digital goods and services. These factors include independent variables such as seller' location, product type, product price, exchange rate, payment method, and existing international e-commerce taxation regulations that brick-and-mortar commerce engages. The moderation impacts on macro (economy, culture, policy) and micro (age, gender, education level) levels are also analyzed. The current research has developed the conceptual model as well as hypotheses.

Questionnaires also have been developed to quantitatively measure these factors in the conceptual model. The future research will be focusing on data collection from firms using the developed questionnaire. Structural equation modeling will be used to perform data analysis and derive findings. The results of this research will help policy makers in governments when they make decisions on tax regulations on digital products' global business. Theoretical, managerial and practical implications will also be presented.

REFERENCES

[1] Birkner, C. Big businesses think small. *Marketing News*, 2012, 46(6), 12–16.
[2] Brown, E. Internet law in the courts. *Journal of Internet Law*, 2016, 19(12), 21–23.
[3] Dabrowski, M. EU cooperation with non-member neighboring countries: The principle of variable geometry. *CASE Network Reports*, 2013, 119(1), 1–67.
[4] Frenkel, J. Something's gotta give: Origin-based e-commerce sales tax. *Brooklyn Journal of Corporate, Financial & Commercial Law*, 2017, 12(1), 133–159.
[5] Goentoro, E. Strategy implementation as intervening for company's resources and regulations in order to form business performance. *CLEAR International Journal of Research in Commerce & Management*, 2016, 7(11), 93–96.
[6] Gorodnichenko, Y., & Talavera, Price setting in online markets: Basic facts, international comparisons, and cross-border integration. *American Economic Review*, 2017, 107(1), 249–282.
[7] Hoopes, J. L., Thornock, J. R., & Williams, B. M. Does use tax evasion provide a competitive advantage to e-tailers? *National Tax Journal*, 2016, 69(1), 133–168.
[8] Khadem, N. Manufacturers in trouble. *BRW*, 2011, 33(34), 1-12.
[9] Kristof, K., & Milstead, D. 10 Great stock from around the world. *Kiplinger's Personal Finance*, 2015, 69(8), 46–50.
[10] Merz, J., Overesch, M., & Wamser, G. The location of financial sector FDI: Tax and regulation policy. *Journal of Banking & Finance*, 2017, 78(1), 14–26.
[11] Pezzola, A. States in the customs house: Institutional reforms and structural change in Mexican trade policy. *International Studies Quarterly*, 2013, 57(2), 341–355.
[12] Sweidan, O. D. The influence of political regime vs political instability on real output. *Journal of Economic Studies*, 2017, 44(1), 154–167.

INTEGRATING SUPER EFFICIENCY AND CROSS EFFICIENCY DEA METHODS FOR RANKING EFFICIENT DECISION-MAKING UNITS

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ABSTRACT

Data envelopment analysis (DEA) method was developed to effectively identify the frontier decision-making units (DMUs). But the conventional DEA (C-DEA) shows several intrinsic weaknesses. To overcome these weaknesses, several methods extending the C-DEA are proposed. Among them, the cross-evaluation DEA (CE-DEA) and super-efficiency DEA (SE-DEA) are considered good alternatives to the C-DEA. Each of these two methods also reveals its own weaknesses, so a few methods based on the CE-DEA are proposed to complement the shortcomings of these two methods. This paper integrates these two methods to improve ranking efficient DMUs beyond the original methods.

Keywords: Decision-making unit, Data envelopment analysis, Cross evaluation, Super efficiency

INTRODUCTION

Data envelopment analysis (DEA) is one of the methodologies that have been widely used to evaluate the relative efficiency of a set of peer organizations called decision-making units (DMUs) that use multiple inputs to produce multiple outputs. DEA has been widely accepted as an effective technique since DEA models need not recourse to the exact behavior function of those organizations regarding the transformation of multiple inputs to outputs. DEA was proposed by Charnes et al. [2], who demonstrate how to change a fractional linear measure of efficiency into a linear programming (LP) format. DEA defines relative efficiency as the ratio of the sum of weighted outputs to the sum of weighted inputs. The non-parametric approach solves an LP formulation for each DMU, and the weights assigned to each linear aggregation are the results of the corresponding LP. The DMUs in DEA to be assessed should be relatively homogeneous. As the whole technique is based on a comparison of each DMU with all the remaining ones, a considerable large set of DMUs is necessary for the assessment to be meaningful (Meza & Jeong [14], Ramanathan [16]). DEA eventually determines which of the DMUs make efficient use of their inputs and produce most outputs and which do not. Thus, the DEA models classify DMUs into two groups, which would separate efficient DMUs from inefficient DMUs.

DEA produces a single, comprehensive measure of performance for each DMU. The best ratio among all the DMUs would identify the most efficient DMU, and every other DMU would be rated by comparing its ratio to the best one. However, a weakness of the conventional DEA(C-DEA)-based assessment is that a considerable number of DMUs out of the set of DMUs to be

rated are classified as efficient. It may suffer from a lack of discrimination immensely. The C-DEA allows each DMU to be evaluated with its most favorable weights due to its nature of the self-evaluation. Thus, the C-DEA model may even ignore unfavorable inputs/outputs to maximize self-efficiency. To remedy this deficiency, the cross-evaluation DEA (CE-DEA) method is suggested by Sexton et al. [17] as a DEA extension to rank DMUs with the main idea of using DEA to do the peer evaluation, rather than DEA's pure self-evaluation. Sexton et al. [17] construct a CE matrix consisting of two evaluation results, the self-evaluation and the peer evaluation. It can usually provide a full ranking for the DMUs to be evaluated and eliminates unrealistic weight schemes without requiring the elicitation of weight restrictions from application area experts (see Anderson et al. [1]). Due to its enhanced discriminating power, the CE evaluation has found a significant number of applications in the DEA literature (see Gavgani and Zohrehbandian [6], Hou et al. [9], Lee [11], Liang et al. [12], Liu et al. [13], Wang and Chin [18])

There have been two critical issues facing the CE method application. The first issue is the proportion/percentage of self-evaluation in computing the CE score (CES). Doyle and Green [5] eliminate diagonal elements in the CE matrix to calculate CESs, which implies the weight of self-evaluation included in the resulting CESs is zero. Several researchers suggest that the percentage of self-evaluation be 1/N, where 'N' denotes the number of DMUs being evaluated. The second issue is that, as Doyle and Green [5] note in their paper, the non-uniqueness of CESs due to the often-present multiple optimal DEA weights. To remedy the weaknesses of CE-DEA, Dole and Green [5] suggest that secondary goals such as **aggressive** and **benevolent** models be introduced in the CE evaluation to improve the discriminating power of CE. These two models show some computational difficulties. Later, Wang and Chin [18] propose the **neutral** CE-DEA model for CE evaluation to avoid the problem of choosing between these two different formulations. They [18] point out that there have been no attempts so far to test if the two different formulations give the same rankings or not. To avoid the difficulty in choosing between the two different formulations, they propose a neutral CE-DEA model that determines one set of input and output weights for each DMU without being aggressive or benevolent to the others. Thus, the resulting CESs would be more neutral. There have not been many works of literature that consider, compare, and apply these CE models to evaluate the units. Hong and Jeong [7] show that CE-DEA does not yield consistent rankings, mainly when CE-DEA is applied to efficient DMUs only. They [7] observe that the top-ranked DMU rated by CE-DEA with all DMUs evaluated is frequently replaced by the lower-ranked DMUs when only efficient DMUs are evaluated. They also claim that the CE-DEA might not be an appropriate method for the decision-makers to evaluate and select the best DMU among the efficient DMUs.

The idea of super-efficiency (SE), mainly developed by Anderson and Peterson [1], is that a DMU under evaluation is not included in the reference set of the C-DEA models and then with its inclusion. Notably, the SE-DEA model has significance for discriminating among efficient DMUs, as Anderson and Peterson [1] demonstrate. Charnes et al. [3] use the SE-DEA model to study the sensitivity of the efficiency classification. See also Deng et al. [4] and Nayebi and Lotfi [15] for further applications of SE-DEA. But the critical issue of using the model is that the adjacent DMUs decide the SE score (SES) of an efficient DMU, so it would be unreasonable for DMUs to be ranked by the SESs.

This study aims to present and demonstrate how to integrate C-, CE-, and SE-DEA techniques so that the decision-makers take advantage of the strengths of each DEA model by eliminating some weaknesses. The contribution of this paper is that the proposed procedure by this study could provide a valuable tool that would help the decision-makers evaluate DMUs more accurately, efficiently, and effectively.

This paper is organized as follows. In the following sections, we provide a brief background for C-, CE-, and SE-DEA. Then, the proposed procedure of combining these three DEA methods is discussed. Next, we demonstrate our proposed approach using numerical examples, followed by conclusions.

DATA ENVELOPMENT ANALYSIS METHODS

Conventional DEA

The mathematical model of C-DEA, which is called a multiplier DEA (m-DEA) model, may be stated as (see Zhu [20])

Objective Function: Maximize the efficiency rating θ for DMU_k

$$max\ \theta = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \tag{1}$$

It is subject to the constraint that when the same set of u and v coefficients (or weights) is applied to all other DMUs being compared, no DMU will be more than 100% efficient as follows:

$$DMU_j \qquad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \forall j = 1, 2, \dots\ N \tag{2}$$

$$u_1, \dots, u_s > 0\ and\ v_1, \dots, v_m \geq 0,$$

where

N = number of DMUs being compared in the DEA analysis
θ = efficiency rating of the DMU_k being evaluated by DEA
y_{rj} = amount of output r generated by DMU_j
x_{ij} = amount of input i used by DMU_j
i = number of inputs used by the DMUs
r = number of outputs generated by the DMUs
u_r = coefficient or weight assigned by DEA to output r
v_i = coefficient or weight assigned by DEA to input i

The above model given by (1) and (2) can be transformed to the following linear programming (LP) problem, which is called a CRS (Constant Returns to Scale) m-DEA model:

$$max\ ES_k = \sum_{r=1}^{s} u_r y_{rk}, \tag{3}$$

subject to

$$\sum_{i=1}^{m} v_i x_{ik} = 1, \tag{4}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1, \dots, N, \tag{5}$$

$$u_r, v_i \geq 0, r = 1 \dots, s; i = 1 \dots, m$$

Let ES_k^* denote the optimal value of the objective function corresponding to the optimal solution (u^*, v^*). DMU_k is said to be efficient if $ES_k^* = 1$. DEA models can be either input-oriented or output-oriented, depending upon the rationale for conducting DEA. The model given by (3)-(5) is called an input-oriented CCR model, and ES_k^* is called CRS efficient score (ES).

Cross Efficiency DEA

The C-DEA allows each DMU to be evaluated with its most favorable weights due to its nature of self-evaluation. The cross-efficiency (CE) method was suggested as a DEA extension to rank DMUs, with the main idea of using DEA to do peer evaluation rather than in pure self-evaluation. It consists of two phases. The first one is the self-evaluation phase (Phase I), where DEA scores are calculated using the model by (3)-(5). In the second phase (Phase II), the weights/multipliers arising from Phase I are applied to all DMUs to get the cross-efficiency score (CES) for each of DMUs. In Phase I, let E_{kk} represent the DEA score for DMU_k, which will be obtained from

$$max\ E_{kk} = \sum_{r=1}^{s} u_{rk} y_{rk}, \tag{6}$$

subject to

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1, \tag{7}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 0, \qquad j = 1, \dots, N, \tag{8}$$

$$u_{rk}, v_{ik} \geq 0, r = 1 \dots, s; i = 1 \dots, m$$

Now, the cross efficiency of DMU_j, using the weights that DMU_k has chosen in the model by (6)-(8), is given by

$$E_{kj} = \frac{\sum_{r=1}^{s} u_{rk}^{*} y_{rj}}{\sum_{i=1}^{m} v_{ik}^{*} x_{ij}}, k \text{ and } j = 1, \ldots, N, k \neq j. \quad (9)$$

DMU_j is called a rated DMU, whereas DMU_k is called a rating DMU. Then, Doyle and Green [5] use Eq. (9) to set up the CE matrix that consists of the self-evaluation value, E_{kk}, in the leading diagonal and peer-evaluation value, E_{kj}, in the non-diagonals. By averaging E_{kj} in (9) without the leading diagonal, Doyle and Green [9] propose the CES for DMU_k, which is defined as

$$\bar{E}_{k(p)} = \frac{1}{N-1} \sum_{j \neq k}^{N} E_{jk}. \quad (10)$$

In (10), '*p*' stands for peer evaluation. In the meantime, some authors, such as Zhu [20] and Hong and Jeong [7], include self-evaluation value in averaging the appraisals by itself and peers as follows:

$$\bar{E}_{k(s+p)} = \frac{1}{N} \sum_{j=1}^{N} E_{jk}. \quad (11)$$

In (11), '*s*' stands for self-evaluation. No literature explicitly has suggested the appropriate proportions of self-evaluation and peer-evaluation in deciding the CE scores (see Hong and Jeong [8]). To solve the dilemma between the above two equations, (10) and (11), let β denote the proportion of self-evaluation evaluation. We propose the following equation to combine (10) and (11)

$$\bar{E}_{\kappa} = \beta * E_{\kappa\kappa} + \frac{(1-\beta)}{N-1} \sum_{\substack{\omega=1, \\ \omega \neq \kappa}}^{N} E_{\omega\kappa}. \quad (12)$$

Note that Eqs. (10) and (11) can be eliminated by a more generalized expression in (12) on the proportion of self- and peer-evaluation in computing the average of cross efficiency. We call the above model in (6)-(12) as the **regular** CE-DEA.

As Doyle and Green [5] note, the non-uniqueness of CE scores due to the often-present multiple optimal DEA weights. They [5] suggest the aggressive and benevolent formulations for CE evaluation to resolve this problem. As mentioned before, the neutral CE-DEA model is developed by Wang and Chin [18] to avoid the difficulty in choosing between the two different formulations. The neutral CE-DEA model determines one set of input and output weights for each DMU without being aggressive or benevolent to the others. Thus, the neutral CE scores will be more neutral, and its model is formulated as follows:

$$Maximize\ w \quad (13)$$

subject to

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1, \tag{14}$$

$$\sum_{r=1}^{s} u_{rk} y_{rk} = E_{kk}^{*}, \tag{15}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 0, \qquad j = 1, \dots, N; j \neq k, \tag{16}$$

$$u_{rk} y_{rk} \geq w, \qquad r = 1, \dots, s \tag{17}$$

$$w \geq 0, u_{rk}, v_{ik} \geq 0, r = 1 \dots, s; i = 1 \dots, m.$$

The above model can be interpreted as "DMU_k searches for a set of input and output weights to maximize its efficiency as a whole and at the same time to make its own every output being efficient as possible to produce sufficient efficiency as an individual."

But, as long as the diagonal elements in the cross-evaluation matrix contain ES of the self-evaluation, all CE-DEA methods, such as regular, aggressive, benevolent, and neutral, do not reflect on the differences in efficiency or performance of efficient DMUs. To remedy this weakness of CE-DEA models, the concept of SE is introduced in the following subsection.

Super Efficiency DEA

The super-efficiency score (SES) is obtained from the C-DEA model after a DMU under evaluation is excluded in the reference set of the C-DEA models, and the resulting model is called a SE-DEA model that has significance for discriminating among efficient DMUs. The SES for DMU_k is expressed as

$$max\, SES_k = \sum_{r=1}^{s} u_r y_{rk}, \tag{18}$$

subject to

$$\sum_{i=1}^{m} v_i x_{ik} = 1, \tag{19}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j \neq k, \tag{20}$$

$$u_r, v_i \geq 0, r = 1 \dots, s; i = 1 \dots, m.$$

In the above SE model, efficient DMUs are not compared to the same standard since the frontier constructed from the remaining DMUs changes for each efficient DMU to be rated. Consequently, the SESs of efficient DMUs are allowed to have higher values than 1. Jeong

and Ok [10] and Yu and Hou [19] maintain that the self-evaluation efficiency would not discriminate efficient DMUs and propose a modified cross-evaluation method using the SES. They demonstrate that their approach can determine efficient DMUs better than the CE-based methods. From (6)-(8), the CE approach based on the SES is expressed as

$$max\, SE_{kk} = \sum_{r=1}^{s} u_{rk} y_{rk}, \tag{21}$$

subject to

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1, \tag{22}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 0, \qquad j \neq k \tag{23}$$

$$u_{rk}, v_{ik} \geq 0, r = 1 \dots, s; i = 1 \dots, m$$

Now, the cross efficiency of DMU_j based on SES that is called **super-cross efficiency** (SCE) in this paper, is given by

$$SCE_{kj} = \frac{\sum_{r=1}^{s} u_{rk}^{*} y_{rj}}{\sum_{i=1}^{m} v_{ik}^{*} x_{ij}}, k \text{ and } j = 1, \dots, N, k \neq j. \tag{24}$$

To find an average value of (24), Jeong and Ok [10] assign a weight of ½ to the diagonal element for self-evaluation efficiency and weight of 1/{2*(N-1)} to each non-diagonal element for the peer evaluation efficiency. There must be some weaknesses in assigning these arbitrary weights. Thus, using (12), the following equation for the average SCE score (SCES) for DMU_{κ} is proposed:

$$\overline{SCE}_{\kappa} = \beta * SE_{\kappa\kappa} + \frac{(1-\beta)}{N-1} \sum_{\substack{\omega=1, \\ \omega \neq \kappa}}^{N} SE_{\omega\kappa}. \tag{25}$$

Now, this study extends the SE-DEA model to the neutral CE-based method. Using SE_{kk}^{*} from (21)-(23), the neutral CE formulation based on SE-DEA is

$$Maximize\, S \tag{26}$$

subject to

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1, \tag{27}$$

$$\sum_{r=1}^{s} u_{rk} y_{rk} = E_{kk}^{*}, \tag{28}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 0, \qquad j = 1, \dots, \Omega; j \neq k, \tag{29}$$

$$u_{rk} y_{rk} \geq S, \qquad r = 1, \dots, s \tag{30}$$

$$w \geq 0, u_{rk}, v_{ik} \geq 0, r = 1 \dots, s; i = 1 \dots, m.$$

Using u_{rk} *and* v_{ik} after solving (26)-(30) for neutral SCE, SCE_{kj} in (24) is obtained. In the following section, C-DEA and two models, regular and neutral, for CE-DEA and SCE-DEA, are applied to solve two numerical examples.

NUMERICAL EXAMPLES

First, we consider the numerical example illustrated by Liang et al. [12], where there are five DMUs. The data for each DMU consists of three inputs denoted by (x_{1k}, x_{2k}, x_{3k}) and two outputs (y_{1k}, y_{2k}), as shown in Table 1. In Table 2, ESs by C-DEA, CESs by CE-DEA, and SCES by SCE-DEA are reported with $\beta = 1/5$. From Table 2, we see that DMU #3 dominates all three inputs and one output (y_{2k}) and is ranked as #1 for all methods. In fact, all ESs, CESs, and SCESs rank the five DMUs consistently in the following sequence, DMU #3, DMU #2, DMU #4, DMU #5, and DMU #1. The effect of β, $0 \leq \beta \leq 1$, on these rankings, is none.

To further investigate the performance of the integrated methods, the data of Zhu [20], which are presented in Table 3, is used. In Table 3, there are fifteen (15) companies from the Top Fortune Global 500 list in 1995, three inputs: (i) assets ($ millions), (ii) equity ($ millions), and (iii) number of employees, and two outputs: (i) revenue ($ millions) and (ii) profit ($ millions). With β =1/15, ES, CES, and SCES, along with the corresponding ranks, are reported in Table 4. There are seven (7) efficient companies with a perfect ES of 1, and both CE-DEA models rank 'Sumitomo' and 'Exxon' as #1 and #2 efficient companies among them. In contrast, both SCE-DEA methods changed rankings of the two most efficient companies, 'Exxon' #1 and 'Sumitomo' #2.

TABLE 1. Five Decision-Making Units

DMU	Input			Output	
	x_{1k}	x_{2k}	x_{3k}	y_{1k}	y_{2k}
1	7	7	7	4	4
2	5	9	7	7	7
3	4	6	5	5	7
4	5	9	8	6	2
5	6	8	5	3	6

TABLE 2. Efficiency Score, Cross Efficiency Score & Super-cross Efficiency Score

DMU	C-DEA	CE-DEA		SCE-DEA	
	ES	Reg.	Neu.	Reg.	Neu.
1	0.6857	0.4473	0.4604	0.5387	0.5387
2	1.0000	0.8895	0.9215	0.9535	0.9535
3	1.0000	0.9571	0.9785	1.0785	1.0786
4	0.8572	0.5842	0.6231	0.6162	0.6162
5	0.8571	0.5185	0.5228	0.6057	0.6057

Reg.: Regular Neu.: Neutral

TABLE 3. Fifteen (15) Companies from Fortune Global 500 Companies List in 1995

DMU	Company	Input			Output	
		Assets	Equity	Employees	Revenue	Profit
1	Mitsubishi	91,920.6	10,950.0	36000	184,365.2	346.2
2	Mitsui	68,770.9	5,553.9	80000	181,518.7	314.8
3	Itochu	65,708.9	4,271.1	7182	169,164.6	121.2
4	General Motors	217,123.4	23,345.5	709000	168,828.6	6,880.7
5	Sumitomo	50,268.9	6,681.0	6193	167,530.7	210.5
6	Marubeni	71,439.3	5,239.1	6702	161,057.4	156.6
7	Ford Motor	243,283.0	24,547.0	346990	137,137.0	4139
8	Toyota Motor	106,004.2	49,691.6	146855	111,052.0	2662.4
9	Exxon	91,296.0	40,436.0	82000	110,009.0	6470.0
10	Royal Dutch/Shell	118,011.6	58,986.4	104000	109,833.7	6904.6
11	Wal-Mart	37,871.0	14,762.0	675000	93,627.0	2740.0
12	Hitachi	91,620.9	29,907.2	331852	84,167.1	1468.8
13	Nippon Life	364,762.5	2,241.9	89690	83,206.7	2426.6
14	Nippon T & T	127,077.3	42,240.1	231400	81,937.2	2209.1
15	AT&T	88,884.0	17,274.0	299300	79,609.0	139.0

Table 4 notes that both CE-DEA methods rank two efficient DMUs, 'General Motors' and 'Nippon Life,' lower than some of the inefficient DMUs, while both SCE-DEA methods rank one efficient DMU, 'General Motors,' lower than some of the inefficient DMUs. Now, after eight (8) inefficient DMUs being excluded, the seven efficient DMUs are evaluated with β =1/7, and the results are listed in Table 5. As mentioned earlier, Regular CE-DEA lists "Itochu' as the top spot, while Neutral CE-DEA still ranks 'Sumitomo' #1. But 'Exxon' grabs a #1 ranking again by both SCE-DEA methods. The notable observation is that 'Nippon Life,' ranked #10 from Table 4 and now #7 (the lowest ranks out of 7 efficient DMUs), is ranked #2 by both SCE-DEA. It can be observed that SCE-DEA models are more consistent in terms of ranking efficient DMUs than CE-DEA. For example, CE-DEA methods rank 'Exxon' as #2 for all DMUs, but as #5 and #3 for the efficient DMUs only.

TABLE 4. Efficiency Score, Cross Efficiency Score & Super-Cross Efficiency Score for Fifteen (15) Companies

DMU	Company	C-DEA		CE-DEA				SCE-DEA			
		ES	R	Reg	R	Neu	R	Reg	R	Neu	R
1	Mitsubishi	0.6628	*11*	0.4701	*9*	0.5019	*9*	0.5097	*10*	0.5097	*10*
2	Mitsui	1.0000*	*1*	0.6349	*5*	0.6549	*7*	0.6899	*7*	0.6899	*7*
3	Itochu	1.0000*	*1*	0.7027	*3*	0.8229	*3*	0.8426	*3*	0.8426	*3*
4	General Motors	1.0000*	*1*	0.5559	*8*	0.5483	*8*	0.6473	*9*	0.6473	*9*
5	Sumitomo	1.0000*	*1*	0.7776	*1*	0.9017	*1*	0.8791	*2*	0.8791	*2*
6	Marubeni	0.9720	*8*	0.6256	*6*	0.7428	*4*	0.7435	*4*	0.7435	*4*
7	Ford Motor	0.7372	*10*	0.3762	*11*	0.3750	*11*	0.4406	*11*	0.4406	*11*
8	Toyota Motor	0.5246	*12*	0.3210	*12*	0.3491	*12*	0.3556	*12*	0.3556	*12*
9	Exxon	1.0000*	*1*	0.7588	*2*	0.8627	*2*	0.8816	*1*	0.8816	*1*
10	Royal Dutch/Shell	0.8414	*9*	0.5871	*7*	0.6765	*5*	0.6854	*8*	0.6854	*8*
11	Wal-Mart	1.0000*	*1*	0.6648	*4*	0.6701	*6*	0.7063	*6*	0.7063	*6*
12	Hitachi	0.3861	*13*	0.2459	*13*	0.2533	*13*	0.2644	*13*	0.2644	*13*
13	Nippon Life	1.0000*	*1*	0.4585	*10*	0.4132	*10*	0.7176	*5*	0.7176	*5*
14	Nippon T & T	0.3486	*14*	0.2367	*14*	0.2498	*14*	0.2633	*14*	0.2633	*14*
15	AT&T	0.2704	*15*	0.1572	*15*	0.1582	*15*	0.1544	*15*	0.1544	*15*

TABLE 5. Efficiency Score, Cross Efficiency Score & & Super-Cross Efficiency Score for SEVEN Efficient Companies

DMU	Company	C-DEA		CE-DEA				SCE-DEA			
		ES	R	Reg	R	Neu	R	Reg	R	Neu	R
2	Mitsui	1.0000*	*1*	0.7419	*3*	0.6596	*4*	0.6329	*7*	0.6329	*7*
3	Itochu	1.0000*	*1*	0.8339	*1*	0.9034	*2*	0.8241	*4*	0.8241	*4*
4	General Motors	1.0000*	*1*	0.7315	*4*	0.5172	*6*	0.7194	*5*	0.7194	*5*
5	Sumitomo	1.0000*	*1*	0.8054	*2*	0.9345	*1*	0.8438	*3*	0.8438	*3*
9	Exxon	1.0000*	*1*	0.6788	*5*	0.7833	*3*	1.4613	*1*	1.4613	*1*
11	Wal-Mart	1.0000*	*1*	0.6412	*6*	0.6133	*5*	0.6721	*6*	0.6721	*6*
13	Nippon Life	1.0000*	*1*	0.6079	*7*	0.4464	*7*	1.0757	*2*	1.0757	*2*

Table 6 displays the effect of β on rankings for each method, where β changes between 0 and 1 with an increment of 0.1. For CE-DEA, except for the case of self-evaluation only, i.e., β =1, the impact of β is negligible. For SCE-DEA, the effect of β on rankings is significant for some DMUs, such as 'Sumitomo' and 'Wal-Mart.' The ranking for 'Sumitomo' starts from #6 for β =0.8, 0.9, and 1.0. Its rank continues to moves up, such as #4 for β =0.3, 0.4, 0.5, 0.6, 0.7. and #3 for β =0.1, 0.2. For β =0, i.e., for pure peer-evaluation only, 'Sumitomo' becomes the top efficient company by replacing the #1 company 'Exxon.' It implies that the ranking for

'Sumitomo' becomes more favorable as the self-evaluation decreases (or the proportion of peer-evaluation increases). On the contrary, the ranking for 'Wal-Mart' shows the opposite trend. Starting from #7, its ranking rises up to #4 as the proportion of self-evaluation increases. An interesting observation is that the rankings for all efficient companies change when the proportion of self-evaluation is zero, β =0. The rankings for four companies, 'Mitsui,' 'Itochu,' 'General Motors,' and 'Sumitomo,' move up, while for the rest three companies, 'Exxon,' Wal-Mart,' and 'Nippon Lite,' their rankings drop.

SUMMARY AND CONCLUSIONS

Several problems have appeared as DEA has been applied to various evaluation areas. The conventional DEA (C-DEA) evaluates DMUs in self-evaluation, allowing each DMU to rate its efficiency score with the most favorable weights to itself. Consequently, problems related to weak discriminating power have arisen as the applications of C-DEA advance since multiple DMUs frequently turn out to be efficient. Lack of discrimination power is the major weakness of the C-DMU. To remedy this weakness and increase the discrimination power, the cross-efficiency DEA (CE-DEA) and the super-efficiency DEA (SE-DEA) models have emerged. But these two methods also show some weaknesses.

This paper proposes a procedure of ranking efficient DMUs by integrating these two methods. To identify efficient DMUs, the C-DEA is applied. The two CE-DEA methods, regular and neutral, are applied for each efficient DMU to obtain the cross-efficiency scores (CESs) using the cross-evaluation matrix for each efficient DMU. For each DMU, the super efficiency score (SES) is obtained by applying SE-DEA. Then, using the cross-evaluation matrix, the average CE based on SES, called a super-cross efficiency score (SCES), is calculated for various values of β, the proportion of self-evaluation.

Using two numerical examples, this paper demonstrates that neutral CE-DEA and SCE-DEA models produce more consistent rankings than regular CE-DEA. Especially, SCE-DEA, after evaluating efficient DMUs, seems to yield more robust rankings than the CE-DEA models. Applying the proposed procedure would introduce another way of ranking DMUs and could be used as an essential tool for decision-makers to identify the most efficient units.

ACKNOWLEDGMENTS

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REFERENCES

References are available upon request from Hong.

TABLE 6. The Effect of Self-Evaluation Proportion, β, on the Rankings for SEVEN Efficient Companies

	Regular CE-DEA							**Neutral CE-DEA**						
β	Mitsui	Itochu	General Motors	Sumi-tomo	Exxon	Wal-Mart	Nippon Lite	Mitsui	Itochu	General Motors	Sumi-tomo	Exxon	Wal-Mart	Nippon Lite
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.9	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.8	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.7	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.6	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.5	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.4	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.3	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.2	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.1	3	1	4	2	5	6	7	4	2	6	1	3	5	7
0.0	3	1	4	2	5	6	7	4	2	6	1	3	5	7
	Regular SCE-DEA							**Neutral SCE-DEA**						
β	Mitsui	Itochu	General Motors	Sumi-tomo	Exxon	Wal-Mart	Nippon Lite	Mitsui	Itochu	General Motors	Sumi-tomo	Exxon	Wal-Mart	Nippon Lite
1	7	3	5	6	1	4	2	7	3	5	6	1	4	2
0.9	7	3	5	6	1	4	2	7	3	5	6	1	4	2
0.8	7	3	4	6	1	5	2	7	3	4	6	1	5	2
0.7	7	3	5	4	1	6	2	7	3	5	4	1	6	2
0.6	7	3	5	4	1	6	2	7	3	5	4	1	6	2
0.5	7	3	5	4	1	6	2	7	3	5	4	1	6	2
0.4	7	3	5	4	1	6	2	7	3	5	4	1	6	2
0.3	7	3	5	4	1	6	2	7	3	5	4	1	6	2
0.2	7	4	5	3	1	6	2	7	4	5	3	1	6	2
0.1	7	4	5	3	1	6	2	7	4	5	3	1	6	2
0.0	6	3	4	1	2	7	5	6	3	4	1	2	7	5

MODELING CLIMATE CHANGE THROUGH DNN AND LSTM

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ABSTRACT

Reputable data sources have shown that multiple factors are increasing both the air and the ocean temperatures which are contributing to significant climate change. Many of these factors are attributed to population- specifically overall population size, urban population size, educational level, life expectancy, poverty rate and population density. Additional attributes for which there are data include land usage types such as agriculture, farming, and forestry as well as energy consumption of both renewable and non-renewable sources. Furthermore, greenhouse gas emissions, which may contain CO2, methane, and nitrous oxide are also contributing factors. These factors are all believed to play a significant role in climate change. Through this analysis, we demonstrate how all these attributes have direct correlation to the increase in the global temperature which is a primary contributing factor to climate change. The data sources are Our World In Data (https://ourworldindata.org) and The World Bank Group (https://www.worldbank.org). The datasets are labeled by year, attribute, and country. Deep Neural Network (DNN) and Long Short-Term Memory Network (LSTM) models were built using Tensorflow and Keras to model the dataset features.

INTRODUCTION

Long short-term memory (LSTM) layers are used to create a model for climate change data. The data used is supplied by Our World In Data [9]. The initial and primary data source was used to build univariate LSTM based models that can make single predictions given the time-based data. Because climate change is believed to be caused by multiple sources, we also integrate the climate change factors data from The World Bank [15] to create a multivariate LSTM model that augments the primary data source. The World Bank lists 28 datasets as belonging to the climate change category. The climate change factor datasets include:

1. Access to electricity (% of population)
2. Agricultural land (% of land area)
3. Arable land (% of land area)
4. CO2 emissions (metric tons per capita)
5. Cereal yield (kg per hectare)
6. Electric power consumption (kWh per capita)
7. Forest area (% of land area)
8. Land area where elevation is below 5 meters (% of total land area)
9. Mortality rate, under-5 (per 1,000 live births)
10. Population growth (annual %)
11. Population living in areas where elevation is below 5 meters (% of total population)
12. poverty headcount ratio at $1.90 a day (2011 PPP) (% of population),
13. Primary completion rate, total (% of relevant age group)

14. Renewable energy consumption (% of total final energy consumption)
15. Urban population
16. Agriculture, forestry, and fishing, value added (% of GDP)
17. CO2 emissions (kt)
18. Energy use (kg of oil equivalent per capita)
19. Forest area (sq. km)
20. Methane emissions (kt of CO2 equivalent)
21. Nitrous oxide emissions (thousand metric tons of CO2 equivalent)
22. Population in urban agglomerations of more than 1 million (% of total population)
23. Population, total
24. Prevalence of underweight, weight for age (% of children under 5)
25. Renewable electricity output (% of total electricity output)
26. School enrollment, primary and secondary (gross), gender parity index (GPI),
27. Total greenhouse gas emissions (kt of CO2 equivalent)
28. Urban population (% of total population).

LSTMs were first proposed by Hochreiter and Schmidhuber [4]. The LSTM has a schematic of:

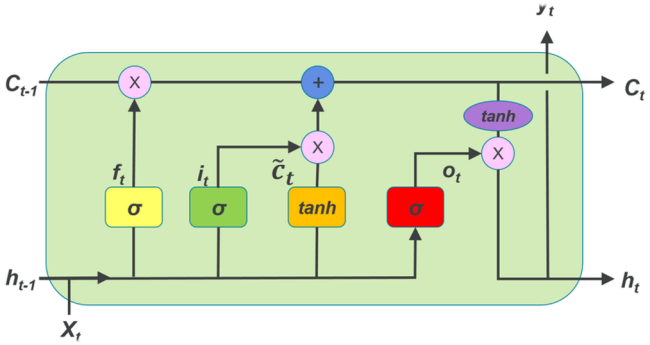

Fig. 1. LSTM Schematic

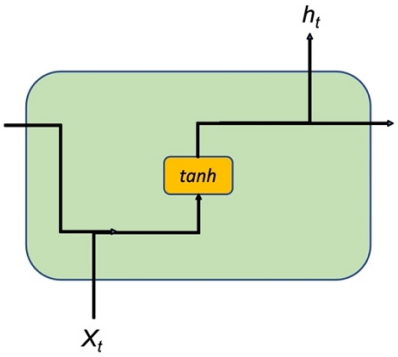

Fig. 2. Vanilla RNN

LSTMs are an improvement over the Recurrent Neural Network model [11]. LSTM greatly improves on the traditional RNN by using gates to control the problem of the vanishing gradient (and the exploding gradient). A standard RNN consists of one layer with a hyperbolic tangent (*tanh)* activation function. An activation function is used within a neural network to transform the data from one layer to another. LSTMs have a repeating module like RNNs but instead of one layer as in the RNN there are four layers. In Figure 1, the four layers are the four colored boxes, yellow σ, green σ, orange *tanh* and red σ. The line running across the top of the LSTM (C_{t-1} to C_t) is considered the cell-state. The cell-state runs across all of the LSTM cells and only minor changes are made to it (pink *x*, blue +). The four layers each contribute to either adding or removing state from an LSTM cell. The first layer (yellow σ) is called the forget-gate. The forget-gate outputs a value between 0 and 1. The next layer (green σ) is called the input-gate and its purpose is to decide which values will get updated. The next layer (orange *tanh*) creates new candidate values that will be considered for updating the cell's state. The new cell-state becomes the old cell-state multiplied by the forget-gate plus the scaled values computed by the second and third layers which are added to the cell-state. The last step (and last layer) uses the output-gate (red σ). The cell-state goes through a *tanh* function which scales the values between -1 and 1 and are then multiplied by the output value from the output-gate. There are variations on the actual implementation, gates and steps of an LSTM cell depending on who developed it.

The vanishing gradient problem is a common problem with RNNs. The vanishing gradient problem is encountered when an update happens to a RNN's weights. The vanishing aspect occurs when the update is proportional to the partial derivative of the error function causing the weight to remain unchanged. A frequent cause of the vanishing gradient problem is the *tanh* function which results in values in the range between -1 and 1. Furthermore, backpropagation (backward propagation of errors) computes the gradients via the chain-rule. When these small numbers are used in the beginning layers of an RNN, then the training process either fails or takes a very long time to converge. Various techniques have been proposed to overcome the vanishing gradient problem including avoiding using a gradient based activation function.

The number of hidden layers within an artificial neural network (ANN) model typically defines whether a model is a deep neural network DNN. Although there is debate on exactly how many layers constitutes a DNN, this writer will use the common definition that a model must have at least two hidden layers between the input and output layers. Taking the argument further, an LSTM cell consists of 4 layers. Does that mean that any model with an LSTM layer is by definition a DNN? One may say that all of our models fall into the broad DNN definition.

LITERATURE REVIEW

In Desai, Hulme, Lempert and Pielke [2], the authors describe the current needs for better climate prediction models in order to provide for and address the vulnerability of climate- influenced decisions. Zhang, Wang, Dong, Zhong and Sun [17] used an LSTM model for the use of predicting sea surface temperatures on the coastal seas of China. They focused on the specific coastal areas given that they have greater fluctuation in temperatures as opposed to areas further out in the ocean. Zhang et al. [17], Yao, Huang and Jia [16], and Li et al. [6] all use the LSTM to predict wind speed. Zhang et al. [17] used both LSTM and bidirectional LSTM models to experiment and

evaluate the prediction of stochastic wind speed to be used in a wind farm for generating electricity. Yao et al. [16] developed a Fuzzy-Rough-Set LSTM to predict the short-term prediction of the wind speed, again for the benefit of optimizing the generation of electricity, while Harilal, Singh and Bhatia [3] show how statistical downscaling fails to provide climate change predictions better than convolutional neural networks (CNN), residual dense block (RDB) and LSTMs. The authors capture spatiotemporal dependencies to improve precipitation predictions over India using a convolutional LSTM that includes weather related variables like humidity, atmospheric pressure, wind-velocity and more. All of the additional features the authors have chosen are not directly attributable to human behavior. Similarly, in Chou, Park, Chou [1], the authors use a ConvLSTM model using spatiotemporal dependencies between the climatic variables. Finally, Lopez and Sekeran [7] combine climate change data that influences the transmission of the vector borne diseases.

METHODOLOGY

Exploratory Data Analysis and Data Preprocessing

The primary data source [9] is given in the date range of January 15, 1880 to November 11, 2021 (as of the time of this writing). Within this dataset the "World" entity values were used and were assigned to the temperature anomaly column as our univariate data source. This dataset states that the temperature anomaly values are: "The combined land-surface air and sea-surface water temperature anomaly is given as the deviation from the 1951 – 1980 mean" [9]. Based on this description of the dataset, there has already been some pre-processing of the dataset. The date values are given as the 15th of each month from the years 1880 to 2021. Because the data had been pre-processed, we chose to use Scikit-Learn's [12] *MinMaxScalar* to normalize the data between 0 and 1. Although the Keras [5] / Tensorflow [14] LSTM has the capability of handling the temperature anomaly data as is, the *MinMaxScaler* was used since it would be required once all of the datasets filled out the multivariate model.

The climate change risk datasets were given in the time range of 1960 to 2020, with one data value per year. Fig. 3. shows the box plot distributions for all 28 datasets.

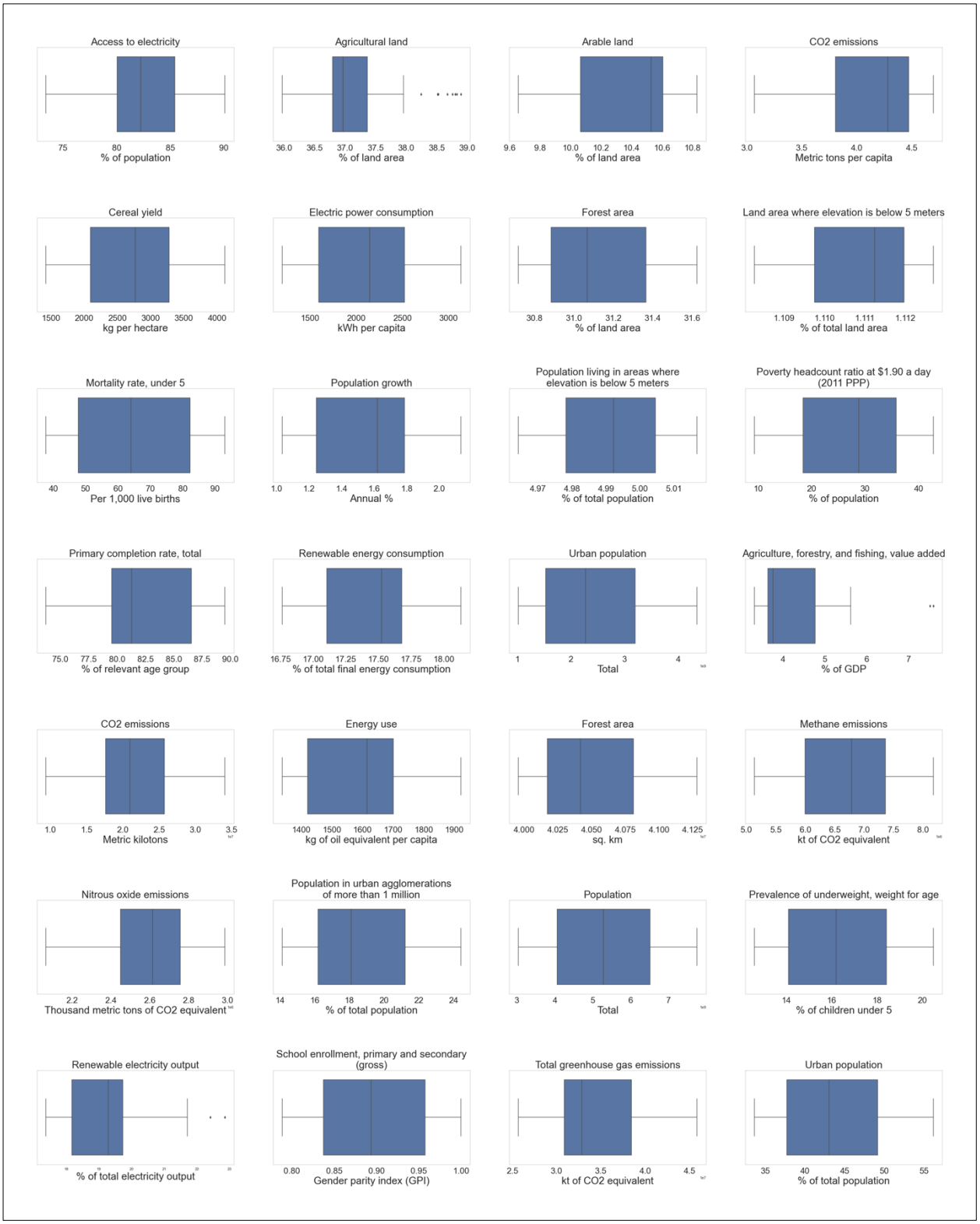

Fig. 3. Box Plot Distributions of Climate Change Factor Datasets

The datasets are broken down by country, region, and world. The "World" column was used so that it would be in line with climate change temperature data from [9]. In order for the multivariate data to be considered to be valid, it needs to be converted into a NumPy [8] array. The first problem to address was that the two data sources had different year ranges (1880 to 2021) and (1960 to 2020). The goal was to keep the entire long-time series temperature anomalies, therefore empty rows for the climate change factors were added so that each dataset had the same number of rows. The second problem was that the climate change factor datasets were yearly instead of monthly like the temperature change dataset. To resolve this, every row of the climate change factors dataset were duplicated 12 times, taking a yearly data value, and replicating as a monthly data point. The climate change factor data have slower changing values and would be difficult to measure every month. For example, mortality rate would not change greatly from month to month and would also be difficult to get an accurate value if actual surveys were needed. All of this data pre-processing was done so that the two datasets, built as Pandas [10] data-frames could be joined doing an inner-merge operation.

Once the dataset was run through the *MinMaxScalar*, the columns were normalized. By doing this step, the larger valued columns would not dominate the model's fitting process. The climate change factor datasets had many missing data points, particularly within the early years. Not a number (*NaN*) values need to be removed before feeding the data to a Keras/Tensorflow LSTM model; otherwise, a single *NaN* value in the validation dataset will cause the validation loss and validation accuracy to not compute, resulting in *NaN* for every epoch during the training phase. To work around this limitation, every *NaN* value could have been set to 0 an indication of missing data, but then the model would not be aware that either the data was missing or just a value of 0. The approach used was to set every *NaN* value to -1. Because the merged datasets were previously processed with the *MinMaxScaler*, within the range of (0, 1), there could not possibly be a valid value of -1 within the dataset. *MinMaxScaler* will leave *NaN* values as is. With the -1 values in place, the model can now make use of the Keras masking layer to ignore all values of -1 during the training process.

The Pearson Correlation values are shown in Table 1. There are some coefficient values that are approaching zero. Negative coefficients are fine for our models. In some cases, it might be beneficial to remove a dataset such as Agricultural land (% of land area) with a correlation coefficient of -0.0565, but all datasets were kept because they are strongly believed by environmentalists to be correlated to climate change.

Table1. Pearson Correlation with Target Feature

Pearson Correlation	
Data Feature	**Coefficient**
World temperature anomaly	1.0000
World ocean temperature anomaly [9]	0.9284
Access to electricity (% of population)	0.7212
Agricultural land (% of land area)	-0.0565
Arable land (% of land area)	0.7222
CO2 emissions (metric tons per capita)	0.3234
Cereal yield (kg per hectare)	0.8963
Electric power consumption (kWh per capita)	0.8635
Forest area (% of land area)	-0.7553
Land area where elevation is below 5 meters (% of total land area)	-0.1786
Mortality rate, under-5 (per 1,000 live births)	-0.8094
Population growth (annual %)	-0.8770
Population living in areas where elevation is below 5 meters (% of total population)	-0.7209
Poverty headcount ratio at $1.90 a day (2011 PPP)	-0.8250
Primary completion rate, total (% of relevant age group)	0.8366
Renewable energy consumption (% of total final energy consumption)	-0.3507
Urban population	0.9120
Agriculture, forestry, and fishing, value added (% of GDP)	-0.7641
CO2 emissions (kt)	0.8859
Energy use (kg of oil equivalent per capita)	0.8168
Forest area (sq. km)	-0.7529
Methane emissions (kt of CO2 equivalent)	0.8821
Nitrous oxide emissions (thousand metric tons of CO2 equivalent)	0.5733
Population in urban agglomerations of more than 1 million (% of total population)	0.9120
Population, total	0.9120
Prevalence of underweight, weight for age (% of children under 5)	-0.7573
Renewable electricity output (% of total electricity output)	0.0820
School enrollment, primary and secondary (gross), gender parity index (GPI)	0.8966
Total greenhouse gas emissions (kt of CO2 equivalent)	0.7776
Urban population (% of total population)	0.9120

Model Analysis

Four univariate models were built. The univariate models took the temperature anomaly dataset as input, trained on the data, and made one future prediction. The first model comprised of a vanilla LSTM incorporating one LSTM layer and a single dense output layer. The second model created was a stacked LSTM model where the sequences from the first LSTM layer are fed directly to the second layer with a single dense output layer. The third model used a bidirectional layer which takes the LSTM layer as input. The values of both directions are concatenated before passing them to the next layer. Again, a single node dense layer was used for the output. The fourth model was a stacked bidirectional model, effectively merging the concepts of Model 2 and Model 3 together. All four models used Keras' *EarlyStopping* callback to terminate the training period when the loss monitor of mean-square-error did not increase within 10 epochs.

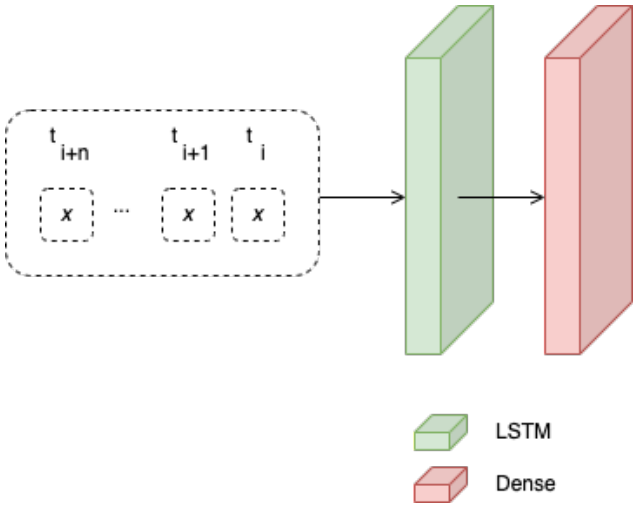

Fig. 4. Univariate Model 1

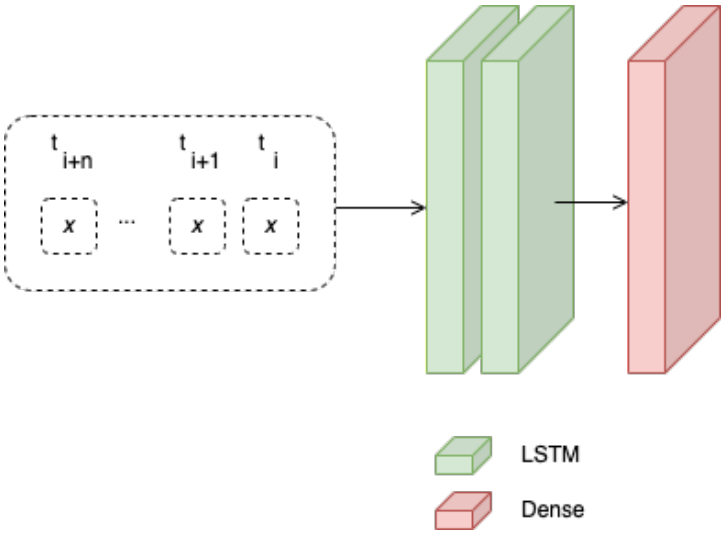

Fig. 5. Univariate Model 2

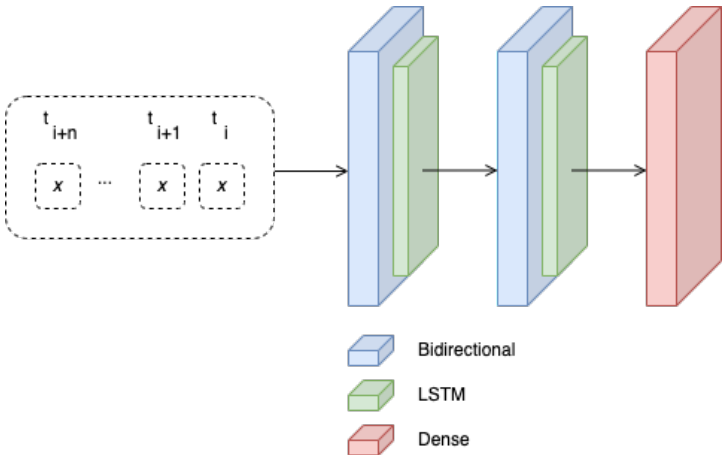

Fig. 6. Univariate Model 3

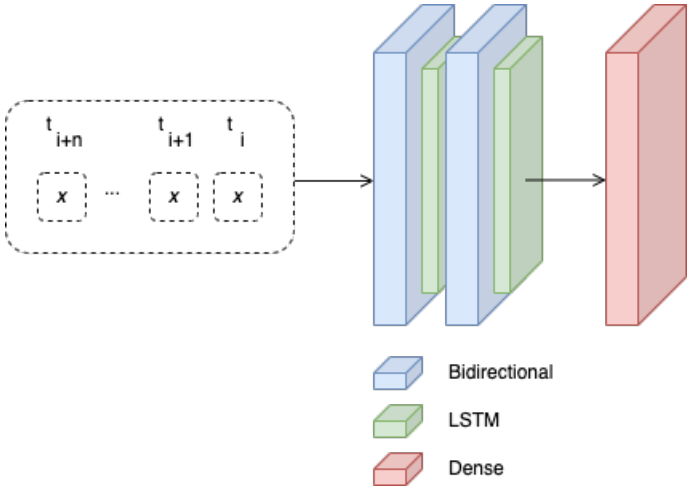

Fig. 7. Univariate Model 4

Table 2. The Univariate Models Evaluation

Univariate Model Fitting					
	Training		Testing		
Model	MAE	MSE	MAE	MSE	R^2
1	0.0400	0.0027	0.0506	0.0039	0.7095
2	0.0430	0.0031	0.0493	0.0037	0.7338
3	0.0401	0.0027	0.0481	0.0036	0.7325
4	0.0398	0.0027	0.0480	0.0035	0.7362

From Table 2 it shows that all models performed similarly with Model 4, the stacked bidirectional model performing the best.

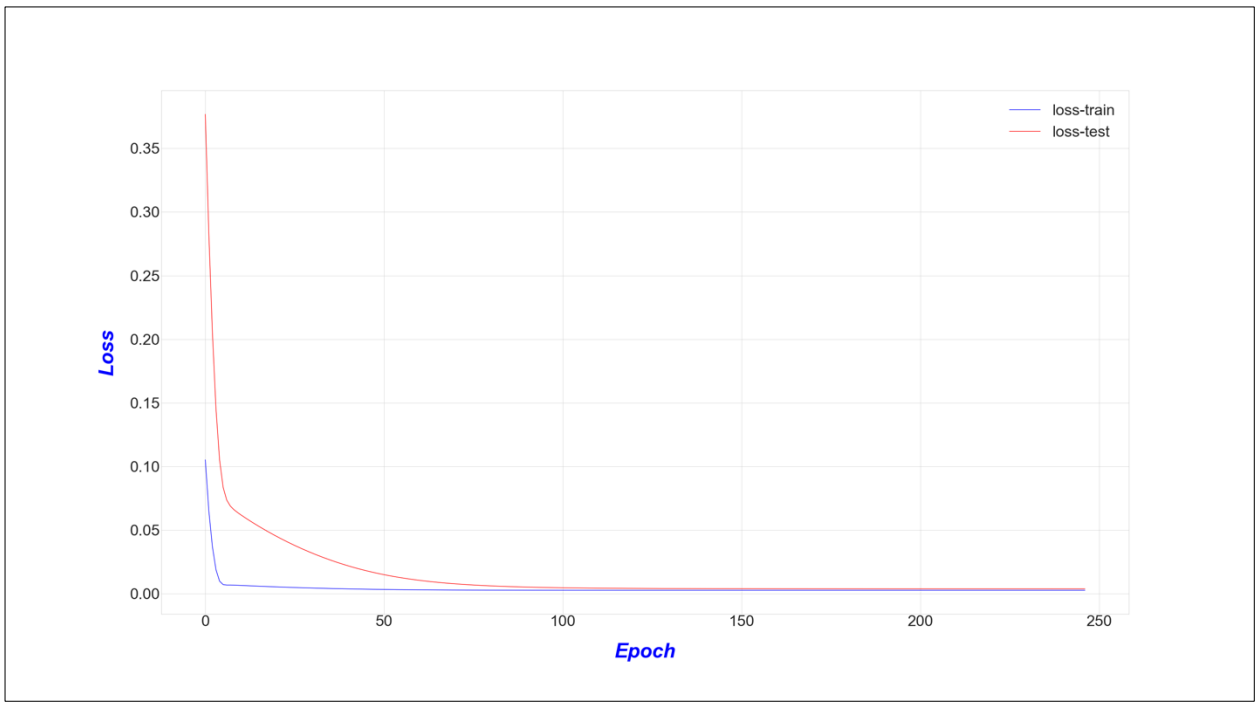

Fig. 8. Univariate Model 1 Loss Plot

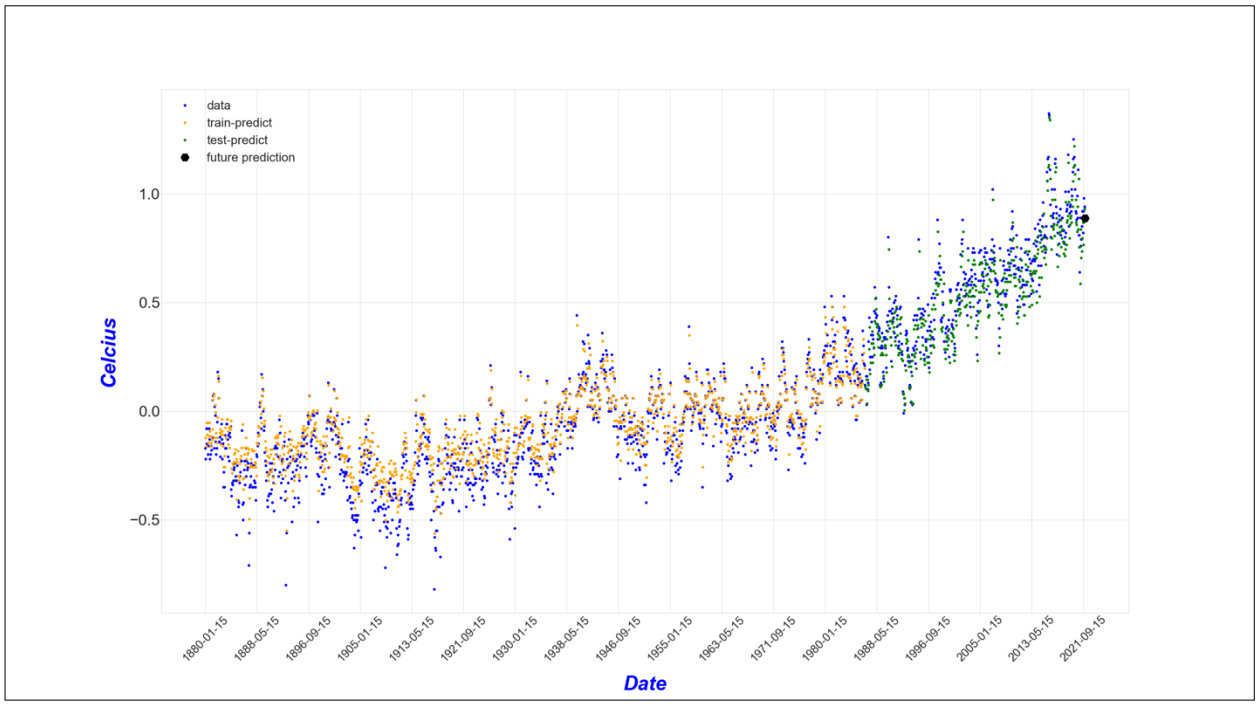

Fig. 9. Univariate Model 1 Train/Test Plot

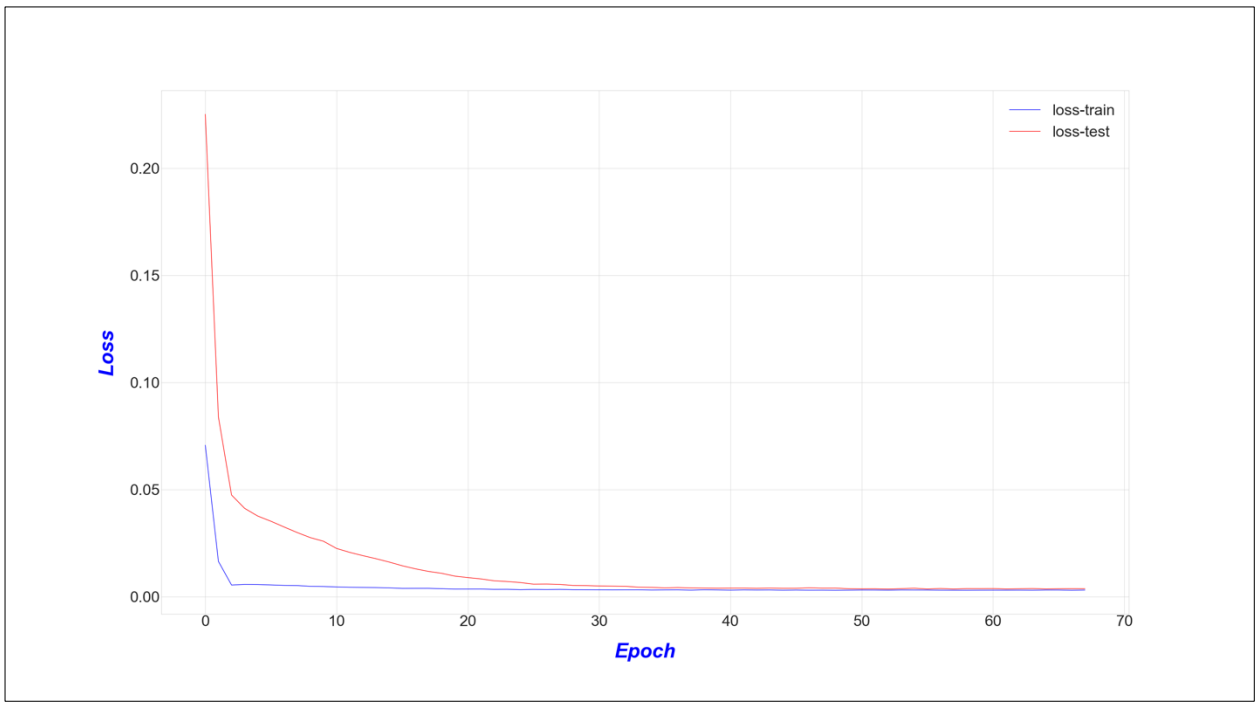

Fig. 10. Univariate Model 2 Loss Plot

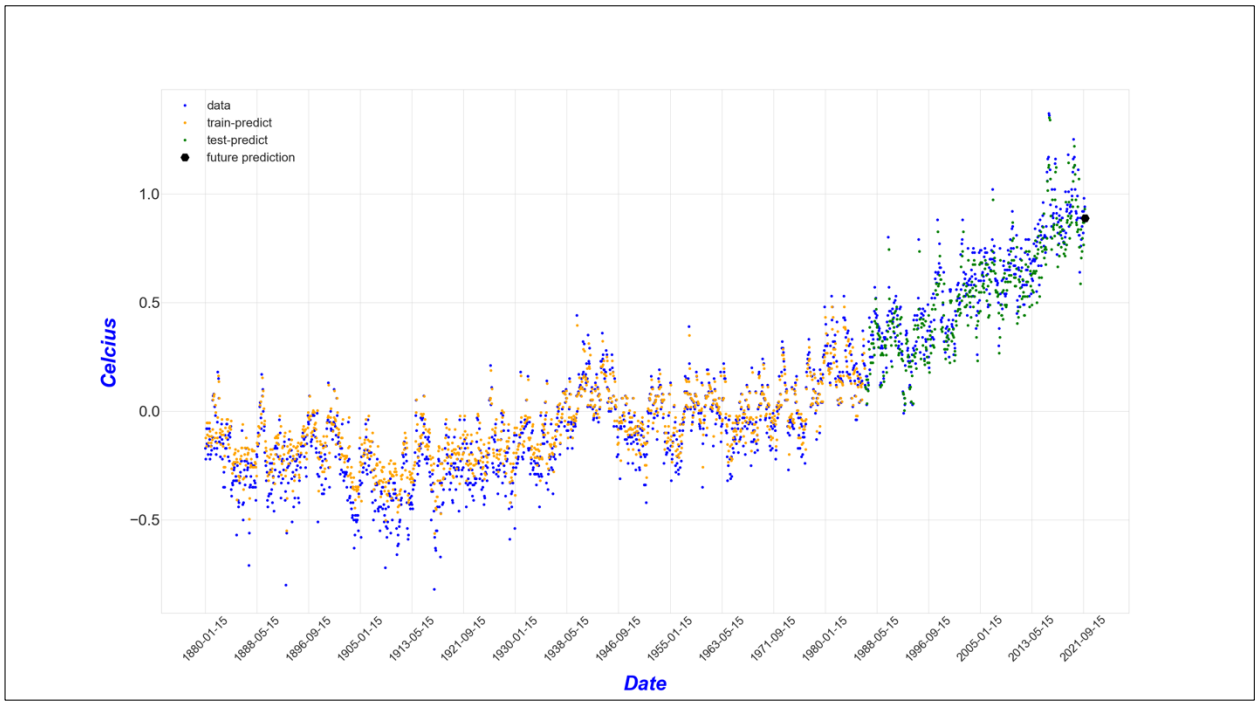

Fig. 11. Univariate Model 2 Train/Test Plot

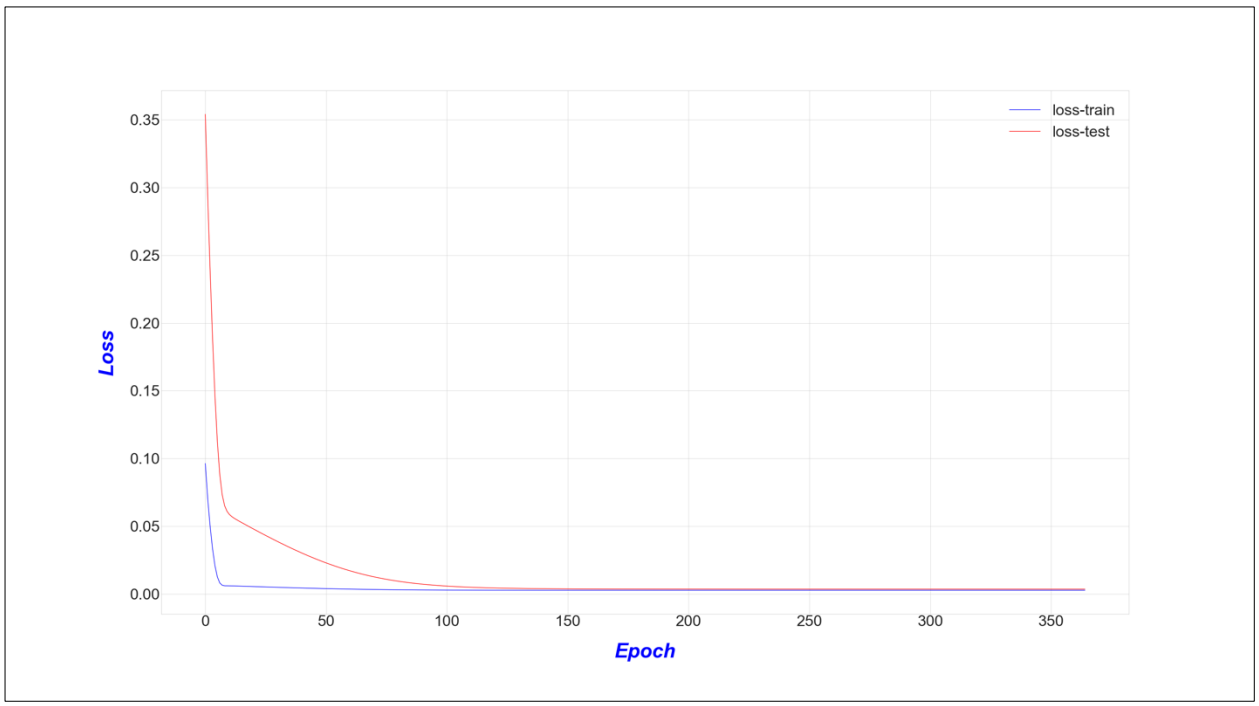

Fig. 12. Univariate Model 3 Loss Plot

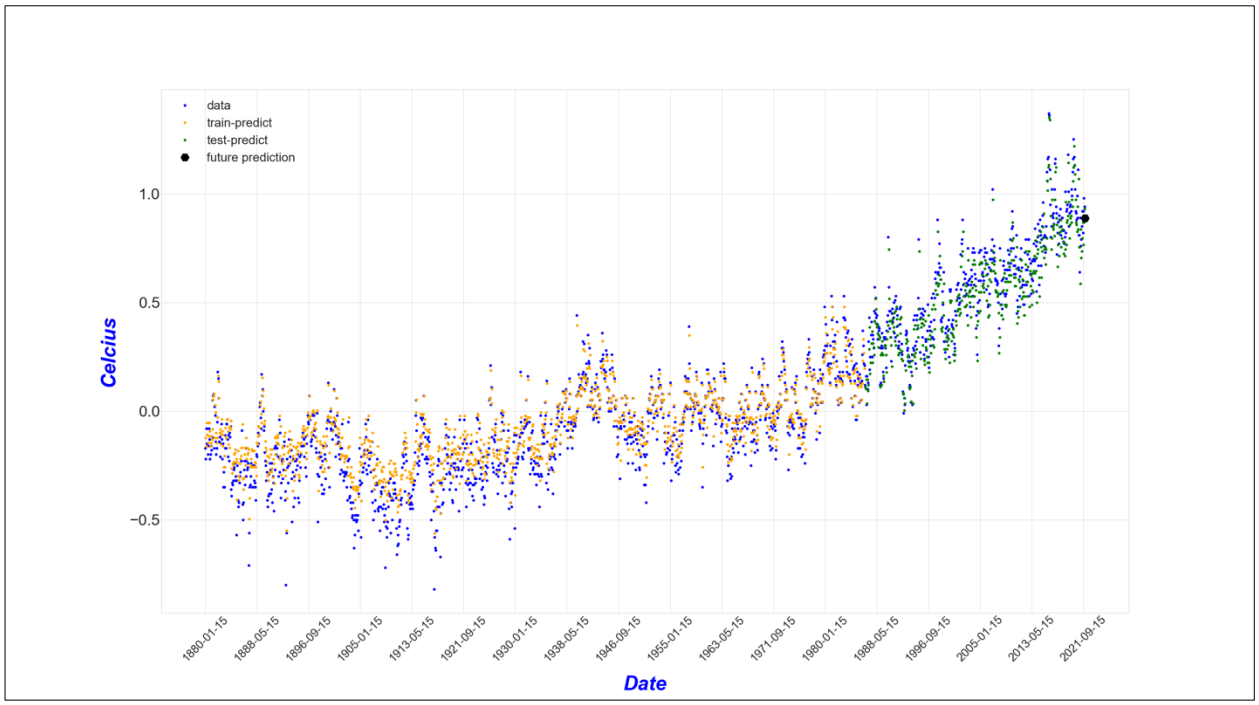

Fig. 13. Univariate Model 3 Train/Test Plot

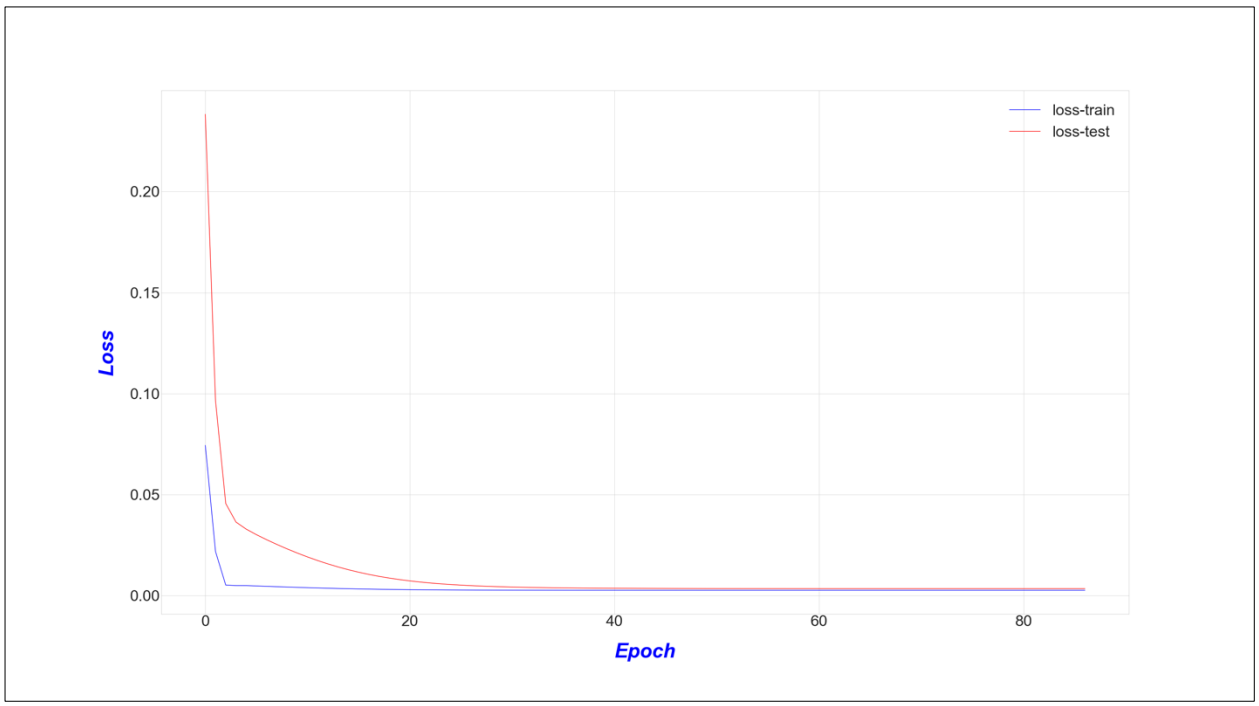

Fig. 14. Univariate Model 4 Loss Plot

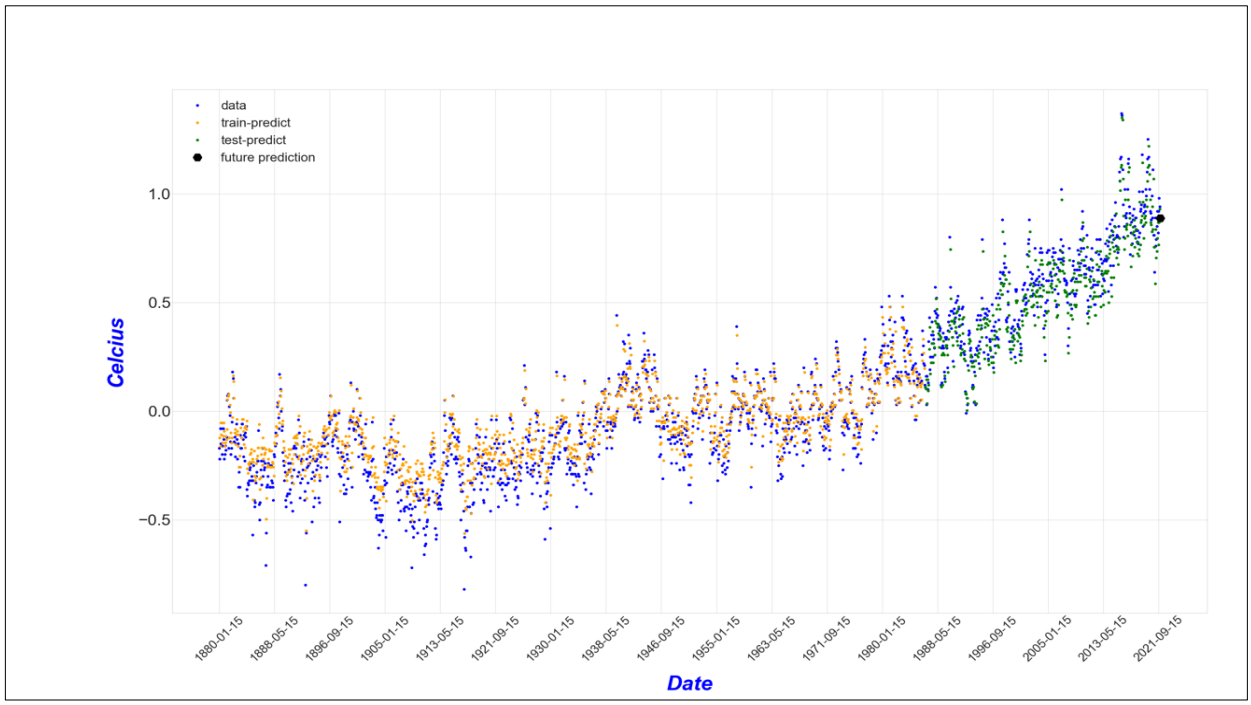

Fig. 15. Univariate Model 4 Train/Test Plot

MODEL EVALUATION RESULTS

The multivariate model performed well. The final DNN model consisted of a masking layer masking out the missing values from the climate change factors datasets by marking them with a -1 value. The next layers within the model were three bidirectional LSTM layers. Two dropout layers were added in between the three bidirectional LSTM layers, which is attributed to Srivastava, Hinton, Krizhevsky, Sutskever and Salakhutdino [13]. Each of the dropout layers used a dropout rate of 10 percent. The output layer consisted of a single cell dense layer. In order for this model to train properly, the key was to use the dropout layers. Without the dropout layers, the test validation fell off at the tail end.

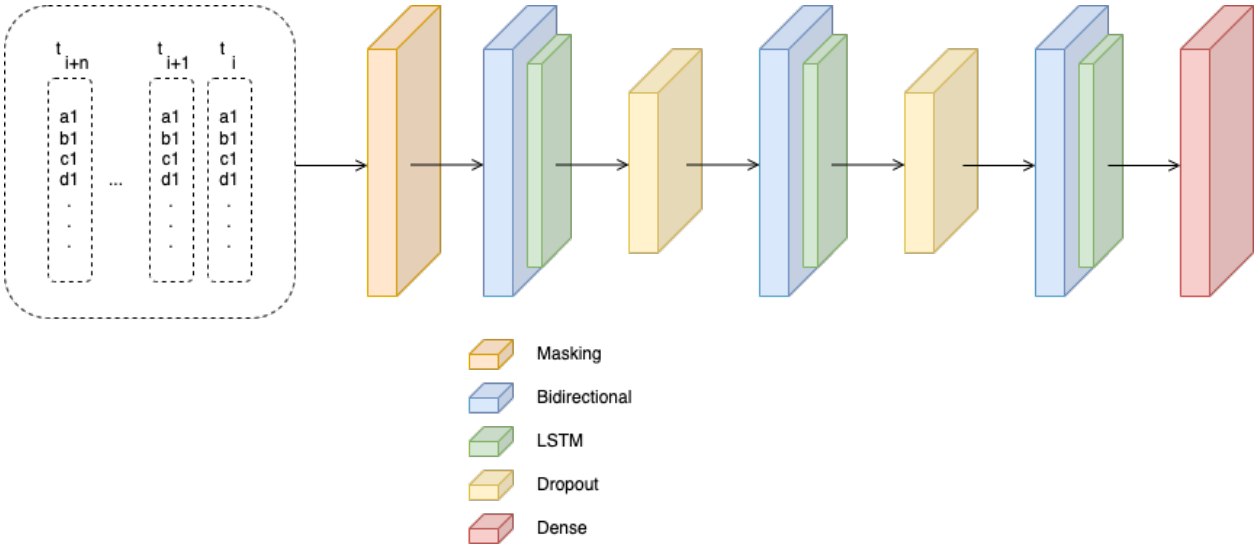

Fig. 16. Multivariate DNN Model

As is typical in model building, there was a lot of trial and error to find the best working model. The Adam optimizer was used simply due to its all-purpose general excellent performance. All default activation functions were kept as is. Although we normalized the data values to be between 0 and 1, which would have made the ReLu (rectified linear unit) activation function a good candidate, we kept the default LSTM activation functions. The goal was to see how a traditional LSTM layer would perform. One of the hyper-parameters that took some testing and evaluation was the learning-rate for the Adam optimizer. A learning rate of 0.00003 was found to give the best results without overfitting or underfitting. Early stopping was used again and was extremely useful by allowing the model to train until its patience level was reached. The environment used was an Apple MacBook Pro, 2.4 GHz 8-Core Intel Core i9 with 64GB of RAM. Tensorflow and Keras version 2.7.0 and Python 3.8.12.

Table 3. The Multivariate Model Evaluation

Multivariate Model Fitting				
Training		Testing		
MAE	MSE	MAE	MSE	R^2
0.0400	0.0027	0.0506	0.0039	0.7095

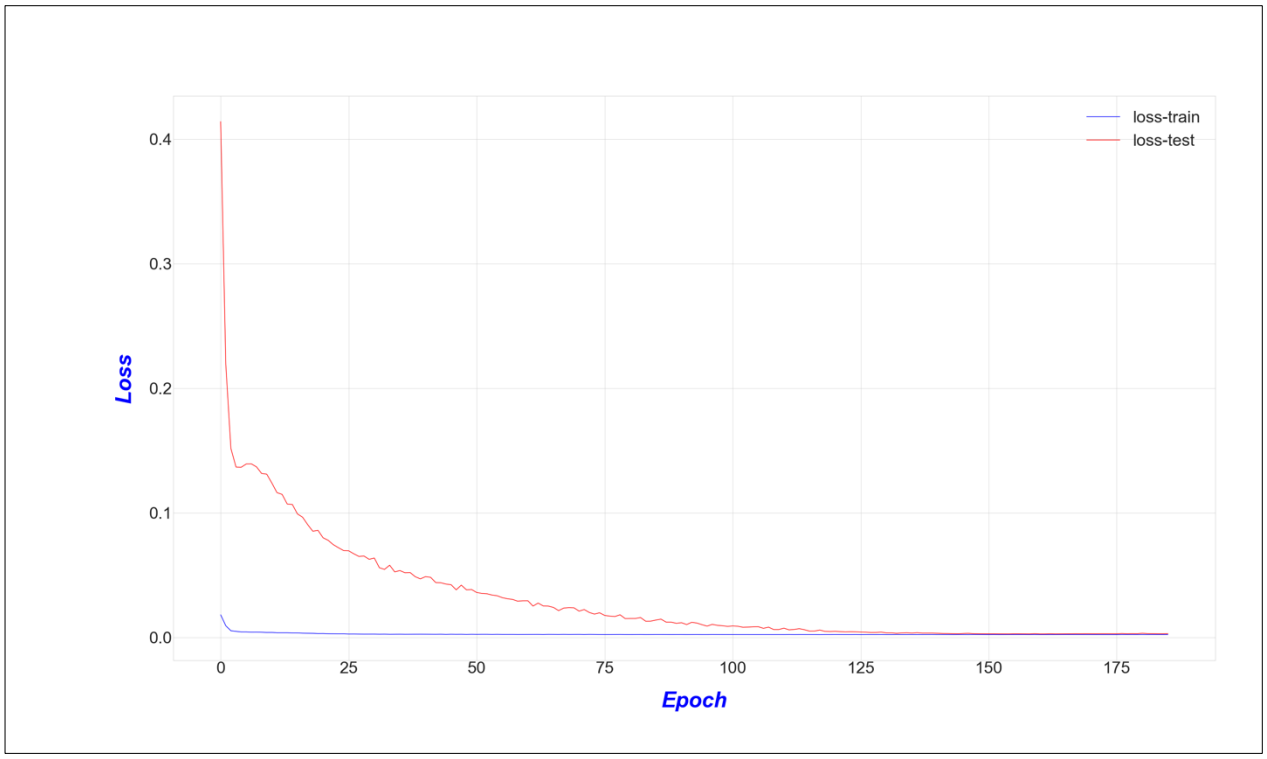

Fig. 17. Multivariate Model Loss Plot

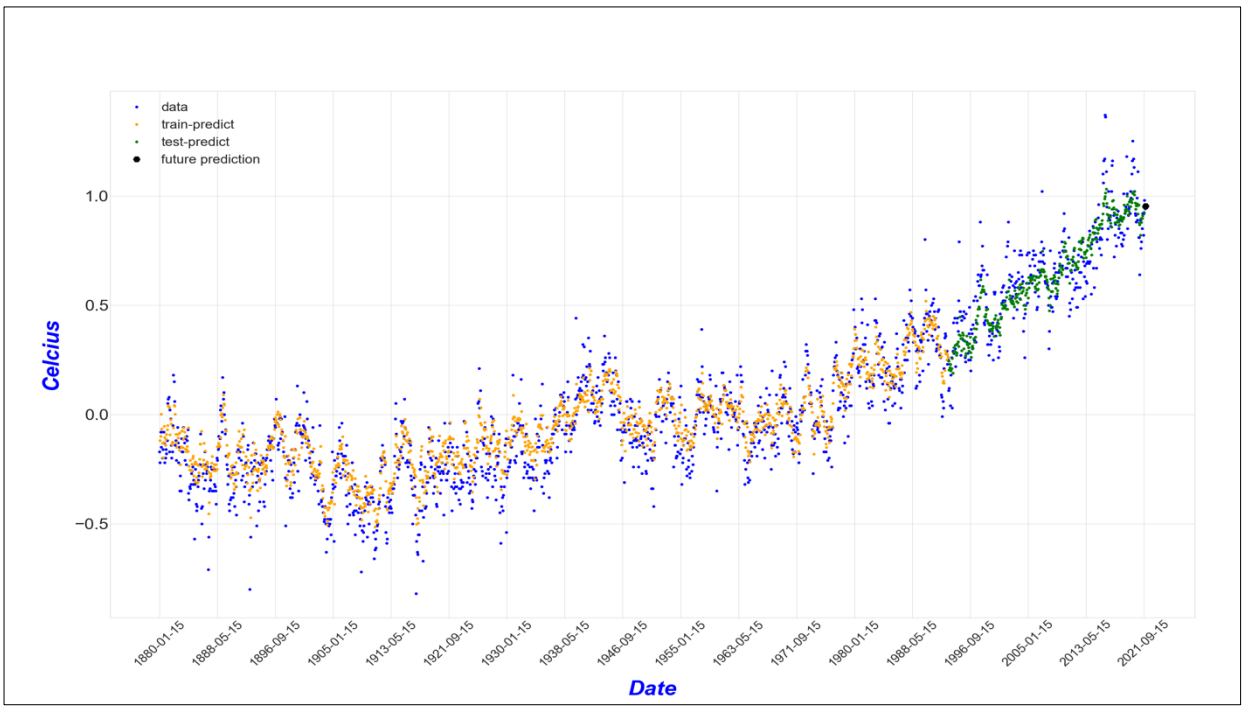

Fig. 18. Multivariate Train/Test Plot

CONCLUSIONS

We created an LSTM model to predict the temperature change anomaly values as provided in datasets [9] and [15]. We formulated techniques for working with the different data sizes and missing data limitations. By using Keras LSTM layers, we were able to create a model that will make a single prediction on a monthly time granularity. We started the testing with various univariate models that took as input the single data feature of the temperature anomaly. Different variations of the model were created including LSTM, stacked LSTM, bidirectional LSTM, and stacked bidirectional LSTM. We then created a multivariate model that took the same temperature anomaly feature, ocean temperature anomaly feature, plus an additional 28 features relating to causes of climate change. The multivariate model used a masking layer to ignore missing data values, three bidirectional LSTM layers with a dropout layer in between them and a dense output layer which outputs a single feature value.

REFERENCES

[1] Chou, C. & Park, J. & Chou, E. "Generating High-Resolution Climate Change Projections Using Super-Resolution Convolutional LSTM Neural Networks," 2021 13th International Conference on Advanced Computational Intelligence (ICACI), 2021, pp. 293-298, doi: 10.1109/ICACI52617.2021.9435890.

[2] Dessai, S. & Hulme, M. & Lempert, R. & Pielke, R. Sr. (2009). Do We Need Better Predictions to Adapt to a Changing Climate?. Eos, Transactions American Geophysical Union. 90. 10.1029/2009EO130003.

[3] Harilal, N. & Singh, M. & Bhatia, U. "Augmented Convolutional LSTMs for Generation of High-Resolution Climate Change Projections," in IEEE Access, vol. 9, pp. 25208-25218, 2021, doi: 10.1109/ACCESS.2021.3057500.

[4] Hochreiter, S. & Schmidhuber, J. Neural Computation, Volume 9, Issue 8, pp 1735–1780, November 1997.

[5] Keras, https://keras.io/

[6] Li, J. & Geng, D. & Zhang, P. & Meng & X. & Liang, Z. & Fan, G. "Ultra-Short Term Wind Power Forecasting Based on LSTM Neural Network," 2019 IEEE 3rd International Electrical and Energy Conference (CIEEC), 2019, pp. 1815-1818, doi: 10.1109/CIEEC47146.2019.CIEEC-2019625.

[7] Lopez, D. & Sekaran, G. “Climate change and disease dynamics-a Big Data perspective.,” Int. J. Infect. Dis., vol. 45, pp. 23--24, 2016.

[8] NumPy, https://numpy.org/

[9] Our Word In Data, https://ourworldindata.org/

[10] Pandas, https://pandas.pydata.org

[11] Recurrent Neural Networks, https://en.wikipedia.org/wiki/Recurrent_neural_network

[12] Scikit-Learn, https://scikit-learn.org/

[13] Srivastava, N. & Hinton, G. & Krizhevsky, A. & Sutskever, I. & Salakhutdino, R. “Dropout: A Simple Way to Prevent Neural Network from Overfitting”, Journal of Machine Learning Research, June 2014, pp. 1929-1958

[14] Tensor Flow, https://www.tensorflow.org/

[15] The World Bank, https://data.worldbank.org/topic/climate-change

[16] Yao, W. & Huang, P. & Jia, Z. "Multidimensional LSTM Networks to Predict Wind Speed," 2018 37th Chinese Control Conference (CCC), 2018, pp. 7493-7497, doi: 10.23919/ChiCC.2018.8484017.

[17] Zhang, Q. & Wang, H. & Dong, J. & Zhong, G. & Sun, X. "Prediction of Sea Surface Temperature Using Long Short-Term Memory," in IEEE Geoscience and Remote Sensing Letters, vol. 14, no. 10, pp. 1745-1749, Oct. 2017, doi: 10.1109/LGRS.2017.2733548.

PRIVACY-ENHANCED FORECASTING OF BEHIND-THE-METER SOLAR PVS USING FEDERATED LEARNING

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ABSTRACT

With the widespread use of distributed renewable energy sources (DRESs) in modern energy systems, accurate estimation of aggregated DRESs is of great importance to keep the grid stability. Currently, the majority of distributed photovoltaic (PV) systems are located behind-the-meter (BTM), rendering them undetectable to utilities. To obtain an accurate aggregated BTM PV electricity forecast, prediction models need a vast number of data from small sites. However, collecting and accessing the data of all on-site PVs scattered in different places is very difficult, if not impossible, due to data security and privacy concerns, availability of measurement devices, and time-consuming administrative processes.This paper introduces federated learning (FL)-based PV energy forecasting as an unique decentralized collaborative modeling technique capable of training a super model on data from a large number of BTM sites. Specifically, a multi-layered perceptron (MLP) is designed as the BTM PV forecasting model without endangering the data's privacy or security. A comparison of the proposed private distributed model to non-private centralized and completely private localized models demonstrates that the proposed FL forecasting has a high degree of accuracy (18.17 % lower RMSE than localized and only 9.9 higher RMSE than centralized model).

Keywords: *small-scale BTM PV; Machine learning; federated learning, PV electricity forecasting; data privacy and security.*

1 INTRODUCTION

In recent years, we have seen a significant increase in the use of small-scale behind-the-meter (BTM) roof-top solar photovoltaic panels. For example, in 2018, it was reported that in California, there were 850,000 sites with a total capacity of 7066 MW [1]. From the power grid operator's point of view, these power generation units are not visible since their electricity production is not monitored and reported in real-time to the grid operator. This is while the produced electricity from these units deflects the electricity grid demand for each grid consumer resulting in changes in the net electricity demand profile. The effect of BTM PV on the electricity grid gets more important to maintain balance between supply and demand as their total capacity increases. For this reason, forecasting the aggregated electricity production of small BTM photovoltaic panels is essential to keep the grid stability.

Various models have been developed in the past to predict the output of small-scale and utility PV sites. These models assume that historical data, meteorological data, and production meters are available at the site. Long et al. [2] analyzed four different data-driven methods to develop a daily solar power prediction model. These models are Support Vector Machine (SVM), Artificial Neural Network (ANN), multivariate linear regression (MLR), and k-nearest neighbor (kNN). Their results show that all algorithms have the same efficiency, and none is superior to the other. In separate research, Chen et al. [3] and

Yang et al. [4], investigated forecasting PV productions on a big and small scale based on the weather classification. Liu et al. [5] introduced higher photovoltaic power forecasting accuracy with the Assistance of Aerosol Index Data in their model. Multiple researchers [6]–[8] were focused on the meteorological variable prediction such as radiation which can be used for PV power generation forecasting.

Although there are extensive researches to estimate single photovoltaic power generation units, there is little research on predicting the aggregated electricity production of the regional large number of small-scale BTM PV. This is because the output energy of each unit is not measured separately, and these data are often not available. Therefore, the proposed data-driven model should work with available historical power generation data for a limited number of representative sites. To address the importance of this issue, there is no infrastructure for real-time monitoring of the aggregated electricity generation of individual units to inform the grid management operator. For the aggregated PV output forecast, Lorenz et al. [9] proposed a method to predict the regional PV output power by mainly focusing on irradiance forecasting as a basis of PV power prediction. The other research [10] studied regional power forecast (hourly resolution of up to 2 days ahead) of PV system utilizing physical models and upscaling method from a representative PV site data. Saint-drenan et al. [11] studied a set of 366 PV plants to analyze the uncertainty of upscaling technique for regional photovoltaic (PV) power generation forecast.

As can be seen, for accurate PV electricity production forecasts, data-driven models require large volumes of historical and weather-related data. However, this high-resolution data is generally considered sensitive and is not available in most cases since it is thought that it can be used to access important and private information that can be utilized to carry out cyberattacks [12]. To address this research gap, this study proposes the use of federated learning (FL) as a subdivision of the machine learning approach. FL is a collaborative non-centralized privacy-preserving machine learning technique in which each unit participates in central model training without data being exchanged [13]. Using FL, the quality and accuracy of the central model could be increased by expanding and diversifying the data set while maintaining data security. With FL, Only the local model parameters are exchanged with the central server for global model aggregation, however the raw training data is stored locally and is not exposed to the other parties. As a result, data privacy may be safeguarded. Several studies have previously used FL in the area of power systems, demonstrating the framework's usefulness. One similar paper discusses an energy management system that uses federated reinforcement learning to improve the energy usage of several smart houses [14].

The proposed model can also solve one of the persistent challenges of machine learning algorithms, namely overfitting through diversifying the model data set. Furthermore, earlier research has been confined to predicting operations for particular places for which forecasting models have been developed, and has been unable to generalize forecasting to adjacent areas. As a result, generalizability has remained a chronic difficulty in solar energy forecasting. Additionally, although integrating machine learning techniques with numerical weather forecasts and terrain-specific circumstances might improve forecasting accuracy, it complicates the models and needs much more processing effort. The purpose of this article is to propose the use of FL to train a privacy-preserving solar energy forecasting model that covers those shortcomings. We use a Multi-layered perceptron, which utilizes previous solar generation data to forecast future generation values. To the best of the authors' knowledge, no research in the literature examines the development of a comprehensive data privacy-preserving model of the aggregated electricity production of a large set of small-scale BTM PV panels where data regarding all generation units are not available. Paper novelty and contribution are summarized as follow:

- A FL-based solar power forecasting scheme is presented to provide a safe means of maintaining data privacy by training forecasting models locally and minimizing raw data interchange across many on-site photovoltaic

(PV) systems. Without data interchange, the suggested approach allows forecasting to benefit from the better performance given by global model aggregation.

- The proposed private distributed model is compared to non-private centralized and completely private localized models, demonstrating the excellent accuracy of the proposed FL-based solar energy forecasts using real-world datasets.
- The suggested model's better generalizability is also shown, while the underlying data's privacy is maintained.

The following is the rest of the paper: The foundation and important mathemathical background for the innovative FL BTM PVs forecasting technique are presented in Section 2. This section also goes over the construction of the representative machine learning model in depth. Section 3 delves into the representative demand data, including its features and characteristics. This section contains the findings of the suggested algorithm. Section 5 concludes with a conclusion and a list of possible study paths.

2 STRUCTURE OF THE PROPOSED FEDERATED LEARNING BTM PV FORECASTING

As a consequence of the advent and growth of Internet of Things (IoT), modern energy systems have started to anticipate the use of more complicated, creative algorithms (e.g, artificial intelligence) in a number of applications, including forecasting. However, with the exception of a few sectors, others have little and/or low-quality data, limiting artificial intelligence's full potential. On the other hand, data privacy and security have lately become a worldwide issue and a persistent challenge for forecasting purposes. To address this issue, the machine learning community has proposed Federated Learning (FL) [15]. FL is a collaborative and decentralized method to machine learning in which each individual data owner participates to the training of a central model without supplying any data. As seen in Figure 1, the server initializes the model by utilizing publically available datasets. The model is then sent to a subset of randomly picked devices (clients) for local training using their data. On the server, each client changes/tunes the model's weights, which are subsequently averaged and used to update the global model. This technique will be repeated until equilibrium is reached in the global model. Other applications such as traffic flow forecasting [16], energy demand forecasting [17], and renewable scenario generation [18] have been previously suggested using FL-based frameworks. Given the critical need of building accurate but generalizable forecasting algorithms based on data from numerous sources while ensuring data privacy, we are unaware of any work in the current literature that directly tackles this problem in BTM solar PV energy generating applications.

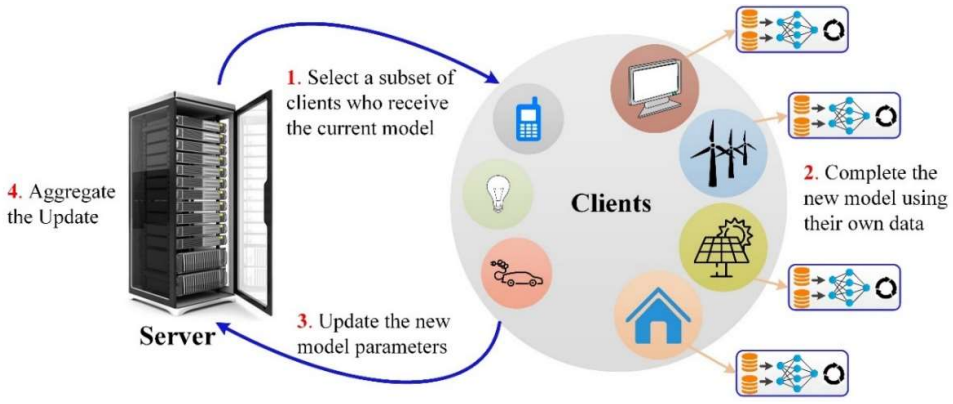

Figure 1. Client-server iterative interactions within federated learning framework.

Numerous variables contribute to the problem of big data sets necessary for cooperative machine learning model training. Thus, it makes sense to investigate strategies for constructing machine learning architectures that do not depend on centralizing

all data for model training. A conceivable strategy is to create a model for each site where a data source is located and then enable those locations to communicate their own models in order to gain agreement on a global model. To maintain the security and privacy of client data, the communication mechanism is painstakingly built to prohibit any site from interfering with another's private data. Simultaneously, the model is built as if the data sources had been combined. Rather of transferring data across sites, model parameters are securely exchanged, preventing third parties from guessing the contents of another party's data.

FL tries to train a model using decentralized data $d_1, d_2, ..., d_m$ that is often skewed and not uniformly distributed. A centralized strategy entails collecting all data necessary for model training as $d = \{d_1 \cup d_2 ... \cup d_m\}$. However, federated learning incorporates collaborative training of a model (M_{fed}) to ensure that its accuracy (A_{fed}) fulfills certain criteria as depicted in Eq (1).

$$\left| A_{fed} - A_{cent} \right| \leq \alpha \qquad 1$$

where α is a non-negative predetrmined number and A_{cent} is the accuracy of the centralized model. This equation provides the concept that the resulting joint model performs similarly to when all data sources are merged in the centralized model. Due to the fact that FL data providers will not share their data with a centralized server or other clients, we allow the FL system to perform somewhat poorer than a joint model. This additional security and privacy protection is much more valuable than the accuracy loss in a variety of applications, including BTM solar energy forecasts.

For solar energy forecasting, we recommend that the FL system make use of a central coordinating server to further develop the joint model. Alternatively, the FL architecture may be created peer-to-peer, obviating the requirement for a coordinator; however, this results in greater computing burden. The suggested FL coordinator method is shown in Figure 2 in the context of a BTM solar energy forecasting system. A central aggregation server (parameter server) acts as the coordinator in this scenario, distributing an initial model to the local data owners *1–M*. (clients or participants). Each data owner *1–M* trains a local model on their own dataset and updates the weights of the model through the aggregating server. The aggregation server then aggregates and delivers back the model updates received from the clients (e.g., through federated averaging [19]). This technique is performed until either the convergence condition is met or the maximum number of iterations is reached. The original data of the individual providers never leaves the local data owners' custody under this architecture. Not only does this technology safeguard user privacy and data security, but it also removes the communication costs involved with raw data transfer. To prevent data leaking, the coordination server's communication with the clients may be encrypted (e.g., utilizing homomorphic encryption [20]).

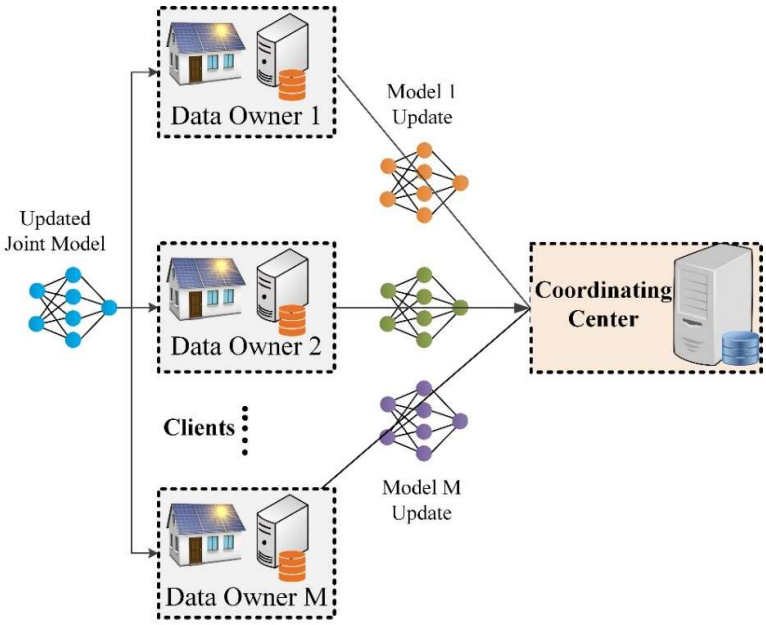

Figure 2. The client-server architecture of the suggested federated learning BTM solar energy forecasting model.

This is a strategy for horizontal federated learning in which several clients with the same feature space but different datasets train a model on a server collaboratively. The following explains the step-by-step process suggested for predicting FL BTM solar energy.

Step 1: To begin, a small group of randomly selected participants, referred to as a mini-batch, computes model parameters locally, encrypts them, and transmits them encrypted to the server. The server is in charge of the whole training procedure. At the outset, a prototype global model is created. The global model parameters are established by prioritizing a typical normal distribution. Following that, a collection of target devices is picked based on a specified participation percentage and client state. The server's initialized or most recent global model parameters are downloaded.

Step 2: Using cable or wireless networks, the on-site gadgets obtain vital data from the photovoltaic station and weather sensors. The data may be kept locally if required. To gather training data, a data pretreatment approach such as normalization is provided. Then, the local MLP model is loaded with the most recent global hyperparameters. Each chosen device performs autonomous training on the local model using its collected training data. The given data is used to train and assess a local model for forecasting solar generation.

Step 3: The encoded local hyperparameters are uploaded to the server. To maximize efficiency, after a sufficient number of uploads is acquired, stragglers may be discarded. Secure aggregation with differential privacy is used to guarantee that the server knows only the aggregated data. The server changes the global model based on the aggregated data from the chosen IoT devices and starts the subsequent iteration. The server then conducts safe aggregation without endangering the privacy of any participant and delivers the aggregated parameters to the participants. Aggregation is a well-known technique based on stochastic gradient descent [21].

Step 4: Finally, participants update their own models using the decrypted parameters. This procedure is continued until the loss function becomes convergent, at which time the training phase is completed.

2.1 Multi-layered Perecptron

In this study, a conventional MLP neural network is used to learn the mapping from an input vector to an output vector through numerous linked layers of processing units. Fig. 3 depicts a schematic of the MLP neural network. The connection between the output and input(s) of each node in a layer, referred to as a neuron, in a conventional neural network is governed by an activation function, as represented in Eq (2):

$$h_j^l = a\left(\sum_{m=1}^{N_{l-1}} w_{jm}^l h_m^{l-1}\right); \forall j \in \{1,2,...,N^l\}, \forall l \in \Gamma \qquad 2$$

where *a(.)* stands for activation function in between the input feeding the current neuron and the output heading for the next layer. Expressed by Eq **Error! Reference source not found.**, the hyperbolic tangent, denoted by *tanh*, is a compelling activation function for neural network applications.

$$a(s) = \tanh(s) = \frac{e^s - e^{-s}}{e^s + e^{-s}} \qquad 3$$

Proper values for the weighting factors $w_{j,m}^l$ are determined during the training process, on which the weights are updated using stochastic gradient descent. The updating process is formulated in Eq (4) where the partial derivatives of the set of parameters during $(k\text{-}1)^{th}$ round of training are multiplied by the learning rate β and then subtracted by the initial values of those weights.

$$\left(w_{j,m}^l\right)_k = \left(w_{j,m}^l\right)_{k-1} - \beta \frac{\partial e}{\partial\left(w_{j,m}^l\right)_{k-1}}; \forall j \in \{1,2,...,N_l\}, \forall m \in \{1,2,...,N_{l-1}\}, \forall l \in \Gamma, \forall k \in \{1,2,...,K\} \qquad 4$$

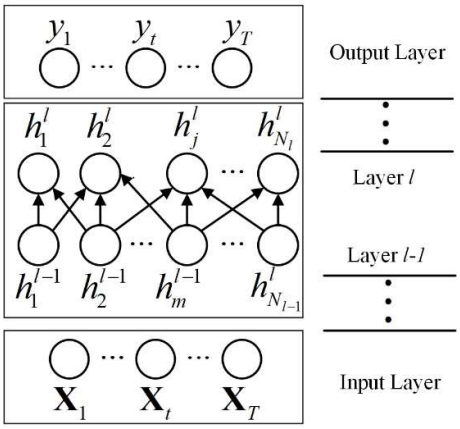

Figure 3. Schematic diagram of the MLP neural network.

2.2 Evaluation Metric

The accuracy measure is the root mean squared error (RMSE), as represented in (5). The root-mean-square error (RMSE) indicates the direction of the mistake by calculating the root of the mean of the distance between forecasts and observations.

$$RMSE = (\frac{1}{N})^{1/2} \sqrt{\sum_{i=1}^{N} (y_i - \tilde{y}_i)^2} \quad 4$$

Where y_i is the predicted values by the algorithm and $\tilde{y}_i$ is the actual values.

3 DATA CHARACTERISTICS, CASE STUDY SCENARIOS, AND RESULTS

This section assesses the FL method's performance on real-world datasets and compares the results to those obtained from centralized models working on non-shared data. The findings demonstrate that the proposed FL system is capable of delivering competitive performance while maintaining data privacy.

3.1 Data Characteristics and Forecasting Horizon

Herein, we use an open-source electrical energy consumption dataset from the Los Alamos Public Utility Department (LADPU) in New Mexico, USA. Landis+Gyr smart meters were used to gather data from 1,120 residences in North Mesa, Los Alamos, NM [22]. One sample per 15 minutes is the sample rate (i.e., 96 observations per day). The data for the majority of users spans around six years, from July 30, 2013 to December 30, 2019. The term is, however, shortened for some consumers. The dataset has null values and redundant observations, which are corrected using well-known preprocessing techniques. Interested readers are invited to read [22] for more information regarding data characteristics. There are 1120 consumers in the test program, comprising 480 residential customers without PVs and 237 residential customers having PVs. Customers' PV production and local demand data are combined to provide net demand statistics. We have considered 9 residential costumers with PVs as the representative clients (data owners).

The dataset is separated into three pieces, which are referred to as the train, validation, and test sets, respectively. One method for dividing the dataset into these three categories is to set aside a fraction of the data (for example, 20%) for each category. Although simple, this method is irrational owing to the possibility of sampling bias. As a result, the split process we use may not be representative of the total population. To avoid this, we must ensure that the train/test/validation sets are reflective of the various frequencies seen across the dataset. Meanwhile, Python has a function called "Stratified-Split" that solves the problem by splitting the data while accounting for the frequency of each attribute. As a result, we used this strategy to partition the dataset into homogeneous training, validation, and testing sets. 70 percent of the data is used in the training phase, 29 percent in the validation phase, and 1% in the testing phase. The forecasting horizon is around 24 days if 1% of the data is used during the testing phase.

Several raw characteristics are used as inputs for training this MLP model using the publicly accessible solar production data, e.g, the net load. In addition to historical data on solar energy generation, a concatenation of climatic variables is necessary to forecast future generation. At the chosen location, weather conditions such as wind speed and solar irradiation must be considered. Additionally, the air pressure, temperature, and humidity are given. Furthermore, date-related variables are used as input to the MLP models. These variables include the hours of the day (from 1 to 24), the day of the month, and the month number. Each day of a particular year is regarded to be a concatenation of 365 binary variables, each corresponds to a numerical value in the dataset. This is referred

to as one-hot encoding, in which all bits are zero except for one that acts as a binary flag for each day of the year. A similar approach is suggested for the other date-related variables.

3.2 Case Studies

To assess the efficacy of applying FL to BTM PV energy forecasting, we compare it to centralized learning, localized learning, and federated-based scenarios. These diverse possibilities are summarized and compared in Table I.

Table 1. Representative cases studies

Case Number	Description	Private Exchange of Data	Generalizable
1	Centralized	×	✓
2	Localized	✓	×
3	Fedearted	✓	✓

In the first scenario, we used a centralized, non-distributed learning strategy that is most commonly employed when data privacy is not a major concern during training. This case brings together a number of issues. This approach gathers data from many datasets and executes training in a single location. In a non-private context, centralized training also creates a baseline for the capabilities of a single, collaborative forecasting model. We train models for 30 epochs before finishing early based on the validation set's lowest error.

The second option is a totally private, isolated localized learning environment in which each data is taught separately of the others and the training process is separated from all other clients. This method generates forecasting models that are unique to each site and are unable to benefit from data from other databases. Training was done for a maximum of 30 epochs in line with the centralized learning approach. It is critical to emphasize that in isolated cases, individual datasets are private and inaccessible to other data owners.

Following that, we provide a scenario based on FL that achieves the same goal as centralized learning: training a single, joint model that generalizes well enough to make correct predictions for all individual data owners. FL, on the other hand, offers more generalizability than a limited learning environment. Unlike centralized learning, the FL does not pool the training data from individual sites. On the other hand, each local client keeps the training data private.

3.3 Results

To begin, we change the hyperparameters of the MLP model to get the optimal network. Hyperparameters are used to either configure a machine learning model or to indicate the technique used to minimize the loss function (e.g., the activation function and optimizer types of the networks). In general, hyperparameters determine the architecture and training of a neural network. The number of network layers, the number of nodes in each layer, the activation method, and other characteristics of machine learning architectures are all hyperparameters. The method of hyperparameter tuning aims to create the ideal model architecture with the optimal hyperparameter settings.

Manual testing, grid search, and decision-theoretic optimization are all traditional approaches for adjusting hyperparameters. In this study, we used a decision-theoretic optimization strategy, modifying the hyperparameters through a Python application called "HyperOpt." This approach is chosen because of better computational to result ratio compared to other alternatives such as random or grid search. Table II lists the hyperparameters associated with the final MLP model.

Table 2. Suggested MLP hyperparameters for BTM solar prediction

Number of Hidden layers	8
Solver	Adam
Hidden layer nodes	180
Activation Function	Sigmoid
Learning rate	0.01
Random state	None
Validation fraction	0.29

To assess the representative methods' performance, we give the root mean square error (RMSE) metric derived on the test set for each of the 10 customers in each case study. Additionally, the average performance indices are shown for all clients (in FL and distributed techniques) or validation sets (in centralized approaches). Table III describes the performance outcomes for Cases 1, 2, and 3. The centralized, localized, and federated learning are different in that we use different procedures for training the MLP algorithms.

Table 3. Forecasting performance values (RMSE in kW) for the 9 databases and overall average—Centralized (case 1) without privacy, Localized (case 2) with privacy, and Federated (case 3) with privacy.

Site	**Case 1**	**Case 2**	**Case 3**
database 1	0.451	0.561	0.498
database 2	0.341	0.488	0.387
database 3	0.322	0.478	0.356
database 4	0.499	0.621	0.513
database 5	0.511	0.738	0.537
database 6	0.422	0.533	0.465
database 7	0.432	0.618	0.515
database 8	0.509	0.749	0.602
database 9	0.497	0.666	0.55
Average	**0.442**	**0.606**	**0.491**

As can be seen, the centralized method enables access to all client-generated databases. As a consequence, model accuracy is expected to be greater than that of competing techniques that use far less data. Using the root mean square error as evaluation metric, the centralized technique outperforms the localized approach by 27.06 percent and the FL by 9.97 percent. This illustrates that centralized models are capable of making accurate predictions, but

at a considerable cost in terms of data and privacy. While centralized approaches enable the learning of collective behaviour, they compromise the energy facilities' privacy by requiring data to be gathered in a single location.

Localized learning entails training a model for each client independently, using just the data available to that site. The lower values of the root mean square error imply that the localized model performs rather well. This demonstrates that the MLP architecture is capable of learning complicated generation characteristics unique to each client. Additionally, the localized paradigm preserves privacy since no data is shared across clients. However, this strategy lacks generalizability due to the fact that the training samples are constrained to a single place, and fresh and unknown data may result in the localized models performing poorly.

For each round of training, the FL approach communicates iteratively between a super model and each client. A selection of clients is chosen, and each client trains their own local data independently for a predetermined number of epochs. As a consequence, a pool of local models is formed that may be utilized to improve the super model's accuracy. By transmitting the parameters associated with the local models, the chosen clients update/co-train the super model. In contrast to the centralized model, the federated model can maintain privacy due to such a training approach. Furthermore, as evaluated by the RMSE score, the FL outperforms the localized model by 18.97 percent. This demonstrates that the FL effectively accounts for the dependent variable's changes and that the disparities between observed and predicted values are small and unbiased.

4 CONCLUSION

Forecasting collective behind-the-meter solar energy is a challenging undertaking, considering the privacy problems associated with PVs' data. Another constant issue in the prior research is the generalizability of forecasting models. By federating the training of machine learning models across numerous on-site PVs, we suggested a privacy-preserving solar power prediction system. This is one of the first papers that we are aware of that analyzes federated learning in the context of learning-based BTM energy prediction. By using a federated learning approach, we have significantly reduced the amount of communication between clients and the central server, since server-client data transfer is eliminated. Because the server does not collect data from specific sites, the server maintains data privacy. Additionally, we preserved the generalizability of energy predictions to a decent level. Federated learning outperforms localized models in our experiments (18.7 % lowe RMSE) and is very competitive with centralized alternatives (9.9% higher higher).

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Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

REFERENCES

[1] "Go solar California," May 2018. [Online]. Available: http://www.gosolarcalifornia.ca.gov.

[2] H. Long, Z. Zhang, and Y. Su, "Analysis of daily solar power prediction with data-driven approaches," *Appl. Energy*, vol. 126, pp. 29–37, 2014.

[3] C. Chen, S. Duan, T. Cai, and B. Liu, "Online 24-h solar power forecasting based on weather type classification using artificial neural network," *Sol. Energy*, vol. 85, no. 11, pp. 2856–2870, 2011.

[4] H. Yang, C. Huang, Y. Huang, and Y. Pai, "A Weather-Based Hybrid Method for 1-Day Ahead Hourly Forecasting of PV Power Output," *IEEE Trans. Sustain. Energy*, vol. 5, no. 3, pp. 917–926, 2014.

[5] J. Liu, W. Fang, X. Zhang, and C. Yang, "An Improved Photovoltaic Power Forecasting Model With the Assistance of Aerosol Index Data," *IEEE Trans. Sustain. Energy*, vol. 6, no. 2, pp. 434–442, 2015.

[6] A. Syahiman, H. Yokoyama, and N. Kakimoto, "High-Precision Forecasting Model of Solar Irradiance Based on Grid Point Value Data Analysis for an Efficient Photovoltaic System," *IEEE Trans. Sustain. Energy*, vol. 6, no. 2, pp. 474–481, 2015.

[7] S. X. Chen, H. B. Gooi, and M. Q. Wang, "Solar radiation forecast based on fuzzy logic and neural networks," *Renew. Energy*, vol. 60, pp. 195–201, 2013.

[8] J. Wang, H. Zhong, X. Lai, Q. Xia, Y. Wang, and C. Kang, "Exploring Key Weather Factors From Analytical Modeling Toward Improved Solar Power Forecasting," *IEEE Trans. Smart Grid*, vol. 10, no. 2, pp. 1417–1427, 2019.

[9] E. Lorenz, J. Hurka, D. Heinemann, and H. G. Beyer, "Irradiance Forecasting for the Power Prediction of Grid-Connected Photovoltaic Systems," *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 2, no. 1, pp. 2–10, 2009.

[10] E. Lorenz, T. Scheidsteger, and J. Hurka, "Regional PV power prediction for improved grid integration," *Prog. Photovoltaics Res. Appl.*, vol. 19, pp. 757–771, 2011.

[11] Y. Saint-drenan, G. Good, M. Braun, and T. Freisinger, "Analysis of the uncertainty in the estimates of regional PV power generation evaluated with the upscaling method," *Sol. Energy*, vol. 135, pp. 536–550, 2016.

[12] A. Ahmadi, M. Nabipour, and B. Mohammadi-ivatloo, "Ensemble Learning-based Dynamic Line Rating Forecasting under Cyberattacks," *IEEE Trans. Power Deliv.*, pp. 1–9, 2021.

[13] T. Li, A. Sahu, A. Talwalkar, and V. Smith, "Federated Learning: Challenges, Methods, and Future Directions," *IEEE Signal Process. Mag.*, vol. 37, no. 3, pp. 50–60, 2020.

[14] S. Lee and D.-H. Choi, "Federated Reinforcement Learning for Energy Management of Multiple Smart Homes with Distributed Energy Resources," IEEE Transactions on Industrial Informatics, pp. 1–1, 2020.

[15] Yang Q, Liu Y, Cheng Y, Kang Y, Chen T, Yu H. Federated learning. Synthesis Lectures on Artificial Intelligence and Machine Learning. 2019 Dec 19;13(3):1-207.

[16] Liu Y, James JQ, Kang J, Niyato D, Zhang S. Privacy-preserving traffic flow prediction: A federated learning approach. IEEE Internet of Things Journal. 2020 Apr 30;7(8):7751-63.

[17] Saputra YM, Hoang DT, Nguyen DN, Dutkiewicz E, Mueck MD, Srikanteswara S. Energy demand prediction with federated learning for electric vehicle networks. In2019 IEEE Global Communications Conference (GLOBECOM) 2019 Dec 9 (pp. 1-6). IEEE.

[18] Taheri S, Ghoraani R, Pasban A, Moeini-Aghtaie M, Safdarian A. Stochastic framework for planning studies of energy systems: a case of EHs. IET Renewable Power Generation. 2020 Feb;14(3):435-44.

[19] Taheri S. A Multi-Period Water Network Planning for Industrial Parks; Impact of Design Periods on Park's Flexibility. arXiv preprint arXiv:2108.01047. 2021 Aug 2.

[20] Taheri S, Razban A. Learning-based CO2 concentration prediction: Application to indoor air quality control using demand-controlled ventilation. Building and Environment. 2021 Nov 1;205:108164.

[21] Davoudi M, Sadeh J, Davoudi M. Analysis of DFIG During Unsymmetrical Grid Fault by Using Crowbar Circuit. In2019 Iranian Conference on Renewable Energy & Distributed Generation (ICREDG) 2019 Jun 11 (pp. 1-6). IEEE.

[22] Souza, Vinicius, Estrada, Trilce, Bashir, Adnan, & Mueen, Abdullah. (2020). LADPU Smart Meter Data [Data set], Jan 2020. https://doi.org/10.5061/dryad.m0cfxpp2c

STUDENT RETENTION IN INSTITUTIONS OF HIGHER LEARNING:
A Case Study with Big Data

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STUDENT RETENTION IN INSTITUTIONS OF HIGHER LEARNING: A Case Study With Big Data

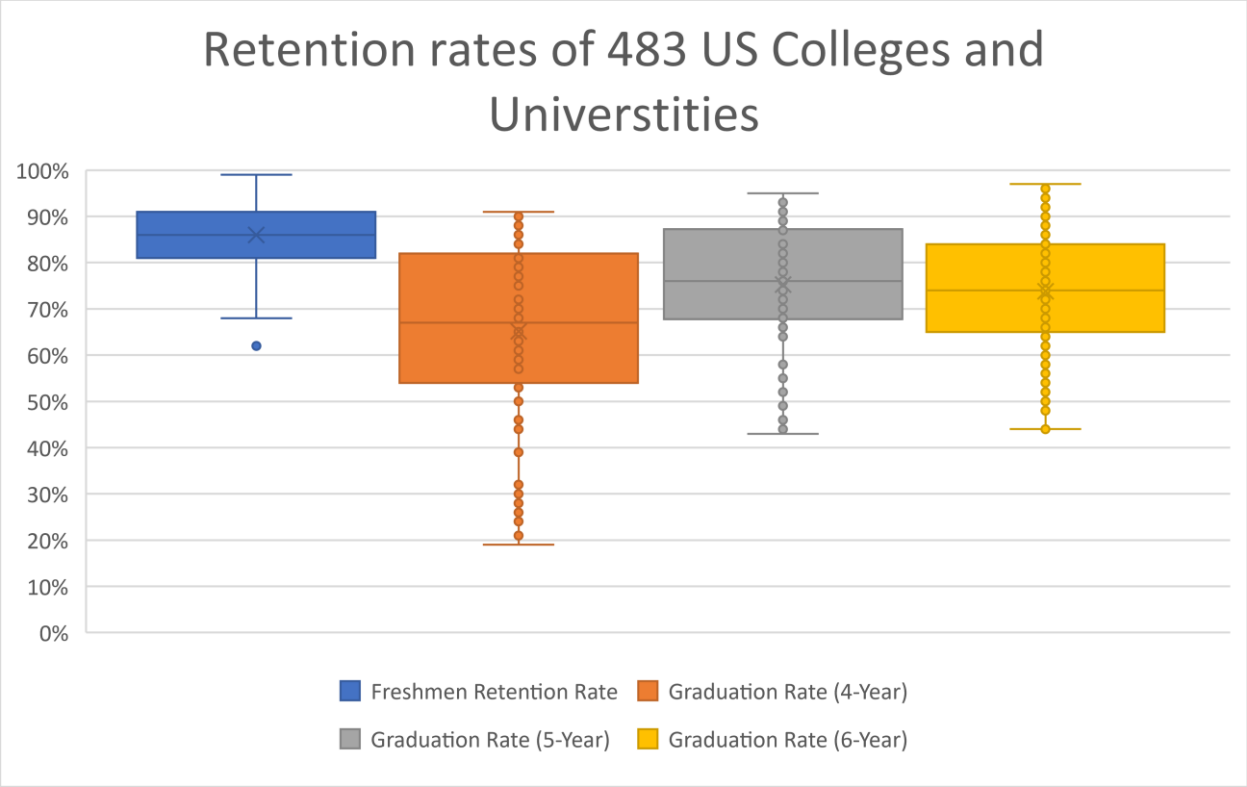
Abstract

Many institutions of higher education are faced with the problem of student retention. Thus, it is imperative to determine the main factors that cause students to drop out or move to other universities. Some studies have suggested that student engagement in their first year of college is an important factor but have concluded that any additional research should go beyond how to keep students engaged. Other studies have suggested introducing factors or treatments that might affect the behavior of students and decrease attrition. Yet, there are others that believe that student retention is determined by creativity, emotional intelligence, and learner self-sufficiency.

Our study will evaluate demographics, student performances, as well as several other variables for the fall of 2011 through the fall of 2020 and will determine the factors that influenced retention. Furthermore, we intend to determine the effect of the pandemic on the learning environment of the institution. Data consisting of information on 209,463 student course registrations and 40,581courses for a period of 10 years were provided by the institutional research department of the University of Tennessee at Chattanooga.

STUDENT RETENTION IN INSTITUTIONS OF HIGHER LEARNING:
A Case Study with Big Data

Among the many challenges faced by institutions of post-secondary education helping students stay in school and graduate is especially complex. Many socio-economic factors impact how well students can overcome obstacles and succeed by graduating within a reasonable time span. A recent study of 483 U.S. colleges and universities presented four measure of student retention rates, namely, Freshmen retention rate, four-year graduation rate, five-year graduation rate and six-year graduation rate. The data they presented is summarized in the following boxplot.



This summary shows that the median retention rate for freshmen is at 85% in about quarter of the institutions nearly 20% of the freshmen students drop out. The median graduation rate in four years is less than 70% with some institutions recording an abysmal 20% rate. Even at the five and six-year marks the graduation rates hover only around 75%.

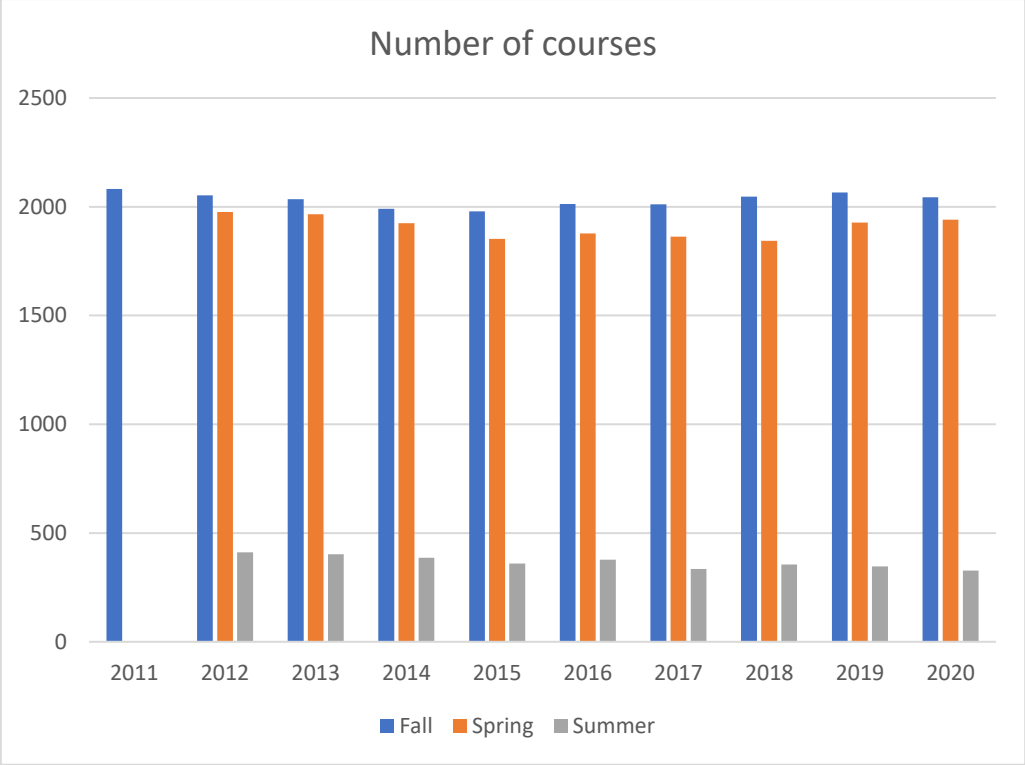
SOME TOOLS of INCREAING RETENTION

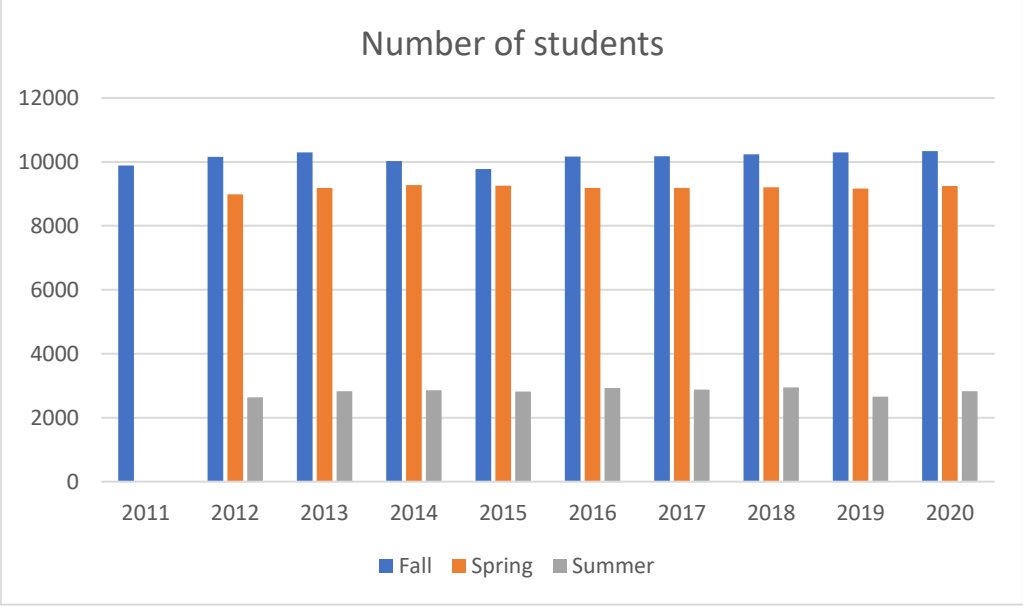
Many universities are trying to keep the retention rate of students high and are searching for the best possible solution. To this end, some companies have developed software which can evaluate an institution of higher learning and come up with solutions. Avisio Retention and Avisio Engage are such software (https://www.avisoretention.com/). Visio Engage is a software that makes it easy for professionals and other university employees to reach out to students struggling or in need of academic aid. This software has been used as a strategy to tend to the needs of students as fast as possible, as well as identifying factors that are preventing the students from succeeding. Avisio allows professors to see where students were struggling, whereas beforehand many professors had to rely on students self-reporting areas of need. Chowan University greatly increased their retention rate among their students by using this software (New York Times, 23 Sep 2021). After the introduction of the software, the second year retention rate was at an all-time high, the 2nd to 3rd year retention rate was the highest in the last 20 years, and the fourth year retention weight was tied for an all-time high.

Black et al tried to determine if certain courses affected the retention rate of students. They evaluated the courses in business, English, seminar, and other first year classes. They found that business courses and other specialized areas of learning had the highest retention rate among all classes. These business courses had a retention rate about 9% higher than classes that were based on seminar or lecture. Freshman experience and English courses were about middle of the pack with just a slightly higher retention rate than others. Seminar classes that were targeting transfer students were the lowest among all the classes research.

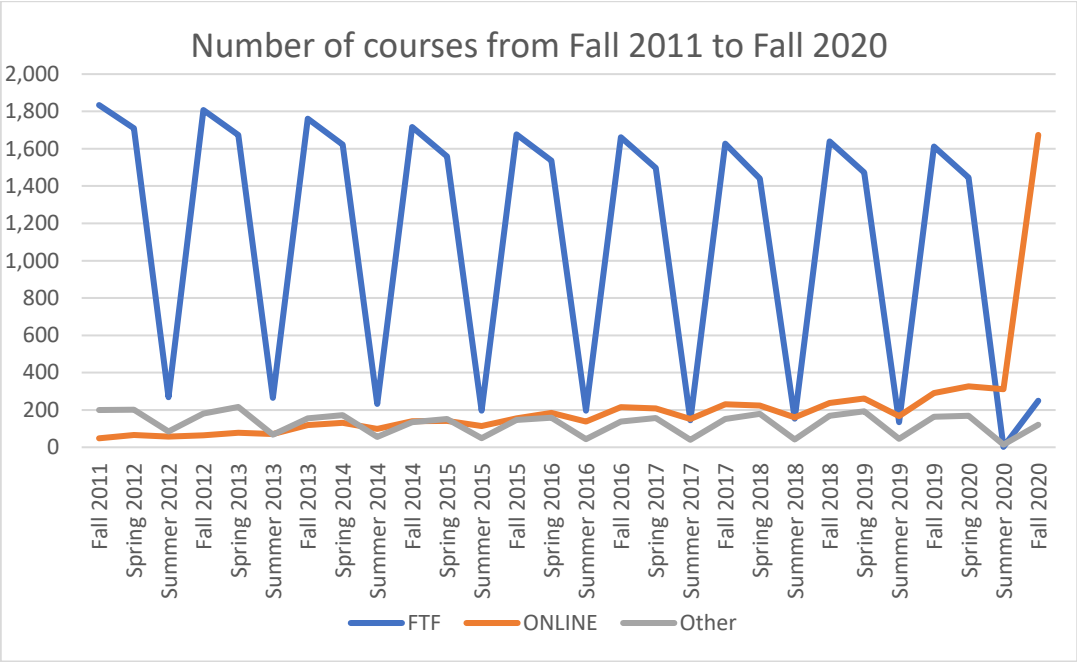
RESULTS

The following charts show graphs of the several variables in our study. The first two charts show that the number of courses offered, and student enrolment remained steady over span of semesters the data covered (2011 to 2020)

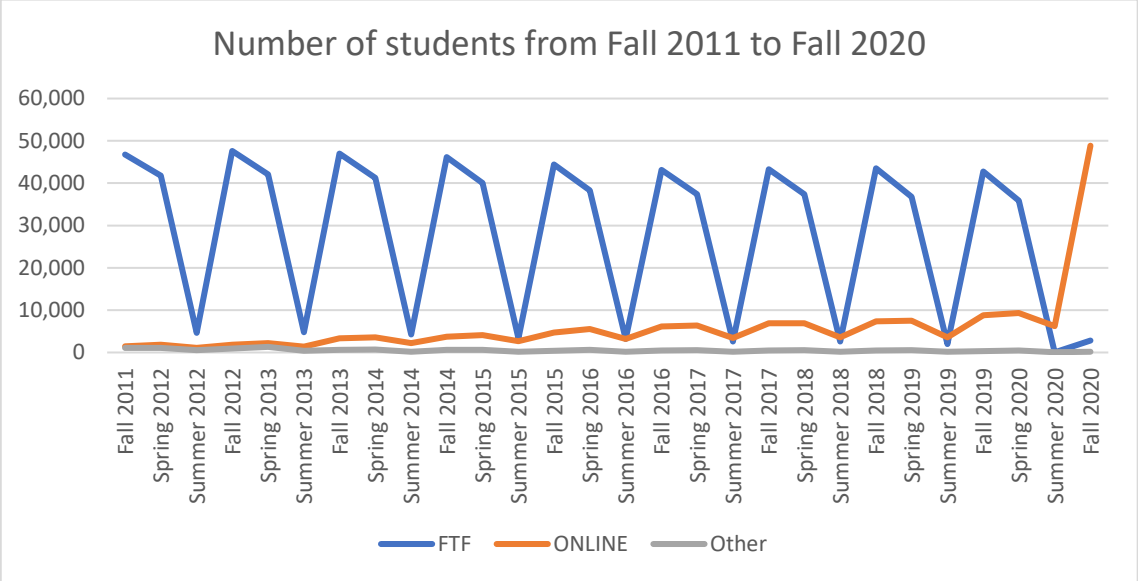




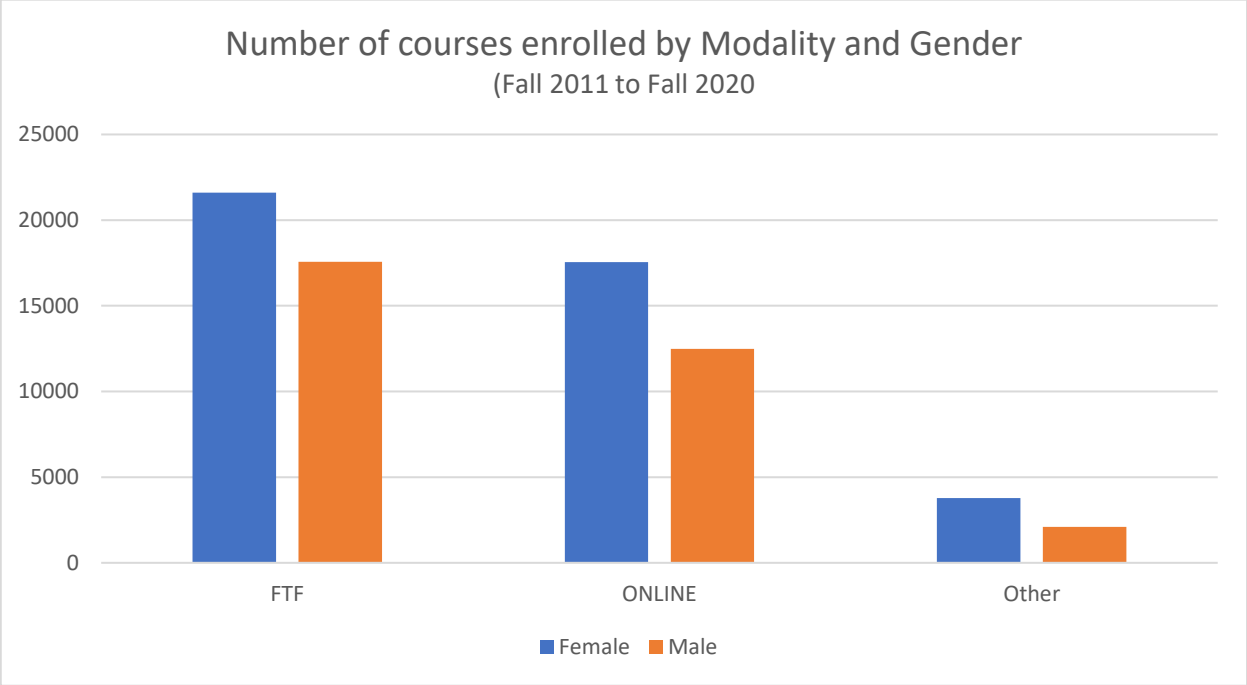
The following chart is the time series trend of the number of courses offered by modality Face-to Face (FTF), online, and others over the duration of data. The time series are steady until Fall 2020, at which time data shows a spike in online courses due to Covid-19.



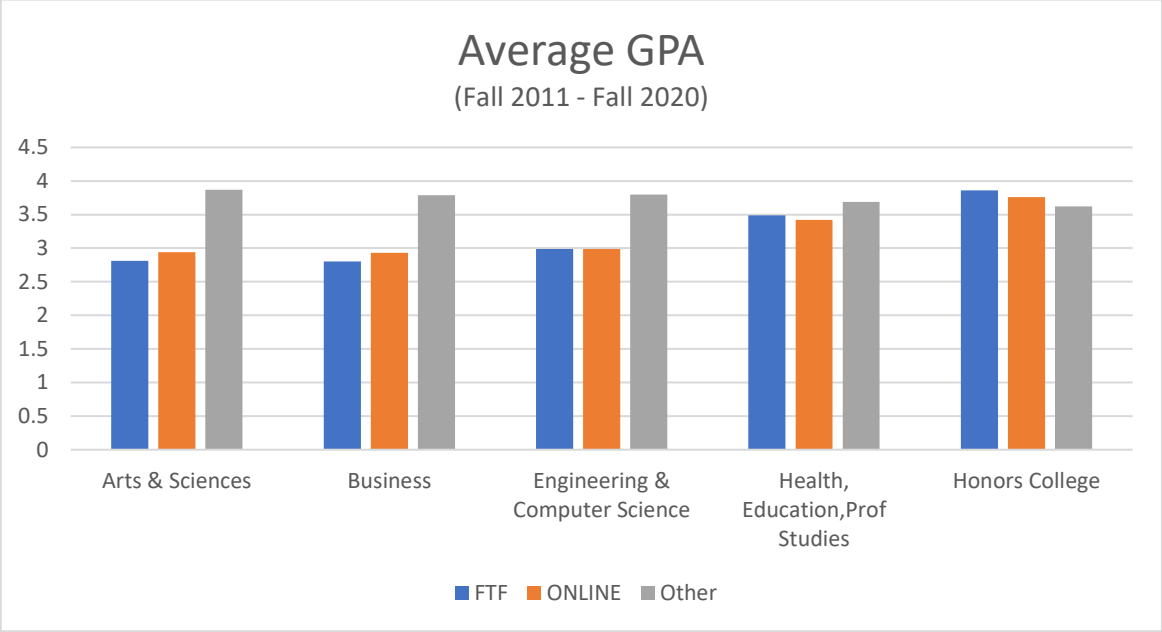
The number of students enrolled in different modality classes are presented in the following chart. As expected, the enrollment was steady until fall 2020, when there was a sike in enrollment in the online chasses,



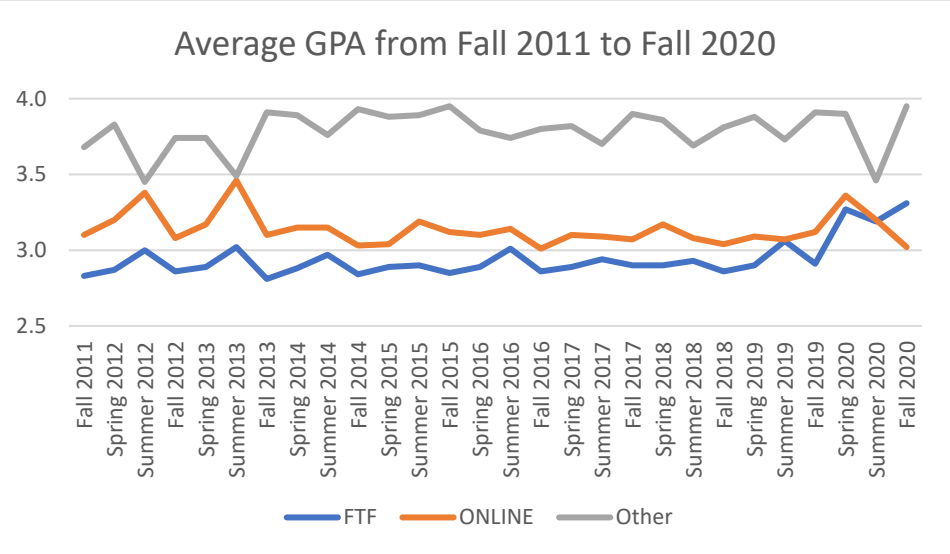
The enrollment by modality and gender are presented below. The ratio of females to males for the FTF, Online, and Others are 1.2, 1.4, and 1.8 respectively.



The following chart represent average GPA by modality and division. In two of the five colleges, Honors College and Health, Educations, and Professional Studies, the GPA of online students were higher the other three colleges (Art and Sciences, Business, and Engineering and Computer Science).

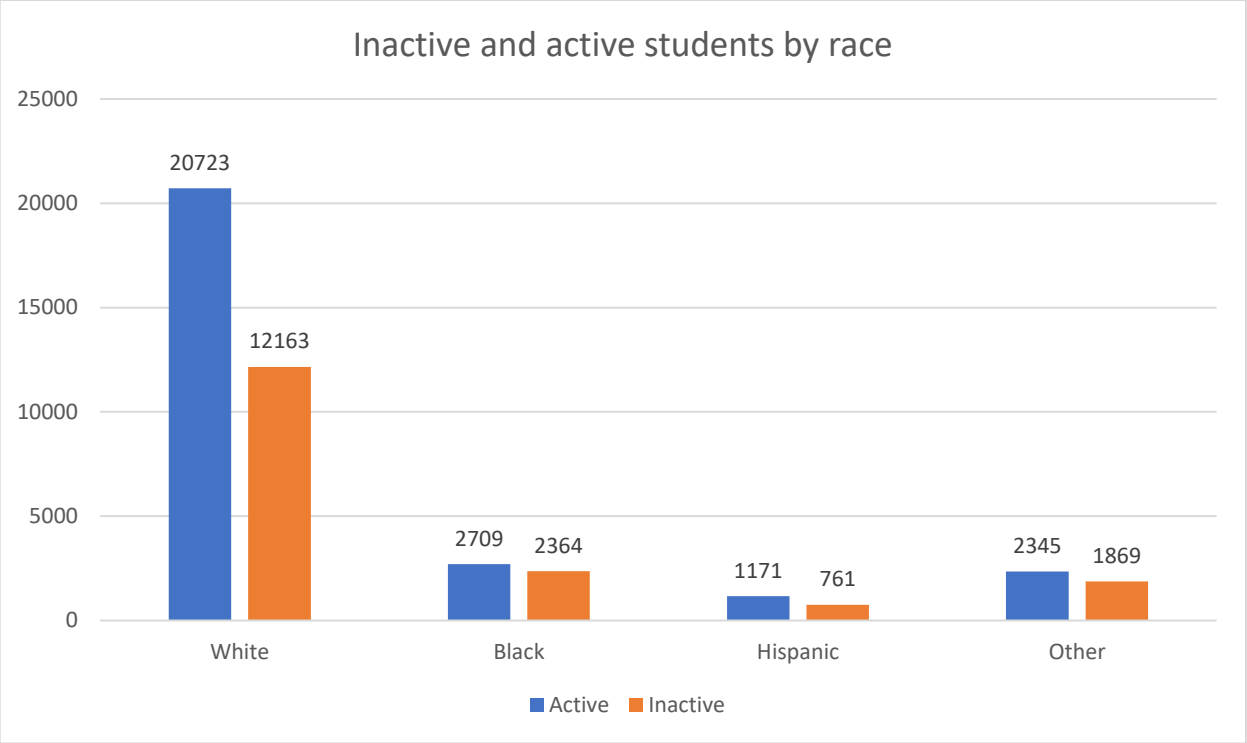


The average GPA is almost steady for the duration of the available data. The following chart presents the average GPA.

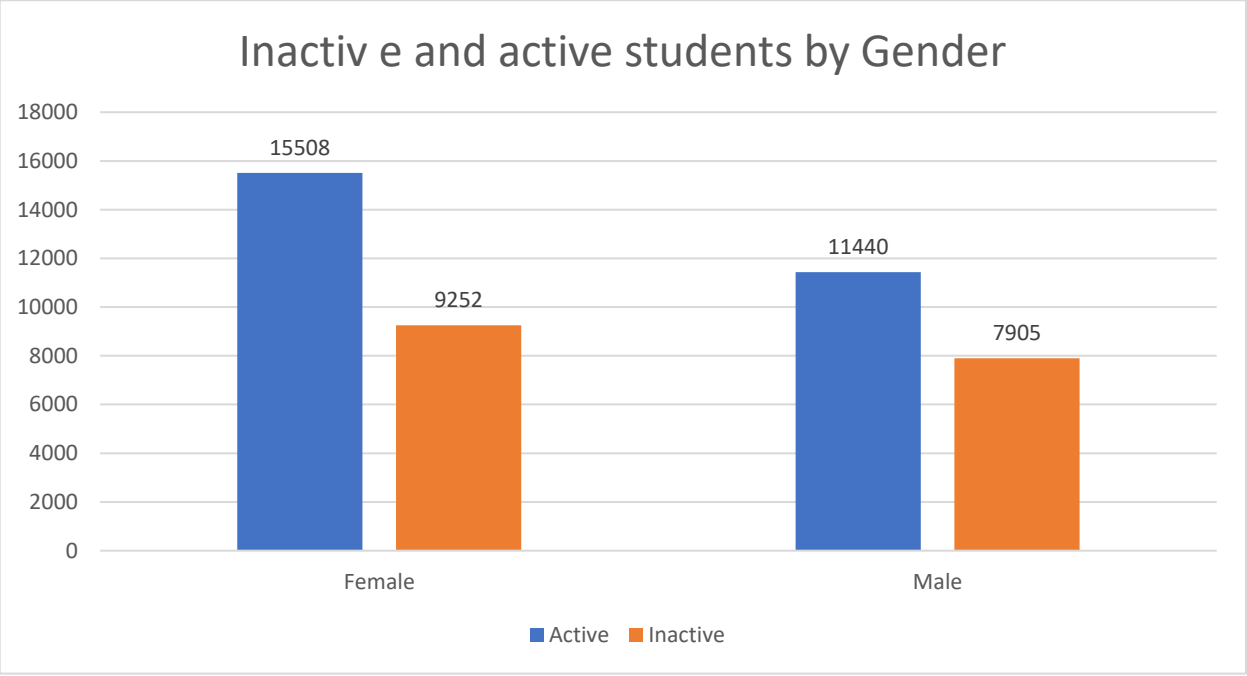


To determine which students were retained, we coded students who have not graduated and not currently enrolled in any class as ***inactive*** with a value of 1 and those who are currently enrolled or have graduated as ***active*** with a value of 0. In the following charts we present bar charts of these student by race, gender and whether the student is first generation in college or not.

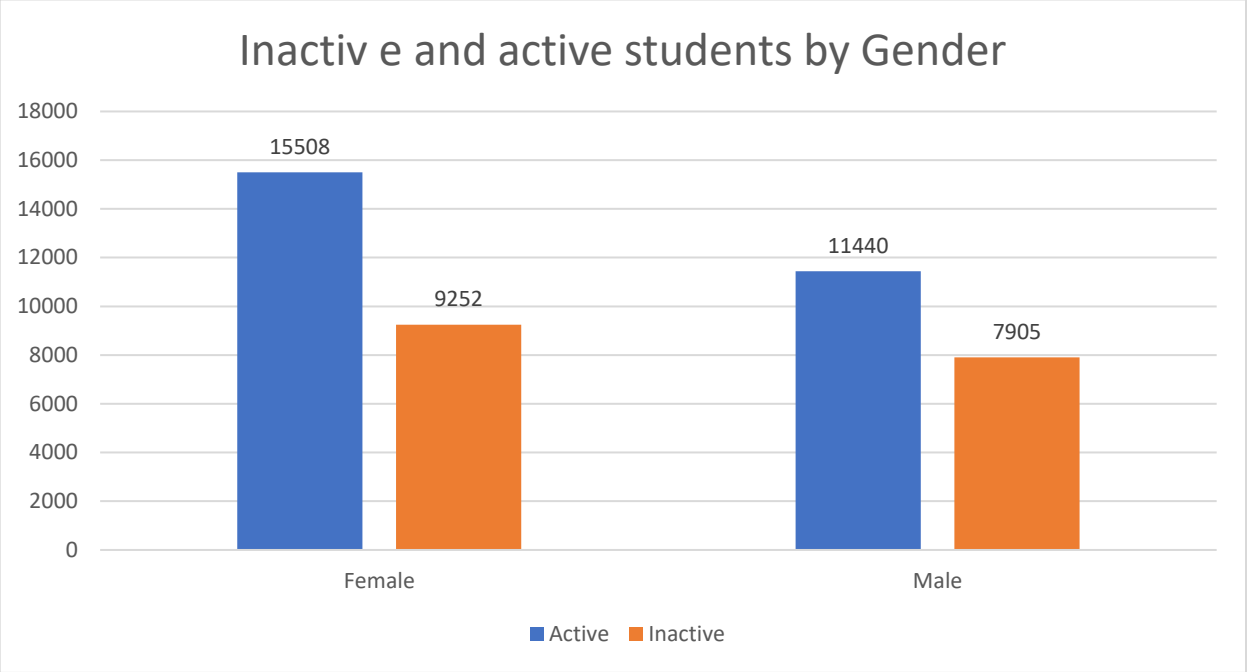
The ration of Active to Inactive for ethnicities White, Black, Hispanic, and Others are 1.7, 1.2, 1.5, and 1.7 respectively, indicating a larger portion of white students are inactive.



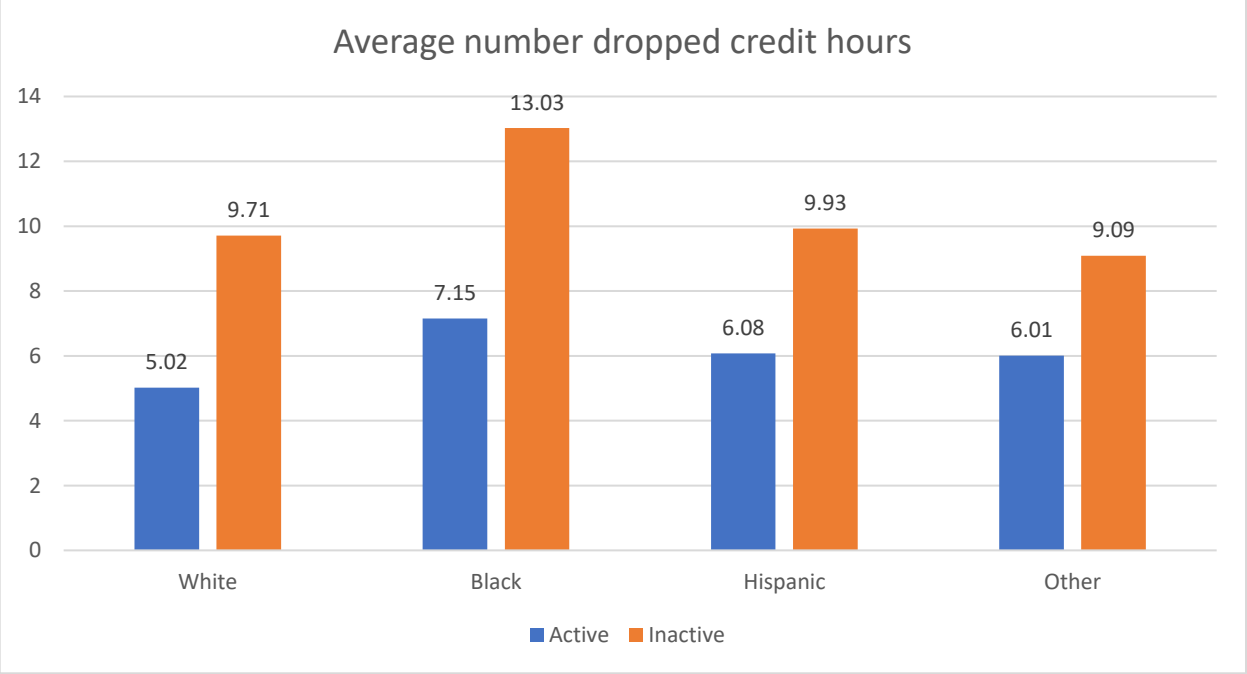
The retention of students by gender is shown below. The ratio of inactive to actives by gender is 1.7 for females and 1.4 for males.

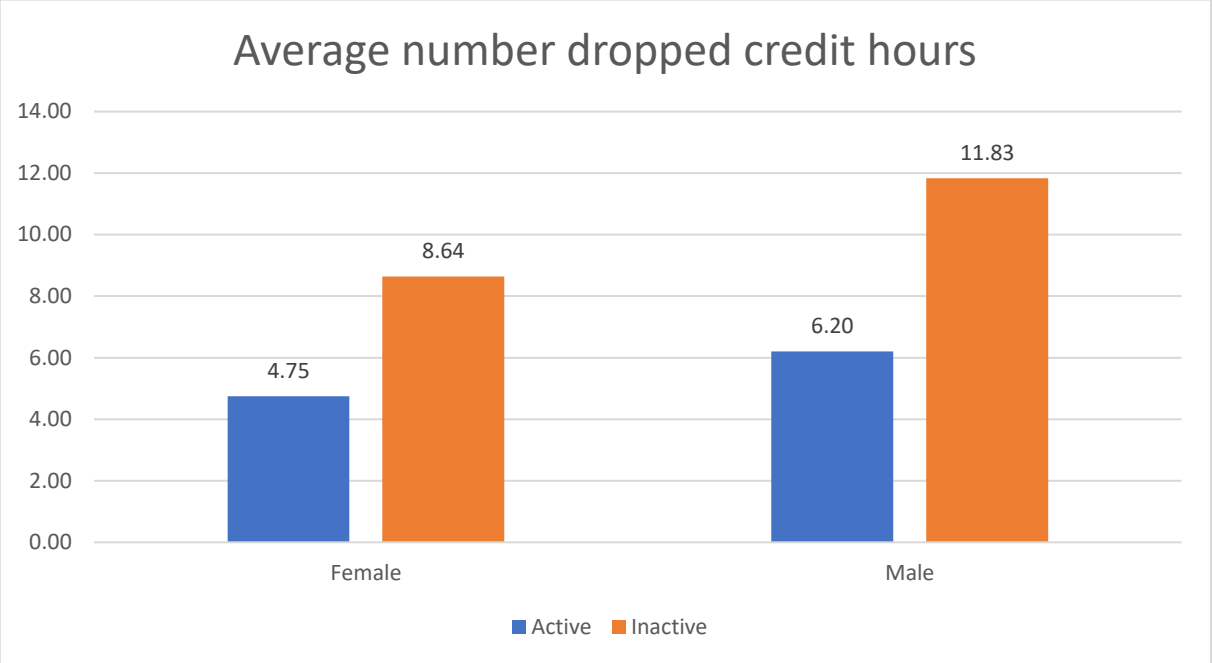


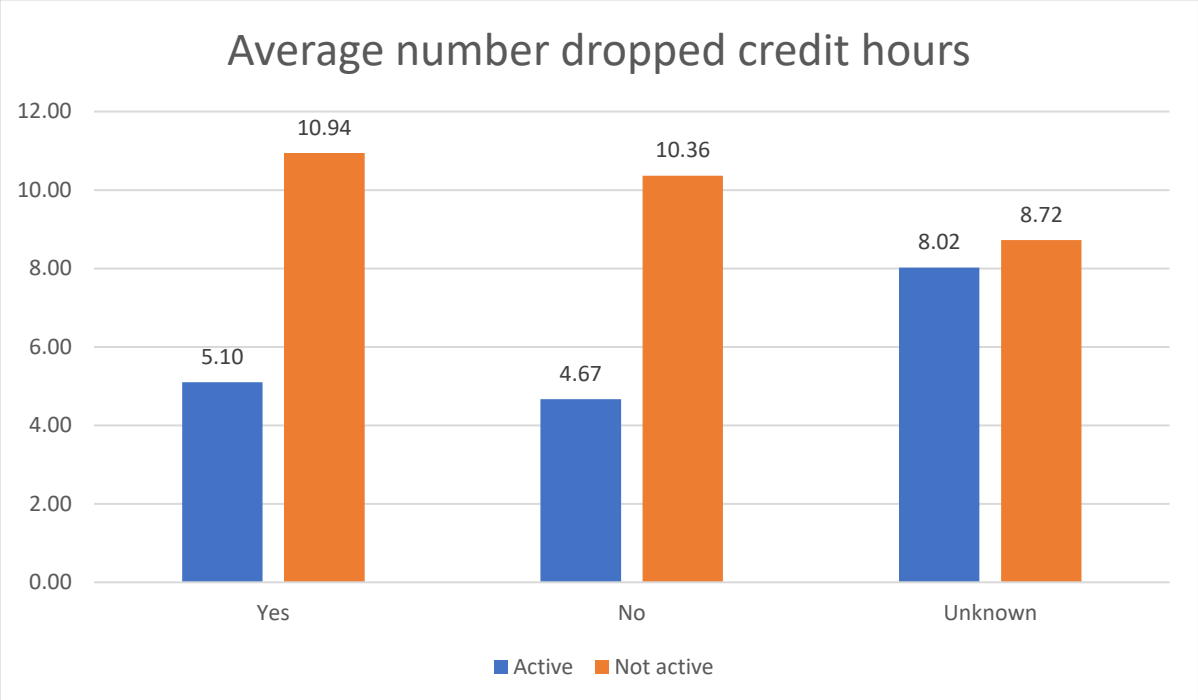
The ratio of inactive to active by whether the student is a first generation student or not are 1.7 and 1.4.



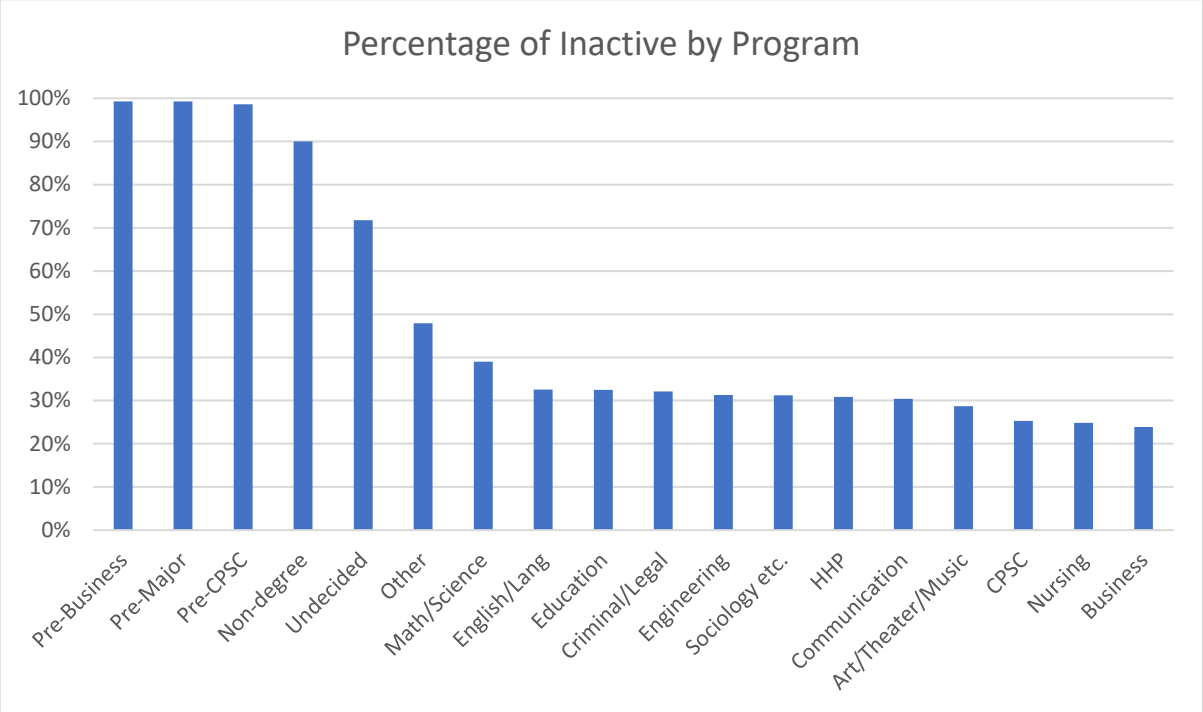
We next present the average number of dropped credit hours by the same demographic variable as above.







Finally, we compared the percentages of inactive by program and the results are presented below. Those who have had a pre-major or have not defined a major have the highest percentages of inactive and those who have defined a major are almost the same, with business having the lowest percentage of 23.9.


Percentage of Inactive by Program
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pre-Business
Pre-Major
Pre-CPSC
Non-degree
Undecided
Other
Math/Science
English/Lang
Education
Criminal/Legal
Engineering
Sociology etc.
HHP
Communication
Art/Theater/Music
CPSC
Nursing
Business

Sources

Black, A., Terry, N., & Buhler, T. (2016). THE IMPACT OF SPECIALIZED COURSES ON STUDENT RETENTION AS PART OF THE FRESHMAN EXPERIENCE. Academy of Educational Leadership Journal, 20(1), 85-92. Retrieved from

Chowan university credits aviso retention for boosting student retention rates: Aviso helps four-year institution achieve all-time high retention rates. (2021, Sep 23). PR Newswire

https://www.collegetransitions.com/dataverse/retention-and-graduation-rates

UNDERSTANDING HOW FOOD BANK OPERATIONS ARE IMPACTED DURING DISASTER (COVID-19 PANDEMIC)

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ABSTRACT

Food insecurity is one of the world's significant issues, including the U.S. Millions of children and families living in America face hunger and food insecurity every day. In North Carolina, more than 600, 000 households regularly suffer from insufficient food, and 1 in 5 children face hunger. The Government and many non-profit organizations are working to solve food insecurity problems. Food banks are non-profit hunger relief organizations that collect food and monetary donations from donors and distribute food to local agencies that serve people in need. Contributions come from local retail, food manufacturers, individuals, groups, federal, and Feeding America. The uncertainty of supply and demand is a significant challenge for food banks in fighting against food insecurity. This study investigates how external shocks such as government policy or pandemics impact food donation and distribution using the data obtained from the Food Bank of Central and Eastern North Carolina. Using Exploratory Data Analysis techniques, we show that from March 2020 to May 2020, most of the contribution comes from Government policies, but food banks' supply from donors decreases, whereas demand increases. In this study we found that food distribution per county has correlation with population number and under 18. Our study is expected to help non-profit organizations like food banks exercise more effective and efficient operations.

Keywords: Foodbank, Food insecurity, Government, Demand, and Supply, Non-profit, Demographic and Socioeconomic

1. INTRODUCTION

Food insecurity is one of the significant issues in the world, including in the U.S. In the 1990s, the U.S. Government undertook the development of a comprehensive national measure of the severity of food insecurity and hunger in the United States [1]. Food insecurity describes a household's inability to provide enough food for every person to live

an active and healthy life. Food insecurity is one way we can measure and assess the risk of hunger [1]. Millions of children and families living in America face hunger and food insecurity every day. According to the USDA's latest Household food insecurity in the United States report, more than 37 million people in the United States struggled with hunger in 2018 [1]. In 2018, 14.3 million American households were food insecure with limited or uncertain access to enough food [1]. Families with children are more likely to experience food insecurity. In 2018, more than 11 million children lived in food-insecure households. According to a USDA report, an estimated 10.5 % of U.S. households were food insecure at least some time during 2019, meaning they lacked access to enough food for an active, healthy life for all household members. The number shows that it is down from 11.1 percent in 2018 and from a peak of 14.9 percent in 2011 [1]. The prevalence of inadequate food security was 4.1 percent in 2019, not significantly different from 2018 [8].

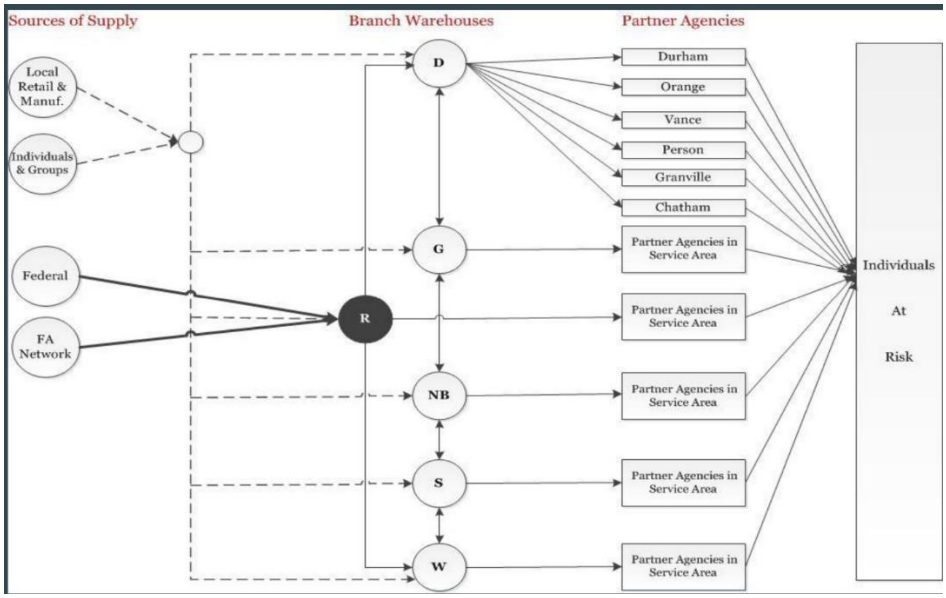
Government, State, federal, and many non-profit organizations have been working to solve food insecurity problems. For example, the Government provides food assistance through federally funded programs such as Supplemental Nutritional Assistance Program (SNAP), Women, Infants, and Children (WIC), Emergency Food Assistance Program (TEFAA), and National School Lunch Program during the month before 2018 [6] [7][8].

1.1. Food Bank of Central and Eastern North Carolina

North Carolina is one of the hungrier State in the U.S. In North Carolina, nearly 600,000 households do not have enough food to eat [4]. 1 in 5 children in North Carolina regularly suffer from insufficient food [4]. In 2011, more than 121 million pounds of food were distributed to those in need by North Carolina Food Banks [9]. In all North Carolina counties, Feeding America Food Banks and 1,700 partner agencies are working hard to serve people in need [9].

Food Bank services attempt to reduce food insecurity by providing food and other necessary products to people in need. Food banks are non-profit organizations that collect and distribute supplies to people. There are six food banks and one shuttle organization in North Carolina: Food Bank of Albemarle, Food Bank of Central and Eastern North Carolina, Manna Food Bank, Second Harvest Food Bank of North Carolina, Second Harvest Food Bank of Northwest North Carolina, Second Harvest Food Bank of Southeast North Carolina, and the Inter-Faith Food Shuttle. Our study focuses on the Food Bank of Central and Eastern North Carolina. The Food Bank of Central and Eastern North Carolina (FBCENC) has provided foods to individuals at risk of hunger in 34 counties in central and eastern North Carolina for the last 40 years [3]. Under this foodbank, there are six branches: Durham, Greenville, New Bern, Raleigh, Sandhills (Southern Pines), and Wilmington. The Food Bank

began operations in 1980. It works across the food system to provide nutritious food that nourishes families, children, seniors, and individuals. There are different partner agencies such as soup kitchens, food pantries, shelters. Six hundred thousand individuals cannot consistently access enough nutritious food to live a healthy, active life or go hungry because they skip meals where FBCENC serves [3]. Around 31% of food insecure people are children [1]. Fiscal Year 2017-18, FBCENC provided 66,659,152lbs of food which equals 56,134,023 meals [3]. Source of supply for foodbanks are Local retailers and manufacturers, State and Federal government, Feeding America network and Farmers, and growers.



L.B. Davis et al. / Int. J. Production Economics 182 (2016) 26–37

Figure 1: Product flow in the foodbank network.

1.2. FBCENC and COVID -19 Crisis Response

The urgent food need of the people in 34 counties has never happened before COVID-19 Crisis. In the fiscal 2020 year, including four months of pandemic crisis response, FBCENC distributed about 92,000,000 pounds of food [3]. In four months (March, April, May, and June) of the pandemic crisis, FBCENC had spent $2.3 million to buy food to keep food going out to the community [3].

2. LITERATURE REVIEW

There are several studies related to food bank operations. The literature review was conducted on food bank research focusing on keywords like donation, distribution, nutrition, and vehicle routing.

Paul, and Davis (2019) developed predictive modeling to analyze and forecast the contribution of different donors [10]. In this study, some numerical studies also quantify the extent of uncertainty regarding donor product, supply chain structure, and predictive model developed to estimate the quantity of in-kind donation. Moreover, the authors proposed a regression model to predict future contributions and evaluations and evaluated model accuracy using the Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE).

Davis et al., 2016 investigated a comprehensive numerical study to quantify the extent of uncertainty in terms of the donor, product, and supply chain structure. In this study, different predictive models were developed to predict the number of in-kind donations.

Nuamah et al., 2015, developed a simulation model to determine the expected quantity of food donations received per month in a multi-warehouse distribution network. The simulation using exponential smoothing shows that good estimation accuracies can be achieved. However, none of these studies have considered the impact of disaster and Government policy on food bank operation. In this study, we consider the impact of COVID-19 and government policy on food bank operation.

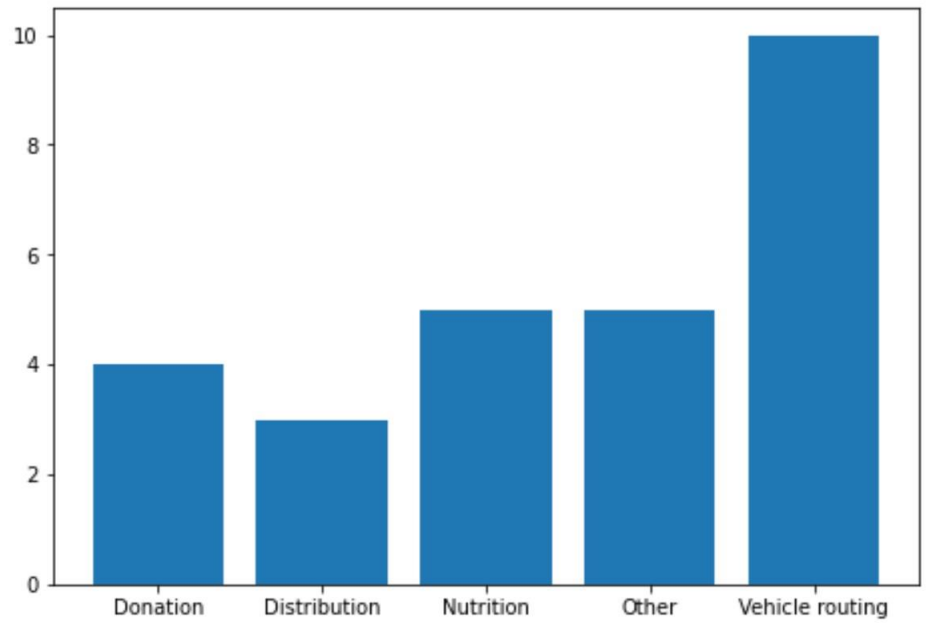


Figure 2: Article review bar graph

3. RESEARCH OBJECTIVES

The organization accumulates data regarding its operation and donation, and distribution. This study explores, analyzes, and visualizes the food bank operational data before and during COVID-19. We also understand the donation, distribution, and plan for different operation activities by knowing the demand and supply in advance. This project seeks to answer the following research questions.

1. What are the donation and distribution patterns overtime before and during the COVID-19?
2. What impacts governmental policies (i.e., subsidies, taxes, and other systems) on humanitarian food supply chains before and during COVID-19?
3. What are the impacts of socioeconomic and demographic factors on Food Bank operation?

4. DATA COLLECTION AND DATA PROCESSING

Data is collected from the Food Bank of Central and Eastern North Carolina (FBCENC) from July 2018 - May 2020. The data contains daily food donation and distribution receipts at all food bank branches by the posting date. The FBCENC database contains approximately 783054 records(observation/rows) and 94 variables. Each observation consists of several fields that describe information about the inventory transaction. However, only relevant areas of variables are considered in this study. The relevant variables evaluated in this study are listed in Table 1. This data's challenges come from the data itself: negative values, sample size, missing values, and messy data. Due to these challenges, the data requires preprocessing. We use data visualizing in R, tidyverse, especially dplyr Package and Tableau in the data processing.

No	Key field	Description	Example
1	Document_No	Receiving Document, No	XFERR-00193
2	Entry_Type	donation source	Transfer
3	Ext_Gross_weight	total	310
4	NC_Branch_Code/Location_Code	Foodbank branches	Durham, Raleigh
5	Item_No	product identifier	PR1004
6	Posting_Date	Date items received	07-01-2018
8	FBC_Product_Type_Code		
9	Inventory_Posting_Group		Donated, Government
10	Food-Type	Vegetables Fresh-Weigh	B.N., TM

Table 1: Samples of the critical variables of the data

5. RESULTS

5.1. Donation and distribution trend over time

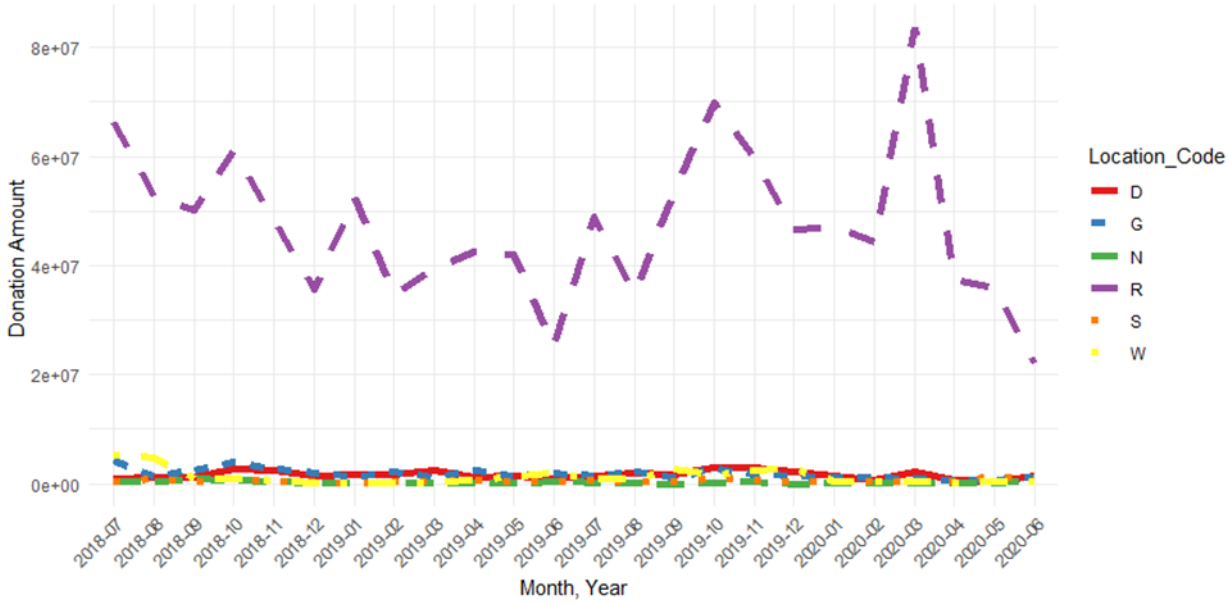


Figure 3: Time series plot of food donations per food bank branch

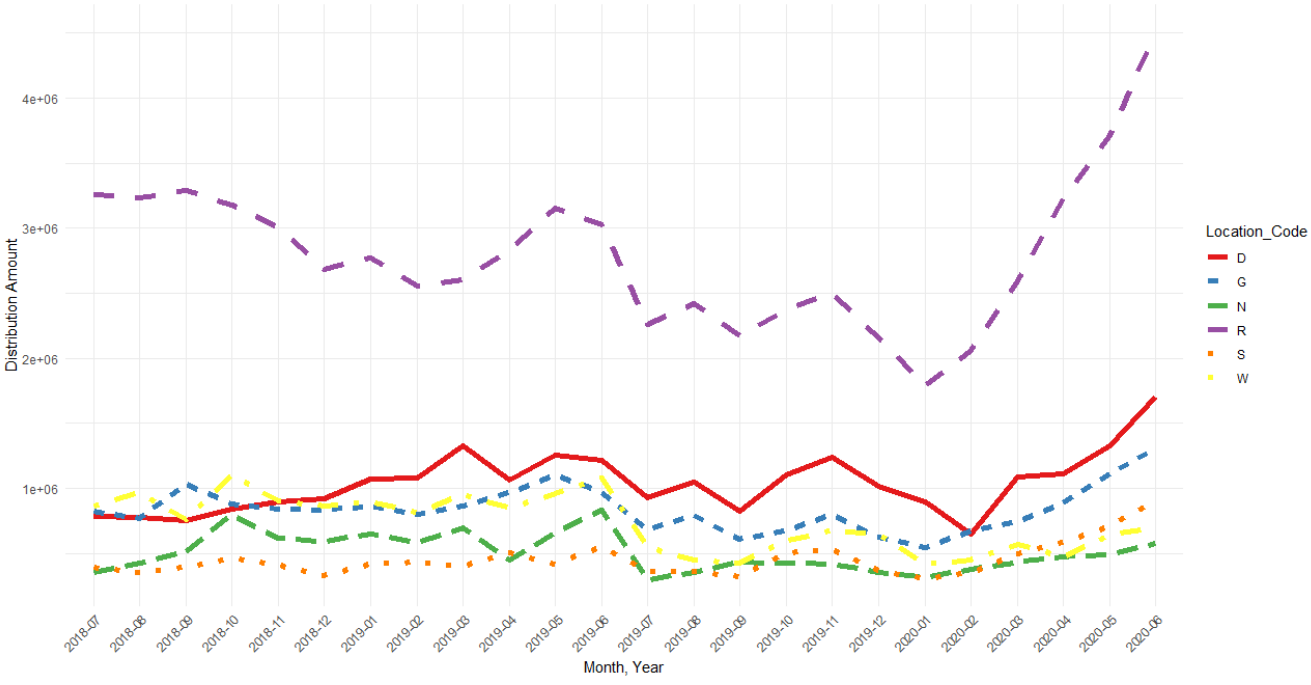


Figure 4: Time series plot of food distribution per food bank branch.

Figures 3 and 4 show the donation to the food bank per branch and distribution from food bank branches, respectively. We can see that the supply from donors decreases because COVID-19 has affected the ability of suppliers to provide donated food items, whereas the demand increase starting from March 2020. Distribution increases due to COVID-19 demand for food as more people become food insecure.

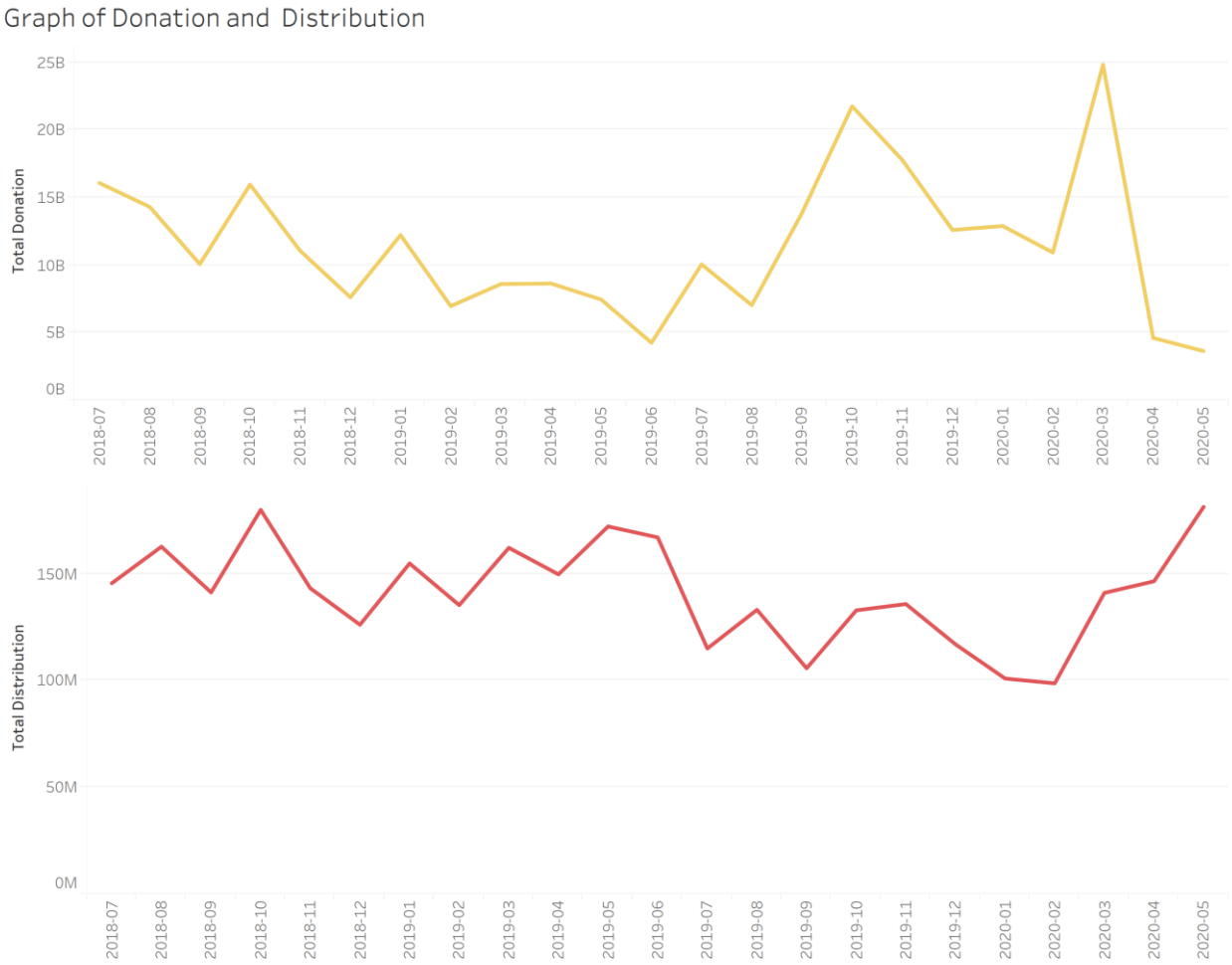
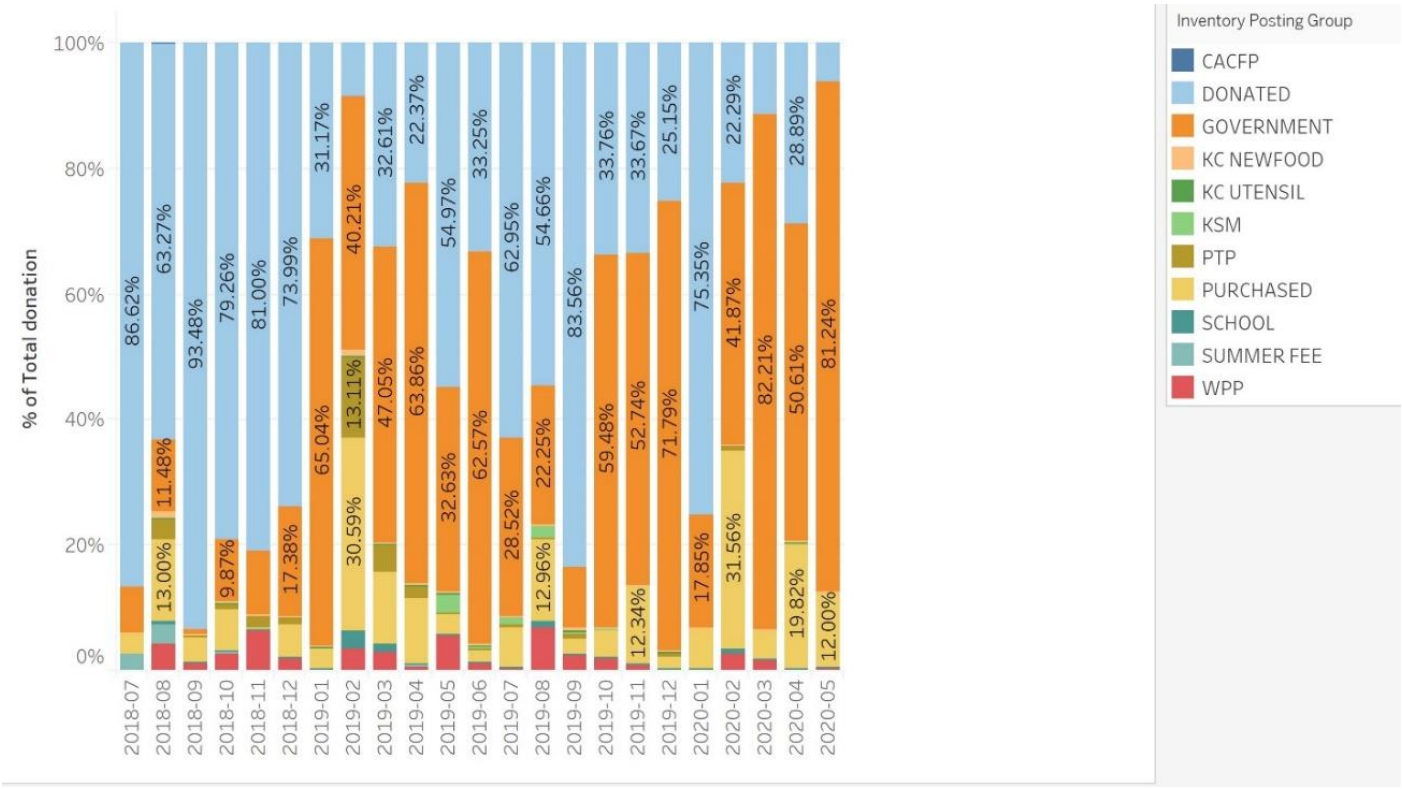


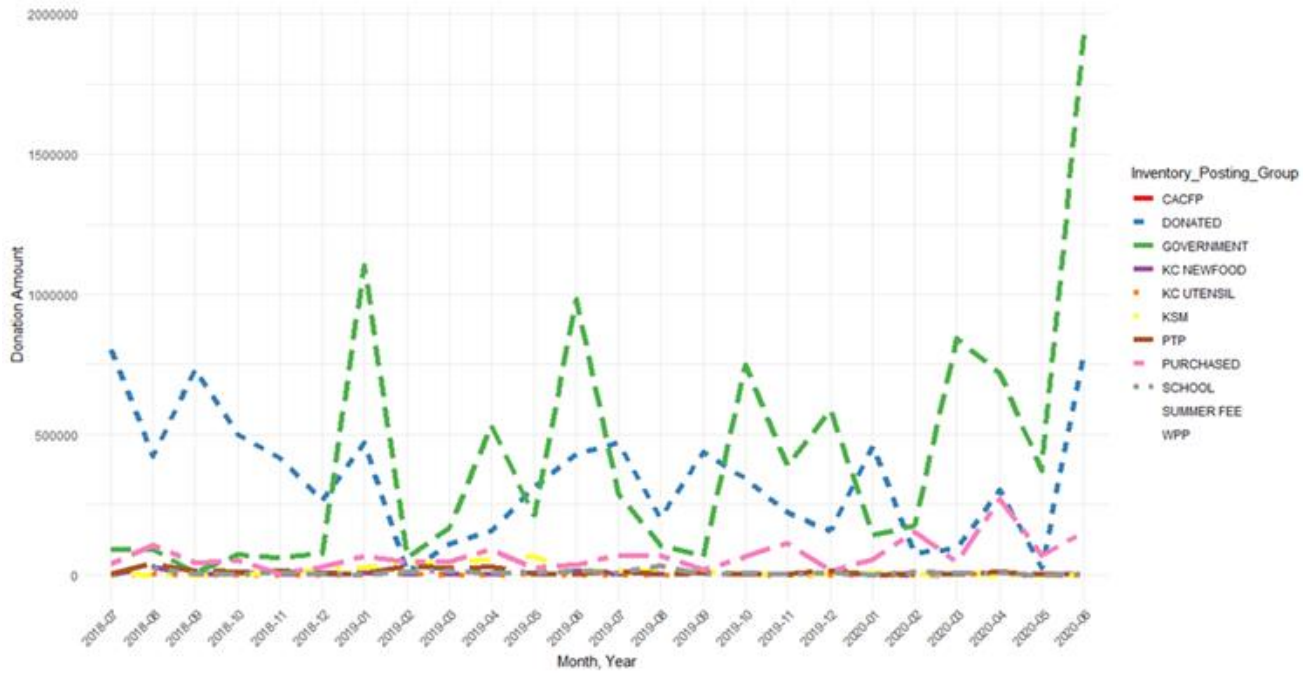
Figure 5: Time series plot of monthly total food donation and distribution of FBCENC.

Figure 5 demonstrates the time series plot for the total pounds of donation received and distribution at FBCENC from July 2018 to May 2020. The graph shows high demand during the COVID-19 Pandemic (March 2020 – May 2020). Due to COVID-19, the number of food-insecure people increased. However, the supply for food banks from donors decrease during the COVID-19. Since COVID-19 impacts the country's economy and the individual's income, the food banks' supply falls.

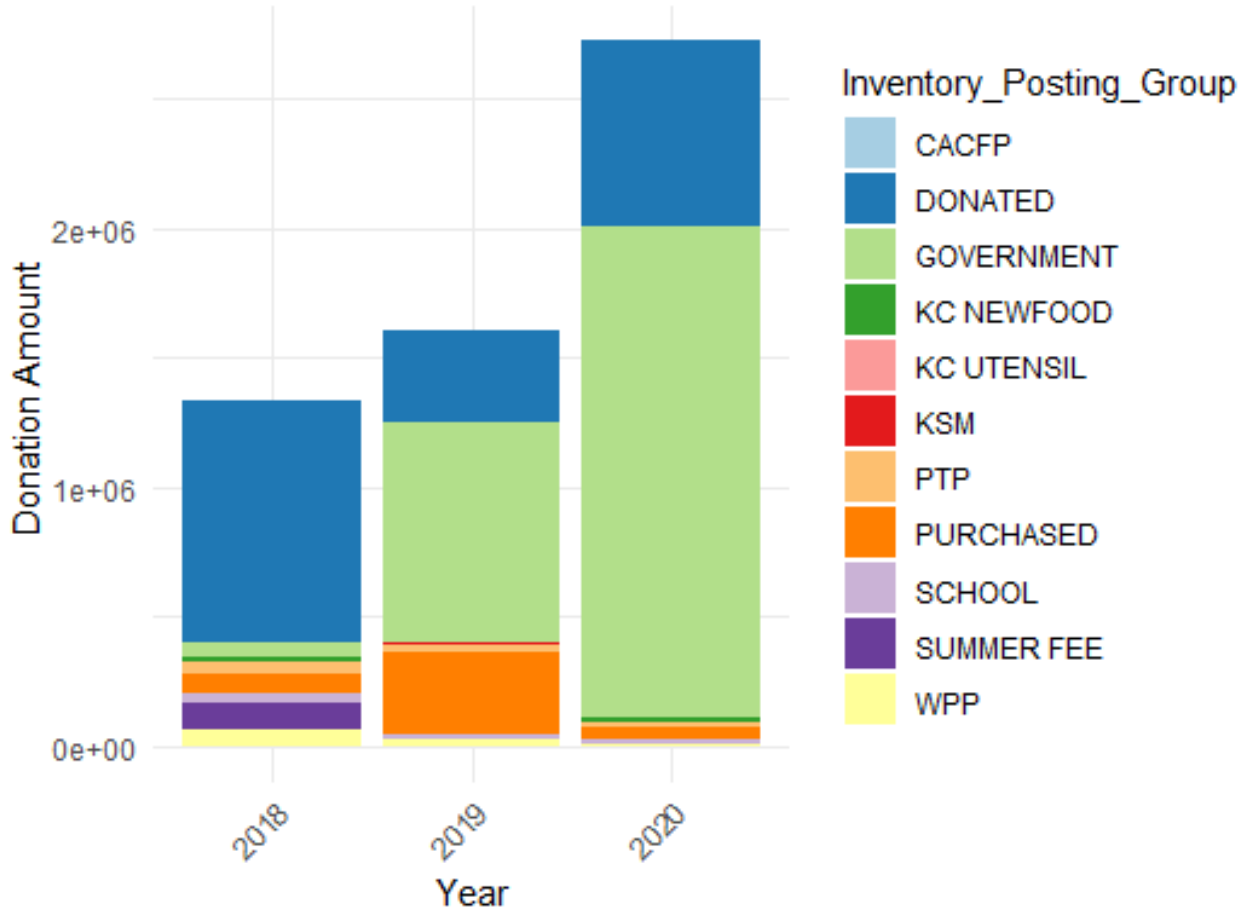
5.2. The source of donation for the food bank


% of Total donation
100%
80%
60%
40%
20%
0%
86.62%
63.27%
93.48%
79.26%
81.00%
73.99%
31.17%
40.21%
32.61%
22.37%
54.97%
33.25%
62.95%
54.66%
83.56%
33.76%
33.67%
25.15%
75.35%
22.29%
28.89%
81.24%
13.00%
11.48%
9.87%
17.38%
65.04%
13.11%
30.59%
47.05%
63.86%
32.63%
62.57%
28.52%
22.25%
12.96%
59.48%
52.74%
12.34%
71.79%
17.85%
31.56%
41.87%
82.21%
50.61%
19.82%
12.00%
2018-07
2018-08
2018-09
2018-10
2018-11
2018-12
2019-01
2019-02
2019-03
2019-04
2019-05
2019-06
2019-07
2019-08
2019-09
2019-10
2019-11
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
Inventory Posting Group
CACFP
DONATED
GOVERNMENT
KC NEWFOOD
KC UTENSIL
KSM
PTP
PURCHASED
SCHOOL
SUMMER FEE
WPP

(a)


Donation Amount
2000000
1500000
1000000
500000
0
Month, Year
Inventory_Posting_Group
CACFP
DONATED
GOVERNMENT
KC NEWFOOD
KC UTENSIL
KSM
PTP
PURCHASED
SCHOOL
SUMMER FEE
WPP

(b)

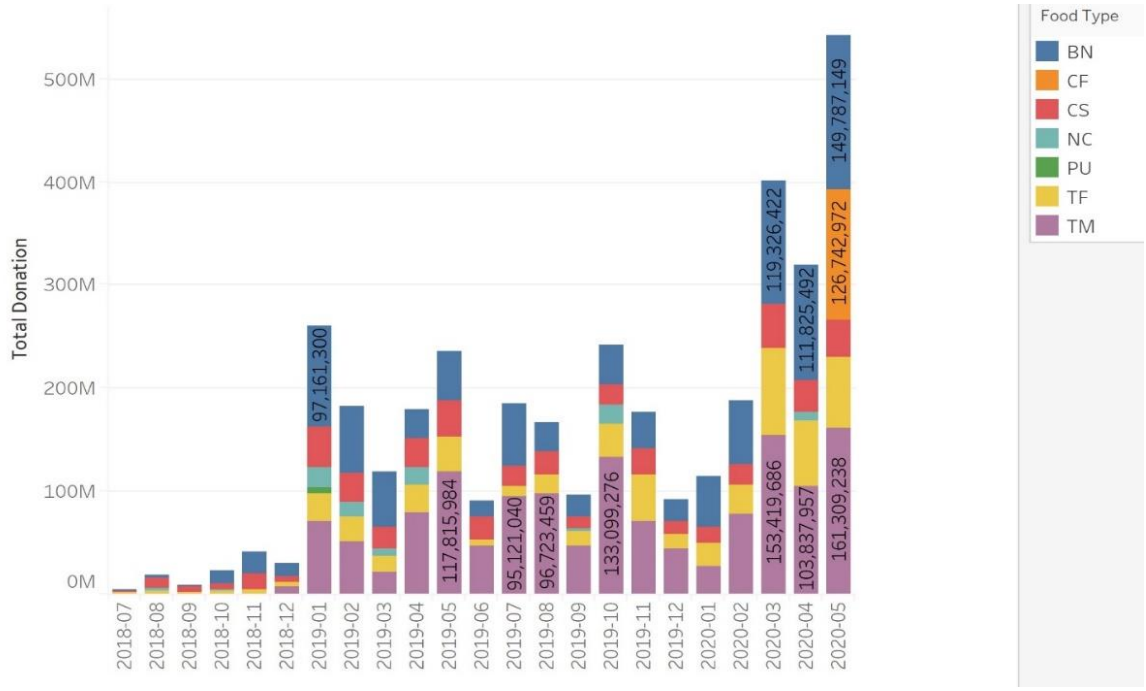


(c)

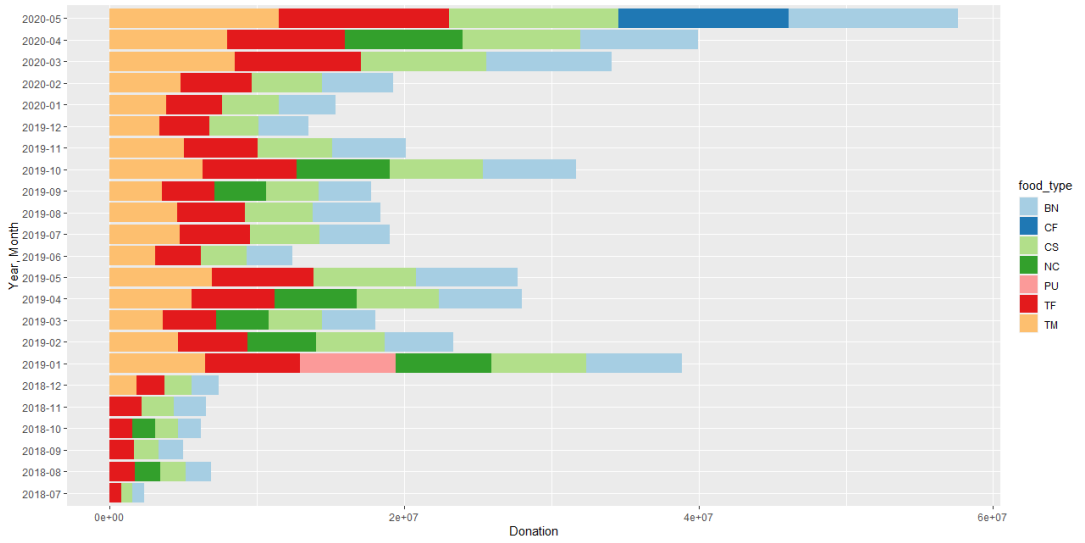
Figure 6: The contribution and source of food donation (a) the amount of contribution of each source of donor's, (b) The pattern of the donators over time, and (c) yearly contribution of different donors

The above figures demonstrate the total pounds of donations received from different donors at FBCENC from July 2018 to May 2020. The graphs show that Government donations were higher than other donators during COVID-19 Pandemic (March 2020 – May 2020) because the Government has implemented different policies to support the food banks. The policies are trade mitigation, commodity supplemental food program, and the Coronavirus Food Assistance Program (CFAP)- provide vital financial assistance to producers of agricultural commodities who have suffered a five percent-or-greater price decline or who had losses due to market supply chain disruptions due to COVID-19 and face additional significant market costs.

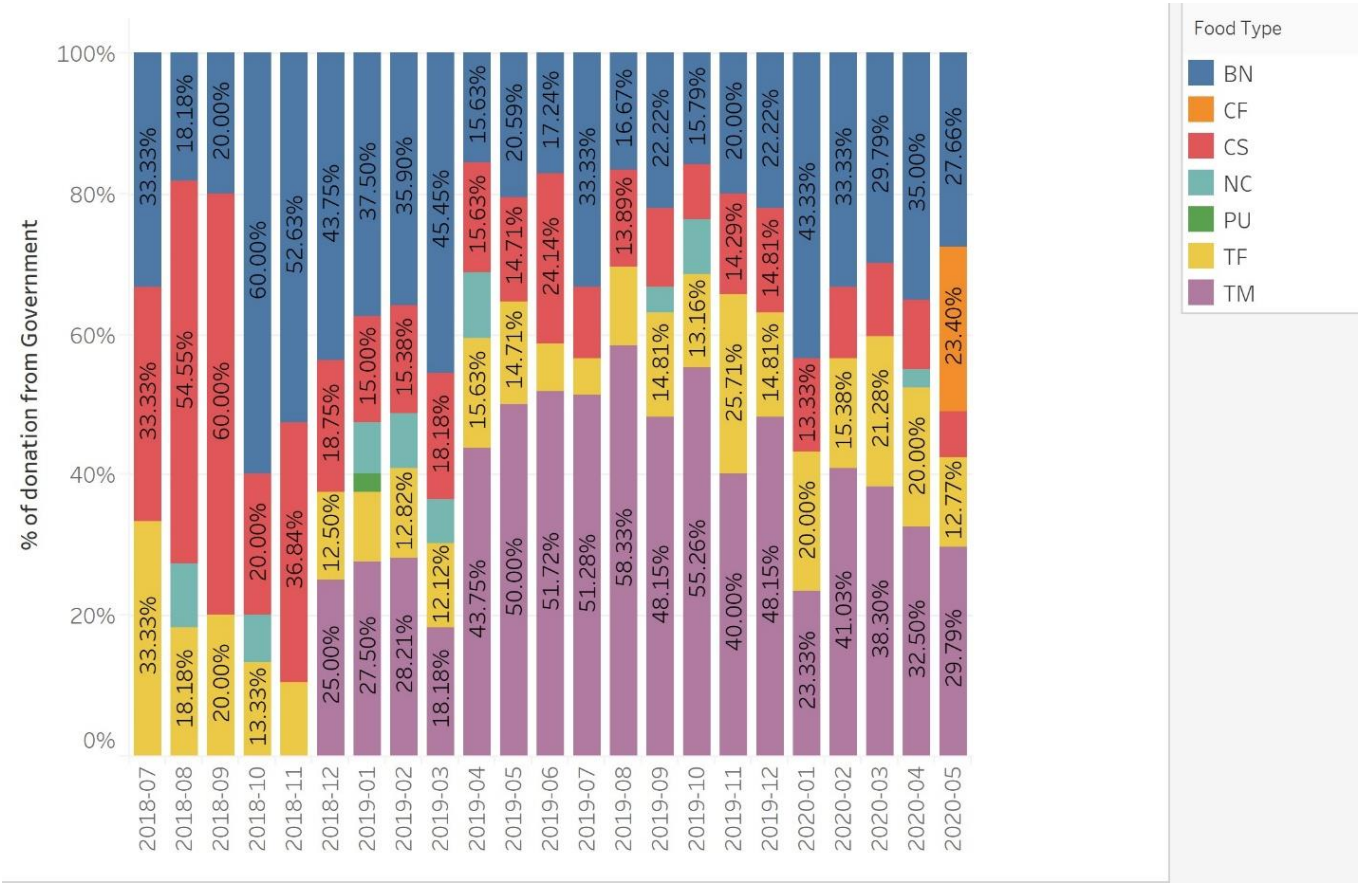
5.3. The impact of different Government policies on food bank operation



(a)


Year, Month
2020-05
2020-04
2020-03
2020-02
2020-01
2019-12
2019-11
2019-10
2019-09
2019-08
2019-07
2019-06
2019-05
2019-04
2019-03
2019-02
2019-01
2018-12
2018-11
2018-10
2018-09
2018-08
2018-07
0e+00
2e+07
4e+07
6e+07
Donation
food_type
BN
CF
CS
NC
PU
TF
TM

(b)


% of donation from Government
100%
80%
60%
40%
20%
0%
2018-07
2018-08
2018-09
2018-10
2018-11
2018-12
2019-01
2019-02
2019-03
2019-04
2019-05
2019-06
2019-07
2019-08
2019-09
2019-10
2019-11
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
Food Type
BN
CF
CS
NC
PU
TF
TM

(c)

Figure 7: Amount of different government policies contribution (a) monthly contribution of Government policy for the food bank, (b) comparison of the monthly contribution from Government policy, (c) The percent of the Government policy contribution.

The above figures demonstrate Government policy contribution to the food bank. Trade mitigation (T.M.) package to assist farmers suffering from damage. The Coronavirus Food Assistance Program (CFAP) will provide vital financial assistance to producers of agricultural commodities who have losses due to market supply chain disruptions due to COVID-19 and face additional significant market costs. N.C. is money from the State Government. T.F., BN., and C.S. are commodity supplements for food programs. Trade Mitigation (T.M.) policy contribution is more significant than other government policies from the three figures. The government policies have been implemented differently and summarized as follows.

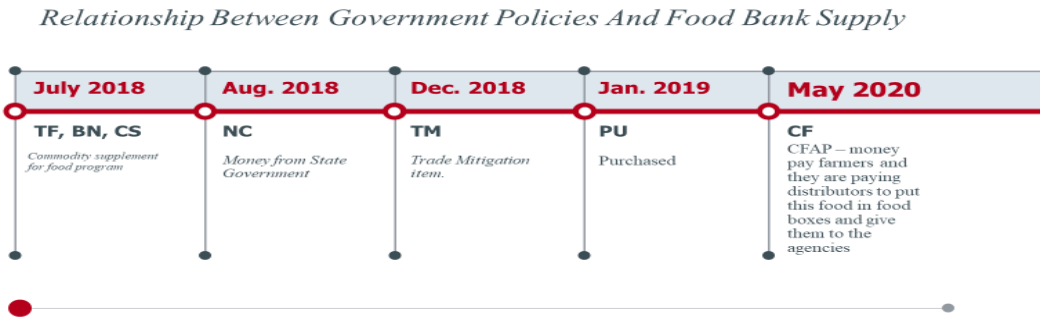
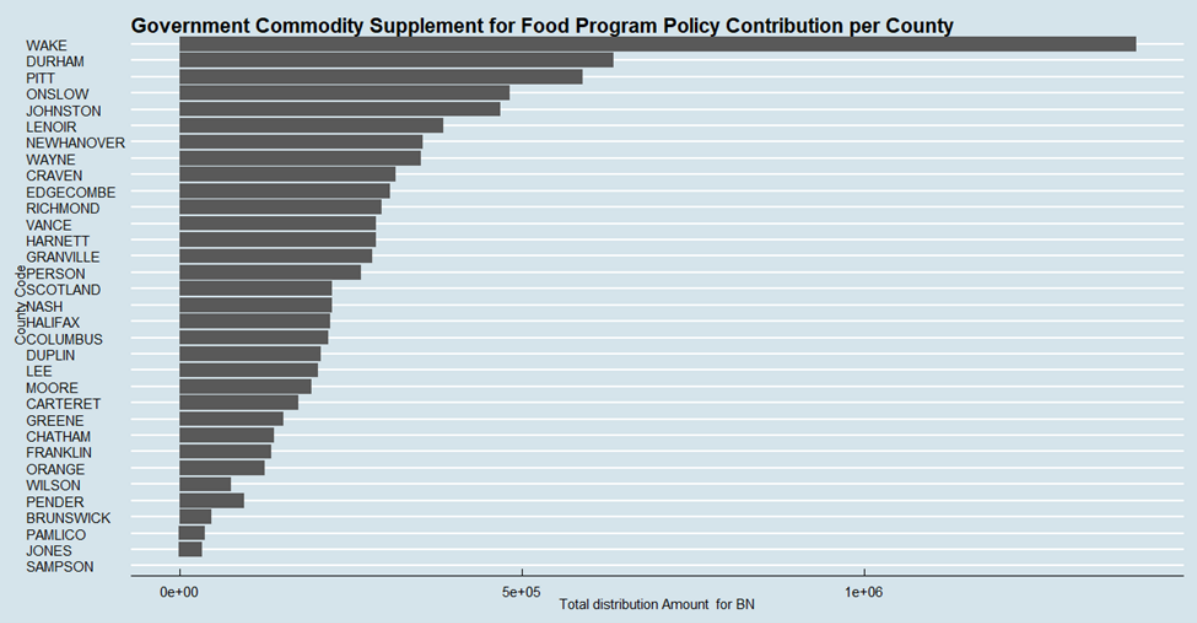
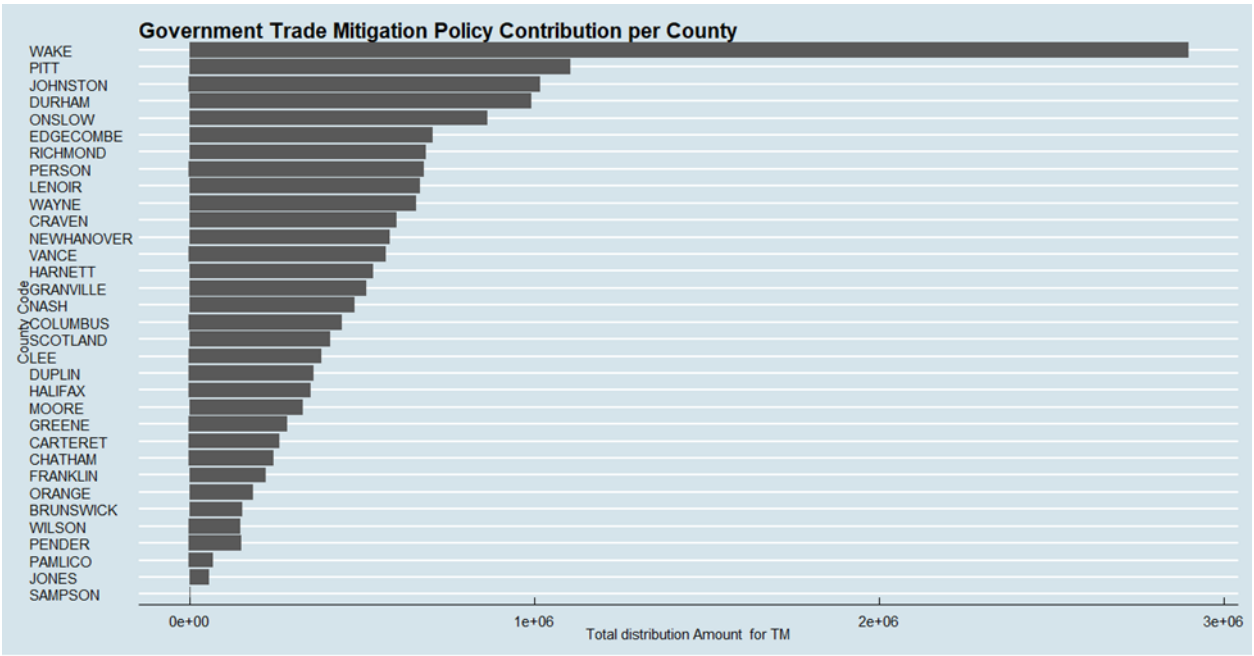


Table 2: Table of Government policy and implemented time

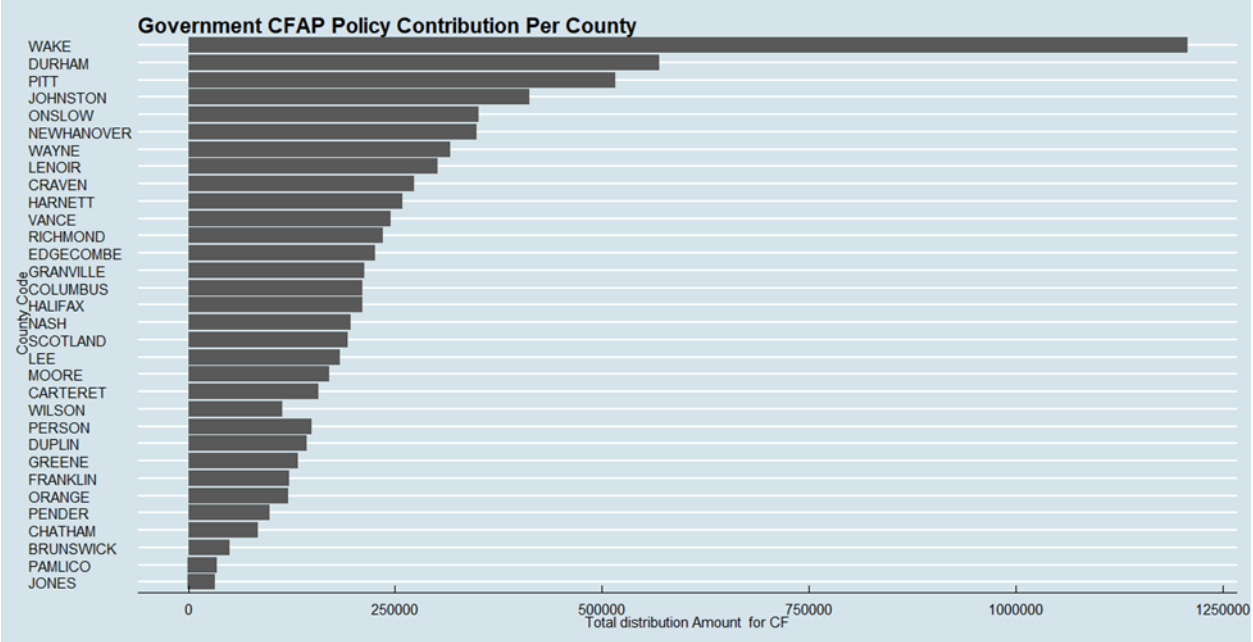
5.4. Government policy contribution per county



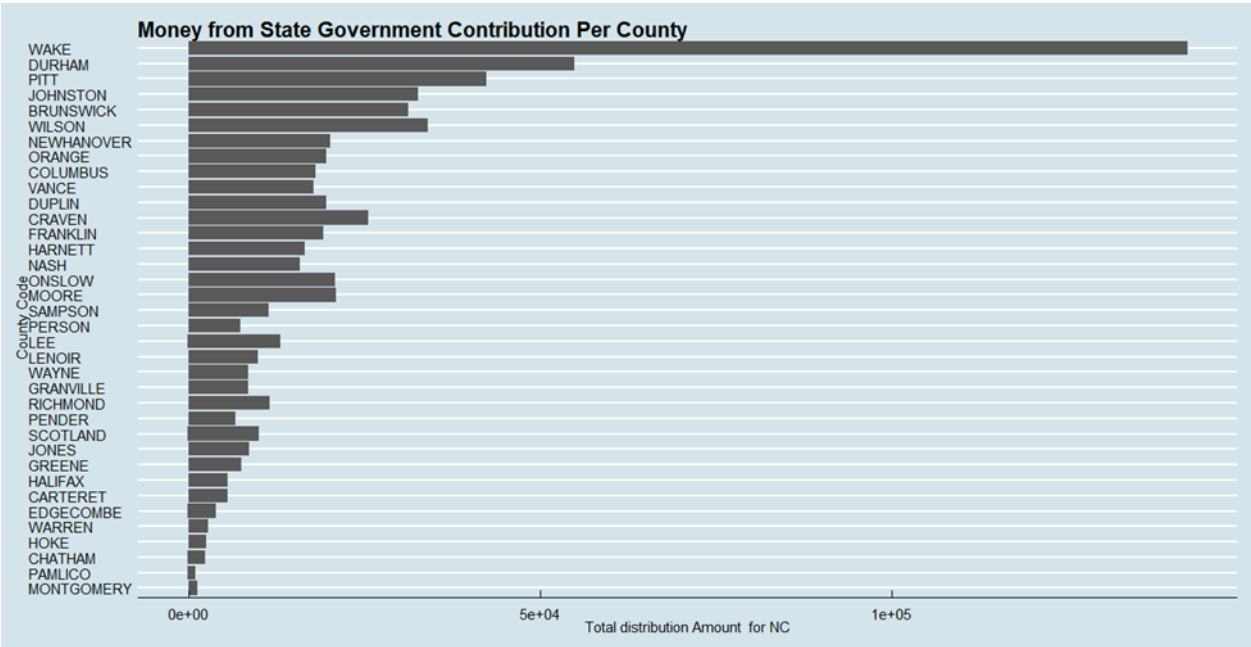
(a)



(b)



(c)



(d)

Figure 8: Donation from Different Government Policy Per County (a) Government commodity supplement for food program policy contribution, (b) Government Trade mitigation policy contribution, (c) Government CFAP policy contribution, and (d) Money from State Government contribution.

From the above plots, we can see that Wake County most benefited from Government policy compared to other counties. Durham and PITT are helped next to Wake County, respectively.

5.5. Relationship between food distribution at county level and demographic and socioeconomic factors

Hypothesis:

Null Hypothesis: The independent variables have no significant effect over the target variable

Alternative Hypothesis: The independent variables have a significant effect on the target variable.

Residuals:

```
      Min        1Q    Median        3Q       Max
-1.062e-09 -1.442e-10 2.920e-12  1.293e-10  6.215e-10
```

Coefficients:

```
                  Estimate       Std. Error       t value     Pr(>|t|)
(Intercept)   7.452e+05   9.610e-09   7.754e+13    < 2e-16 ***
hhincome      2.663e-14   2.276e-14   1.170e+00    0.25572
med_age      -1.306e-10   8.484e-11   -1.539e+00    0.13945
population    -3.282e-14   8.918e-15   -3.680e+00   0.00149 **
under18       1.306e-13   3.599e-14    3.629e+00    0.00167 **
age65_prop     1.543e-09   8.418e-09   1.830e-01    0.85641
female_prop   -2.613e-09   1.350e-08   -1.940e-01    0.84847
white_prop    -2.511e-09   3.342e-09   -7.510e-01    0.46129
black_prop    -1.294e-09   3.638e-09   -3.560e-01    0.72590
ratio_inc_pov  3.876e-09   1.531e-08    2.530e-01    0.80272
poverty_prop  -1.915e-08  1.076e-08   -1.780e+00   0.09035 .
disabl_prop    1.156e-08    1.106e-08   1.045e+00    0.30855
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Residual standard error: 3.741e-10 on 20 degrees of freedom

Multiple R-squared: 0.4831, Adjusted R-squared: 0.1988

F-statistic: 1.699 on 11 and 20 DF, p-value: 0.1459

The above analysis shows that the population and under18 have a p-value less than 0.05; as a result, the null hypothesis is rejected. From socioeconomic and demographic factors, population and under18 significantly impact food distribution per county. From figure 8, Wake County is the most benefited due to its population number because according to the 2020 census bureau Wake County has the largest population.

Figure 9: Correlation between food distribution and county-level demographic and socioeconomic factors.

SUMMARY

This research is based on the Food Bank of Central and North Carolina data before and during the COVID-19 Pandemic. We analyzed and visualized the dataset from this food bank. The research demonstrated that donation overtime during the COVID-19 Pandemic (March to May 2020) decreased, whereas the distribution trend overtime during the COVID-19 Pandemic (March to May 2020) increased. The supply of foodbank and demand is not proportional. During the COVID-19 Pandemic, the food bank received more supplies

from the Government to make up for the shortfall from donors. Data visualization helps to understand the trend of donation and distribution of analysis over time, which is essential for foodbank operation activity by knowing the demand and supply in advance. Moreover, food distribution correlates with some county-level demographic and socioeconomic factors. For instance, population umber and under 18 significantly impact food distribution at the county level.

Acknowledgment:

I want to acknowledge my project research advisor, Dr. Davis, for providing me with an opportunity to work with her. Her continuous encouragement, faith, and support have helped shape my research project. It has been a pleasure working with her and learning something new from every discussion we had over the project research.

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REFERENCES

[1] United States Department of Agriculture, Economic Research Service. Available at https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx

[2] Steven J. Carlson, Margaret S. Andrews, Gary W. Bickel (1999): Measuring food insecurity and hunger in the United States: Development of a National Benchmark Measure and Prevalence Estimates.

[3] www.fbcenc.org

[4] Feeding America, Hunger in North Carolina. Available at https://www.feedingamerica.org/hunger-in-america/north-carolina

[5] Feeding America, Child Food Insecurity in N.C. by county. Available at https://www.feedingamerica.org/sites/default/files/research/map-the-meal gap/2016/child/NC_AllCounties_CDs_CFI_2016.pdf

[6] Coleman-Jensen, A., M. Nord, M. Andrews, and S. Carlson, (2011). United States Department of Agriculture. "Household Food Security in the United States in 2010."

[7] Coleman-Jensen, Alisha, Matthew P. Rabbitt, Christian A. Gregory, and Anita Singh. 2019. *Household Food Security in the United States in 2018*, ERR-270, U.S. Department of Agriculture, Economic Research Service.

[8] Feeding America. https://www.feedingamerica.org/take-action/advocate/federal-hungerrelief programs.

[9] Jiang, S., Davis, L., De Mleo, H. T., & Terry, J. (2013). Using data mining to analyze donation data for a local food bank. *In Proceedings of the International Conference on Data Mining (DMIN)*, 1 - 10. The Steering Committee of The World Congress in Computer Science, Computer Engineering, and Applied Computing (World Comp).

[10] Shubhra Paul, Lauren B. Davis (2019). Predicting Food Donor Contribution Behavior Using Support Vector Regression, *Proceedings of the 2019 IISE Annual Conference.*

USING AI ON THE ONTOLOGY FOR INTELLIGENT BIG DATA VISUALIZATION: A CASE STUDY ON CROP FUTURE PRICE PREDICTION

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ABSTRACT

There are many financial predictive models with good performance for predicting the price trends. However, those models did not link the related information for explaining the data. Financial analysts require to search the related information to explain the predictions and market phenomenon. Therefore, the aim of this research is to propose an intelligent big data visualization tool to relate and visualise the related information. Since ontology defines the attributes of the objects and can set rules in the ontology to link the related information for reasoning, this research used a novel approach of applying AI to an ontology for relating the textual and numerical information to explain the relationships of the price trends and predictions. A dashboard including maps, bar charts, line charts, and news was designed. A case study on predicting crop future price was used to demonstrate the application of ontology onto the big data visualization tool for financial analysis and decision making. A review on how trading activities and weather influencing the crop future price was done. A prototype demo was implemented for illustrating how to relate the relevant information for intelligent visualization, and to support financial analysts in investment decision making.

KEYWORDS: big data visualization, ontology, artificial intelligence

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1. INTRODUCTION

Food and drug administration have included 43 categories of food commodities, such as rice, corn, wheat, soybean, oat, etc., that are the essential food for human consumptions [11]. Due to different weather conditions, economic conditions, population distributions, and available resources, some countries suffered from food shortage while some have many surpluses. With the help of import and export, or the so-called international trade, food moves from surplus production places to deficit ones with prices that people can accept [14]. Gillson et al (2014) has shown that international trade can stabilize fluctuations in food supply and prices, reduce prices for consumers, and generate more profits for farmers.

The seven basic factors: nutrition transition, population growth, water, land, energy, climate change and labor, exert renewed pressure to the global food system and constrain the food supply [2]. As stated by Gardner (2013), because of the government interference, unsatisfactory harvests and depressed stocks, there has been severe food shortages which drove up prices. For instance, in 2012, maize crop dropped by an approximate 50 percent in U.S. as the result of a drought, which increased the price by about 23 percent [13]. To deal with the uncertainties during the food trade, people have to buy and sell futures. In other words, by buying and selling a specific amount of commodity at certain time, people can lower the price risks. Food futures also attract those who are not involved and interested in the commodity as they can generate some gains for them [10]. People always use these futures for portfolio diversification because returns from them have negative relations with those from bonds and equities [10]. Therefore, it is necessary that people are able to predict future prices of food accurately so that they can earn considerable amount of money by trading with food futures.

To predict the future price, the commonly used methods include correlation analysis [8], time series [8], regression [7], [22]. risk premium model [7], future indexes [27], data visualization [23], etc., for price prediction. They mainly focus on using different statistical techniques on numerical data for future price prediction, and visualize the results. However, a recent study found that future price is sensitive to the news [19]. Since information overflow is the current problem in big data visualization [3], how AI can be used to filter, relate, and visualize the predicted results and the news at several levels for human to reason, deduce, and draw conclusions for investment decision making.

Thus, the objectives of this research are to use a novel method of ontology and AI to build the big data visualization tool for relating the information to explain the data, and to perform reasoning for decision making. This research mainly focuses on six countries, which are China, India, Thailand, Russian Federation, Australia and United States of America since they are some major countries that provide a high volume of trade in food commodity. By using the import and export data, rainfall and temperature data, news information, and the predicted future prices, an ontology and a dashboard were implemented. The dashboard includes various graphs that visualize and comprehend the related news, predicted prices, and the environmental data for helping financial analysts in making investment decision. Maps, bar charts, line charts are used to visualize the data geographically and periodically.

2. USING ONTOLOGY AND AI FOR DATA VISUALIZATION

Ontology defines the attributes of entities and allows users to set rules in the ontology to relate the entities or their attributes for discovering new knowledge [18]. In data visualization, ontology can be used to capture the information structure of the data objects. Since financial data is huge and includes the textual and numerical data, it requires to organise and integrate the unstructured data into a structured format for analysis. However, since there is information overflow in financial market, it is difficult to filter and organise the information. Although some artificial intelligence methods can extract and integrate the unstructured data for analysis [1], it requires lots of data, time and efforts for trainings the models for information extraction and relating. Therefore, ontology can reduce the time and efforts of the artificial intelligence methods. Users can predefine the information structure such as attributes and rules of the objects in the ontology, and map the unstructured information into the ontology information structure. The metadata can be used to describe the unstructured data and map them into the ontology entities' structures. In this way, the data visualization tool can dynamically extract, integrate and relate the huge textual and numerical data by reasoning and mapping the relationship of the object entities and attributes for analysis.

3. RESEARCH METHODOLOGIES

In order to demonstrate how the ontology extracts the related information for data visualization and analysis. This research used a case study to demonstrate the processes of the knowledge discover with the ontology attributes and rules. A case study on predicting crop future prices was done. The case study focuses on mainly six countries including China, United States, Australia, India, Thailand, and Russian to find out the import and export relationships. The data were collected from the Food and Agriculture Organization of the United Nations (FAO) database, which provides the food and agriculture data of over 245 countries from 1961 to the recent available year [12]. The dataset of the six countries mentioned above from 2011 to 2020 was downloaded from its official website. The trade commodities in the dataset including wheat, oat, maize, rice, and soybeans were collected. The trade values, such as export net weight and export trade values, were used in this demo. The rainfall, temperature, and future prices were also collected. In the coming sections, a review on the relationships of crops trading, weather and food price was done. A prototype to illustrate how the ontology extracting the related information for analysis was implemented and explained.

4. A CASE STUDY ON CROP PRICE PREDICTION

4.1 Case Background and Data to be Used for Crop Price Prediction

Trade provides benefits for both rich and poor countries by moving food from surplus production places to deficit production areas. Mary et al (2019) stated that trade liberalization helps to improve food security and solve hunger problems in those developing countries [20]. When population grows much faster than local food production, import strategies are always used to avoid the food storage problem [21]. Research studies found that there is a strong relationship between international trade (import and export) and food prices. Chen et al (2019) have proposed that if the ratio of imports to total consumption increases by 1%, the food prices

will reduce by 0.29% [6]. When countries make decisions on imports and exports of food commodities, they should be aware that different amounts of changes will lead to local and global food price changes. For instance, if a country imports many food commodities from abroad, it will put much pressure and affect the local food demand, and thus change food price. The extent to which local food prices change due to changes in world food price is also proven to be strongly related to trade policy measures [4]. By being informed of the trends of exports and imports year by year, people will be able to predict some future changes, and thus take appropriate actions that help them make more profits. Therefore, imports data, exports data and future prices can be used to build the big data analytics prototype for linking the related information to the future price changes.

Climate conditions have a strong relation with the food supply and food prices. Brown et al (2017) stated that the global food system faces both challenges and opportunities when there is a changing climate since it affects the availability, access, utilization and security of food [5]. Environmental variability gives rise to risks related to food shortage, food quality as well as price spikes [9]. The study predicted that global crop production will reduce by 9% in 2030s and by 23% in 2050s because of the climate change, and it will also lead to a 1 to 3 percent higher yearly fluctuations of crop production during the next 4 decades [15]. It is all known that agricultural production influences food directly, and some climatic variables affects the production biophysically [25]. When food supply changes, food price will change automatically. Solaymani et al (2018) have found that economic performance is contracted by the simultaneous changes in temperature and rainfall. The rainfall-temperature variability impacts the availability of food negatively, and thus gives rise to an increase in commodity price and a reduction in income [24]. To investigate specifically, greater rainfall generates both winners and losers when considering its spill over effects, with a rise in household consumption due to greater own-district rainfall while a reduction in the neighbouring districts [16]. Zhao et al (2017) found that there is a negative relation between crop yield and temperature, and one degree-Celsius increase in temperature creates a reduction in yields of wheat by 6%, soybean by 3.1%, maize by 7.4% and rice by 3.2% [26]. Therefore, by visualizing the changes of temperature and rainfall over the years, people are able to figure out the corresponding change in food supply and price. Also, by making predictions based on historical data, a clearer direction to make more profits can be shown to those investors. In this project, we will mainly focus on rainfall and temperature in the six countries to implement the prototype since they are necessary factors for photosynthesis to take place.

4.2 An Ontology Design for Knowledge Discover

Regarding the above review, the major factors impacting to the crop future prices include temperature, rainfall, import data, and export data. The entities and their attributes of these factors were modelled in the ontologies in figure 1. The rules in the ontology can be learnt by using the artificial intelligence [17] but not in the scope of this study.

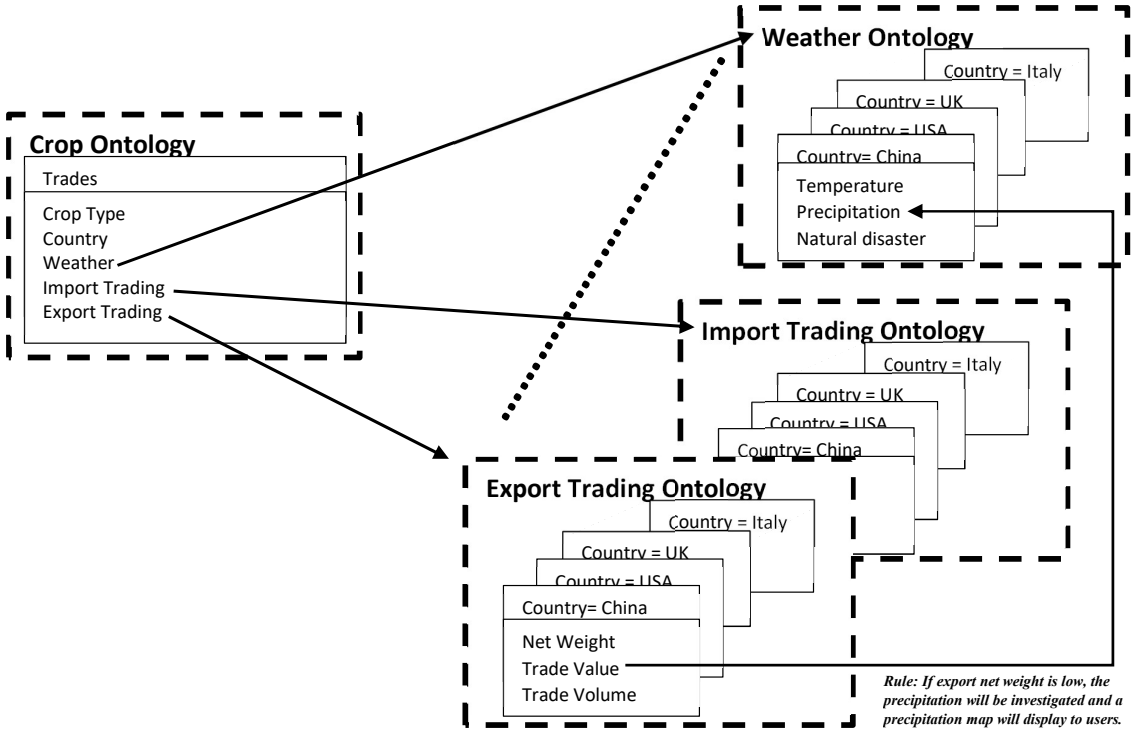


Figure 1 An ontology to capture the information for Crop Price Prediction

4.3 Design of the Big Data Visualization

To help the decision marker better to visualize and relate the information, a dashboard that includes different types of graphs to illustrate relevant trends was built.

Data to be Displayed

The import and export data: The trade values, net weights, and food prices of the imports and exports from different countries are displayed. The predictions of the imports and exports trading and potential trading partners were predicted with a predictive model and an optimization model respectively that helps decision markers to identify the food insecurity risks and discover the potential trading partners, to plan their trading strategies, and to reduce the high food cost in their countries due to high prices or the shortage of food. Since the predictive model and optimization model is not the scope in this research, we did not mention here.

The rainfall and temperature data: The weather condition such as natural disaster, temperate range, rainfall, etc, are shown. There is a close relation between weather condition and food price. When the supply of crop changes due to climate change, the price moves automatically.

Different kinds of crop have different requirements for optimal production, some of which need many rainfalls while some need warm temperature.

Big Data Visualization Tool Design

In this section, we presented an overview of the big data visualization tool design.

The first layer for visualising the trading and weather information: In the first layer, two maps are showed in the dashboard. They display the net weight and trade value of the imports and exports of the six countries from 2011 to 2020, and the values of environmental factors such as temperature and precipitation of these countries from 2011 to 2020. To be more specific, the map is a choropleth map that gives different colours to some pre-defined areas, and the darkness or brightness of colours are in proportion to the chosen statistical variable, such as net weight and trade value. Therefore, the decision makers can find the difference between those countries by evaluating their colour differences. A detailed information will come out when users click a specific area on the map.

The second layer for visualising the trading information changes: In the second layer, two bar charts are used. Maps are used to compare the quantities with some geographic considerations at the same time while the bar charts give a more specific and direct illustration of the changes. One bar chart is to compare the net weight and trade value of different countries in different years. The other bar chart is to compare the import and export values of different countries in different years.

The third layer for visualising the temperature and precipitation changes: The third layer contains two-line charts. The bar charts and line charts can illustrate and compare the variations within a period. The line chart shows the temperature and precipitation change of different countries within a year, and the bar chart shows the net weight and trade value change within a year. In this way, it is easy to find some relations between the trade quantities and the weather conditions.

The fourth layer for the predicted crop production and future prices: Two different line charts are shown. These charts include the predicted trends as well as the actual trends, with the red line representing the actual data from January 2019 to December 2020 and the blue line representing the predicted data from January 2019 to June 2020. By comparing the blue and red lines together, we can see how accurate this predictive model can be, and by observing the end of the blue line, decision makers are able to see the trends in the next few months so that they can be aware of the future changes. Further, the import and export partners are recommended.

The fifth layer for the related news and recommendation: In the fifth layer, some news is provided. By selecting the year, month and day, the headlines of the news on that date will come out and indicate what have been happening at the time. Decision makers can understand the reasons of the production or price changes. The rules in the ontology reasoner can relate the related news with the predictions for further exploration.

4.4 A Prototype Demo for Relating Information for Investment Decision Making

In this prototype, we demonstrated how to use the ontology to relate the temperature, rainfall, import and exports data to analyse crop price trends in China. In map 1 of figure 2, the export net weight and trade value in China are displayed. The map shows that the export net weights and trade values are quite low as the light-yellow color shows. The import values in China are quite high as the dark-red colour shows. The export mean price is quite high compared to other countries. Since the ontology provides rules relating the export and precipitation entities (e.g. If export net weight is low, the precipitation will be investigated and a precipitation map will display to users), the precipitation map in figure 3 will be popped up automatically once the low net weight export event is trigged.

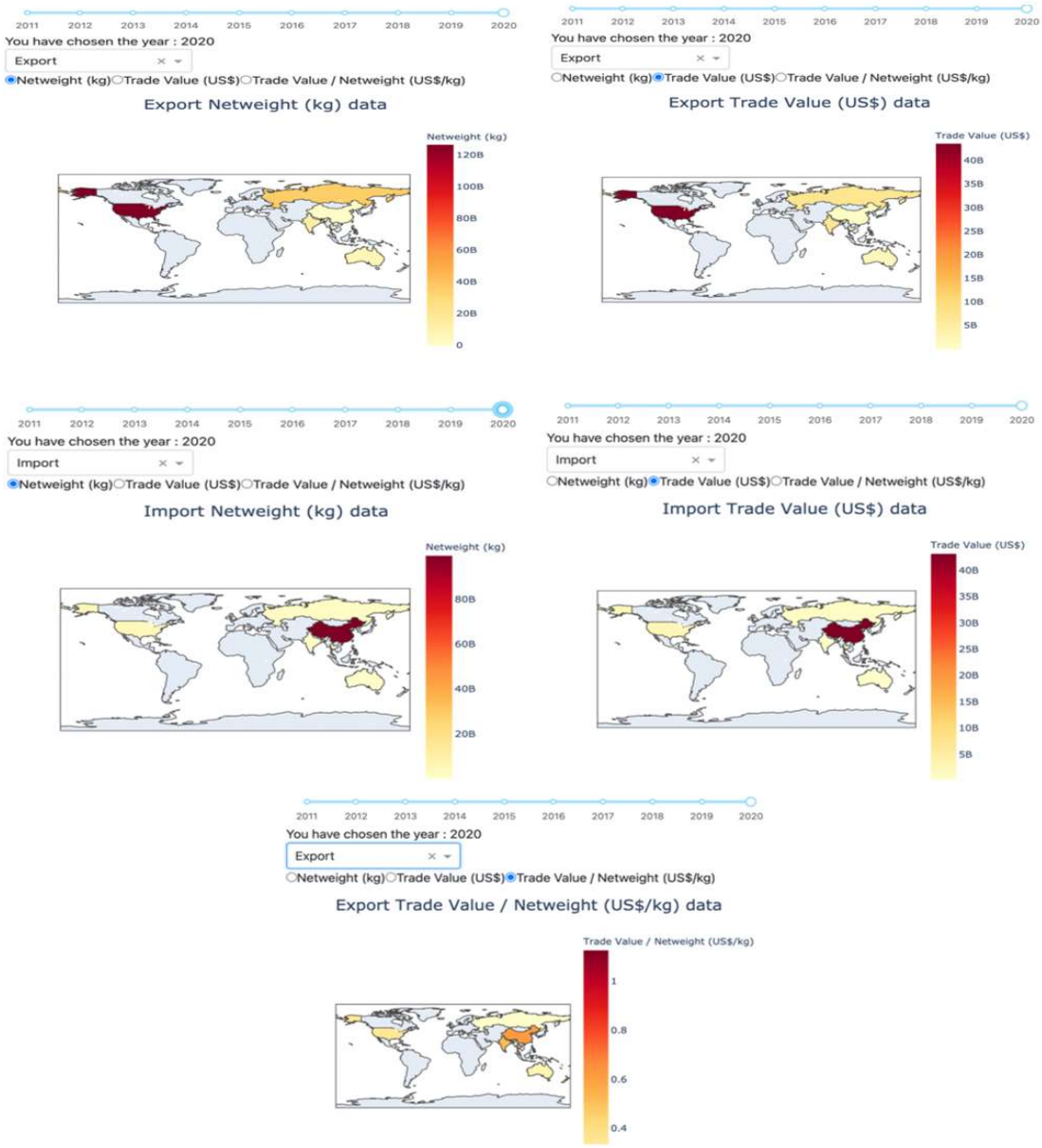


Figure 2 Map 1 displaying the trading information in China

In map 2 of figure 3, the precipitation level in China was quite low, which can be considered as a reason for its low crop yield, and thus it exports less and imports more.

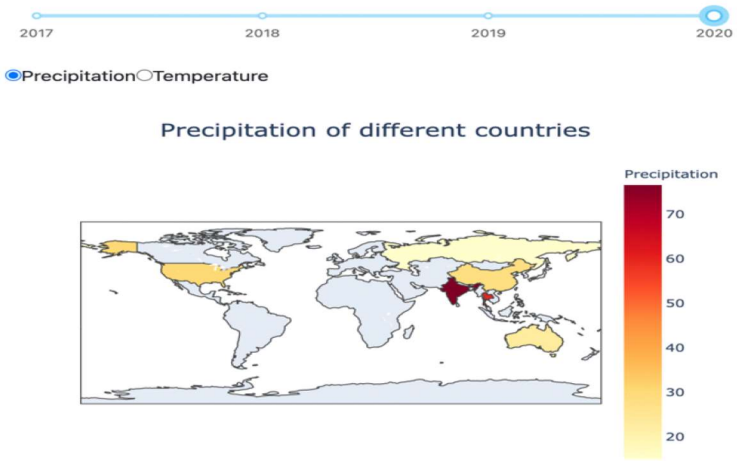


Figure 3 Map 2 displaying the precipitation information

To have a more specific view, the analysts can drag down the data visualization in next layer by clicking the area of China in map 1. The ontology extracts all the country objects of the export and import entries in figure 4. The bar chart 1 of figure 4 compares the import and export data of different countries. It shows that the red (net weight) and blue (trade value) bars in China is extremely shorter than other countries. The import red and blue bars are relatively higher, which corresponds with the above maps.

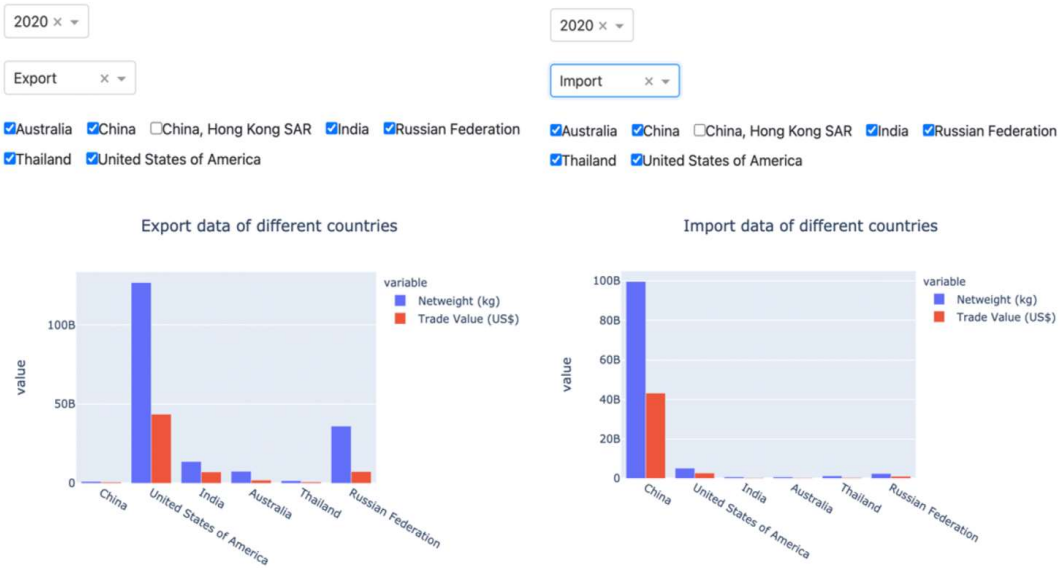
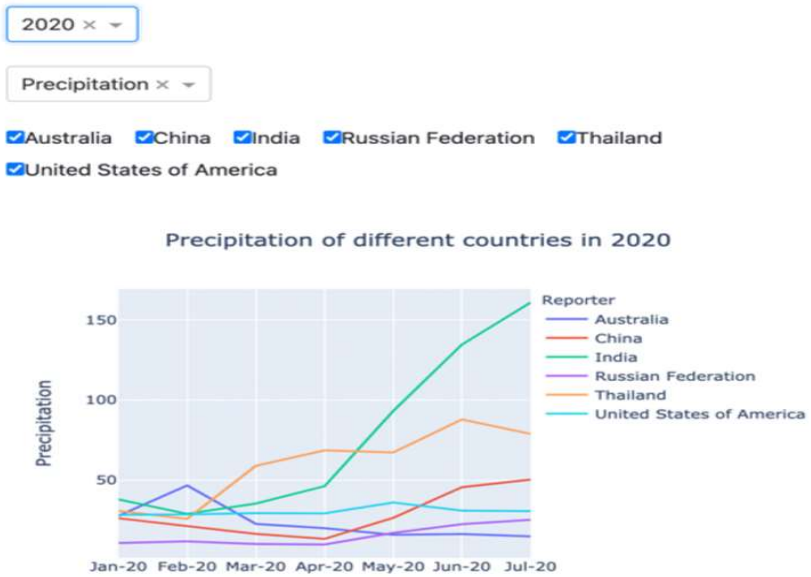


Figure 4 Bar chart 1 comparing the export and import data in different countries

For further comparing the import and export data, the attributes of the import and export entities defined in the ontology are retrieved in the selection box of figure 5. In bar chart 2 of figure 5, the import red bar is considerably higher than the export blue bar for both net weight and trade value. For the import and export prices, the differences become smaller.

Figure 5 Bar chart 2 for detailed information of the export and import data

Similarly, for the precipitation map, the ontology extracted the attributes of the precipitation entity and the attributes (e.g. year) are displayed in the selection box of figure 6. The map can make better comparisons between countries. Line chart 1 of figure 6 shows that the red precipitation line in China stays in the second lowest position.



visualisation Figure 6 Line chart 1 for detailed information of the precipitation data

The line chart 2 of figure 7 is similar to the line chart 1 of figure 6 but the import and export entities' attributes are extracted from the ontology in the selection boxes. User can select to display which attributes' chart (e.g. view by export net weights or view by export trade value). In line chart 2, the red line stays in the lowest position in export values, but it goes to a very high level with the import conditions.

Figure 7 Line chart 2 for detailed information of the export or import data

Therefore, the predative line chart 1 of figure 8 integrates the selected/predefined parameters in a page for analysis. Designers can define the rules on how the information can be related. They can set rules in the ontology to extract and relate the ontology entities or their attributes to implement the knowledge flow of the market analysis. Financial analysts can predict the future prices, relate and display the information in a chart.

Figure 8 Predictive line chart 1 for displaying the predictions

In figure 8, if both the export net weight and trade value only have moderate movement, it implies that China will not export too much. However, the export price changes from month to month and will be the highest in October 2021. Both the import net weight and trade value may also follow the previous patterns, indicating China will also import more, and its import price will reach the highest in December 2021. By viewing the predicted prices, analysts compare across the predictions with the data related in the map, and make decision on whether to buy grain futures when the price reaching the lowest, and selling them when price reaching a high level or not.

5. CONCLUSIONS

In conclusion, this research proposed a novel method of using ontology with AI for identifying the related entities or attributes of the data for visualization and analysis. The big data visualization tool helps financial analysts to relate the data, to explain the phenomena, and to perform decision marking. By using map1 and 2, bar chart 1 and 2, and line chart 1 and 2, analysts can identify the historical trends. By relating similar scenarios in previous years or extracting the related news and information, the analysts can perform a more precise prediction and explain the predicted results. Therefore, the ontology and big data visualization tool helps analysts to relate the graphs one by one in a dashboard for discovering new knowledge, and for performing comparisons and analysis.

6. REFERENCES

[1] Adnan, K., and Akbar, R. (2019). An analytical study of information extraction from unstructured and multidimensional big data. Journal of Big Data, 6: 91.

[2] Ambler-Edwards, S., Bailey, K. S., Kiff, A., Lang, T., Lee, R., Marsden, T. K., ...and Tibbs, H. (2009). Food futures: rethinking UK strategy. A Chatham House report.

[3] Al-Shiakhli, S. (2019). Big Data Analytics: A Literature Review Perspective.

[4] Bekkers, E., Brockmeier, M., Francois, J., & Yang, F. (2017). Local food prices and international price transmission. World Development, 96, 216-230.

[5] Brown, M. E., Carr, E. R., Grace, K. L., Wiebe, K., Funk, C. C., Attavanich, W., ... and Buja, L. (2017). Do markets and trade help or hurt the global food system adapt to climate change?. Food Policy, 68, 154-159.

[6] Chen, B., & Villoria, N. B. (2019). Climate shocks, food price stability and international trade: evidence from 76 maize markets in 27 net-importing countries. Environmental Research Letters, 14(1), 014007.

[7] Chow, Y. F., McAleer, M., & Sequeira, J. (2000). Pricing of forward and futures contracts. Journal of Economic Surveys, 14(2), 215-253.

[8] Dai, W., Dai, X., Ye, H., & Liu, J. (2011). Prediction of Futures Price Fluctuation: Modeling, Computing and Analysis System. Journal of Computers, 6(8), 1683-1690.

[9] Davis, K. F., Downs, S., & Gephart, J. A. (2021). Towards food supply chain resilience to environmental shocks. Nature Food, 2(1), 54-65.

[10] Easypol. (2010). Price Surges in Food Markets How Should Organized Futures Markets be Regulated?

[11] EPA. (2021, February 26). Commonly consumed food commodities. Retrieved From https://www.epa.gov/minimum-risk-pesticides/commonly-consumed-food-

commodities#:~:text=Food%20commodities%20can%20be%20either,40%20CFR%20180.950(a)

[12] Food and Agriculture Organization of the United Nations. Retrieved April 10, 2021, from https://www.fao.org/home/en.

[13] Gardner, B. (2013). Global food futures: feeding the world in 2050. Bloomsbury Publishing.

[14] Gillson, I., & Fouad, A. (Eds.). (2014). Trade policy and food security: improving access to food in developing countries in the wake of high world prices. The World Bank.

[15] Haile, M. G., Wossen, T., Tesfaye, K., & von Braun, J. (2017). Impact of climate change, weather extremes, and price risk on global food supply. Economics of Disasters and Climate Change, 1(1), 55-75.

[16] Hossain, F., & Ahsan, R. (2018). When it rains, it pours: Estimating the spatial spillover effect of rainfall. SSRN Electronic Journal.

[17] Lau, A. (2009). Implementation of an onto-wiki toolkit using web services to improve the efficiency and effectiveness of medical ontology co-authoring and analysis. Informatics for Health and Social Care 34(1):73-80. doi:10.1080/17538150902779543

[18] Lau, A., Tsui, E., and Lee, W.B. (2009). An Ontology-based Similarity Measurement for Problem-based Case Reasoning. Expert systems and Application, 36(3), 6574-6579.

[19] Phan, H. L., & Zurbruegg, R. (2020). The time-to-maturity pattern of futures price sensitivity to news. Journal of Futures Markets, 40(1), 126-144.

[20] Mary, S. (2019). Hungry for free trade? Food trade and extreme hunger in developing countries. Food Security, 11(2), 461-477.

[21] Porkka, M., Guillaume, J. H., Siebert, S., Schaphoff, S., & Kummu, M. (2017). The use of food imports to overcome local limits to growth. Earth's Future, 5(4), 393-407.

[22] Reichsfeld, D. A., & Roache, S. K. (2011). Do commodity futures help forecast spot prices? (No. 2011/254). International Monetary Fund.

[23] Sharma, A., Modak, S., & Sridhar, E. (2019). Data Visualization and Stock Market and Prediction. International Research Journal of Engineering and Technology (IRJET) e-ISSN, 2395-0056.

[24] Solaymani, S. (2018). Impacts of climate change on food security and agriculture sector in Malaysia. Environment, Development and Sustainability, 20(4), 1575-1596.

[25] Wong, K. K. S., Lee, C., & Wong, W. L. (2019). Impact of climate change and economic factors on malaysian food price. Journal of the International Society for Southeast Asian Agricultural Sciences, 25(1), 32-42.

[26] Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., ... & Asseng, S. (2017). Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences, 114(35), 9326-9331.

[27] Zeckhauser, R., & Niederhoffer, V. (1983). The performance of market index futures contracts. Financial Analysts Journal, 39(1), 59-65.

Data Analytics and Statistics Instruction (DASI) - Abstracts

Important Capabilities for Analytics Instruction that are Often Overlooked

Oral Presentation

Dr. Stephen Custer [1], ***Ms. Barrhonda White*** [1], ***Dr. Regina Gramling*** [2], ***Dr. Atiya Avery*** [2]

1. *Virginia Commonwealth University,* ***2.*** *Auburn University*

:30-10:30 AM Friday, Session Title: **Important Capabilities for Analytics Instruction that are Often Overlooked**
Meeting Room: Jacksonville A&B

Abstract: This session addresses the importance of Soft Skills and Data Ethic Principles and how they can be integrated into analytics instruction. For a VCU Master of Decision Analytics with almost 10% of credit hours devoted to essential soft skills, in a survey of alumni about very valuable skills in their subsequent careers 71% cited presentation skills and 64% cited teamwork. A set of guiding principles is proposed for defining the data ethics portion of an analytics governance framework and how it can be integrated into entry-level business analytics to prepare the next generation of emerging business professionals.

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu
Presenters: Steve Custer, Virginia Commonwealth University, swcuster@vcu.edu
Regina Gramling, Auburn University, rch0013@auburn.edu
Atiya Avery, Auburn University, atiya.avery@auburn.edu

Is Your Instruction for the Beginning and End of the Analysis Process Adequate?

Oral Presentation

Dr. Qi Huang [1], ***Ms. Fatemeh Valizadeh Gamchi*** [2], ***Dr. Wilma Andrews*** [3]

1. *University of Florida,* ***2.*** *Virginia,* ***3.*** *Virginia Commonwealth University*

4-5 PM Thursday, Session Title: **Is Your Instruction for the Beginning and End of the Analysis Process Adequate?**

Meeting Room: Jacksonville A&B

Abstract: An analysis process begins with data and ends with communication of the findings from the analysis. In the middle of these two components, is the analysis of the data. Like a chain, the quality of an analysis process is no better than the weakest link in these three components. Bad data yields a bad result no matter how strong the analysis and communication parts. Similarly, great data and analysis is of little value if they are not communicated so that the consumer understands and has confidence in using the information for decision making. Is your instruction adequate for all three parts?

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu

Presenters: Qi Huang, University of Florida, huangq6@alumni.vcu.edu

Fatemeh Valizadeh, Virginia Commonwealth University, valizadehf@vcu.edu

Wilma Andrews, Virginia Commonwealth University, wandrews@vcu.edu

Regression Modeling for Analytics and Machine Learning

Oral Presentation

Dr. Bob Andrews [1], ***Dr. Mike Ellis*** [2]

1. *Virginia Commonwealth University,* ***2.*** *University of Central Arkansas*

10:45-11:45 AM Friday, Session Title: **Regression Modeling for Analytics and Machine Learning**
Meeting Room: Jacksonville A&B

Abstract: Statistical analyses of data try to identify statistically significant predictors, hence statistical significance, often measured by p-values, is a primary criterion of interest for building statistical models. However, things change for analytics and machine learning where there is a focus on modeling with a purpose of obtaining information from data that can be used to make more informed decisions. The session will have a discussion of model building and the use of typical metrics from a business analytics perspective first and secondly from a machine learning perspective.

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu
Presenters: Bob Andrews, Virginia Commonwealth University, randrews@vcu.edu
Mike Ellis, University of Central Arkansas, mellis@uca.edu

Reproducible Research: Why it is Important & Documenting with R Markdown

Oral Presentation

Dr. Kellie Keeling [1], ***Dr. Tobin Turner*** [2]

1. *University of Denver,* ***2.*** *Presbyterian College*

2:30-3:30 PM Thursday, Session Title: **Reproducible Research: Why it is Important & Documenting with R Markdown**

Abstract: Reproducible research/reporting is an important topic that is typically not covered in business courses. A framework will be presented for "Reproducible Research" steps and technical documentation so that the analysis can be duplicated and/or extended in the future. Presentations will address motivation for and benefits of adding this to the curriculum, examples of reproducible habits to promote, sample student assignments and reporting using the Rmarkdown in the R language so that a reader understands what and how things were done and then reproduce it as desired.

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu

Presenters: Kellie Keeling, University of Denver, kkeeling@du.edu

Tobin Turner, Presbyterian College, jtobinturner@gmail.com

Research Results for Student Learning in Modeling & Introductory Analytics Courses

Oral Presentation

Dr. Eric Tucker [1], ***Dr. Ping Wang*** [2]

1. *United States Air Force Academy,* ***2.*** *James Madison University*

8-9 AM Friday, Session Title: **Research Results for Student Learning in Modeling & Introductory Analytics Courses**

Meeting Room: Jacksonville A&B

Abstract: The first part reports on how a classroom response system was used to administer different formative assessment question types and the resulting impact on summative assessment performance to better understand if the alignment of formative assessment questions to summative assessment questions in specific subject areas improves student performance. The second part presents a comparison of students' beliefs, attitudes and behavior for learning online and in face to face settings for introductory business analytics. The online classes were in Spring 2021 and the face to face classes were in Fall 2021.

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu

Presenters: Eric Tucker, United States Air Force Academy, eric.tucker@afacademy.af.edu

Ping Wang, James Madison University, wangpx@jmu.edu

Understanding Data Pre-processing

Oral Presentation

Dr. Roy Jafari [1]

1. *University of Redlands*

1-2 PM Thursday, Session Title: **Understanding Data Pre-processing**

Abstract: The first step in data analytics is to prepare data. To be able to effectively preprocess data, students need to acquire a diverse set of skills such as understanding databases, understanding the analytic models and tools, and computer programing. The session introduces a recently published book titled "Hands-on Data Pre-processing in Python: Learn how to effectively prepare data for successful data analytics" (http://amzn.to/3Fc3KqA). The text is written to support the MSBA Course Data Science Foundations at the University of Redlands. The presentation will go over the four parts of the book: Technical Needs, Analytic Goals, The Preprocessing, and Case Studies.

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu

Presenters: Roy Jafari. University of Redlands, roy_jafari@redlands.edu

Workshop/Demonstration: Automatic Excel Workbook Grading Platform

Oral Presentation

Dr. Michael King [1]

1. *George Mason University*

2:30-3:30 PM Wednesday Session Title: **Workshop/Demonstration: Automatic Excel Workbook Grading Platform**

Meeting Room: Jacksonville A&B

Abstract: Has grading of homework, tests or exams become an untenable task due to increasing class sizes, remote learning complexities, unpredictable GA availability or pressure to spend more time on research or other activities? *ExPrep*, an automatic, custom, MS Excel worksheet grader can dramatically reduce grading time and improve grading consistency. The session will feature a basic overview to the *ExPrep* platform, a discussion of the specific values of utilizing this third-party grading platform, and finish with a live hands-on demonstration for participants.

Session Chair: **Bob Andrews**, Virginia Commonwealth University, randrews@vcu.edu

Presenter: Michael King, George Mason University, mking34@gmu.edu

Healthcare, Public Sector and Not for Profit Management - Abstracts

A CONTINGENCY THEORY BASED VIEW OF THE IMPACT OF HIT AND PATIENT COMPLEXITY ON HOSPITAL FINANCIAL OUTCOMES

Oral Presentation

Mr. Jim Jenkins [1], ***Dr. Rahul Singh*** [1]

1. *University of North Carolina at Greensboro*

Between 2008 and 2018, US hospitals invested over $35B on Hospital Information Technology (HIT). These investments were supposed to realize improvements in the safety, satisfaction, and health outcomes of the patients while reducing cost of care. Information Systems researchers have studied the impact of the presence of individual HIT systems but they have found mixed results across dimensions of patient satisfaction, expense of care, and health outcomes. One potential contributor to these mixed results is the treatment of patient complexity. The healthcare literature shows patient complexity to be multidimensional and to have a significant impact on health and hospital financial outcomes. We use the theoretical lens of contingency theory and econometric analysis techniques to investigate the question of whether Routinized IS interventions have been effective in mitigating the impact of multidimensional patient complexity on hospital financial outcomes.

AN EXAMINATION OF THE IMPACT OF COVID-19 ON FLIGHT SAFETY

Oral Presentation

Dr. James Gibson [1], ***Dr. Youngran Choi*** [2], ***Dr. Shanan Gibson*** [2]

1. *College of Business, Embry-Riddle Aeronautical University Worldwide,* ***2.*** *O'Maley College of Business, Embry-Riddle Aeronautical University*

The aviation industry is an essential part of the global economy. It supports $3.5 trillion (4.1%) of the world's gross domestic product (GDP). The impact of COVID-19 on the aviation industry was significant. It is estimated that airlines suffered $370bn in lost revenue during 2020 due to the coronavirus outbreak.

Although much has been written regarding the large scale economic impact on the aviation industry, research is just beginning to examine the impact of COVID-19 on areas such as stress, skills, and safety within the aviation industry. The purpose of this study was to conduct a preliminary assessment of the nature of potential threats to aviation safety as judged by ASRS analysts, at varying periods during the COVID-19 pandemic.

Data was obtained from NASA's Aviation Safety Reporting System (ASRS). Incident reports from January 2018 through May 2021were examined (N= 18,590). In order to compare the nature of said reports during various periods of the Covid-19 pandemic, reports were grouped into four categories: Pre-Covid (prior to March 2020), Lockdown (April 2020 – July 2020), Restrictive Measures (August 2020 – February 2021) and Post-Vaccine/Recovery (March 2021 forward).

The two variables examined as part of the current study were the primary problem category of the incident and the nature of the human factors involved in the incident. Comparisons across the four time periods were conducted using chi-square analyses with post-hoc comparisons utilizing Bonferroni's method z-tests.

Observed differences in primary problem included: company policy, human factors and software and automation. Noteworthy differences associated with human factors included: confusion, distraction, situational awareness, workload, and training & qualifications.

Future research should expand examination of the nature of unsafe occurrences within the aviation sector and do so taking into consideration both the self-report data and the interpretative coding of the ASRS analysts. Better understanding of the impact of unique stressors, such as the Covid-19 pandemic, on mental health, safety culture and actual outcomes will yield beneficial insights useful for future training and policy actions.

An Exploratory Study of a Hunger Relief Agency's Clients

Oral Presentation

Dr. Shona Morgan [1], ***Dr. Brandis Phillips*** [2]

1. *North Carolina A&T State Univ.,* ***2.*** *North C*

Although hunger in the United States has always been intertwined with poverty, it has been brought to the fore during the COVID 19 pandemic. There is now a heightened awareness that hunger is pervasive throughout many communities in the United States. This study surveys food pantry clients to gain an understanding of who is subject to food insecurity in a large southeastern U.S. community. Demographic data is collected, and questions are included that help define the extent of their food and transportation insecurity. Preliminary demographic results suggest clients are primarily U.S. minorities (African American and Hispanic), are just as likely to be employed as unemployed and they do not receive food assistance of any kind by a two to one margin. Future research will examine how demographic characteristics are statistically associated with varying levels of food insecurity.

AN INVESTIGATION OF FACTORS AFFECTING ORGAN DONOR STATUS AMONG MILLENNIALS AND GEN Z

Oral Presentation

Dr. Susie Cox [1]***, Dr. MD Al-Emran*** [2]

1. *University of Louisiana at Monroe,* ***2.*** *McNeese State University*

As each generation reaches an age of maturity, we are able to witness the forces that have shaped their views of social issues. One social issue of great importance is organ donation status. Currently, 107,000 Americans are waiting for a lifesaving organ and 17 will die each day while waiting (organdonor.gov). It is paramount that individuals are informed and able to make educated decisions about organ donor status. This is especially important for the millennial and Z generations. Understanding the viewpoints of millennials and Gen Z can help organizations develop successful strategic marketing plans to educate young adults about organ donation and becoming organ donors. To develop our research questions, we pull from several theories. The theory of planned behavior (Ajzen, 1991) helps us understand the attitudes toward behavior, subjective norms, and perceived behavioral control and guide the development of marketing strategies. Social marketing is fundamentally the application of commercial marketing principles of a planned behavior change strategy (Lee and Kotler 2011). In addition to examining the intention to register as an organ donor, we examine the willingness to disclose one's organ donor status with family and friends. Mum theory provides a foundation for understanding why some individuals may not want to disclose their status (Totten, Cox, and Al-Emran, 2019). In this study, we look at driving forces that shape the attitudes and behaviors of millennials and Gen Z, including their perceptions and potentially their fears associated with organ donation and the willingness to communicate organ donor status with family and friends. We extend our research beyond personal attitudes to investigate family, friends, and media influences on the behaviors of young adults.

References

Ajzen, Icek (1991). "The theory of planned behavior". Organizational Behavior and Human Decision Processes. 50 (2): 179–211. Organ Donation Statistics https://www.organdonor.gov/learn/organ-donation-statistics. Accessed on October 24, 2021.

Lee, Nancy R. and Philip Kotler (2011). Social Marketing: Influencing Behaviors for Good, Sage Publications.

Totten, J. Cox, S. and Al-Emran, Md. (2019). Don't Mum your Mom: Communication Apprehension and the Family's Decision to Support Organ Donation, Southern Marketing Advances Annual Conference, New Orleans, LA. Note: The research project was started by Dr. Jeff W. Totten†, an Associate Professor of Marketing at McNeese State University. Dr. Totten passed was in 2020.

Analyzing the Effectiveness of Readmission Rate Reduction in Hospital Emergency Rooms

Oral Presentation

Ms. Dar Bejerano [1], ***Dr. Thomas Maroney*** [2], ***Dr. Serina Al Haddad*** [1]

1. *Rollins College,* ***2.*** *Data Analyst*

Hospital readmissions can be defined as unplanned rehospitalizations within 30 days of a patient's index discharge. Hospital readmissions are problematic from the perspective of both a patient's health and a facility's monetary and labor efficiency. As a result, the Affordable Care Act (ACA) was enacted in October of 2012 to incentivize hospitals to reduce readmissions through the Readmissions Reduction Program (PRP) and Value Based Purchasing (VBP). The goal of this research is to analyze hospitals' success rates in implementing PRP and VBP, specifically focusing on the efforts put in place to try and prevent readmission. These preventative measures include properly tending to patients during their initial visit, educating them effectively before they are discharged, and following up with well-timed phone calls and appointments after the index visit. In addition to the preventative measures, readmission rates may vary depending on demographics of the patient as well as the cause of their initial admission.

Some patients' cohorts have been identified as more susceptible to readmission, leading to the availability of Acute Myocardial Infarction (AMI), heart failure, and pneumonia readmission rates. This research will conduct further analysis to better understand the correspondence between patient conditions, treatment, and readmission rates, with a goal of identifying and implementing the successful strategies to effectively reduce readmission rates on a national level.

AUTONOMOUS VEHICLES IN A PUBLIC TRANSPORTATION ECO-SYSTEM: LEVERAGING THE TECHNOLOGY ACCEPTANCE MODEL (TAM) TO RATIONALIZE CIVIC ACCEPTANCE

Oral Presentation

Mr. Michael Feldman [1], ***Dr. Zachary Davis*** [1], ***Dr. Zonghui Li*** [1]

1. *Jacksonville University*

As Public Transportation enterprises place a concerted focus on corporate social responsibility and sustainability within their strategic long-range transportation frameworks, Autonomous Vehicles (AVs) play an important role for transportation alternatives. The principal objective of this study is to examine what factors influence an individual's adoption of AV integration as a modal option in a Public Transportation eco-system by extending the Technology Acceptance Model (TAM). For that reason, a self-administered 32-item Likert based questionnaire was distributed to 250 qualified respondents to collect transit user level data from both current and prior users.

Creating an Organizational Culture that Reduces Nurse Burnout

Oral Presentation

Ms. Teray Johnson [1]***, Dr. Sameh Shamroukh*** [1]

1. *Harrisburg University*

This study examines the use of organizational culture to reduce nursing burnout, which is a prevalent issue in healthcare that results in worse patient outcomes, decreased quality of care, and high staff turnover. Previous literature has identified the correlation between organizational culture and burnout. However, none of the extant empirical studies focus on specific behaviors and aspects of culture that organizational leaders can develop to decrease nurse burnout. Therefore, the purpose of this study is to identify aspects of organizational culture that decrease nurse burnout so that organizational leaders can create a positive culture that promotes nurse well-being. Furthermore, five reproducible regression models are created that can be used to measure the correlation between specific aspects of organizational culture and burnout. The study was designed based on three domains that form organizational culture: leadership behavior, employee behavior (with the understanding that employers are responsible for how their employees behave), and organizational behavior. The data were collected using a survey from 1,706 nurses around the United States that included 86 questions surrounding managerial, employee, and organizational behaviors. The response rate was 68%. The data were used to identify behaviors that could lead to burnout and study the relationship between those behaviors and burnout symptoms, such as low job satisfaction and high workloads. The statistically significant results showed that organizational culture is negatively correlated with nurse burnout; negative managerial, employee, and organizational behavior led to higher rates of burnout. This study contributes to both nursing literature and the nursing industry.

CRITICAL ANALYSIS OF COVID-19 INFORMATION PROCESSING, MENTAL HEALTH ON JOB SATISFACTION

Oral Presentation

Dr. Xiaohui You [1]

1. *Metropolitan State University of Denver*

The COVID-19 has devastated the economy, imposed increased employment insecurity, and significantly affected the day-to-day life, health, and social economics in the U.S. Thus, critically analyzing the health and socioeconomic impacts faced by many people during the pandemic and the perceived seriousness of the pandemic among those impacted (or not) is extremely important. Understanding the potential correlations between personal impact and perceived severity of the COVID-19 pandemic allows researchers to connect macro-level public health issues with individual health and wellbeing. This research analyzed the association between mental health and employment during the coronavirus crisis, specifically focusing on the relationship among perception of the impact, belief of the social and government responses, vaccination, NPIs practices, mental health and job satisfaction using structural equation modeling (SEM) based on the Organizational Information Processing Theory (OIPT). Utilizing the Structural Equation Modeling (SEM) approach with a sample of 454 responses from the public in the U.S., the empirical results indicated that the mental health during the pandemic was significantly reducing job satisfaction, while the perception, belief have detrimental effects on job satisfaction directly. In addition, the combination of perception, belief, vaccine and practice have a significant effects on mental health, which in turn affects job satisfaction. The theoretical and practical implications of the study are discussed to provide researchers and public health officials with new options and strategies when dealing with this pandemic issue.

KEYWORDS
COVID-19; mental health; employment; job satisfaction; organizational information processing theory; SEM

Developing Machine Learning Rules for Fraud Detection and Management Oversight of Healthcare Providers

Oral Presentation

Dr. Gary Hackbarth [1], ***Dr. Matthew Kolakowski*** [1]

1. *Valdosta State University*

Healthcare fraud is complex and expensive to detect. An evaluation of publicly available healthcare provider fraud cases leads to several insights. Fraudulent healthcare providers tended to treat an abnormally high number of patients, had practices that were either too large or too small and failed to communicate with patients about their medical care adequately. Service providers communicating poorly with patients seemed to signal red flags. While the relationships are not causal, managers might monitor physician practice size, the number of patients treated, and time spent per patient. Supervised machine learning models might also benefit from these same relationships.

Exploring the Benefits of Robotics to Assist People with Disabilities

Oral Presentation

Dr. James Lawler [1]

1. *Pace University*

Robotics continue to be developed in devices for people with disabilities. In the paper the authors begin to describe the established features of an initial sample of robotic tools for people with diverse disabilities, in a research-in-progress study. This study can help non-profit organizations considering further investment in this technology for disadvantaged populations.

Fuzzy Decision Making: Managing Backorders in Healthcare Environments

Oral Presentation

Dr. Kim Whitehead [1]

1. *Anderson University*

Managing backorders is a key component of managing efficient supply chains. Healthcare organizations (HCOs) balance the management of backorders with the protection of human life and quality delivery of health care services. Hospital supply chain managers are responsible for an average of over 35,000 SKUs per facility many of which are suffering from supply chain disruptions leading to backorders. There are many backorder management strategies utilized by healthcare facilities, however, there is a need to formalize and prioritize those techniques to assist HCOs to manage backorders across multiple SKUs more effectively. This research aims to identify and prioritize backorder techniques and strategies for HCOs by utilizing multi-criteria decision-making (MCDM) techniques for analysis. The research will use fuzzy analytical hierarchy process (AHP), fuzzy technique for order of preference by similarity to ideal solution (TOPSIS), and fuzzy quality function deployment (QFD) to determine and prioritize what needs can be satisfied with backorder management, and to identify and prioritize actions that meet those needs. The result of the analysis is intended to be a list of best practices that can be used by HCOs to manage backorders across multiple SKUs in a formal and replicable manner.

Influence of Patient Quality Measurements and HCAHPS Scores on Hospital Payments

Oral Presentation

Dr. Christie Chen [1], ***Mr. Monty Taylor*** [1], ***Dr. Tommy Cates*** [1]

1. *University of Tennessee at Martin*

The Centers of Medicare & Medicaid Services (CMS) ties hospital reimbursement to quality metrics. The Hospital Value-Based Purchasing (VBP) program provides financial incentives to acute-care hospitals based on performance improvements on several quality measures based on the national Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. Thus, hospitals desire to perform well on the survey in order to avoid financial penalties. The objective of this present study is to determine if the hospitals which reported higher complications and frequency of pressure sores would be negatively impacted in hospital reimbursements/payments. Based on our results, data from CMS Care Compare for acute-care hospitals did not reveal any financial penalties when hospitals reported higher complications and increased numbers of pressure sores. However, higher complication measures were associated with lower patient satisfaction. Controversially, lower patient satisfaction scores reflected higher reimbursement rates.

Student Learning Style Preference Of Healthcare Management Students Prior To Coronavirus Disease (COVID-19).

Oral Presentation

Dr. TaQuesa McLeod [1], ***Dr. Lisa Wills Keister*** [2]

1. *Lander University,* ***2.*** *Principle Evaluation, Assessment, and Research Group, LLC*

This project seeks to understand the learning style preferences for health care management students at a Southern regional university prior to the Coronavirus disease (COVID-19) pandemic. This paper reports on the psychometric properties of the electronic survey following large-scale piloting of a revised paper version. The original paper survey yielded 84 complete responses, with a KMO value over 0.5 (0.528) and a significance level for the Bartlett's test below 0.5 (sig. = .000). Parallel analysis and orthogonal rotation confirm four factors extracted: time of day, length of class, learning tools and modality. A negative Cronbach's alpha suggests that researchers may obtain a good measure of reliability by converting the survey from a dichotomous response to a four-point, forced-choice Likert response scale. Large-scale testing will reflect this major survey revision, in addition to more insightful demographic questions. Over the past two years, the academic unit has experienced an increase (approximately 40%) in student interest and enrollment. This surge in enrollment and shift in professional access affords investigators to conduct a follow-up survey of healthcare management students post-pandemic and assess preferences and educational trends. Future results will be used to understand student preferences as it relates to learning styles, modality, and preference of graduate degree programs.

The 'Sustainable Public Health Index': A proposal

Oral Presentation

Prof. Rui Marques [1], ***Mr. Miguel Pereira*** [1]

1. *Instituto Superior Técnico (University of Lisbon)*

In this day and age, the perception of public health has been renovated by the notion of sustainable development. As a matter of fact, "ensuring healthy lives and promoting the well-being for all at all ages", established by the United Nations (UN) as one of the Sustainable Development Goals (SDGs), aims towards the reinforcement of this conception and the saving of lives considering the physical, mental, and social well-being of populations whose "development meets the needs of the present without compromising the ability of future generations to meet their own needs". For this reason, interpreting and conveying information regarding this multidimensional concept is useful and can be achieved by means of a composite indicator. We propose a sustainable public health index (SPHI) framework based on the 13 targets of the UN's SDG 3, assessed between 2016 and 2020. Therefore, using the well-known 'Benefit-of-the-Doubt' approach to consider desirable and undesirable indicators, we apply the SPHI framework to 181 Member States of the World Health Organization and show that, in the considered five-year period, less than 28% of them remained efficient. Furthermore, the European Region demonstrated a clear dominance over the other five WHO regions, which tended to decrease their performance, on average. At last, we also show that there were global efforts in the improvement of the *Proportion of births attended by skilled health personnel* and the *Density of medical doctors per 10,000 population*, but there was also an inability to achieve acceptable results in terms of the *Neonatal mortality rate*, the *Under-five mortality rate*, and the *Number of people requiring interventions against neglected tropical diseases*.

KEYWORDS

Public health, Sustainable development, Composite indicator, Benefit-of-the-Doubt,
Sustainable Development Goals.

The impact of COVID-19 on health and socioeconomic factors

Oral Presentation

Dr. Xiaohui You [1]

1. *Metropolitan State University of Denver*

This study attempts to investigate and provide a comprehensive review of health and socioeconomic impacts during the COVID-19 and the perceived seriousness of the pandemic among those impacted (or not). The pandemic has caused a significant impact on people's health and socioeconomic status in the U.S. This study attempts to investigate and provide a comprehensive review of health and socioeconomic impacts during the COVID-19 pandemic by conducting a survey with a series of questions related to perceptions, beliefs, health behaviors, and socioeconomic status toward the influencing factors of COVID-19. Applied with the Ordinal model, Generalized Linear Model, and Multinomial logistic regressions, this research estimates the mental health, employment status, government response, and the aging effects on job satisfaction, using the data collected from the Denver area. Results highlight the significant impact of the pandemic on the individual's employment status and mental health, especially to the young group (students) and unemployed. According to the estimations, the unemployed group, students, and those with emotional problems, such as feeling depressed and anxious, have significant dissatisfaction with their job during the COVID-19 period. On the contrary, the aging group and those with regular job or the retired have less impact and higher satisfaction about the job situation.

To collect sufficient amounts of data, this study consists of a survey that will be administered to individual participants in public, on MSU Denver's college campus, through social media and email recruitment. The participants were asked to answer a series of questions related to perceptions, beliefs, health behaviors, and socioeconomic status toward the influencing factors of COVID-19. According to the data we collected from the Denver area, the pandemic has significantly impacted people's employment and mental health, especially for the low-income groups. Among the non-pharmaceutical interventions (NPIs), wearing masks is the most effective NPIs than "reducing family or friends' gatherings", "working and studying at home", "social distancing and controlling"…etc. The higher the people wearing masks, the better the rate of their mental health, statistically significant. In addition, this study also explores any possible correlation between impacts caused by COVID-19 and an individual's opinion on the future of COVID-19 and other pandemics.

KEYWORDS COVID-19, Socioeconomic Impacts, Health Impacts, Personal beliefs

The Impact of Product Innovation and Value-based Contracts on Firm Performance: Evidence From Pharmaceutical Firms

Oral Presentation

Dr. Michael Porter [1]

1. *Alabama A and M University*

The rising price of drugs and medical treatment has exerted pressures for healthcare institutions, states, and insurers to find alternative means of lowering prices without reducing the quality of the drugs and care received by patients. With this increasing pressure, there has been a slow but mounting acceptance of value-based contracts as an effective means of promoting price transparency, lowering costs, and expanding access. Over the last ten years, there have been 71 publicly disclosed value-based contracts entered into between pharmaceutical firms and payers. This subject has been widely studied in medical and pharmacoeconomic contexts but has been underexplored from a management perspective. This paper examines the innovation activities and firm performance of pharmaceutical firms that have entered into value-based contracts with states and payers. It highlights implications for practice and discusses a future research agenda around value-based contracts and firm innovation.

Keywords: Value-based Pricing, Pharmaceuticals, Product Innovation, Firm Performance

Using simulation for improving patient care in the emergency department in Barbados

Oral Presentation

Dr. Jennifer Bushelle Edghill [1], ***Dr. Burcu Adivar*** [1], ***Dr. Bola Ekezue*** [1], ***Dr. Su Dong*** [1], ***Dr. Chaynie Williams*** [1]

1. *Fayetteville State University*

The decentralized universal healthcare system in Barbados provide access to care for all citizens regardless of their socio-economic status. Overcrowding at the hospital emergency department (ED) has been a challenge. The expansion of public polyclinics and the establishment of privately-owned Urgent Care (UC) facilities is expected to alleviate congestion in the ED. This study focuses on patient flow within two independently owned UCs and the public ED using nonclinical throughput measures for process flow. The ER typically host 20 nursing staff per day, 19 doctors per day, 3 front of office clerks and 15 supporting staff (such as those who transport patients) and see an average of 110 patients per day. One urgent care facility is 24 hours while the other operates an 18-hour day. Discrete event system simulation method is used to reduce patient waiting times and to improve overall service delivery for better management of the overcrowding. Simulation model of the Emergency Department in Barbados has been constructed using ARENA software. The operation of the Emergency Department during the past 12 months has been observed to capture the input data for model development. Data was collected in real-time for patients 18 years and over visiting two UCs and the ED. We obtained time spent (walk-in to checkout) during patient visit and time patients spent at various steps in the process. The simulation model consists of the triage process, patient flow, consultation process, tests and laboratory activities in detail. The validity of the simulation model is tested using confidence interval approach.

Alternative performance improvement strategies are proposed, and their performances are compared with respect to average patient waiting time, average *length of stay per* patient for each *triage category, average* doctor, nurse and bed capacity utilization.

Healthcare, Public Sector and Not for Profit Management - Papers

A CONTINGENCY THEORY BASED VIEW OF THE IMPACT OF HIT AND PATIENT COMPLEXITY ON HOSPITAL FINANCIAL OUTCOMES

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ABSTRACT

Between 2008 and 2018, US hospitals invested over $35B on Hospital Information Technology (HIT). These investments were supposed to realize improvements in the safety, satisfaction, and health outcomes of the patients while reducing cost of care. Information Systems researchers have studied the impact of the presence of individual HIT systems, but they have found mixed results across dimensions of patient satisfaction, expense of care, and health outcomes. One potential contributor to these mixed results is the treatment of patient complexity. The healthcare literature shows patient complexity to be multidimensional and to have a significant impact on health and hospital financial outcomes. We use the theoretical lens of contingency theory and econometric analysis techniques to investigate the question of whether Routinized IS interventions have been effective in mitigating the impact of multidimensional patient complexity on hospital financial outcomes.

1.0 INTRODUCTION

The US government has been encouraging healthcare providers to accelerate their conversion to electronic health records through their allocation of over twenty-seven billion dollars toward Electronic Health Record (EHR) incentive payments included the Health Information Technology and Clinical Health (HITECH) Act that was enacted as part of the 2009 American Recovery and Reinvestment Act (ARRA). The federal investments made through the HITECH

Act increased the rate of adoption of Electronic Health Records (EHRs) from 3.2% in 2008 to 14.2% in 2015. By 2017, 86% of office-based physicians had adopted an EHR and 96% of non-federal acute care hospitals has implemented certified health IT [44]. The HITECH Act also included guidelines on minimum functionalities that the implemented systems should contain to provide value to the overall US Healthcare system, or "meaningful use". The Meaningful Use requirements were intended to ensure that the EHRs would improve care coordination, reduce healthcare cost, and improve healthcare quality [28]. The program of Meaningful Use was focused on the internal impacts of EHRs, with stage one requirements focused on data capture and sharing, stage two requirements targeted on the inclusion of advanced clinical processes within the established system, and stage three requirements are constructed ensure that the hospital is using their EHR for benefiting a broad range of patients to improve patient health outcomes. Similarly, the HIMSS organization created maturity models to benchmark the status of hospitals with respect to their digital healthcare systems (www.himss.org). The Electronic Medical Record Adoption Model (EMRAM) is a more granular, eight-stage model that allows for vendor-neutral benchmarking of the presence and adoption of HIT systems that are designed to improve patient care, patient outcomes, and hospital financial outcomes. Both the Meaningful Use and EMRAM criteria were developed to measure and provide clear operational targets for improving hospital and patient outcomes though the persistent use of IT solutions.

With the use of information systems like computerized provider order entry (CPOE), it is expected that care coordination should be improved across the patient care team resulting in higher quality of care, lower hospital expense for care, improved patient perception of care, and better patient health outcomes; however, in other contexts the introduction of information systems have not resulted in a positive changes with respect to intraorganizational coordination

[14] and customer service [15]. In a healthcare context, it has been seen that coordination resultant from CPOEs does have a moderating effect on patient satisfaction for more complex patients, but that the relationship was not as strong for patients that have lower complexity [47]. Research largely supports the assertion that CPOE usage reduces procedural errors [2,34]; however, other studies of CPOE use found mixed or unintended negative consequences [27]. These mixed results indicate that there may be other factors either within or outside of the hospitals control that impact the efficacy of information systems introduced into the health care setting and that we have not reached consensus regarding the factors that influence the relationship between HIT and the outcomes they are meant to influence.

One potential contributor to the mixed results of the prior research of the effect of HIT on healthcare outcomes is the treatment of complexity. It has been established higher patient complexity is generally associated with lower expectations for a positive outcome for either the patient perception of care or the hospital cost for care [38,40]. Research in the extant IS literature does not directly consider patient complexity. The one metric that is commonly seen in IS studies is Case Mix Index (CMI). CMI is representative of the relative effort and resources required to treat a patient [13]. In the extant IS literature, CMI has widely been used as a control variable in regression analyses to control for the medical conditions of the heterogeneous patient populations [4,5,51]. Within a particular diagnosis group, higher values of CMI represent the presence of more comorbidities, and higher cost treatments [24,53]. This increase in costs can be partially attributed to larger care teams with higher care coordination requirements [56,59]. Healthcare researchers use a term “high-need, high-cost” (HNHC) patients which succinctly summarizes the established correlation between higher complexity and higher system utilization and thereby higher costs [22].

Estimates for this relationship between complexity and cost are that 5% of the population accounts for 50% of the country's annual healthcare spending costs [8]. However, there are other considerations such as demographic, socio-economic, and cultural factors that should be considered when evaluating the complexity that will be encountered while treating a [45,49]. Although there are studies that consider the effects of additional comorbidities on outcomes [24], we could find no studies that investigated the impact of patient complexity on HIT enabled outcomes. The complexity and health conditions of the patients that a hospital treat is exogenous to the hospital. Various federal laws such as Title VI of the Civil Rights Act of 1964 and the Age Discrimination Act of 1975, prevent hospitals from selecting patients with lower complexity to treat. Therefore, the hospital must treat the patients that present for treatment. As higher complexity patients cost disproportionately more to treat and tend to have lower perceptions of the care, improvements in performance while treating these patients could provide the largest returns for the hospitals.

Operating expense and patient perception of care both have financial implications for hospitals. The implications of operating expense are obvious; however, the implications of patient perception of care may not be so plain. The Centers for Medicare & Medicaid Services (CMS) annually calculate the Patient Experience of Care (HCAHPS) Domain score for the Hospital Value-Based Purchasing program. This score is used to set reimbursement rates for treatments covered by Medicare (https://qualitynet.cms.gov/inpatient/hvbp-). As Medicare is the single largest payer for healthcare in the United States, with over 90 million people covered by CMS programs (www.cms.gov), in 2017, the HVPB adjusted reimbursements for the highest performing hospitals by +1.8%, while the lowest performing hospitals suffered a 1.83% reduction in payments.

The motivating question for the research is: *does the routinized use of HIT improve outcomes, particularly for more complex patients?* As discussed previously, current research has not addressed the role of patient complexity in achieving better healthcare outcomes using HIT. This research will directly address a multidimensional view of patient complexity and the effects that routinized use of HIT can have in achieving better results for more complex patients. The research also will explain the implications of the routinization of IS interventions in achieving the goals for the implemented systems.

The results of this research will identify the operating implications and contingencies of routinized information systems for hospitals. The objective of this study is to investigate two issues related to the business value of information integration to hospitals. First, we empirically examine the effects of information integration in a health care setting. Second, we explore the effects of selected determinants of information integration on hospital performance outcomes to answer the following research question: *Do hospitals with high routinized HIT provide care for patients with high CC and SEC while maintaining cost efficiency?*

2.0 THEORETICAL FOUNDATION

It is long recognized that hospitals are complex organizations that provide care to patients through the coordinated efforts of multiple inter-organizational or intra-organizational units that provide very specialized services that go towards the overall care of patients. Moreover, hospitals work under conditions of significant uncertainty in terms of the complexity of patient needs. Therefore, hospitals make complex contingent choices regarding the selection of the specific structural components of the health system (the group of inter- and intra-organizational units that provide care for patients) that must come together to meet the needs of specific

patients. Moreover, these choices must be made on a per-patient basis to meet the unique needs of the patient and provide the best care for the patient in the most cost-efficient manner.

Galbraith [25] proposed the information processing view of organizational design which recognizes as a central tenet that the organization's reliance on efficient information processing has a direct relationship with the level of uncertainty of the task environment. "*The greater the task uncertainty, the greater the amount of information that must be processed among decision makers during task execution in order to achieve a given level of performance.*" [25, pg. 28]. Here, information processing implies includes gathering, interpreting, and synthesizing information to support decision making. For health systems providing care for complex patients, information processing encompasses the multiple inter- and intra-organizational units that must effectively share information to coordinate care activities as they provide effective and cost-efficient care for patients. Greater uncertainty and complexity in patient characteristics and care needs limit the health system's ability to plan and make decisions about activities in advance of their execution. Thus, organizations must increase their flexibility and adaptability and improve the coordination among the dynamically configured set of tasks across the health system, which is needed to provide effective care for the specific patient at fiscally viable levels of process efficiency. Mature HIT systems facilitate such coordination by providing the necessary information processing capability across the organization.

Therefore, we expect that greater availability and routinized use of HIT across a health system will improve care coordination and lead to reduced costs (H1a) and improve patient satisfaction(H2a). Moreover, we expect that such improvements will be higher for health systems that deal with more complex patients, i.e., higher CMI (H1b, H2b), lower incomes (H1c, H2c), and higher racial diversity (H1d, H2d).

Daft and Lengel [18] note that uncertainty and equivocality in the task environment leads to the inability of the organization to pre-plan activities, which in turn forces organizations to process information; and the efficacy of the information processing is influenced significantly by the structure and behavior of the organization and its processes, whose efficacy is directly impacted by efficient coordination of tasks. Information is processed to accomplish internal tasks, to coordinate diverse activities, and to interpret the external environment.

To manage the complexity of the individual tasks performed within the health system, hospitals develop integrated information processing capabilities to access and share information in a timely manner to coordinate the complex set of activities needed to provide effective care across the units in the health system. Thus, the information integration capability of health systems, stem from their EHR systems' ability to ***access and share information across the health system*** as hospitals provide care. As organizations adopt ***inter-operable EHR***, the expectation is that the ability to coordinate complex tasks across the health system will improve and the organization will be able to ***provide better quality of care***, ***improve cost efficiencies*** and ***improve patient satisfaction***. However, empirical evidence to support this belief and expectation is mixed, at best.

The mixed evidence suggests a need to develop research which examines the interaction between an organization's structural properties as well as its information processing capabilities to build better understanding of how the two key characteristics of hospitals interact and impact the quality of care, cost of care and patient satisfaction – all key indicators of hospital efficacy as well as key elements of fiduciary policy that significantly impact the financial conditions hospitals operate under. The purpose of this paper is to investigate these relationships and build a

better understanding of how information technology capabilities can impact the relationship between patient complexity and outcomes for the hospital.

2.1 Contingency Theory

Contingency theory explains a firm's performance through the match between the organization's strategic behaviors and the internal and external conditions that the organization operates in.

Naylor, Aiken, Kurtzman, Olds and Hirschman [42] identify that points of transition of patients, care providers and information contribute to high healthcare costs, and low quality of care due to increased potential for errors or delays in the timely coordination of information. The more complex the patient the more of these transition points will be present in their course of care. Since *complex patients* with multiple chronic conditions [8, 48] exhibit different disease conditions, have diverse needs, and respond differently to different treatments [61], providing coordinated care for them is particularly challenging due to the unpredictable outcomes from dynamic interactions between their comorbidities [62]. Each patient presents a different set of comorbidities that may interact in different ways at different points in time [29]. Often these comorbidities are chronic conditions that interact with a variety of extraneous demographic and socioeconomic conditions that further impact the quality of care for complex patients. Treating complex patients through routine care programs that focus on individual conditions can result in uncertain quality of care. While relatively fewer in number, complex patients incur high costs to a health system and are at high risk for poor health outcomes [39]. As a result, complex patients contribute a disproportionately high share of the nation's health care [8,9]. This relationship between exogenous patient complexity and the required response of the internal systems to deliver the required complexity of care, speaks to the need for coordinating systems. Literature recognizes that complex patients need coordinated care from the multiple specialties and care

services within the health system [1,10]. Different units in the health system must interact with each other to perform the diverse range of operations required of the complex care management efforts needed to care for complex [32,58]. These activities are managed across the health system and rely on efficient information sharing for seamless delivery of effective care [1,31].

Efforts to coordinate the care for patients is a strategic action. hospitals invest much financial and care provider-time resources to effectively manage care for complex patients. The delivery of healthcare, particularly for chronic care patients, is a highly interdependent task environment because the nature of coordination needs often change from one patient to another, as well as from one care episode to another. Clinical staff must improvise and adapt their actions and be responsive to patients' emergent conditions. As high quality, safe and timely care for patients with chronic illness often requires services from multiple clinical and support departments, care providers must evaluate the specific needs of patients and adaptively coordinate their activities to address their patients' emergent needs.

Hospitals' performance is highly dependent on the efficacy of well-coordinated activities that provide effective care for patients. Effectively meeting the specific needs of individual patients, while managing performance and cost efficiency of operations across the hospital is the challenge that hospital administrators face. Patients with acute chronic conditions often suffer from multiple comorbid conditions that often interact with one another and require specialized treatment from care specialist at specific points of their condition. Previous literature finds that patients with complex and chronic care needs contribute to a majority of healthcare costs [8], have a disproportionately high number of hospital visits [54], require the most ambulatory visits [33] and a disproportionately high number of annual visits to the emergency department [31].

Chronic care often extends over multiple clinical specialties and health facilities [1,10] making the efficient delivery of effective care particularly complex. Multiple care providers need to engage in concurrent and asynchronous processes to diagnose, treat, and navigate the patient through the complex set of activities that comprise their plan of care. Without effective coordination, this can result in situations where care is provided through an aggregation of potentially incoherent, uncoordinated, and interfering processes [63], which leads to costly care that is neither effective for, nor satisfactory to the patient.

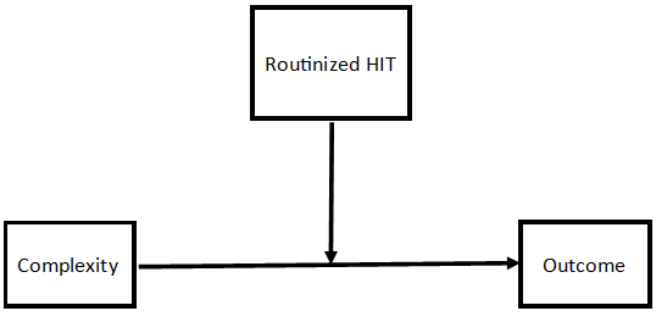
2.2 Role of Information

With increasing environmental complexity and uncertainty, organizations become more complex, loosely coupled and more decentralized [60] in their information processing and decision making. Organizations are influenced and constrained by external forces and conditioned and impacted by internal attributes [3,64]. Organizations must adapt and react to the uncertainties in the external environment over which they have little control. This adaptation takes the form of organizational structures and strategic actions they take in order to effectively manage resources and improve performance in reaction to the external uncertainties. Complexity of the patients they serve represent external uncertainties that hospitals must adapt and react to, in addition to the ever-changing requirements of the policy setting organizations, such as the CMS. Coordinated care programs represent a strategic behavior hospitals and health systems have adopted to effectively meet the needs of complex patients they serve, while meeting the regulatory requirements of health care policy. The efficacy of these care programs is heavily dependent of the effectiveness of information integration and sharing of information throughout the hospital. However, the impact of the information integration and coordination care programs is under-researched. Moreover, research on the nature of the factors that influence the success of

the information integration efforts health systems take to manage the care of complex patients is absent.

2.3 Model

Using the lens of Contingency Theory, we constructed the following model to test the



hypotheses concerning the impact of Routinized HIT on the financial outcomes of hospital expense and patient perception of care while managing the uncertainty presented by multidimensional patient Complexity.

Figure 1. Research Model.

3.0 RESEARCH DESIGN AND DATA

The unit of analysis in this study is the U.S. acute care hospital. We collected secondary data from multiple sources for the four calendar years from 2014 to 2017 for the 4,337 U.S. acute care hospitals included in the CMS database as of 2014.

Information concerning IS usage and financial results were extracted from the Healthcare Information and Management Systems Society (HIMSS, previously the Dorenfest Institute for Health Information Technology Research) database. The HIMSS database is a nationally representative survey that includes meta data, IT usage metrics, and operational data from over

5000 hospitals. Operating expense information for each of the four years was converted to 2012 dollars using the CPI for hospital inpatient services, as compiled by the USDA Economic Research Services, to remove the effects of inflation. Patient perception of care metrics were collected from the HCAHPS patient satisfaction survey results. We extracted CMI and some of the controls from the CMS Impact File. Final adjusted values were used from the CMS Impact files when using values that could be retrospectively adjusted by the CMS.

As our collected data is at the individual health care facility, we approximated the social, economic, and cultural composition of the patients by taking measures for these parameters from the populations that the health care facilities serve. We used weighted averages for these values based on the ZIP codes of the patients treated by the hospital for each of the four years considered in the study.

3.1 Independent Variables

Complexity

The Merriam-Webster dictionary defines something complex as “a whole made up of complicated or interrelated parts” or “a group of obviously related units of which the degree and nature of the relationship is imperfectly known”.

In the framework for patient complexity proposed by Safford and her colleagues [49], they show that the “determinants of health include biology/genetics, socioeconomics, culture, environment/ ecology, behavior, and the medical system”. In their vector model of patient complexity, they describe each of these determinants of health to be additive and variable from customer to customer.

Clinical Complexity

The Case Mix Index (CMI) is the average relative Medicare Severity-Diagnosis Related Group (MS-DRG) weight of a hospital's inpatient discharges, calculated by summing the MS-DRG weight for each discharge and dividing the total by the number of discharges (www.cms.gov). The CMI reflects the diversity, clinical complexity, and resource needs of all the patients in the hospital treated over a certain time-period. A higher CMI indicates a more complex and resource-intensive case load. Although the MS-DRG weights, provided by the Centers for Medicare & Medicaid Services (CMS), were designed for the Medicare population, they are applied here to all discharges regardless of payer. The case-mix index is a gauge of the comparative cost needed to treat a patient group in a hospital within a time-period, usually a calendar year. An index of one indicates that it costs the national average amount of resources per patient to treat the hospital's specific patient group. A hospital that performs higher cost care or has more resource intensive operations, such as neurosurgery or cardiac surgery, has a higher CMI compared with another that performs less costly care. A natural log transformation was required to yield a normally distributed form of the data.

Sociological Complexity

The racial disparity of health outcomes has been widely studied in the healthcare literature [20,41,65]. These studies show that the healthcare outcomes minority populations achieve are inferior to those of the majority population. As a measure of sociological diversity was made using the racial disparity, which was calculated by summing the percentages of minority populations for a given ZIP code. A square root transformation was required to yield an approximately normal distribution of values.

Economic Complexity

The measure of economic complexity was calculated by dividing the number of tax returns had a AGI of less than $25k by the total number of returns submitted by ZIP Code for each of the four years considered in the study.

3.2 Routinized HIT

At the industry level, the results comparing IS usage to firm performance are mixed, with some studies documenting a positive impact of IS investments [35,52] while other studies by Berndt and Morrison [7] and Koski [37] detect no significant improvements gained through IT investments and another study found a negative relationship [46].

Research by DesRoches and her colleagues [19] found no evidence of significant differences total hospital costs of healthcare for hospitals that have implemented EHR systems and those without EHRs. This may have been a consequence of the time difference between when a HIT is implemented and when the benefits from the HIT can be seen by the health care organization. Devaraj and Kohli [21] found that there was a time lag between the investment and when the effects of that investment could be measured.

Routinization is defined as the extent to which interfirm activities follow regular and repetitive patterns [23]. Developing these regular and repeated patterns takes time. In our study we use the achievement of Electronic Medical Record Adoption Model (EMRAM) Stage 6 as an indicator that the HIT for efficient operations is both present and been integrated into the normal operations of the hospital. The EMRAM is an eight stage (Stages 0-7) cumulative measure of the availability and use of various HIT within the organization. For a hospital to achieve Stage 6 they must have all critical systems installed including full physician documentation, tracking of nurse order and task completion with clinical decision support (CDS) that at least performs

rudimentary conflict checking and a second stage CDS related to evidence-based medicine protocols. Critically, EMRAM Stage 6 requires external audit of systems to assure compliance to standards (www.himss.org).

3.3 Outcomes

In this study we are focusing on the relationship between multidimensional patient complexity and Routinized use of HIT as expressed in measures of a hospital's financial efficiency; therefore, we have selected the dependent measures of Experiential Quality of Care and Cost per Bed.

Experiential Quality of Care

Researchers have established that consumer's perception of their interactions with service providers is an effective proxy for experiential quality [36]. In 2006, the CMS and the U.S. Agency for Healthcare Research and Quality finalized the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey to measure patients' perspectives of hospital care (www.cms.gov). The survey measures the patient's perception about their treatment experience by asking questions pertaining to the patient's communications with the care team, communications about medications, and the patient's overall opinion of the hospital. These questions are asked against a response palled of "always", "usually", "sometimes/never", with the exception of the question of would you recommend the hospital which only offers a binary "yes/no" choice. As previously mentioned, the HCAHPS scores are an important factor in the calculation of CMS reimbursement rates and have had an impact on the financial performance of hospitals since 2013. Researchers have found positive relationships between Experiential Quality of Care and readmission rates [11] and adherence to discharge instructions [12]. To achieve improvements in Experiential Quality can increase the cost of care through additional time

required by the care team to conduct these communications and HIT to facilitate written instructions to the patient and coordination of care within the care team. We followed the approach of Senot et al. [53] in calculating a normally distributed version logit form of Experiential Quality (EQ_{it}) and we use their method for building our construct, using $E_{i,t}$ as the average score for each hospital, i, over each time period, t, for the experiential quality dimensions in the HCACPS, or

$$E_{i,t} = \sum_{n=1}^{6} \frac{Q_n}{6}, \quad (1)$$

$$and\ EQ_{i,t} = \ln\left(\frac{E_{i,t}}{1-E_{i,t}}\right). \quad (2)$$

Expense per bed

Expense is a commonly used measure of hospital efficiency [19]. In this study we have chosen to normalize the total operating costs by the number of active beds in the hospital. Devaraj and Kohli [21] found evidence of the positive effect of IT capital and labor on outcome measures among hospitals. However, other researchers did not observe this relationship between IT and firm performance [6,56]. We chose this measure of hospital efficiency to examine the overall firm impacts of Routinized HIT. To produce a normally distributed form of the data we took the natural log of the Total Expense ($TE_{i,t}$) for each hospital, i, over each time period, t, divided by the number of beds at the hospital ($B_{i,t}$). So, Expense per Bed ($BE_{i,t}$) is calculated by

$$BE_{i,t} = \ln\left(\frac{TE_{i,t}}{B_{i,t}}\right). \quad (3)$$

For each of the Outcomes the value is modeled based on

$$Outcome = \boldsymbol{\beta_k}\, \boldsymbol{Complexity_{it}} + \boldsymbol{\beta_l X}_{it} + \gamma_i + \delta_t + \beta_1\, Routinized\ HIT_{it} + \beta_2 (\, Routinized\ HIT\ x\ Complexity)_{it} + \varepsilon_{it} \quad (4)$$

Where,

$\boldsymbol{\beta}_k$ = vector of estimators for measures of complexity

$\mathbf{Complexity}_{it}$ = vector of the fixed effect resulting from the routinized IS interventions implemented each hospital

$\mathbf{X}_{it}$ = vector of control variables for the hospital

γ_i for hospital fixed effect

δ_t = fixed effects of time

ε_{it} = observation specific error term

Control variables

Our analysis includes six time-varying controls: Teaching Intensity, calculated as a ratio of residents per bed [55]; Hospital size, calculated as ln(number of beds); Magnet hospital status, which is an indication of hospitals that have nursing programs focused on "setting the standard for excellence through leadership, scientific discovery and dissemination and implementation of new knowledge" (www.nursingworld.org); OPDSH Adjustment Factor, or CMS operating disproportionate share hospital adjustment factor, which reflects the rate at which a hospital

propensity treats uninsured and Medicaid patients who often require more resources [16]; and Outlier Adjustment Factor, which reflects exceptionally costly cases treated by the hospital during the time period. Both OPDSH and Outlier Adjustment Factors are calculated and reported by the CMS. Additionally, we used median age and sex distribution of the treated populations, which were calculated as a weighted average of data from the US Census in the same manner as the socio-economic complexity factors as instrumental variables.

4.0 ANALYSIS

The 3,153 U.S. hospitals demonstrate sufficient variation in experiential quality and cost per bed. Table 1 shows overall summary statistics while Table 2 shows summary statistics with the data grouped by hospital.

Statistic	N	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
LogBE	11,717	0.5384	-2.7918	-0.3277	0.3449	2.8782
EQ	11,717	4.3497	-48.0842	-2.5842	2.5824	25.2491
sqrtNW	11,717	0.1577	-0.3370	-0.1255	0.1161	0.4704
LogCMI	11,717	0.1960	-0.8602	-0.1195	0.1192	1.0548
pov	11,717	0.0756	-0.3007	-0.0453	0.0513	0.2364
Year	11,717	1.1111	-1.5022	-0.5022	0.4978	1.4978
Magnet	11,717	0.3282	-0.1228	-0.1228	-0.1228	0.8772
LogBeds	11,717	0.8627	-4.0649	-0.5684	0.6506	2.4866
LogR2B	11,717	0.1272	-0.0564	-0.0564	-0.0180	0.8975
LogDSHOPG	11,717	0.0295	-0.0311	-0.0191	0.0075	0.1711
LogOUT	11,717	0.0570	-0.0371	-0.0278	0.0085	1.2691
perc_f	11,717	0.0136	-0.1590	-0.0053	0.0071	0.0474
med_age	11,717	3.9384	-14.0443	-2.3169	2.0696	26.0943

Table 1. Summary Statistics.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
LogBE	3,153	13.4392	0.5395	11.3025	13.1139	13.7964	16.3292
EQ	3,153	74.0518	4.4111	25.8333	71.6667	76.3750	98.1667
sqrtNW	3,153	0.4969	0.1572	0.1776	0.3723	0.6126	0.9641
LogCMI	3,153	0.4086	0.2037	-0.4429	0.2876	0.5293	1.4113
pov	3,153	0.6333	0.0745	0.3420	0.5888	0.6849	0.8536
Year	3,153	2,015.4850	0.3106	2,014.0000	2,015.5000	2,015.5000	2,017.0000
Magnet	3,153	0.1190	0.3147	0	0	0	1
LogBeds	3,153	5.1115	0.9008	1.7483	4.5109	5.7869	7.6502
LogR2B	3,153	0.0553	0.1262	0	0	0.04	1
LogDSHOPG	3,153	0.0307	0.0291	0.0000	0.0118	0.0380	0.1984
LogOUT	3,153	0.0373	0.0556	0.0000	0.0100	0.0454	1.0901
perc_f	3,153	0.5101	0.0138	0.3512	0.5049	0.5170	0.5534
med_age	3,153	38.4484	3.8868	25.0371	36.1380	40.5066	64.0745

Table 2. Summary statistics grouped by hospital.

We will use the plm package in R-Studio to analyze this un-balanced panel data. The plm package is A set of estimators and tests for panel data econometrics, as described in Hsiao [30], Analysis of Panel Data, and Croissant and Millo [17], Panel Data Econometrics with R. We expect that we will use the linear modeling estimators pertaining to estimate a fixed effects model, though we will also estimate a random effects model to determine if it describes the data more completely. We will use instrumental variables to address any endogeneity that may be brought into the model by using CMI as the measure for clinical complexity.

Preliminary Results will be presented at the conference.

5.0 REFERENCES

[1] Albert, N. M., Barnason, S., Deswal, A., Hernandez, A., Kociol, R., Lee, E., Paul, S., Ryan, C. J., & White-Williams, C. (2015). Transitions of care in heart failure: A scientific statement from the American heart association. *Circulation: Heart Failure*,

8(2), 384–409. https://doi.org/10.1161/HHF.0000000000000006

[2] Aron, R., Dutta, S., Janakiraman, R., & Pathak, P. A. (2011). The impact of automation of systems on medical errors: evidence from field research. *Information Systems Research*, 22(3), 429-446.

[3] Astley, W. G., & Van de Ven, A. H. (1983). Central perspectives and debates in organization theory. Administrative Science Quarterly, 245-273.

[4] Bardhan, I., Oh, J. H., Zheng, Z., & Kirksey, K. (2015). Predictive analytics for readmission of patients with congestive heart failure. *Information Systems Research*, *26*(1), 19–39. https://doi.org/10.1287/isre.2014.0553

[5] Bardhan, I. R., & Thouin, M. F. (2013). Health information technology and its impact on the quality and cost of healthcare delivery. *Decision Support Systems*, *55*(2), 438–449. https://doi.org/10.1016/j.dss.2012.10.003

[6] Barua, A., Kriebel, C. H., & Mukhopadhyay, T. (1995). Information technologies and business value: An analytic and empirical investigation. *Information Systems Research*, 6(1), 3-23.

[7] Berndt, E. R., & Morrison, C. J. (1995). High-tech capital formation and economic performance in US manufacturing industries An exploratory analysis. *Journal of Econometrics*, 65(1), 9-43.

[8] Blumenthal, D., & Abrams, M. K. (2016). Tailoring Complex Care Management for High-Need, High-Cost Patients. *Journal of the American Medical Association*, 1–2. https://doi.org/10.1001/jama.2016.12388

[9] Blumenthal, D., Bruce, C., Fulmer, T., John, L., & Jeffrey, S. (2016). Caring for High-Need, High-Cost Patients. *The New England Journal of Medicine*, *375*(10), 909–911.

[10] Bodenheimer, T. (2008). Coordinating Care — A Perilous Journey through the Health Care System. *New England Journal of Medicine*, *358*(10), 1064–1071. https://doi.org/10.1056/NEJMhpr0706165

[11] Boulding W, Glickman SW, Manary MP, Schulman KA, Staelin R (2011) Relationship between patient satisfaction with inpatient care and hospital readmission within 30 days. *Amer. J. Managed Care* 17(1):41–48.

[12] Cameron, C. (1996). Patient compliance: recognition of factors involved and suggestions for promoting compliance with therapeutic regimens. *Journal of Advanced Nursing*, 24(2), 244-250.

[13] Carling, P., T. Fung, A. Killion, N. Terrin, M. Barza. 2003. Favorable impact of a multidisciplinary antibiotic management program conducted during seven years. *Infect. Control Hosp. Epidemiol*. 24(9): 699–706.

[14] Clemons, E. K., Reddi, S. P., & Rowe, M. C. (1993). The impact of information technology on the organization of production: The Move to the Middle hypothesis. *Journal of Management Information Systems*, 10(2), 9–35.

[15] Closs, D. J., & Savitskie, K. (2003). Internal and external logistics information technology integration. *The International Journal of Logistics Management*.

[16] Coughlin, T. A., & Liska, D. (1998). Changing State And Federal Payment Policies For Medicaid Disproportionate-Share Hospitals: How states are responding to changes in the federal rules that govern their ability to support hospitals that serve the poor. *Health Affairs*, 17(3), 118-136.

[17] Croissant, Y., & Millo, G. (2018). Panel Data Econometrics with R. John Wiley & Sons.
[18] Daft, R. L., & Lengel, R. H. (1986). Organizational Information Requirements, Media Richness and Structural Design. *Management Science*, *32*(5), 554–571
[19] DesRoches, C. M., Campbell, E. G., Vogeli, C., Zheng, J., Rao, S. R., Shields, A. E., Donelan, K., Rosenbaum, S., Bristol, S. J., & Jha, A. K. (2010). Electronic health records' limited successes suggest more targeted uses. *Health Affairs*, *29*(4), 639–646. https://doi.org/10.1377/hlthaff.2009.1086
[20] DeSantis, C. E., Ma, J., Goding Sauer, A., Newman, L. A., & Jemal, A. (2017). Breast cancer statistics, 2017, racial disparity in mortality by state. *CA: A Cancer Journal for Clinicians*, 67(6), 439-448.
[21] Devaraj, S., & Kohli, R. (2000). Information technology payoff in the health-care industry: a longitudinal study. *Journal of Management Information Systems*, 16(4), 41-67.
[22] Elixhauser, A., Steiner, C., Harris, D. R., & Coffey, R. M. (1998). Comorbidity measures for use with administrative data. *Medical Care*, 36(1), 8–27.
[23] Feldman, M. S. (2000). Organizational routines as a source of continuous change. *Organization Science*, 11(6), 611-629.
[24] Friedman, B., Jiang, H. J., Elixhauser, A., & Segal, A. (2006). Hospital Inpatient Costs for Adults with Multiple Chronic Conditions. *Medical Care Research and Review*, 63(3), 327–346. https://doi.org/10.1177/1077558706287042
[25] Galbraith, J. R. (1974). Organization Design: An Information Processing View. *Interfaces*, *4*(3), 28–36.
[26] Goh, K. T., & Pentland, B. T. (2019). From actions to paths to patterning: Toward a dynamic theory of patterning in routines. *Academy of Management Journal*, 62(6), 1901-1929.
[27] Han, Y. Y., Carcillo, J. A., Venkataraman, S. T., Clark, R. S., Watson, R. S., Nguyen, T. C., Bayir, H. & Orr, R. A. (2005). Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. *Pediatrics*, 116(6), 1506-1512.
[28] HITECH Act, Public Law 111-5, SEC 3001, pg. 146, codified in 42 USC 300jj-11 (2009).
[29] Hoogendoorn, M., Feenstra, T. L., Asukai, Y., Briggs, A. H., Borg, S., Negro, R. W. D., Hansen, R. N., Jansson, S., Leidl, R., Risebrough, N., & Samyshkin, Y. (2016). Patient Heterogeneity in Health Economic Decision Models for Chronic Obstructive Pulmonary Disease : Are Current Models Suitable to Evaluate Personalized Medicine ? *Value in Health*, *19*(6), 800–810. https://doi.org/10.1016/j.jval.2016.04.002
[30] Hsiao, C. (2014). Analysis of panel data (No. 54). Cambridge University Press.
[31] Iezzoni, L. I., Dorner, S. C., Sc, M., & Ajayi, T. (2016). *Community Paramedicine — Addressing Questions as Programs Expand*. 1107–1110.
[32] Kannampallil, T. G., Schauer, G. F., Cohen, T., & Patel, V. L. (2011). Considering complexity in healthcare systems. *Journal of Biomedical Informatics*, *44*(6), 943–947. https://doi.org/10.1016/j.jbi.2011.06.006
[33] Katzelnick, D. J., Simon, G. E., Pearson, S. D., Manning, W. G., Helstad, C. P., Henk, H. J., Cole, S., Lin, E., Taylor, L., & Kobak, K. A. (2000). Randomized trial of

a depression management program in high utilizers of medical care. *Archives of Family Medicine*, 9(4), 345.

[34] Kaushal, R., Shojania, K. G., & Bates, D. W. (2003). Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review. Archives of internal medicine, 163(12), 1409-1416.

[35] Kelley, M. R. (1994). Productivity and information technology: The elusive connection. *Management Science*, 40(11), 1406-1425.

[36] Kellogg, D. L., & Chase, R. B. (2018). Constructing an Empirically Derived Measure for Customer Contact. *Management Science*, *41*(11), 1734–1749.

[37] Koski, H. 1999. The implications of network use, production net- work externalities and public networking programmes for firm's productivity. *Res.Policy* 28(4) 423–439.

[38] Krieger, N. (2001). The ostrich, the albatross, and public health: an ecosocial perspective--or why an explicit focus on health consequences of discrimination and deprivation is vital for good science and public health practice. *Public Health Reports*, 116(5), 419.

[39] Lipsitz, L. A. (2012). Understanding Health Care as a Complex System. *JAMA*, *308*(3), 243. https://doi.org/10.1001/jama.2012.7551

[40] Lynch, J., & Smith, G. D. (2005). A life course approach to chronic disease epidemiology. *Annu. Rev. Public Health*, 26, 1-35.

[41] McLaren, J. (2021). Racial disparity in COVID-19 deaths: Seeking economic roots with census data. *The BE Journal of Economic Analysis & Policy*.

[42] Naylor, M. D., Aiken, L. H., Kurtzman, E. T., Olds, D. M., & Hirschman, K. B. (2011). The importance of transitional care in achieving health reform. *Health Affairs*, 30(4), 746-754.

[43] Office of the National Coordinator. (2018, December). *2018 Report to Congress Annual Update on the Adoption of a Nationwide System for the Electronic Use and Exchange of Health Information.* (https://www.healthit.gov/sites/default/files/page/2018-12/2018-HITECH-report-to-congress.pdf).

[44] Orszag, P. R., & Emanuel, E. J. (2010). Health care reform and cost control. *N Engl J Med*, 363(7), 601-603.

[45] Peek, C. J., Baird, M. A., & Coleman, E. (2009). Primary care for patient complexity, not only disease. *Families, Systems, & Health*, 27(4), 287.

[46] Polák, P. (2017). The productivity paradox: A meta-analysis. *Information Economics and Policy*, *38*, 38–54. https://doi.org/10.1016/j.infoecopol.2016.11.003

[47] Romanow, D., Rai, A., & Keil, M. (2018). CPOE-enabled coordination: Appropriation for deep structure use and impacts on patient outcomes. *MIS Quarterly*, 42(1), 189-212.

[48] Rudin, R. S., Gidengil, C. A., Predmore, Z., Schneider, E. C., Sorace, J., & Hornstein, R. (2016). Identifying and Coordinating Care for Complex Patients Findings from the Leading Edge of Analytics and Health Information Technology. In *Rand Corporation Report*.

[49] Safford, M. M., Allison, J. J., & Kiefe, C. I. (2007). Patient complexity: more than comorbidity. The vector model of complexity. *Journal of General Internal Medicine*, 22(3), 382-390.

[50] Senot, C., Chandrasekaran, A., & Ward, P. T. (2016). Role of bottom-up decision processes in improving the quality of health care delivery: A contingency perspective. *Production and Operations Management*, 25(3), 458-476.

[51] Setia, P., Setia, M., Krishnan, R., & Sambamurthy, V. (2011). The effects of the assimilation and use of IT applications on financial performance in healthcare organizations. *Journal of the Association for Information Systems*, *12*(3), 274–298. https://doi.org/10.17705/1jais.0060

[52] Siegel D, Griliches Z. Purchased services, outsourcing, computers, and productivity in manufacturing. In: Griliches Z. Editor, Output measurement in the service sector. Chicago: University of Chicago Press; 1992: 429-58.

[53] Senot, C., Chandrasekaran, A., Ward, P. T., Tucker, A. L., & Moffatt-Bruce, S. D. (2016). The impact of combining conformance and experiential quality on hospitals' readmissions and cost performance. *Management Science*, 62(3), 829-848.

[54] Simon, G. E., Katon, W. J., VonKorff, M., Unützer, J., Lin, E. H., Walker, E. A., Bush, T., Rutter, C., & Ludman, E. (2001). Cost-effectiveness of a collaborative care program for primary care patients with persistent depression. *American Journal of Psychiatry*, 158(10), 1638-1644.

[55] Sloan, F. A., Picone, G. A., Taylor Jr, D. H., & Chou, S. Y. (2001). Hospital ownership and cost and quality of care: is there a dime's worth of difference?. *Journal of Health Economics*, 20(1), 1-21.

[56] Steinwald, B., & Dummit, L. A. (1989). Hospital case-mix change: sicker patients or DRG creep?. Health Affairs, 8(2), 35-47.Tan, J., Wen, J., & Awad, N. (2005). Health care and services delivery systems as complex adaptive systems. *Commun. ACM*, *48*(5), 36–44. https://doi.org/10.1145/1060710.1060737

[57] Strassmann, P. A. (1990). *The Business Value of Computers: An Executive's Guide*. Information Economics Press.

[58] Tan, J., Wen, J., & Awad, N. (2005). Health care and services delivery systems as complex adaptive systems. *Commun. ACM*, *48*(5), 36–44. https://doi.org/10.1145/1060710.1060737

[59] Theokary, C., & Justin Ren, Z. (2011). An empirical study of the relations between hospital volume, teaching status, and service quality. *Production and Operations Management*, 20(3), 303-318.

[60] Weick, K. The Social Psychology of Organizing 1979 2nd ed Reading. MA Addison-Wesley.

[61] Willke, R. J., Zheng, Z., Subedi, P., Althin, R., & Mullins, C. D. (2012). From concepts, theory, and evidence of heterogeneity of treatment effects to methodological approaches: a primer. *BMC Med Res Methodol*, *12*, 185. https://doi.org/1471-2288-12-185 [pii]\r10.1186/1471-2288-12-185 [doi]

[62] Wilson, T., & Holt, T. (2001). Complexity Science : Complexity And Clinical Care. *British Medical Journal*, *323*(7314), 685–688.

[63] Winge, M., Johannesson, P., Perjons, E., & Wangler, B. (2015). The coordination hub: Toward patient-centered and collaborative care processes. *Health Informatics Journal*, 21(4), 284-305.

[64] Wong, C. W., Lai, K. H., & Cheng, T. C. E. (2011). Value of information integration to supply chain management: roles of internal and external contingencies. Journal of Management Information Systems, 28(3), 161-200.

[65] Yedjou, C. G., Sims, J. N., Miele, L., Noubissi, F., Lowe, L., Fonseca, D. D., ... & Tchounwou, P. B. (2019). Health and racial disparity in breast cancer. *Breast Cancer Metastasis and Drug Resistance*, 31-49.

DEVELOPING MACHINE LEARNING RULES FOR FRAUD DETECTION AND MANAGEMENT OVERSIGHT OF HEALTHCARE PROVIDERS

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ABSTRACT

Healthcare fraud is complex and expensive to detect. An evaluation of publicly available healthcare provider fraud cases leads to several insights. Fraudulent healthcare providers tended to treat an abnormally high number of patients, had practices that were either too large or too small and failed to communicate with patients about their medical care adequately. Service providers communicating poorly with patients seemed to signal red flags. While the relationships are not causal, managers might monitor physician practice size, the number of patients treated, and time spent per patient. Supervised machine learning models might also benefit from these same relationships.

INTRODUCTION

The Office of Management and Budget (OMB) identified Medicare Fee-For-Service (FFS), Medicare Part C, Medicare Part D, Medicaid, and the Children's Health Insurance Program (CHIP) as at-risk programs for significant improper payments. As a result, the Center for Medicare and Medicaid Services (CMS) created a fraud framework to identify strategies to combat fraud. The Fraud Risk Framework combats fraud by creating an organizational structure conducive to fraud risk management. This framework consists of accessing risks to determine fraud risk profiles, designing, and implementing specific control activities, evaluating outcomes, and adapting new actions to improve fraud risk management. The stakes are high. Improper Medicare payments cost taxpayers an estimated $52 Billion in the Fiscal Year 2017. Claims fraud contributes to increased healthcare costs, but its impact can be lessened through fraud detection using machine learning methods [2] [19].

CMS utilizes improper payment measurement programs to address the drivers of unacceptable payment rates through aggressive corrective action plans. CMS estimates the Medicare FFS wrong payment rates through the Comprehensive Error Rate Testing (CERT) program. The FY 2020 Medicare FFS estimated improper payment rate is 6.27 percent, representing $25.74 billion in improper payments. The estimated unacceptable payment rate for FY 2019 was 7.25 percent, representing $28.91 billion in improper payments. CMS attributes reductions by decreasing the unacceptable payment rates for home health and skilled nursing facility claims. For FY 2020, the

Part C improper payment estimate is 6.78 percent, representing $16.27 billion in improper payments.

Similarly, FY 2020 showed a decrease from the FY 2019 rate of 7.87 percent, representing $16.73 billion in improper payments. It was driven down primarily by Medicare Advantage organizations submitting a more significant number of medical records that validated paid diagnoses and procedures. The transition to Electronic Healthcare Records (EHRs), access to insurance claim data, physician data, prescription data, and other transaction data aided CMS in reducing fraud by providing additional analyzable data. The transition to automated fraud detection occurred because manual auditing requires detailed knowledge of the healthcare field and time-consuming manual work by skilled investigators [19].

Fraud is often difficult to detect [11][4]. The Association of Fraud Examiners suggests that the more significant the dollar amount of fraud, the longer the fraud has occurred. Healthcare service providers' scams go unnoticed because of intricate and complicated patterns of concealing data with trivial specifications. Frauds enacted by a service provider happen when a provider does not perform the required medical services, unbundles medical services, bills for more expensive services than needed, and misrepresents uncovered healthcare services (unbundling), or falsifies diagnostic and treatment histories. Given the considerable accumulation of data over time, detecting fraud patterns becomes more challenging to detect. Technological improvements in data mining and machine learning may detect anomalies and use fraud behavioral profiling methods to configure and check for deviations from standards [9]. Unfortunately, machine learning techniques have not met the expectations of fraud examiners in identifying patterns of fraud.

The Association of Certified Fraud Examiners suggests increased managerial oversight, training, and active fraud prevention programs to reduce fraud. They recommend developing more uncomplicated guidelines to aid supervised machine learning models and offer managers rules of thumb that identify potentially improper procedures carried out by service providers. They also believe a two-fold approach to fraud would include managerial behavior standards for service providers that would allow administrative actions to detect and avoid fraud. By searching for and understanding successful fraud schemes (those that went undetected for years) from a managerial perspective, clues might emerge, leading to preventative organizational actions that identify deviation from standards allowing for corrective action before a departure from standards occurs. These same clues may also become supervised machine learning rules that might lead investigators to likely places to start looking for service provider frauds.

Not all improper actions or wrong-doing lead to fraud, so there must be a distinction between service providers' wrong procedures, policies, or misguided actions and the illegal. Not all improper payment rates indicate fraud but may not meet statutory, regulatory, administrative, or other legally applicable requirements and may be overpayments or underpayments. Additionally, improper payments do not necessarily represent expenses that should not have occurred but may

mean insufficient, incomplete, or missing documentation. A significant amount of improper payments is due to instances where a lack of documentation or errors in the documentation limits CMS's ability to verify that payments are correct. However, the requested payments might have been appropriate if the proper documentation had been submitted or adequately maintained.

We begin the paper by searching publically available fraud cases and identifying service provider standards that most service providers managers would recognize as odd or out of the ordinary. We then seek to identify these behavioral standards and what deviations a manager might consider unconventional. Comparing general standards of service provider behavior with behavioral outliers would lead to managerial actions to prevent service providers from acting badly and possibly improve patient care. Detected deviations from accepted norms suggest organizational changes, useful administrative reports, and future research directions.

PUBLIC FRAUD CASE

Healthcare provider fraud is often in the news involving large sums of money and implying a shockingly high number of providers [15][17]. Providers rely on creative schemes such as forgery, bribes, fake patients, and falsified billing. Providers may bill improperly, use duplicate billing, and bill for services not needed. The Department of Health and Human Services (HHS) Office of the Inspector General (OIG) found a healthcare provider in Westlake, OH that billed for "not" medically needed services such as catheterizations, tests, stent insertions, and unnecessary coronary artery bypass surgeries. Falsified claims account for about 25.5% of provider fraud cases and usually involve fake medical personas and identity theft [18]. Illegal kickbacks and bribery accounted for approximately 20 % of fraud cases in 2016. Providing unnecessary medications accounted for 10.8% of provider fraud cases in 2016. Public and commercial healthcare users should look for and review troubling or uncertain claims and the providers submitting these claims to protect themselves and their beneficiaries.

There is almost always a lack of supporting documentation in the patient files in nearly every fraud investigation [14]. The documentation identifies the patient, time spent with the patient, and the medical services provided. Documentation may also indicate how many times the physician is seeing a patient. In one case, insurance claim forms showed patients were being seen five times a week for allergy shots but only came into the office twice a week [14]. In some cases, doctors sign off doing the medical services when, in fact, someone else did the services.

Notably, the doctor providing the services was not on the premises in many cases. In some cases, patients were unaware of insurance claims for benefits they did not receive. This evidence from a small set of fraud cases suggests that provider-patient communication is essential or that the lack of this communication signals a possible problem. A dentist in a recent fraud filed 991 claims in one day [20]. Payers should review everything on their statement and ensure their benefits are received. It also helps to ask a healthcare provider for more information [20], 2020 #4498}.

From Valdosta, Georgia, Dr. Moss falsified Medicare and Medicaid claims by either billing for services not performed or utilizing his PA as an extender (a physician practitioner) to render services billed as if Dr. Moss had performed the services himself, netting a more significant reimbursement. The evidence showed that Doctor Moss routinely did not deliver services he billed for under his name and even visited Las Vegas casinos when he submitted bills for 147 patients for services rendered in Valdosta, Georgia (Valdosta Daily Times, October 2019).

A recent federal law enforcement action involving genetic testing results in charges against 35 individuals responsible for over 2.1 billion dollars in CMS losses. The defendants allegedly paid doctors to prescribe CGx testing, either without patient interaction or with only a brief telephonic conversation they had never seen or met. This kind of fraud would suggest that doctors saw more patients than would seem normal and authorized unnecessary tests. In another case, Doctors contracted with MedSymphony approved bogus doctor's orders that were not medically necessary and not eligible for Medicare reimbursement. The doctors did not engage in the treatment of the beneficiaries, had no physician-patient relationship, and did not even speak with the patient for whom they ordered the tests. Lack of communication between patient and doctor and the lack of a doctor-patient relationship may be a clue that something is wrong. Dr. Anthony T. Securo, a medical doctor, signed thousands of orders for durable medical equipment for Medicare beneficiaries he claimed to treat "but never met." Daniel R. Canchola, a medical doctor, signed an order for medically unnecessary tests, cancer screenings, and genetic tests without examing or speaking to patients and in the absence of any patient-physician relationship. Dr. Sekhar Rao committed similar frauds; however, beneficiaries did not receive the results of their medically unnecessary tests. Furthermore, the doctor requested that tests be repeated multiple times for the same patients.

PANEL SIZE

Doctors can only manage a limited number of patients (Ozen & Balasubramanian, 2013). There is a limit to the number of patients a doctor can see and the number of services they can provide [12]. This limit is called "Panel Size." Panel size is the number of individual patients under the care of a specific provider. The panel for an entire practice is the unique number of patients who have seen any provider within the last 18 months. Many variables might influence panel size. Panel size is affected by the number of patients seen per day, the number of days the provider is available per year, the average number of patient visits [12]. For example, a provider who sees 20 patients a day, 210 days a year, with an average patient being three times a year, a provider could manage a panel of 1400 patients. By increasing capacity to 25 patients a day, the panel size increases to 1,750 patients. Duke University researchers found that the time doctors needed to deliver all the recommended preventative, chronic, and acute services needed by 3,000 patients, across a typical US age and disease distribution, a doctor would have to work 17 hours a day, seven days a week, all year, without a break [10]. The San Francisco Center for Excellence in Primary Care found that if a doctor did everything (i.e., screening, counseling, immunization, drug prescription, routine chronic care, and treatment of acute conditions, they would be working 43 hours a week for 47.1 weeks a year. More recent studies suggest realistic panel sizes ranging

from 1200 to 1900 patients [13]. Figure 1 shows the number of patients physicians in the US saw per day from 2012 to 2018 [16].

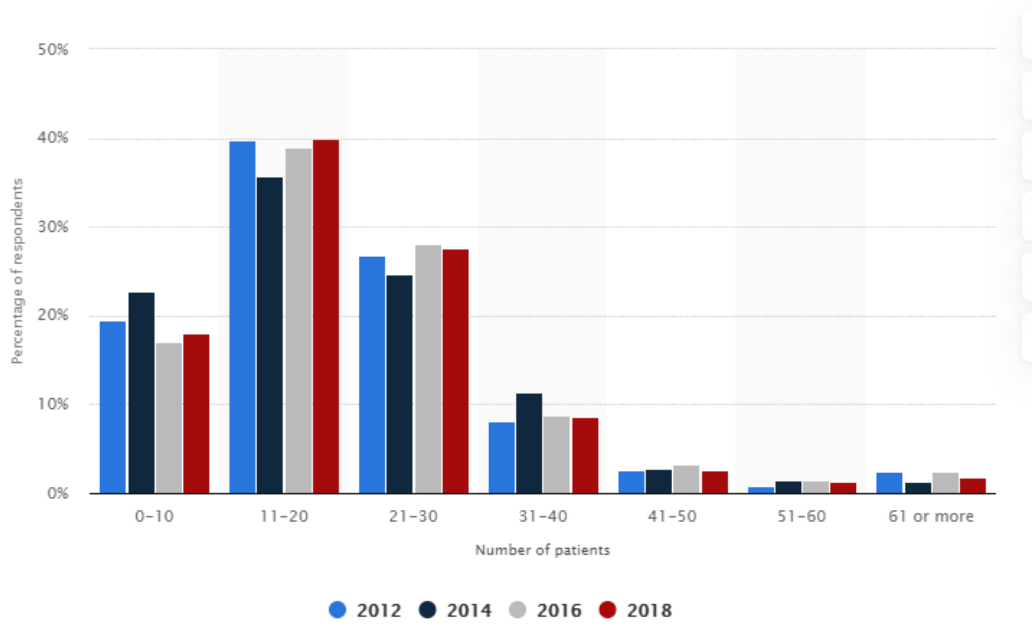

Figure 1: Number of patients that physicians in the US saw per day from 2012 to 2018

Figure 1 suggests that most physicians see 20-30 patients per day. Some doctors may see more patients because they have extensive staff, spend less time on paperwork, and communicate less with patients. While there may be reasonable explanations for seeing more patients per day, seeing large numbers of patients may lead to lower career satisfaction, burnout and may indicate attempts at overbilling, duplicate patients, not seeing patients, and claiming undelivered services.

PATIENT VISIT TIME

Physicians spend an average of just over 16 minutes on each patient based on Electronic Healthcare Record data [5]. A Portuguese Observatory for Palliative care study found that half of palliative care teams doctors only have nine minutes or less daily for each patient and psychologists and social workers one to two minutes. There is evidence that improved scheduling, support, and delegation of task manipulations can slightly increase the number of patients seen and increase revenue [6]. The point is that even with improved doctor support systems in place, there are still realistic upper and lower limits of the number of patients doctors and practices can see. There are other realities. Most physicians work between 40-60 hours per week, but nearly one-quarter work 61-80 hours per week, according to the 2014 Work/LifeProfiles of Today's Physician. In the 2018 June issue of Today's Physician, all physicians' average number of hours worked was 52 hours, family Physicians 51 hours, and Internists 54 hours. The current trend is for doctors to work fewer hours to prevent burnout and increase career satisfaction [3].

PATIENT COMMUNICATION

The Health Information National Trends Survey (HINTS) collects nationally representative data routinely about the American public's use of cancer-related information. HINTS provides a testbed to researchers to test new theories in health communication and fraud detection. HINTS data monitors historical changes in patient channel-doctor health communication and patients' everyday use of technology. Participants are 18 years and older and use different communication channels, including the Internet, to obtain vital health information for themselves and their loved ones. HINTS program planners use the data to overcome barriers to health information usage across populations and receive the data to create more effective communication strategies. This research uses HINTS 5, Cycle (2019) data, updated in April 2021, reflecting current trends just before COVID-19.

Data from HINTS suggests insights into doctor-patient relationships and communications. Approximately 68.0% of patients often see a particular doctor, nurse, or healthcare professional. It would be ideal, if unrealistic, for a patient to see the same doctor every visit. However, managers should consider why 30.1% of patients do not. In the past 12 months, 61.1 % of patients saw their doctor, nurse, or other healthcare professionals, consistent with national averages. More telling, approximately 0.7% of HINTS patients could not ask all the health-related questions they had. 3.4% did not give their patients the attention they needed to their feelings and emotions. 1.7% never involved their patients in decisions about their healthcare. 0.8% did not understand the things they needed to do to take care of their health. 0.6% did not understandably explain patient care, while 2.6% never spent time with the patient. Moreover, 4.9% did not help their patients with feelings of uncertainty.

Doctors and healthcare givers who never communicate or explain medical necessities or procedures are poor doctors and raise red flags for fraud. Other red flags are the 11.7% of patients who had to wait longer for test results than thought reasonable and 5.5% of patients who redid a test or procedure because the earlier tests or procedures results were unavailable. A similar 5.0% of patients provided their medical history because the chart was missing. Only 24.1 % of patients are offered online access to their medical records by their health insurer. It is encouraging that 42.5% of patients have accessed their online medical records from their health insurer. Approximately 34.9% of patients used online medical records to look up test results. 21..8% of online medical records contain clinical notes or a healthcare provider's notes that describe a visit. 35.7% of patients found it easy to understand the health information found in their online medical records.

Genetic testing is a common fraud scam. 1.3% heard about, and 6.4% of patients were unsure they heard about genetic testing for cancer screening. Of this small percentage, 15.2% heard about genetic testing from their healthcare provider. Moreover, approximately 6.0% took genetic tests.

CONCLUSIONS AND RECOMMENDATIONS

Healthcare fraud is occurring, harms patients, and costs taxpayers' money. Data analysis can clarify fraud detection strategies in the information age and offer new and better recommendations for reducing fraud in healthcare. Most doctors and practices follow the rules and communicate clearly and accurately with their patients. Very few cause problems and require additional managerial oversight and added organizational direction.

Looking at public records of fraud suggested that health providers who engage in fraud tend to not communicate with patients and treat more patients than a typical care provider might. To generate more income, fraudulent providers see patients for short periods or not at all. Doctors request unnecessary tests to co-conspirators for testing or processing. Tests and procedures may be processed multiple times, done wrongly, or not at all. Patients may be unaware that the test was unnecessary or incorrectly reported, and patients might not even see the results. Fraudulent doctors avoid documentation within the patient's medical records because it is time-consuming and may raise red flags with patients and insurers. Caregivers engaging in fraud seem to treat more patients than industry norms or claim to and may use other providers to mask their lack of patient engagement.

Typical caregivers work approximately 50 hours a week and may see 1400 to 1900 patients a year [12]. The average patient is with a caregiver for approximately 16 minutes per visit [5]. In practices with multiple caregivers, patients see their regular provider about 75% of the time. Two crucial but often conflicting metrics for any primary care practice are: (1) Timely Access and (2) Patient-physician Continuity. Timely access is the ability of a patient to get access to a physician as soon as possible. Patient-physician continuity refers to building a solid or permanent relationship between a patient and a specific physician by maximizing patient visits to that physician [1]. Measuring the wait time to see a physician and how many times a patient sees the same doctor are vital indicators. It is also clear that most doctors communicate clearly with their patients, with just a very few not engaging at all. These are the caregivers who raise red flags.

Healthcare managers should create reports that look at time spent per patient and the number of patients in a doctor's or practices pane. Tracking repeated tests, the number of similar tests and tests per patient may lead managers to identify caregivers who may be overly aggressive in generating revenue. Evaluating patient satisfaction to improve patient-doctor interactions is another vital clue to weed out doctors not doing a good job. In many Medicare fraud cases, elderly patients submit DNA samples for free genetic testing and never receive the results. Tracking patient reports of doctor-patient communications may indicate doctors committing fraud.

Medical practices with large patient panels are suspect of fraudulent practices. A simple calculation of time spent per patient is cause for concern. Managers should address poor patient

communication satisfaction scores and their causes. Managers may track the number of pain prescriptions written or the average number of tests per doctor. Doctors working long hours may be burning out or not working the hours they say they are. Dr. Moss of Valdosta, Georgia, was on vacation in Las Vegas when he reported treating 147 elderly patients. Doctors who see patients only once are suspect, as are doctors who see patients much more than the industry average of 3 patient visits a year. Doctors typically spend 1-2 hours a day doing paperwork, and doctors who spend more or less time should cause concern.

Not all deviations from standards of care indicate fraud. There may be other reasons. Managers should know that female doctors typically spend more time documenting patient care than their male counterparts. Most physicians are overextended or at capacity and facing burnout. Data suggests that doctors work fewer hours than in previous decades to avoid burnout and improve career satisfaction. Physicians paid entirely on quality may elect to see a limited number of patients because seeing a high volume of patients leads to lower care numbers. They can better achieve quality outcomes by focusing on just a few.

Preventative services account for as much as 77 percent of a doctor's time, and delegating preventative might be safely assigned to non-clinician care team members. While some doctors abuse this office management option, careful reporting of each caregiver's hours worked, the number of patients treated, and the number of appropriate tests will limit opportunities for fraud. Another 47 percent of the hours a doctor devotes to patients managing common chronic conditions might shift to other personnel — registered nurses, pharmacists, health educators, and medical assistants — aided by health information technology and working under physician standing orders. Increasing patient involvement and access to their medical records limits the potential for a conspiracy between caregivers as transparent information allows patients to report irregular processes, billing, claims, or unnecessary tests.

The HINTS data suggests that patients want to be engaged and that managers might increase patient access to medical records. Physicians should be encouraged to communicate and spend time with patients. Healthcare organizations are under pressure to increase profitability and generate revenue. However, there must be a recognition that better oversight is needed and an understanding of the number of patients that any caregiver can see. Telemedicine offers a bit of hope in allowing patients to access caregivers faster, more conveniently while doctors can increase the number of patients they see daily. Oversight works because of recent publicity and legal action against doctors who overprescribed oxycodone; physicians prescribe fewer pain medications because too many alerts the authorities and invite investigations.

FUTURE DIRECTIONS

Detecting fraud is critical in identifying and, subsequently, stopping unscrupulous physicians and caregivers. The application of machine learning methods and data mining strategies leverage and

improve current fraud detection processes and reduce the resources needed to find and investigate possible fraudulent activities [2] [7]. It will be necessary to rapidly analyze large amounts of varied data from different sources to detect fraud. Improved health-system functions and increased personalized care by physicians lead to a greater public good. However, machine learning technologies will not replace the fundamental components of the health system, such as ethical leadership and governance, or avoid the need for a robust ethical and regulatory environment [8].

EHR data have not been widely available to academic researchers in quantities sufficient to support extensive data analysis. Data exists in a variety of disparate locates and sources. Instead, the data are aggregated, analyzed, and sold by insurance companies, EHR vendors, and other medical informatics firms. We hope to leverage recently purchased aggregate healthcare data to identify fraud and better support managerial identification and oversight of healthcare organizations.

REFERENCES

[1] Balasubramanian, H., Muriel, A., & Wang, L. (2012). The impact of provider flexibility and capacity allocation on the performance of primary care practices. *Flexible Services and Manufacturing Journal, 24*, 422-447.
[2] Bauder, R. A., & Khoshgoftaar, T. M. (2017). *Medicare Fraud Detection Using Machine Learning Methods.* Paper presented at the 16th IEEE International Conference on Machine Learning and Applications (ICMLA).
[3] Christopher, A. S., Smith, C. S., Tivis, r., & Wilper, A. P. (2014). Trends in the United States Physician Work Hours and Career Satisfaction. *The American Journal of Medicine, 127*(7), 674-680.
[4] Dupont, B. (2017). Bots, cops, and corporations: on the limits of enforcement and the promise of polycentric regulation as a way to control large-scale cybercrime. *Crime, Law and Social Change, 67*(1), 97-116.
[5] Finnegan, J. (2020). For each patient visit, physicians spend about 16 minutes on EHR's, FIERCE Publishing.
[6] Gikalov, A. A., Baer, D. M., & Hannah, G. T. (1997). The effects of work task manipulation and scheduling on patient load, revenue, eyewear turnover, and utilization of staff and doctor time. *Journal of Organizational Behavior Management, 17*(1), 3-35.
[7] Herland, M., Bauder, R. A., & Khoshgoftaar, T. M. (2020). Approaches for identifying US medicare fraud in provider claims data. *Health Care Management Science, 23*(1), 2-19.
[8] Ho, C. W. L., Ali, J., & Caals, K. (2020). Ensuring trustworthy use of artificial intelligence and big data analytics in health insurance. Garantir un usage fiable de l'intelligence artificielle et de l'analyse des big data dans le domaine de l'assurance maladie *World Health Organization. Bulletin of the World Health Organization, 98*(4), 263-269.
[9] Joudaki, H., Rashidian, A., Minaei-Bidgoli, B., Mahmoodi, M., Geraili, B., Nasiri, M., & Arab, M. (2015). Using Data Mining to Detect Health Care Fraud and Abuse: A Review of Literature. *Global Journal of Health Science, 7*(1), 194-202.

[10] Leadership, American Association of Physician leadership. (2019). How Many Patients Can a Primary Care Physician Treat?
[11] Meyers, T. J. (2017). Examining the network components of a Medicare fraud scheme: the Mirzoyan-Terdjanian organization. *Crime, Law and Social Change, 68*(1-2), 251-279.
[12] Murray, M., Davies, M., & Boushon, B. (2007). Panel Size: How Many Patients Can One Doctor Manage?, American Academy of Family Physicians.
[13] Neuman, D. (2019). How Many patients are most Primary Care Physicians Seeing?
Ozen, A., & Balasubramanian, H. (2013). The impact of case-mix on timely access to appointments in a primary care group practice. *Health Care Management Science, 16*, 101-118.
[14] Piper, C. (2013). 10 Popular Health Care Provider Fraud Schemes. *Association of Certified Fraud Examiners Magazine(Jan/Feb 2013),* 1-26.
[15] Sommersguter-Reichmann, M., Wild, C., Stepan, A., Reichmann, G., & Fried, A. (2018). Individual and Institutional Corruption in European and US Healthcare: Overview and Link of Various Corruption Typologies. *Applied Health Economics and Health Policy, 16*(3), 289-302.
[16] Statista. (2021). *Number of Patients That Physicians in the US saw per day from 2012 to 2018*.
[17] Stowell, N. F., Schmidt, M., & Wadlinger, N. (2018). Healthcare fraud under the microscope: improving its prevention. *Journal of Financial Crime, 25*(4), 1039-1061.
[18] Thinkstock. (2017). Top 5 Most Common Healthcare Provider Fraud Activities. *Policy and Regulation News.*
[19] Waghade, S. S., & Karandikar, A. M. (2018). A Comprehensive Study of Healthcare Fraud Detection based on Machine Learning. *International Journal of Applied Engineering Research, 13*(6), 4175-4178.
[20] www.coverage.com. (2020). 5 Medicaid and Medicare Fraud Everyone Pay For. *COVERAGE(April 23)*.

EXPLORING THE BENEFITS OF ROBOTICS TO ASSIST PEOPLE WITH DISABILITIES

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ABSTRACT

Robots can assist disadvantaged people. Robotics continue to be developed in devices for people with disabilities. In the paper the authors begin to describe the established features of an initial sample of robotic tools for people with diverse disabilities, in a research-in-progress study. The paper explores foundationally the potential of robotic tools for people with disabilities. In the new normal of a pandemic this study can help non-profit organizations considering further investment in this technology for disadvantaged populations.

Keywords: Assistive Technology (AT), Community Outreach, Pandemic, People with Disabilities, Robotics

BACKGROUND

"Any equipment [or hardware] … customized [or not customized] … commonly [applied] to [help] in the capability of people with disabilities" is defined as assistive technology (AT) by the Assistive Technology (AT) 29 USU Act of 1998 (Domin, & Shepard, 2021). Covidpreneurs, or entrepreneurs in general, continue to develop assistive technology devices. Devices continue to be developed as almost partners for people with mental and physical disabilities to help in daily living. Devices of robotics help people with disabilities to be independent or semi-independent in living tasks. Robotics essentially help people with disabilities from the inherent power of the systems.

Robotics are evident in algorithmic hardware and software of highly smart technology. Brain-computer features are evident in robotics (Shein, 2017). Firms are improving robotics beyond

daily living for people with disabilities. Firms, such as RoboKind, are improving robots in covid-19 focused robotics (Margolin, 2021). Institutions, such as as the Massachusetts Institute of Technology (MIT) Biomimetic Robotics Lab, are innovating in humanoid robotics tools (Ackerman, 2021) that may be helpful to people with disabilities. Roboticists are frequently innovating in artificial intelligence (AI) breakthrough tools that may be further helpful to people with disabilities.

Assistive technology for people with disabilities may not be designed effectively enough however for people with disabilities. Despite evolving fifth generation (5G) innovations (Knight, 2021), roboticists may not be caring or empathic to the needs of people with disabilities. Roboticists may not be empathic enough of accessibility disability guidelines as known by people with disabilities (Churchill, 2021), even if they know basic design principles (Norman, 2007); or frankly they may not be knowledgeable of the lives of people with disabilities. Robotics may have to be frequently re-engineered for people with disabilities in iterations of the tools (Sargent, 2021). The potential of robotics for people with disabilities may be even more of a promise than a reality in the software (Smith, & Smith, 2021). In this paper, therefore, the authors begin to explore a sample of robotics tools that may or may not have high potential for those with diverse disabilities.

INTRODUCTION TO PAPER

This paper begins anew to explore assistive robotics technology for people with disabilities, from an outreach program of the Office of the Provost of Pace University in New York City. From best-in-class fields of disability practitioner (e.g., *Disability Scoop*) and non-disability peer-reviewed scholarly literature (e.g., *Communications of the ACM* and *IEEE* Robotics), this paper explores an initial random sample of robotics technology. Features of the robotics technology fundamentally help people with mental and physical disabilities, as synopsized in Table 1:

Table 1: Assistive Robotics Technology Tools

Robotics Technology	Functionality of Robotics Tools				
	Communication	Daily Living	Hearing	Learning	Mobility
AIDA Co-Robot					
DOUBLE 3 Robot					
IROMEC Robot					
OBI Robotic System					
PR2 Robotic System					
RAPUDA Robotic System					

SAWYER Robot					
TEMI Robot					

Film illustrations and links of the robotics tools are in Figures 1-8 of the Appendix.

Functionality of the robotics tools in Table 1 is from The Center for Assistive Technology Act Data Assistance - CATADA (Domin, & Shepard, 2021).

The robotics technology is determined from the literature as applicable to established 2021-2022 tools for people with disabilities, appropriate for the first phase of this research-in-progress study.

The history behind this paper is a community engagement course of the second author-professor in pandemic spring 2021, on Web Design for Non-Profit Organizations, during which the first author-student helped people with developmental and intellectual (IDD) disabilities on presence projects on the Web. Due to the impacts of the pandemic, the first author learned that robotics might be helpful to people with mental or physical disabilities to be independent or semi-independent in the isolation in their residences. Robotics technology motivated the first author-student to explore robotics tools for people with disabilities not having enough of non-profit organization nursing.

This paper contributes a path that can help in the independent livelihood of people with disabilities, with the further inclusion of assistive robotics technology and with the further investment by non-profit organizations in this technology.

FOCUS

The focus of this paper is to explore as an experiment the feasibility of robotics technology for people with disabilities. How might the design of robotics sampled tools be of efficacy for people with disabilities, in the descriptive explorations of the authors, in a first phase of study? How might the design of the robotics sampled tools be of empathy for people with disabilities, in the critical eye evaluations and experiences of people with disabilities, in a second phase of study? How might the design of robotics state-of-the-art tools be of further investment potential, from non-profit organizations helping people with disabilities, in a third phase of study? From an exploratory foundation in this paper, the authors furnish further inquiry for new phases of study involving people with disabilities and non-profit organizations helping them. For a better equitable society, this paper is a foundational study.

METHODOLOGY

This paper explores assistive robotics technology for people with disabilities, as an interdisciplinary outreach program of the Office of the Provost of Pace University. The program involves the first author as the principal investigator aided by the second author-professor of disability studies and information technologies and by the third author as an additional researcher. Both the first author and the third author are students attuned to communities of people and students with disabilities at the university.

The methodology of this paper is exploratory in incremental phases of study. In the June – November 2021 period of this first phase of the study, the students are descriptively exploring the features of robotics sampled tools for people with disabilities, in a focused narrative review. In the February – July 2022 period of the second phase, the professor and the third-author student will be empirically exploring in focus groups the functionality of the robotic tools with people with mental and physical disabilities and with non-profit organizational staff helping these people with disabilities, in the metropolitan region of the university (Ravitch, & Carl, 2021), in a systemic review. In the final September - November 2022 period of the final third phase of the study, the professor will be exploring financially the further investment potential of robotics tools, including state-of-the-art tools that might be introduced in the industry since the first phase, with the non-profit organizational staff.

In this paper the students are descriptively exploring the n=8 robotics sampled tools from Table 1. The students are exploring the tools from accessibility design principles for people with disabilities, learned in the aforementioned Web Design for Non-Profit course of the second author-professor, and from basic design principles (Norman, 2007). The professor is aiding in the interpretation of the collective principles with the students. The findings from this paper are foundational from the June – November 2021 period of study, for the subsequent periods of the study.

EXPLORATORY FINDINGS OF PAPER

In the June – November 2021 period of the first phase of the study, the robotics systems, explored and interpreted from a diversity of domestic and international non-roboticist sources by the author-students of the university, include the following snapshots:

AIDA Co-Robot

The AIDA Social Co-Robot (Williams, Williams, Moore, & McFarlane, 2019) enables people with developmental and intellectual disabilities in friendly hearing interactions, in living in the motivating presence of an interactive perceptible “person” residential robot.

DOUBLE 3 Robot

The DOUBLE 3 Telepresence Robot (Tota, Vaida, & Pop, 2019) enables people with developmental and intellectual disabilities in interactions in engaging interactively and living perceptibly with other persons, enables the people with disabilities semi-independently in flexibly “forwarding” health and medical inquires to medical staff, and enables monitoring of the people with disabilities by the medical staff.

IROMEC Robot

The IROMEC Leka Smart Robot (Conchinna, Osorio, & deFreitas, 2015 and Klein, Gelderblom, deWitte, & Vanstipelen, 2011) enables environmental learning and information perceptibility, living and playing skills, and rehabilitation tasks in therapy, for students and youngsters with developmental and intellectual disabilities.

OBI Robotic System

The OBI Self-Feeding Robotic System (Gushi, Shimabukuro, & Higa, 2020) facilities flexible fluid and food indigestion independently, for people with physical disabilities, in seven degrees-of-freedom navigation on the system.

PR2 Robotic System

The PR2 Voice-Controlled Robotic System (Poirier, Routhier, & Campeau-Lecours, 2019) facilitates flexible highly independent living, for people with higher limb physical disabilities, in interactions with other persons by voice.

RAPUDA Robotic System

The RAPUDA Robotic Arm System for People with Cervical or Muscle Dystrophy Higher-Limb Disabilities (Wakita, Yoon, & Yamanobe, 2012) helps in daily eating, environmental flexible semi-independent living, mobility, and navigation tasks.

SAWYER Robot

The SAWYER Black Robot Trainable Arm System (Fall, Turgeon, Campeau-Lecours, Maheu, Boukadoum, Roy, & Gosselin, 2015 and Zaheer, Sundaram, & George, 2018) helps people with physical disabilities in flexible functional living, mobility and navigation tasks, and notably in intuitively performing repetitive residential tasks.

TEMI Robot

The TEMI Human-to-Human Robot (Riek, & Robinson, 2011) helps people with disabilities in empathetic and friendly hearing interactions, in living with persons with or without disabilities.

Summary

The robotics are considered customized to the needs of people with mental and physical disabilities but have inherent limitations native to the technology, which argues for further investigation of new state-of-the-art tools in the third if not second phase of the study.

Film illustrations and links of the robotics tools are in Figures 1-8 of the Appendix of this paper.

In the essential February – July 2022 period, the robotics systems interpreted by the students will be explored with the people with disabilities and with the non-profit organizational staff helping them, for effectiveness in the practicality of the tools in the living tasks of those with disabilities.

Finally, in the September – November 2022 period of the study, the investment potential of the tools, and of promising tools that might be introduced in the industry in the interim from the first phase (Ford, 2021), will be reviewed with the non-profit organizational staff.

POTENTIAL IMPLICATIONS OF PAPER

Functionality of the robotics in this paper appears to benefit people with disabilities. The robotics sampled by the author-students appear from the literature of non-roboticists to fundamentally help the livelihood of people with disabilities. The immediate implication is that this paper is contributing a foundation for continued review of the assistive robotics technology with non-profit organizations already helping people with disabilities and involved with Pace University.

Increased inclusion of non-profit organizations helping people with disabilities is a critical next step of the study. The perceptions of the people with disabilities are crucial as to the realities of robotics tools positioned by roboticists. The perceptions of the non-profit organizational staff are also crucial in the customization of the robotic tools. Staff, such as therapists, can be more proactive in numerous projects of reframing robotics, such as AmpSurf and California Polytechnic State University, in its study of surf therapy in trials with people with physical disabilities. The implication is that this paper is enabling a model for further progressive study of this technology.

Non-profit organizations not currently focused on funding robotics due to the pandemic might inquire of assistive technology funding programs. Notably the Assistive Technology (AT Act) might be furnishing grants for robotics technology for organizations helping people with mental and physical disabilities (Domin, & Shepard, 2021). The implication is the feasibility of funding opportunities for non-profit organizations pioneering in this technology.

Nevertheless, non-profit organizations pioneering for example in m-health robotics for people with disabilities have to be sensitive as to the smartness of the technology. Though m-health robotics are evidently helping people with disabilities, roboticist technologists might not be sensitive to tailoring the tools to those with disabilities. The m-health robotics might moreover not be tailored notably in privacy to the smart system tools that those with disabilities might have in their residences (O'Brolchain, & Gordijn, 2019). These robotics tools are not infrequently perceived as the "Wild West" (Whitcomb, 2021). The implication is that non-profit organizations might be helped by partnering with a university researching the state-of-the-art of this technology.

The outreach program of this paper is benefiting the author-students of Pace University. The students are enthusiastically helping in innovative interpretation of robotics tools for people with disabilities. Especially for the first author, the students are learning from the mentoring of the author-professor the potential of the robotic tools if properly tailored to those with disabilities. The motivation of the students is a model of passionate positivism for pursuing the research in the forthcoming phases of the study. The final implication is that undergraduate students might be more involved in non-profit organizational outreach partnerships researching the robust technology of this study.

LIMITATIONS AND OPPORTUNITIES IN RESEARCH

The descriptive findings are a clear limitation of this paper. The experiment of the June – November 2021 period, in the foundational interpretation of the literature in the narrative review, is a limitation of this paper. The focus of the initial period without the people with disabilities and without the non-profit organizational staff that will be in the February – July and September – November 2022 periods is a limitation of this paper.

Nevertheless, this paper initiates a progressive study. Opportunities for robotics tools posit in this first paper will be further reviewed in primary sources, such as www.enablingdevices.org and www.robots.ieee.org, in the future periods of study. The pandemic will posit more possibilities, such as Apple (Heasley, 2021) and Microsoft (Heasley, 2021), for robotic tools for those with disabilities. The field of human – robot robotics tools is promising for non-profit organizational staff helping those with disabilities and for those with disabilities. The research resources of a university, such as Pace University, will benefit investigation of robotics state-of-the-art tools.

CONCLUSION

Robotics can clearly benefit people with disabilities. This paper contributes a discussion of robotics technology that are currently helping people with disabilities. The feasibility findings of the students posit possibilities as to the future potential of robotics tools for people with mental and physical disabilities. The methodology of this paper provides a progressive study with non-profit organizational staff helping those with disabilities. In short, the outreach program of this paper, involving passionate students in technologies for those with disabilities, is timely.

REFERENCES

Ackerman, E. (2021). Massachusetts Institute of Technology (MIT) Is Building a Dynamic, Acrobatic Humanoid Robot. *IEEE Spectrum*, June 7, 1-7.

Churchill, E.F. (2021). Refactoring Design to Reframe (Dis)ability. *Interactions*, May-June, 24-26.

Conchinna, C., Osorio, P., & deFreitas, J.S. (2015). Playful Learning: Educational Robotics Applied to Students with Learning Disabilities. *Proceedings of the 2015 IEEE International Symposium on Computers in Education (SIIE)*, November, 167-171.

Domin, D., & Shepard (2021). A National Data Summary of State Assistive Technology Programs – Fiscal Year 2020. *Assistive Technology (AT) Act Data Brief*, 13.

Fall, C.L., Turgeon, P., Campeau-Lecours, A., Maheu, V., Boukadoum, M., & Gosselin, B. (2015). Intuitive Wireless Control of a Robotic Arm for People Living with an Upper-Body Disability. *Proceedings of the 2015 37th Annual Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, August, 4399-4402.

Ford, M. (2021). Rule of the Robots: How Artificial Intelligence Will Transform Everything. Basic Books, New York, New York, 109-160.

Gushi, S., Shimabukuro, Y., & Higa, H. (2020). A Self-Feeding Assistive Robotic Arm for People with Physical Disabilities of the Extremities. *Proceedings of the 2020 IEEE 5th International Conference on Intelligent Informatics and Biomedical Sciences (ICHBMS)*, November, 61-64.

Heasley, S. (2021). Microsoft Takes Aim at the 'Disability Divide'. *Disability Scoop*, May 7, 1-5.

Heasley, S. (2021). Apple Launching New Accessibility Features for Those with Disabilities. *Disability Scoop*, May 24, 1-2.

Klein, T., Gelderblom, G.J., deWitte, L., & Vanstipelen, S. (2011). Evaluation of Short-Term Effects of the IROMEC Robotic Toy for Children with Developmental Disabilities. *Proceedings of the 2011 IEEE International Conference on Rehabilitation Robotics (ICORR)*, June, 1-5.

Knight, W. (2021). Remote Control: As Robots Take on More Challenging Work, A Growing Industry Is Giving Them a Helping (Human) Hand. *Wired*, June, 28-29.

Margolin, R. (2021). RoboKind Announces Robots4Autism: Tackling COVID-19 Virtual Learning Hardships. *DIVERSEability Magazine*, Summer, 86.

Norman, D.A. (2007). The Design of Future Things. Basic Books, New York, New York, 86-90, 133-134, 160-165.

O'Brolchain, F., & Gordijn, B. (2019). Privacy Challenges in Smart Homes for People with Dementia and People with Intellectual Disabilities. *Ethics and Information Technology*, 21, 253-265.

Poirier, S., Routhier, F., & Campeau-Lecours, A. (2019). Voice Control Interface Prototype for Assistive Robots for People Living with Upper Limb Disabilities. *Proceedings of the 2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR)*, June, 46-52.

Ravitch, S.H., & Carl, N.M. (2021). Qualitative Research: Bridging the Conceptual, Theoretical, and Methodological. Sage Publications, Inc., 2nd Edition, Thousand Oaks, California.

Riek, L.D., & Robinson, P. (2011). Using Robots to Help People Habituate to Visible Disabilities. *Proceedings of the 2011 IEEE International Conference on Rehabilitation* Robotics *(ICORR)*, June, 1-8.

Sargent, J. (2021). Global Accessibility Awareness Day Highlights Need for Developer Education. *SD Times*, 1-9.

Shein, E. (2017). Overcoming Disabilities: Brain-Computer Interfaces Hold the Promise of Fully Featured Replacements for Body Parts That Do Not Work or Are Missing. *Communications of the ACM*, 60(11), November, 17-19.

Smith, P., & Smith, L (2021). Artificial Intelligence and Disability: Too Much Promise, Yet Too Little Substance*? AI and Ethics*, 1, 81-86.

Tota, P., Vaida, M.F., & Pop, P.G. (2019). Telepresence Robotics Applied to Transport, Monitoring and Assisting People with Disabilities. *Proceedings of the 2019 e-Health and Bioengineering Conference (EHB)*, November, 1-4.

Wakita, Y., Yoon, W.K., & Yamanobe, N. (2012). User Evaluation to Apply the Robotic Arm RAPUDA for an Upper-Limb Disabilities Patient's Daily Life. *Proceedings of the 2012 IEEE International Conference on Robotics and Biomimetics (ROBIO)*, December, 1482-1487.

Whitcomb, I. (2021). Mental Wellness Applications (Apps) Are Basically the Wild West of Therapy. *Popular Science*, 2-17.

Williams, A.B., Williams, R.M., Moore, R.E., & McFarlane, M. (2019). AIDA: A Social Co-Robot to Uplift Workers with Intellectual and Developmental Disabilities. *Proceedings of the 2019 ACM / IEEE International Conference on Human-Robot Interaction (HRI)*, March, 584-585.

Zaheer, A., Sundaram, D., & George, K. (2018). Trainable Robotic Arm for Disability Assistance. *Proceedings of the 2018 9th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, November, 700-704.

APPENDIX

Figure 1: AIDA Social Co-Robot

Link: http://www.aidarobotics.com/

Figure 2: DOUBLE 3 Telepresence Robot

Illustration: https://youtu.be/zSDL9pR0A6I

Link: https://www.doublerobotics.com/

Figure 3: IROMEC Leka Smart Robot

Illustration: https://youtu.be/luN84iqllIA

Link: https://leka.io/

Figure 4: OBI Self-Feeding Robotic System

Illustration: https://youtu.be/3jcwheEMcfg

Link: https://ndassistive.org/blog/obi/

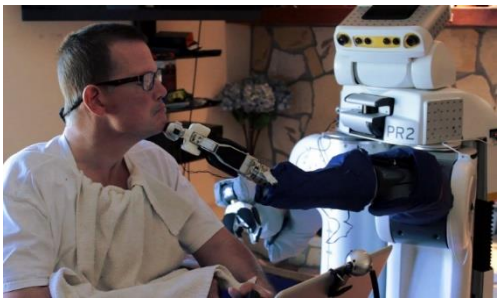

Figure 5: PR2 Voice-Controlled Robotic System

Illustration: https://youtu.be/Xv0ovUb_LVs

Figure 6: RAPUDA Robotic Arm System for People with Higher-Limb Disabilities

Illustration: https://youtu.be/yqOUexGKusg

Figure 7: SAWYER Black Robot Trainable Arm System

Illustration: https://youtu.be/S4mULTknb2I

Link: https://www.rethinkrobotics.com/

Figure 8: TEMI Human-Human Social Robot

Illustration: https://youtu.be/3bnGG4Xo0GE

Link: https://www.robotemi.com/

Note: Illustrations and Links in the Appendix are dated November 2021.

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IS, IT, Blockchain Technology and Social Media - Abstracts

AN EVALUATION FRAMEWORK FOR ENTERPRISE BLOCKCHAINS ADOPTION

Oral Presentation

Dr. Birsen Karpak [1], ***Dr. Deepa Iyer*** [1]

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It is a great challenge for enterprises to adopt the blockchain platform of the right fit. This is partially attributed to the limited availability of reliable evaluation frameworks. Such an evaluation requires technical knowledge to select a suitable platform for each application as well as consideration of the fit of the platform to the organizational context. In this study, we are proposing an integrated diffusion of Innovation (DOI) and Technological, Organizational and environmental (TOE) model. To our knowledge there is only one framework in literature to evaluate block chain platforms that uses only the TOE factors and doesn't consider any alternative blockchain platforms. We know from our earlier research that importance of factors influencing the decisions are impacted by the alternatives. Our research fulfills this research gap in literature. We, therefore, assert that frameworks that do not incorporate alternatives have limited applicability.

In this paper, we propose an evaluation framework that comprises a list of criteria and a typical process for practitioners to assess the suitability of alternative enterprise blockchain platforms using these criteria based on the characteristics of the use cases. We categorize the adoption criteria into technology, external environment, organizational and innovation factors. Technology factors include compatibility and size of the platform, external task environment comprises of technology standards, rewards and trust. Organizational context includes governance, knowledge/expertise, financial constraints and management commitment. Innovation factors are the most loaded adoption factor. It encompasses advantages, complexity, trialability, observability, security, maturity Immutability and network latency.

These criteria are developed based on an extensive literature search yet it is open for expert modification since we are considering a multicriteria methodology, as a future research, that depends on eliciting expert judgments for prioritizing factors affecting enterprise blockchain adoption for a particular supply network. Framework encompasses alternative blockchains as well, and as we stated above, priority of the criteria are impacted by the alternatives considered. No research, to our knowledge, has tackled the impact of alternatives on the importance of criteria for enterprise blockchains yet. Validation of the framework by an industrial business case is another extension considered as a future study. Implications for research and industrial practice will also be discussed.

Blockchains: Disruptive Technology in Business Processes

Oral Presentation

Dr. Tamela Ferguson [1]***, Dr. Ron Cheek*** [1]

1. *University of Louisiana*

Blockchains are systems, or groupings, of technology that allow computer networks to process cryptologically linked embedded data to be distributed, but not copied, across cyberspace, facilitating an incorruptible digital ledger for financial transactions and other recordable valuable things. Because the database is not stored in a particular place but across a multitude of computers at once, it doesn't have a hackable single point of vulnerability, and it is public and truly verifiable in real time. Originally developed as a means to conduct Bitcoin transactions, blockchains have grown to be recognized across industries as a disruptive and cheaper approach to many business models and processes. Of particular note are potential influences in financial services, foreign currency exchange, supply chain management retail/e-commerce advertising and identity management. We explore here blockchain basics and how they will likely disruptively influence these and related areas of business, and how this might drastically alter how we teach fundamentals of business processes or deliver online degree programs. This topic is in process of being developed as an elective class in a newly launched online Management degree program at an AACSB accredited school. While it will initially be delivered in a standard online class format, it is hope that blockchains themselves may prove useful in the delivery and management of online degree programs.

REFERENCES

[1] DeLone, W. H. & McLean, E. R. Information systems success: The quest for the dependent variable, Information systems research, 3(1) (1992) 60-95.

[2] DeLone, W. H. & McLean, E. R. The DeLone and McLean model of information systems success: a ten-year update, Journal of management information systems, 19(4) (2003) 9-30.

[3] FoxNews. "Miami mayor: Cryptocurrency has 'huge economic impact' ". Published November 13, 2021 at https://www.youtube.com/watch?v=dIZQiW9NtfE.

[4] Guild, J. (2017). FinTech and the Future of Finance. Asian Journal of Public Affairs, 10(1), e4.

[5] Levin, Jonathan. "Miami Mayor Says Plan Advancing to Pay City Employees in Bitcoin". Published October 12, 2021. Bloomberg at https://www.bloomberg.com/news/articles/2021-10-12/miami-mayor-says-planadvancing-to-pay-city-employees-in-bitcoin.

[6] NBC. Miami to Distribute 'Bitcoin Yield' to Residents: Mayor Suarez. Published November 11, 2021 at https://www.nbcmiami.com/news/local/miami-to-distributebitcoin-yield-to-residents-mayor-suarez/2618085/.

[7] Rossi, M., Mueller-Bloch, C., Thatcher, J. B., & Beck, R. (2019). Blockchain research in information systems: Current trends and an inclusive future research agenda. Journal of the Association for Information Systems, 20(9), 14.

[8] Wimmer, H., & Aasheim, C. (2019). Examining factors that influence intent to adopt data science. Journal of Computer Information Systems, 59(1), 43-51.

FINTECH: A SURVEY OF CONSUMER USE TO BENEFIT NON-PROFITS

Oral Presentation

Dr. Cheryl Aasheim [1], ***Dr. Hayden Wimmer*** [1]

1. *Georgia Southern University*

FinTech, or financial technology, applies technological innovation to the financial industry. It includes peer-to-peer platforms for lending, monetary transfers and cashless digital transactions. FinTech includes protocols like blockchain that enable crypto currencies like Bitcoin. Recently, the Journal of the Association for Information Systems had a special issue on blockchain technologies that sought to identify gaps in the information systems research as well as identify a framework for addressing that gap (Rossi, Meuller-Block, Thatcher & Beck, 2019). In addition, Miami is the first city to make $21 million using Miamicoin, a version of Bitcoin used by the city of Miami (FoxNews, 2021), and is awarding it to their residents via a Bitcoin wallet (NBC, 2021). The city also wants to examine paying their employees in Bitcoin (Levin, 2021). There are a number of countries leveraging FinTech to be more financially inclusive (Guild, 2017). As an example, Guild (2017) explores China's peer-to-peer lending platforms and Kenya's and India's digital cash transfer services. Guild (2017) also examines the role of government policies in making these FinTech applications sustainable and financially inclusive.

FinTech has a number of applications that can help non-profit organizations as well. Crowdfunding applications such as GoFundMe may allow for opportunities to help non-profit causes. Round-up applications for charities allow people to "round-up" their purchases on debit and credit cards to donate the "change" to charities. There are also a number of applications that enable fundraising by using recurring and one-time donations.

The purpose of this research is to design an instrument that will assess people's intent to use FinTech, especially as it relates to non-profit organizations. The survey will be based on the theory of planned behavior (TPB) and the IS Success Model (ISSM) as adapted to FinTech applications. The ISSM measures quality of a system through three dimensions: information quality, system quality and service quality (DeLone & McLean, 1992; Delone & McLean, 2003). Information quality measure the accuracy, meaningfulness and timeliness of the information. System quality measures usability, reliability, adaptability and response time of a system. Service quality addresses the technical support provided for the system. The TPB posits that a person's attitude towards a behavior impacts their intentions towards a behavior. The scales used in (2018) will be adapted for this project to assess the people's attitudes towards the use of FinTech in the non-profit arena.

Once the survey is administered, the results can be employed to assist non-profits in adopting FinTech that most efficiently enable their cause

REFERENCES

[1] DeLone, W. H. & McLean, E. R. Information systems success: The quest for the dependent variable, Information systems research, 3(1) (1992) 60-95.

[2] DeLone, W. H. & McLean, E. R. The DeLone and McLean model of information systems success: a ten-year update, Journal of management information systems, 19(4) (2003) 9-30.

[3] FoxNews. "Miami mayor: Cryptocurrency has 'huge economic impact' ". Published

November 13, 2021 at https://www.youtube.com/watch?v=dIZQiW9NtfE.
[4] Guild, J. (2017). FinTech and the Future of Finance. Asian Journal of Public Affairs, 10(1), e4.
[5] Levin, Jonathan. "Miami Mayor Says Plan Advancing to Pay City Employees in Bitcoin". Published October 12, 2021. Bloomberg at https://www.bloomberg.com/news/articles/2021-10-12/miami-mayor-says-planadvancing-to-pay-city-employees-in-bitcoin.
[6] NBC. Miami to Distribute 'Bitcoin Yield' to Residents: Mayor Suarez. Published November 11, 2021 at https://www.nbcmiami.com/news/local/miami-to-distributebitcoin-yield-to-residents-mayor-suarez/2618085/.
[7] Rossi, M., Mueller-Bloch, C., Thatcher, J. B., & Beck, R. (2019). Blockchain research in information systems: Current trends and an inclusive future research agenda. Journal of the Association for Information Systems, 20(9), 14.
[8] Wimmer, H., & Aasheim, C. (2019). Examining factors that influence intent to adopt data science. Journal of Computer Information Systems, 59(1), 43-51.

HOW DECISION MODELING CONTRIBUTES TO THE DIGITAL TRANSFORMATION OF THE SERVICE INDUSTRY

Oral Presentation

Mr. Ziboud Van Veldhoven [1], ***Mr. Alexandre Goossens*** [1], ***Mr. Vedavyas Etikala*** [1], ***Prof. Jan Vanthienen*** [1]

1. *KU Leuven*

Digital transformation is a popular research topic about the broad changes happening in business due to the increased impact of digital technologies. While the academic attention is high, the importance of decision management is underresearched. In this paper, we elaborate on how decision modeling can aid companies in the digital transformation of their services. We illustrate this with four practical approaches using decision models to: i) automate decision services ii) explain existing decision services, iii) automatically construct service chatbots, and iv) model government regulations for applications. With this work, we promote future work on decision model applications for the digital transformation of services.

Learning platform performance in blockchain: How valuable are the management efforts of a decentralized autonomous organization?

Oral Presentation

Dr. XI Zhao [1], ***Dr. Xin (Robert) Luo*** [2], ***Dr. Fujun Lai*** [3]

1. *Xi'an JiatoTong University,* ***2.*** *The University of New Mexico,* ***3.*** *University of Southern Mississippi*

Blockchain technology has ushered in a plethora of opportunities and challenges to many fields, including operations and supply chain management. The realization of disintermediation and decentralization by blockchain breaks new ground for platform organization and management mechanisms, giving rise to DAO—a decentralized, autonomous, and automated governance mode. However, there is a paucity of evidence on how people perceive and react to the management efforts of DAOs. In response to this latest technological phenomenon, we investigated how the disclosed voting activities of DAOs influence the operational performance of the blockchain platform. We propose two voting-related variables correlated with the cooperation of DAO members that may have a moderating effect: voter participation and voter consensus. We also explored the relationship between the operational performance of the blockchain platform and the value of DAO's governance token. Utilizing objective data of 6.4 million transactions from a leading blockchain platform, as well as the voting records of the DAO governing the platform, we discovered evidence of the significant influence of DAO-related management activities on platform performance. In addition, this study unveils that the lower the voter participation and the greater the voter consensus, the greater the positive impact of voting activities concerning strategic decision-making on platform performance. Additionally, we found a positive relationship between platform performance and the value of the governance token.

NUTRITION TRACKING AND MANAGING SYSTEM FOR PATIENT NUTRITION

Oral Presentation

Dr. Qingsong Zhao [1]

1. *LSUS*

ABSTRACT

Proper nutrition plays an essential role in disease prevention, recovery from illness, and ongoing good health. However, many patients leave the hospital in a poor nutritional state, and healthcare professionals know very little about their patients' post-discharge nutrition care. This paper develops a nutrition tracking and managing system implemented using the OpenEMR and Apple HealthKit frameworks. The system tracks and manages patients' nutrition, from pregnancy and lactation to patients with diabetic or Inherited Metabolic Disorders (IMD), enabling healthcare professionals to make personalized nutrition treatment plans. The system addresses the shortcomings of the current care workflow in patients' post-discharge by collecting and integrating both nutrition information and contextual metrics with the Electronic Medical Record (EMR) system. The system serves as a powerful platform for both patients and healthcare professionals to improve patient health.

PRIVACY CONSIDERATIONS OF LOCATION TRACKING IN SOCIAL WELFARE APPLICATIONS

Oral Presentation

Dr. Dalal Alarayed [1], ***Dr. Donna Schaeffer*** [1]

1. *Marymount University*

Covid-19 rapidly spread across the world starting December 2019, reaching peak numbers in the first quarter of 2021. As of October 28, 2021 Covid-19 deaths have surpassed 5,000,000 globally, with the highest death tolls in the United States (761,354), Brazil (610,491), and India (463,245). Governments around the world scrambled to combat the pandemic using various techniques including social welfare and pandemic tracking applications. This accelerated the progress of the digital revolution by the proliferation of numerous social welfare applications around the world. These applications are used for tracking vaccination status, contact tracing, social distancing, symptoms, positive cases as well as for enforcing quarantine and lock down policies and detecting violations. The integration of artificial intelligence and other technology advances raises concerns about security, privacy and equity, since many of these applications work with personal information from one's health records, employment information, and location data. The applications even pull in information from family members.

In this paper, we examine such applications in the Kingdom of Saudi Arabia and the Kingdom of Bahrain and develop best practices that can be followed to enhance the security of and equitable access to social applications. Its significance is a heightened awareness of how emerging technologies can support a more equitable access to social net programs. The platform is content analysis of government policies and current media focusing on the automation of social net programs. The focus is on policies in effect and stories covered, which point attention to the Covid-19 pandemic. We investigate the social applications' scope, reach, adoption rates and effectiveness in tracking the pandemic. We also examine the cultural attitudes on privacy as they relate to constant location tracking that is carried out by these applications. The reason we chose to study KSA and Bahrain is the high adoption rates and usage of the applications and the privacy-sensitive nature of the data collected and analyzed by them. We also investigate the reasons behind the proliferation and high adoption and usage rates.

Technology and Innovation, Linchpin of the Startup Agencies in the Creative Industry

Oral Presentation

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1. *Embry-Riddle Aeronautical University*

ABSTRACT

The creative industry is not foreign to integrating new innovations and technologies in its creative projects. However, today's enormous contribution of information technology and digital technologies, has transformed the creative industry at its core. Digitization is leading the advertising sector in particular, into a new era where worldwide spending on digital ad platforms will surpass expenditures on traditional ad formats. While technology and innovation are sustaining the advertising industry development, the industry is witnessing a rapid growth of local startup agencies with great capacity for innovation. Unequivocally, information and communication technology (ICT) and digital technologies are the preeminent contributors to the emergence of new paradigms for the advertising industry. This research illustrates the growing importance of collecting, managing, and making sense of consumer data that have driven the creative industry to invest and adopt cutting-edge technologies. Additionally, the research explores the potential dominance of data-driven startup agencies in the advertising industry, marketing, and the business world.

Keywords: Startup Agencies, Data-Driven, Digital Technologies, Innovation, Advertising 4.0

The Role of Context Variables in the Effective use of Social Computing in Organizations for Knowledge Management among Employees: An Empirical Study

Oral Presentation

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1. *Georgia Gwinnett College*

Social media are Internet-based communication tools and collaboration channels. They have been used widely for Intra organizational Knowledge Management (KM)since about 2005, especially in technology-oriented organizations. In this paper, we focus specifically on the use of social computing in organizations for KM among employees and individual-level context variables. We empirically tested and found that in most cases, KM context variables play an influential role in the effective use of social computing for KM among the employees of an organization.

IS, IT, Blockchain Technology and Social Media - Papers

HOW DECISION MODELING CONTRIBUTES TO THE DIGITAL TRANSFORMATION OF THE SERVICE INDUSTRY

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ABSTRACT

Digital transformation is a popular research topic about the broad changes happening in business due to the increased impact of digital technologies. While the academic attention is high, the importance of decision management is underresearched. In this paper, we elaborate on how decision modeling can aid companies in the digital transformation of their services. We illustrate this with four practical approaches using decision models to: i) automate decision services ii) explain existing decision services, iii) automatically construct service chatbots, and iv) model government regulations for applications. With this work, we promote future work on decision model applications for the digital transformation of services.

INTRODUCTION

The world is going through a rapid digital transformation (DT). This process is characterized by an increasing usage and reliance on digital technologies which impacts not only business but also society [10]. This process results in a myriad of changes in each aspect of the firm. The DT literature is broad with over 2,400 papers [41] and almost every aspect of it is actively researched, such as the changes in the organizational structure, culture, processes, leadership, and services [43].

In service innovation, however, one of the underresearched aspects is about the role of business decision management. With decision management, we understand modeling, maintaining, and communicating the decision logic throughout the company to all respective stakeholders [39]. While the importance of evidence-based [5, 44] and decentralized [22, 23] decision-making is evident for both researchers and companies, the significance and potential technological impact of robust decision modeling are often neglected. This is surprising considering that business decisions are a crucial element of many services and are essential for the automation of processes [35]. Hence, a discussion on the implications of decision modeling for the DT of services is required.

In this paper, we discuss how decision models can be exploited to aid the DT of corporate services. We illustrate this with four practical approaches. These include:

- Modeling decision services for requirements engineering
- Explaining existing services and logic
- Automatic generation of service chatbots
- Automating government regulations for service applications

We base our work on the decision model and notation (DMN) standard [29] to model decisions. This modeling language allows complex business decision logic to be translated into easily understandable and hierarchical models and decision tables.

In the next section, DT and DMN are explained in more detail. Then, we elaborate on the importance of digital services transformation. Next, an overview of the four approaches we researched on the use of DMN for improving services is given. We discuss these approaches and their implications for companies in the following section and conclude the paper with a call for further research.

RELATED WORK

Digital transformation

DT is often defined in the business context as 'a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies' [43]. For companies embarking on DT, this means not only adapting their current business operations with the technological capabilities of today but also investing in business agility to quickly sense and seize future disruptions in the market [27, 42].

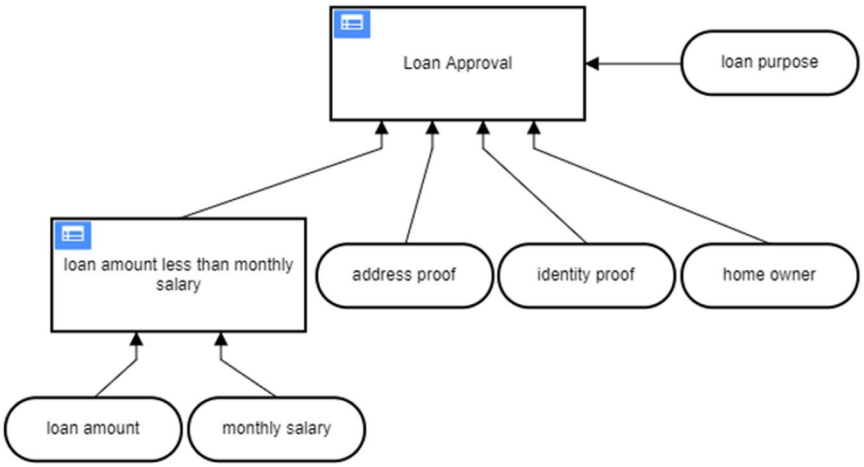
DT is not an entirely new concept. Its roots can be found in digitization, meaning the conversion of specific analog processes into digital processes [19], and in digitalization which is a term used to discuss the sociotechnical process in which digital technologies are being adopted at a large scale throughout the entire company [25]. In general, DT is considered the broader change that is happening throughout society due to the increasing impact of novel digital technologies in daily life such as social media, mobile phones, data analytics, cloud computing, and the internet of things [33].

Decision model and notation

DMN is a recently introduced modeling standard by the Object Management Group in 2015 [29]. DMN aims to model daily operational decisions by visually representing the decisions' structure and logic [14, 37, 40]. A DMN model consists of two parts. The first part visualizes the structure of a decision in a decision requirements diagram (DRD). As shown in Figure 1, decisions are represented by rectangles, input data by rounded rectangles and information requirements by solid arrows. An information requirement can link input data with a decision, or it can link the output of a decision with another decision. In Figure 1, a DMN model is shown which determines when a loan application gets approved. As can be seen, the final decision, whether a person gets approved for a loan requires several inputs. Some are data items such as loan purpose or identity proof. Next to data items, the decision Loan

Approval also requires the output of decision 'loan amount less than monthly salary'. This decision checks whether the loan amount asked is less than the monthly salary and requires both loan amount and monthly salary as inputs.

At the bottom of Figure 1, the second part of a DMN model called the decision logic level is shown in the form of a decision table for the decision 'Loan Approval'. The decision table, in this case, can be read as follows: If 'address proof' is False then the loan approval is rejected. Note that if no value is given for input, it means it can take any value. In this case, the decision table has a first hit policy meaning that the first rule that applies to a certain input combination is the one that will be fired. There exist different hit policies and more data types are supported by DMN.



Loan Approval

F	address proof	Identity proof	less than monthly salary	loan purpose	house owner	loan approval
1	FALSE	-	-	-	-	"Reject"
2	-	FALSE	-	-	-	"Reject"
3	TRUE	TRUE	TRUE	-	-	"Approve"
4	TRUE	TRUE	-	"To buy home"	TRUE	"Approve"
5	TRUE	TRUE	FALSE	"To pay tax"	-	"Approve"
6	TRUE	TRUE	-	"Others"	-	"Approve Manually"

Loan amount less then monthly salary

U	loan amount	monthly salary	less than monthly salary
1	-	-	(loanAmount< monthlySalary)

Figure 1: An example of a DMN model

THE IMPORTANCE OF THE DIGITAL TRANSFORMATION OF SERVICES

There are many types of services and thus their DT entails a broad range of developments that require more research [8, 31]. A large development is the digitalization of services meaning that they can be accessed and completed online such as e-government services. Optimization i.e., reducing the number of steps and streamlining the process, plays a significant role in this regard. The end goal is often partial or complete automation of the service where possible. This is easy for strict processes; however, the focus of this paper is on the digitalization and automation of services that deal with business knowledge and logic which is more complex and requires more attention.

In addition, for every automation there exists a hidden service cost. Customers and citizens have many questions regarding procedures or applications and find it difficult to get appropriate answers. Organizations struggle with these requests and try to direct the numerous needs to call centers, frequently asked questions, online documentations, service desks, chatbots, intelligent assistants such as the Google Assistant, video-supported consultations, and numerous similar initiatives. However, these initiatives do not always meet customer demands. Call centers often have long wait times, while documentations are often incomplete and impersonal. This is problematic because the customer experience is essential for the longevity and success of any DT project [4, 26, 36]. Any attempt to improve the situation has a high labor cost because it requires skilled employees that are familiar with the domain at hand. Part of what is saved by automating the daily operations is eliminated through high individual service costs.

One of the future challenges in service automation therefore will be managing routine knowledge-intensive tasks. These tasks are relatively easy, daily routine tasks but require some form of knowledge. Customers must be able to get advice and personalized service by answering questions such as how, what if, why not, how to, when, and where. The knowledge referred to can be found in the day-to-day rules, regulations, and procedures that are written down in texts, manuals, and so forth. Seldom is this knowledge complex but it must be applied in a highly flexible and scalable way. For instance, many companies must respond to simple customer requests regarding their products and services. Automatically supporting these services (even partially), through for example chatbots [15] will have a big economic impact [2, 24].

Not only must the business knowledge be explained to the end-user, but it must also be usable in software applications. If the business logic were a separate component that can be plugged into various applications and services, a great deal of application building would become automated. In a similar vein, research is being conducted in model-driven engineering in which models are separate components that are automatically transformed into software [6]. In the case of knowledge-intensive services such as giving advice, decision models could provide a similar solution for the knowledge handling aspect of the applications.

DECISION MODELING APPROACHES FOR THE DT OF SERVICES

Decision modeling can contribute to service transformation in many ways:

- modeling the business decisions of the services with advantages such as consistency, completeness, impact analysis, requirements engineering, and communication (case a, case d)
- automating decisions from inputs to outcome; can be used to automate decision services and improve their efficiency and maintainability (case c, case d)
- explaining the decision logic to the employees and the end-users. This brings transparency to the line of reasoning and improves the fairness of data models (case b)
- offering advice based on the decision model: how to obtain outcome A, what if input B changes, what if input C is unknown, etc. (case b, case c)
- using the decision model to automatically generate user-friendly chatbots that support the model's explainability capabilities and can be extended with natural language communication abilities (case c)

In this chapter, we illustrate the above ways with four practical approaches of how decision models aided companies in the DT of their services. The approaches are inferred from case studies conducted by the authors and from the literature. These examples only reflect a subset of what is possible with decision models.

a. Modeling a knowledge base for the automation of services

The starting point for any service automation is a good knowledge of the business problem and requirements [32]. This knowledge often comes from the business side in the form of textual documents, requirement diagrams, or oral communication. For logic-intensive processes, textual documents quickly become unclear and complex. This is problematic not only for the translation into digital products but also when changes occur and the decision-making part of the application must be updated. A DMN model can provide a solution to these problems. By modeling a DMN model, all stakeholders agree upon the business logic that must be translated into the application. Moreover, the business logic in a DMN model can be checked for consistency and completeness and be communicated to all stakeholders before attempting to automate the problem.

For example, one case study we conducted was at Televic, a large Belgian software development company that creates the software for the information boards in the national trains and train stations. A crucial problem in these information boards is which information to display at what time. This problem becomes complex when multiple messages can be displayed at once. For example, if train A on track 1 has a 10-minute delay but at that same time train B arrives at track 1, which message should get priority? If you display the delay of train A, passengers for train B might be confused. On the other hand, if

you display the arrival of train B, passengers of train A might not know that their train got delayed. This is just a simple example of a complex system with more than 15 different messages that can be displayed on multiple types of displays or played through several different speakers.

To delineate this interwoven system of rule priorities and information messages, together we built a DMN model that describes the rule priorities for each possible situation according to the various discussions we had with the different stakeholders. This model consisted of multiple sub-decision tables with each sub-decision carried to the next table. The benefits of this notation for business decisions are as follows. First, there is a substantial reduction in the number of rules when compared to manually describing every scenario. This reduction is crucial in case the number of rules increases. The original documentation would grow significantly larger than the DMN model. Second, the output of the DMN model gives an overview of all the possible aspects of the outcome compared to what a textual documentation would return. The third benefit deals with agility. When a change in the business rules happens, only the respective decision table must be modified. The rest of the DMN model can remain untouched. Most importantly, due to the fixed notation of the possible outputs and inputs, software can be made to automatically use such model as a knowledge-reasoning base to a working digital service. This method can then be used to quickly scale the service to new countries, transport systems, or information boards.

b. Decision models to improve the explainability of decision services

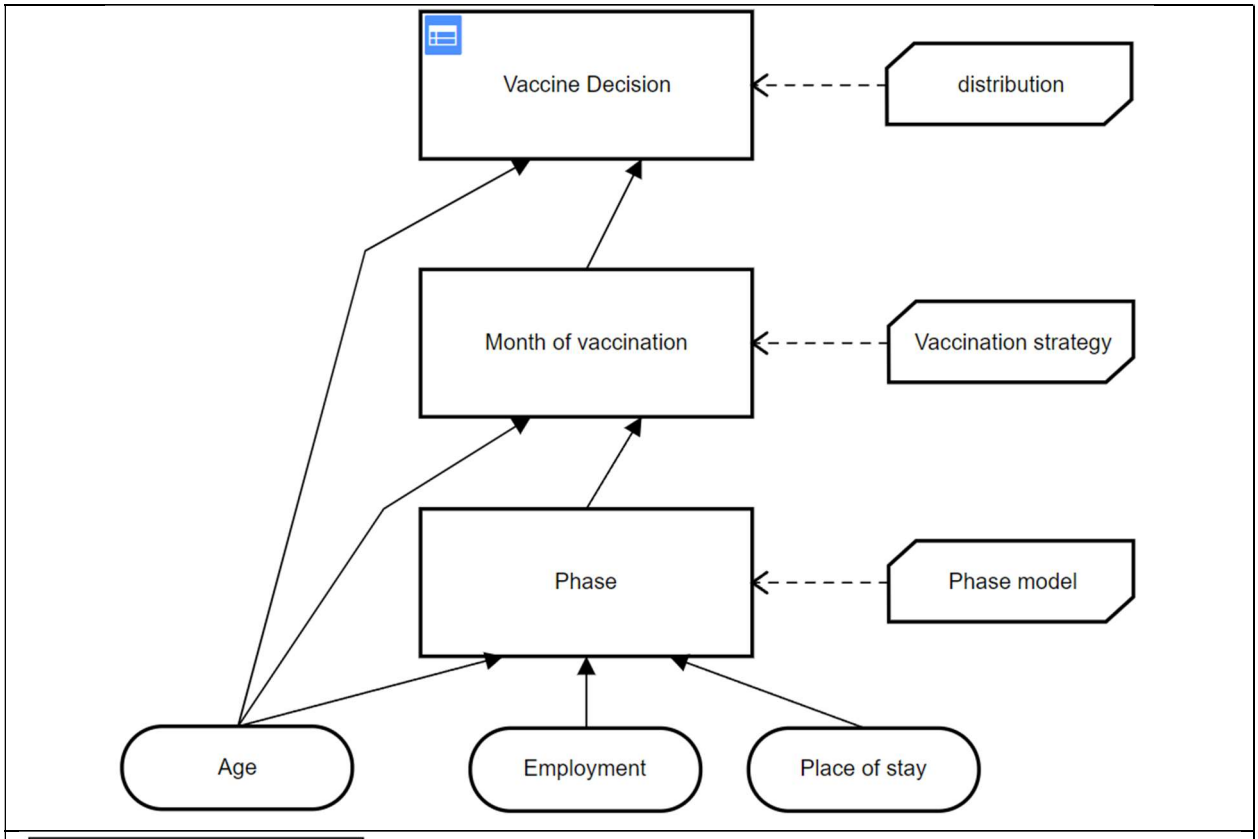
In recent years, the explainability of services that use artificial intelligence (AI) and machine learning has seen a surge in interest [45]. This interest has mainly been fueled by the realization that black box models can have a significant impact on our society. For example, Caliskan, Bryson, and Narayanan (2017) conclude that when machine learning models are applied to human language, human biases are deduced which can negatively affect certain groups. Other examples include timeline suggestions on social media that add to societal polarization. Because of these issues, some people have come to distrust AI which is why transparency is a requirement for model trustworthiness [11].

With this realization, numerous explainability techniques have been proposed. A taxonomy of explainability techniques is provided by Lipton (2018) and an overview of explainability techniques for black boxes by Guidotti et al. (2018). However, most of these explainability solutions still require a technical background of understanding why certain outcomes are determined by the model. In Rudin et al. (2021), the argument is made that fully interpretable models are to be preferred over partially interpretable models. Of course, they point out that not all problems can be solved with fully interpretable models which tend to be more applicable in low-stake decisions. These decisions tend to be daily

operational decisions that when taken in high volumes have a substantial impact on a company or organization.

This is where DMN can play a key role as it was designed to model daily operational decisions. In the case of services that follow textual descriptions of business decisions, research is ongoing to extract DMN models from a text by using patterns [13] or deep learning [16]. DMN can also be used to communicate decision rules extracted from less interpretable sources such as logs or AI models to stakeholders. With the use of decision tables, conformance checking, i.e. whether the actual decision conforms to what is expected, is possible. This can be done by extracting decision models from process logs [38] or neural networks [3]. Even though extracting the decision logic from models will not resolve bias issues, it increases the interpretability of such models with is a crucial stepping stone towards fairness. It allows stakeholders to verify whether their AI model is taking decisions based on the right conditions.

To illustrate how DMN can be used to explain how decisions are taken, we will use the same example introduced in [12]. The example is based on the vaccination strategy of Belgium. In the Figure below the DRD and decision tables can be found. As in many countries, the Belgian public services got flooded with questions regarding the vaccination campaign during the Covid-19 pandemic. Even though the procedures and conditions were explained online, it was quite complicated to navigate through all the conditions before knowing in which category you belonged.



Vaccine Decision

U	Age	Month of Vaccination	Vaccine	Number of doses
1	[0..16]	-	No vaccination	0
2	]16..18[	-	Pfizer	2
3	[18..100]	January	Pfizer	2
4		February or March	Moderna	2
5		April	AstraZeneca	2
6		May	Johnson & Johnson	1
7		June	AstraZeneca	2
8		July	Moderna	2

Month of Vaccination

U	Phase	Age	Month of Vaccination
1	Phase 1	[49..100]	January
2		[0..49[	February
3	Phase 2	[49..100]	March
4		[0..49[	April
5	Phase 3	[49..100]	May
6		[28..49[	June
7		[0..28[	July

Phase

U	Place of Stay	Employment	Age	Phase
1	"Hospital" or "Residential care center"	-	-	Phase 1
2	"At home"	Healthcare	-	Phase 1
3		Police	-	Phase 2
4		Retired or Other	[0..65[	Phase 3
5			[65..100]	Phase 2

Figure 2: Vaccine DMN model, adapted from [12]

With a DMN model made on hand, it is possible to determine the allocated month and type of vaccination more easily for both the public services and the citizens. In addition, it is

possible to see every possible outcome and how to reach it. The main contribution of this method is that the tabular format can be traversed in many ways to answer other types of questions. For instance, one can ask under which conditions a Pfizer vaccine is administered or who is vaccinated in June. It is also possible to answer questions with incomplete data. When a person, for example, is not certain whether his employment falls under healthcare or other, they can see the two possible outcomes. Many more questions in the form of why, when, what if, if not, and so forth are supported by DMN. There are numerous other application areas to which these kinds of solutions can be applied to such as eligibility for child money, eligibility for a visa or citizenships, traveling limitations, or personalized recipe suggestions considering allergies and other desiderata.

c. Automatic generation of service chatbots

Digital services often include a promise of full-time availability of customer support. In this aspect, chatbots or conversational agents are becoming increasingly popular to reduce manual customer support services [30]. Conventionally, chatbots refer customers to the right webpage, the frequently asked questions, or link the customer with the right employee. In recent years, chatbots have become more personalized and could help customers with more complex problems [1]. However, decision support chatbots are time-consuming to build and maintain, and they rarely offer the answer to a specific question in knowledge-intensive domains.

We created a novel architecture to automatically generate chatbots from DMN models to facilitate customer support services [12]. This means that companies do not have to invest in expensive software development because the DMN model is enough to create a working chatbot. In essence, our approach uses the data elements of the DMN model to inquire general Q&A questions needed for obtaining the final decision. The proposed architecture has the following components:

- Using a custom interface API, the given DMN file can be read and an interface with menu options can be presented to the user. These menu items function as a starting point of the conversation.
- The dialog manager processes inputs from the user and passes them to the reasoning mechanism. It also builds the context and the state of the conversation.
- The knowledge reasoner contains the various reasoning mechanisms which would apply the context on the knowledge of the DMN to generate the appropriate decision output. It also sends the output back to the dialog manager.
- The I/O processor generates the custom responses to the user as voice or text or as a menu option, e.g. “what is age?”.
- The menu and text-based interaction were extended with natural language communication using state-of-the-art technologies for text and speech processing such as Microsoft LUIS and IBM Watson.

In addition to generating the final decision through Q&A, the DMN generated chatbots can explain more complex user queries such as why the outcome is received or how another

outcome can be obtained thanks to the decision model knowledge base. Consider for instance the application domain of eligibility for loans in a bank. Typical questions might be "how much more could I loan if my income changed", or "what are the most important factors to get a loan?". Such interaction requires powerful knowledge representation and reasoning techniques [9], which DMN chatbots can provide. Furthermore, the possibility of asking these questions improves the transparency of the chatbot and increases human-machine trust. This technique is highly flexible and scalable and requires minimal maintenance. It can be a major step towards the automation of handling knowledge-intensive customer questions. In Figure 3, we show our proof-of-concept chatbot for the vaccine decision example of Figure 2.

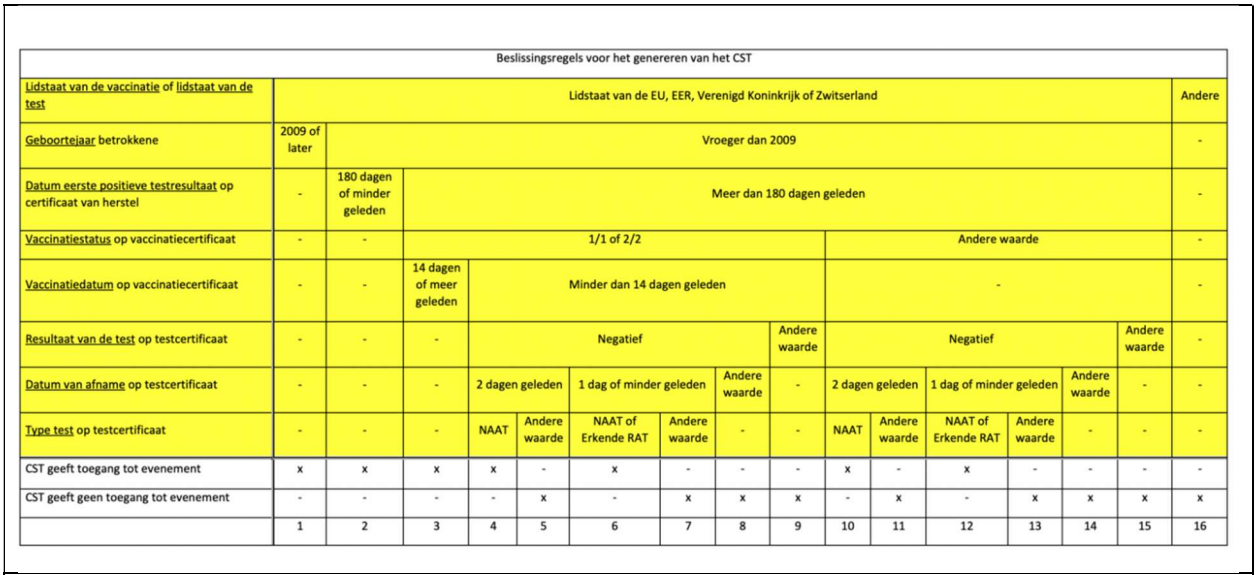
Figure 3: Example of automatically generated DMN bot

d. Model-driven engineering of government regulations

Most often laws and regulations are published in a textual format by a national government entity. These laws must be complete and consistent which is not easy for problem areas with complex rules. Some authors state that decision tables should be preferred over textual rules due to their performance [21]. Moreover, decision tables have the distinct

advantage of being easily checked for consistency and completeness, making it easier to validate that every case is covered by the law. Regulations in the format of decision models allow for easier transformation into digital services.

For instance, Belgium citizens were required to show a Covid Safe Ticket (CST) during the COVID-19 pandemic to access restaurants and events. Whether the CST grants access to a recreational activity depends on many variables such as age, vaccination status, time since last vaccination or test, the result of last test, type of test, and so forth. To make sure that all possibilities were covered, the Belgian government made a decision table with the software tool Prologa (https://feb.kuleuven.be/prologa/). This table was then published as part of the corona law. Figure 4 shows the decision table of the CST in Belgium.



Beslissingsregels voor het genereren van het CST																
Lidstaat van de vaccinatie of lidstaat van de test	Lidstaat van de EU, EER, Verenigd Koninkrijk of Zwitserland															Andere
Geboortejaar betrokkene	2009 of later	Vroeger dan 2009														-
Datum eerste positieve testresultaat op certificaat van herstel	-	180 dagen of minder geleden	Meer dan 180 dagen geleden													-
Vaccinatiestatus op vaccinatiecertificaat	-	-	1/1 of 2/2							Andere waarde						-
Vaccinatiedatum op vaccinatiecertificaat	-	-	14 dagen of meer geleden	Minder dan 14 dagen geleden						-						-
Resultaat van de test op testcertificaat	-	-	-	Negatief					Andere waarde	Negatief					Andere waarde	-
Datum van afname op testcertificaat	-	-	-	2 dagen geleden		1 dag of minder geleden		Andere waarde	-	2 dagen geleden		1 dag of minder geleden		Andere waarde	-	-
Type test op testcertificaat	-	-	-	NAAT	Andere waarde	NAAT of Erkende RAT	Andere waarde	-	-	NAAT	Andere waarde	NAAT of Erkende RAT	Andere waarde	-	-	-
CST geeft toegang tot evenement	x	x	x	x	-	x	-	-	-	x	-	x	-	-	-	-
CST geeft geen toegang tot evenement	-	-	-	-	x	-	x	x	x	-	x	-	x	x	x	x
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Figure 4: Decision table of CST in Belgian law (https://www.vlaanderen.be/cjm/sites/default/files/2021-07/CovidSafeTicket-UitvoerendSamenwerkingsakkoord.pdf)

Later, the 'CovidSafe' app was built to access your CST digitally on your phone. The app was built using the decision table from the law as a knowledge source to generate whether the user has a valid CST. The crucial element here is that the CST app required minimal maintenance whenever the government would change the decision table, as the app automatically updates when the decision table updates.

Writing a law or regulation into a decision table also offers new possibilities to governments because these can easily be translated into service applications. For example, the Flemish government makes use of DMN decision tables for automated advice concerning job-seekers benefit premiums. As can be expected, these rules are complex and require a great deal of information before advice can be given. Hence, decision tables were used to easily create online services (https://overheid.vlaanderen.be/informatie-vlaanderen/ontdek-onze-producten-en-diensten/automatisch-advies).

DISCUSSION

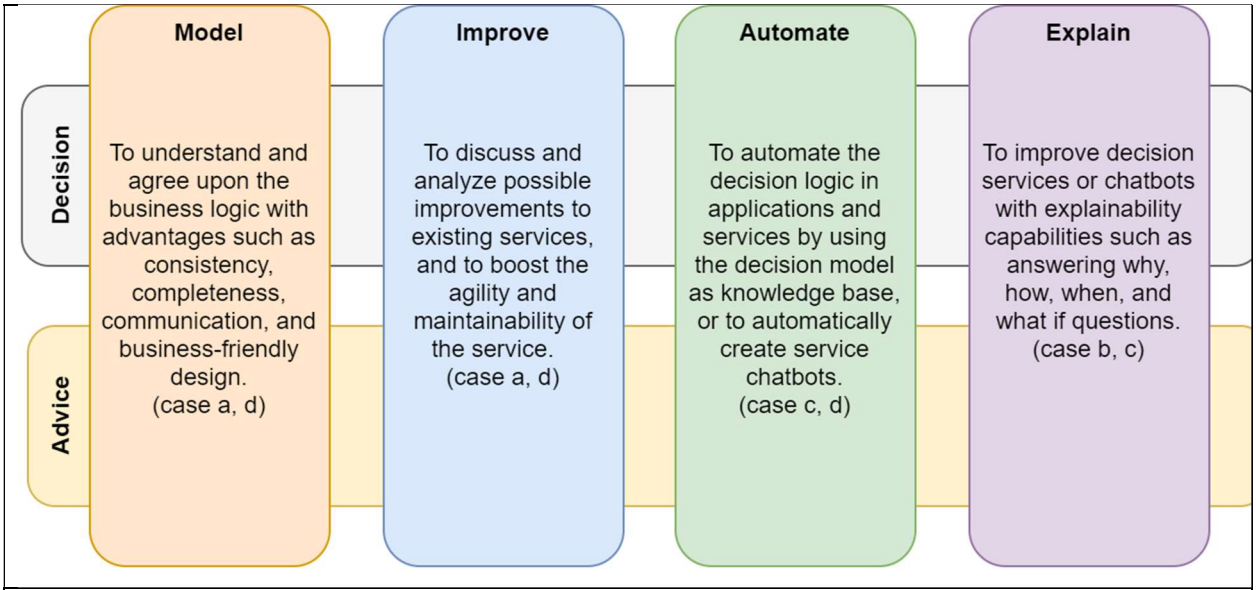


Figure 5: DMN strategies for DT

In this paper, we have discussed how DMN can aid in the DT of services, of which an overview is shown in Figure 5. We illustrated these with four practical approaches, case a-d. These examples highlight the potential and importance of decision models. Having a robust, structured, and easily understandable knowledge base for business decisions is crucial for the agile development, maintenance, and rollout of digital services. In addition, the knowledge base allows for services to be improved with explainability capabilities. It allows not only for questions such as 'why did I receive outcome A' and 'how can I get outcome B' but also to reason with incomplete input data or uncertainty. Moreover, decision models can be used for novel service innovations such as DMN generated chatbots. It is clear that DMN has the capability to improve existing services with automation, improvements, and explainability, as well as to be used for service innovation.

From a research perspective, this paper highlights the extent of the possibilities that DMN and its applications have to offer for the DT of services. However, research in this area is still in the early stages. First, more research must be conducted in the usage of decision models as a knowledge base in software applications. Interesting avenues include investigating the problem areas where this technique can be beneficial, the limitations of current decision models, and creating novel architectures that support this methodology. Secondly, the explainability capabilities of DMN models and how to integrate these into services require more attention. In this paper, we showcased online services and chatbots with these capabilities, however other integrations are possible as well. Especially how to make the bridge between the DMN model and the end user could be an interesting topic for further research. Third, our approach for quickly generating chatbots is a promising solution. There is abundant room for further improvements in this area such as optimizing this method for other knowledge models or improving user feedback on explainability.

Lastly, there are still many opportunities in decision modeling for government regulations and their applications.

From a practical viewpoint, it is important to inform businesses, organizations, and governments about the possibilities of DMN. By showcasing how DMN can be used to solve real-life problems, its adoption and academic attention can be increased. Good examples, in addition to the ones in this paper, can be found in [18] where DMN was used to check code compliance of railways designs, or in [20] where DMN was used within the context of disaster management. This is an important matter for both practitioners and researchers.

CONCLUSION

This paper set out to discuss the use of decision models for the DT of services. We have shown different approaches of how decision models in the form of DMN models were used to automate decision services, explain services, build chatbot service capabilities, and model government regulations. Overall, this study highlights the importance and potential of decision models to use as a foundation for service DT. A natural progression of this work is to investigate each approach in more detail, as well as researching other approaches on the exploitation of decision models for service automation and digitalization.

REFERENCES

[1] Adamopoulou E, Moussiades L (2020) Chatbots: History, technology, and applications. Mach Learn with Appl 2:100006. doi: 10.1016/j.mlwa.2020.100006

[2] Aguirre S, Rodriguez A (2017) Automation of a business process using robotic process automation (RPA): A case study. Commun Comput Inf Sci 742:65–71. doi: 10.1007/978-3-319-66963-2_7

[3] Baesens B, Setiono R, Mues C, Vanthienen J (2003) Using neural network rule extraction and decision tables for credit-risk evaluation. Manage Sci 49:312–329. doi: 10.1287/mnsc.49.3.312.12739

[4] Berman SJ (2012) Digital transformation: Opportunities to create new business models. Strateg Leadersh 40:16–24. doi: 10.1108/10878571211209314

[5] Bonnet D, Westerman G (2021) The new elements of digital transformation. MITSloan Manag Rev 62:8

[6] Brambilla M, Cabot J, Wimmer M (2017) Model-driven software engineering in practice. Synth Lect Softw Eng 3:1–207

[7] Caliskan A, Bryson JJ, Narayanan A (2017) Semantics derived automatically from language corpora contain human-like biases. Science (80-) 356:183–186. doi: 10.1126/science.aal4230

[8] Carlborg P, Kindström D, Kowalkowski C (2014) The evolution of service innovation research: A critical review and synthesis. Serv Ind J 34:373–398. doi: 10.1080/02642069.2013.780044

[9] De Cat B, Bogaerts B, Bruynooghe M, Janssens G, Denecker M (2018) Predicate logic as a modeling language: the IDP system. In: Declarative Logic Programming: Theory, Systems, and Applications. pp 279–323

[10] Ebert C, Duarte CHC (2018) Digital Transformation. IEEE Softw 35:16–21. doi: 10.1109/MS.2018.2801537
[11] von Eschenbach WJ (2021) Transparency and the Black Box Problem: Why We Do Not Trust AI. Philos Technol. doi: 10.1007/s13347-021-00477-0
[12] Etikala V, Goossens A, Van Veldhoven Z, Vanthienen J (2021) Automatic Generation of Intelligent Chatbots from DMN Decision Models. In: RuleML. Springer International Publishing, pp 142–157
[13] Etikala V, Van Veldhoven Z, Vanthienen J (2020) Text2Dec: Extracting Decision Dependencies from Natural Language Text for Automated DMN Decision Modelling. Springer International Publishing, pp 367–379
[14] Figl K, Mendling J, Tokdemir G, Vanthienen J (2018) What we know and what we do not know about DMN. Int J Concept Model 13:16. doi: 10.18417/emisa.13.2
[15] Følstad A, Skjuve M, Brandtzaeg PB (2019) Different chatbots for different purposes: Towards a typology of chatbots to understand interaction design. Lect Notes Comput Sci 11551 LNCS:145–156. doi: 10.1007/978-3-030-17705-8_13
[16] Goossens A, Claessens M, Parthoens C, Vanthienen J (2021) Extracting Decision Dependencies and Decision Logic Using Deep Learning Techniques. In: BPM 2021 DEC2H workshop
[17] Guidotti R, Monreale A, Ruggieri S, Turini F, Giannotti F, Pedreschi D (2018) A survey of methods for explaining black box models. ACM Comput Surv 51. doi: 10.1145/3236009
[18] Häußler M, Esser S, Borrmann A (2021) Code compliance checking of railway designs by integrating BIM, BPMN and DMN. Autom Constr 121:1–24. doi: 10.1016/j.autcon.2020.103427
[19] Henriette E, Feki M, Boughzala I (2015) The Shape of Digital Transformation: A Systematic Literature Review. Mediterr Conf Inf Syst Proc 1–13
[20] Horita FEA, Link D, De Albuquerque JP, Hellingrath B (2016) ODMN: An integrated model to connect decision-making needs to emerging data sources in disaster management. Proc Annu Hawaii Int Conf Syst Sci 2016-March:2882–2891. doi: 10.1109/HICSS.2016.361
[21] Huysmans J, Dejaeger K, Mues C, Vanthienen J, Baesens B (2011) An empirical evaluation of the comprehensibility of decision table, tree and rule based predictive models. Decis Support Syst 51:141–154
[22] Ivanov II (2019) Chasing the Crowd: Digital Transformations and Digital Driven System Design Paradigm. In: Lecture Notes in Business Information Processing. Springer International Publishing, pp 64–80
[23] Janik A, Ryszko A (2018) Mapping the field of Industry 4 . 0 based on bibliometric analysis. In: IBIMA conference. pp 1–15
[24] Lacity MC, Willcocks LP (2016) A new approach to automating services. MIT Sloan Manag Rev 58:41–49. doi: 10.7551/mitpress/11633.003.0015
[25] Legner C, Eymann T, Hess T, Matt C, Böhmann T, Drews P, Mädche A, Urbach N, Ahlemann F (2017) Digitalization: Opportunity and Challenge for the Business and Information Systems Engineering Community. Bus Inf Syst Eng 59:301–308. doi: 10.1007/s12599-017-0484-2
[26] von Leipzig T, Gamp M, Manz D, Schöttle K, Ohlhausen P, Oosthuizen G, Palm D, von Leipzig K (2017) Initialising Customer-orientated Digital Transformation in

Enterprises. Procedia Manuf 8:517–524. doi: 10.1016/j.promfg.2017.02.066
[27] Leonhardt D, Haffke I, Kranz J, Benlian A (2017) Reinventing the IT Function: The Role of IT Agility and IT Ambidexterity in supporting Digital Business Transformation. ECIS Proc 2017:968–984
[28] Lipton ZC (2018) The mythos of model interpretability: In machine learning, the concept of interpretability is both important and slippery. Queue 16:1–28. doi: 10.1145/3236386.3241340
[29] OMG (2015) Decision Model and Notation 1.0
[30] Oracle (2016) Can Virtual Experiences Replace Reality ? Keeping up with digital customers. Oracle Corp 1–19
[31] Ostrom AL, Parasuraman A, Bowen DE, Patrício L, Voss CA (2015) Service Research Priorities in a Rapidly Changing Context. J Serv Res 18:127–159. doi: 10.1177/1094670515576315
[32] Paetsch F, Maurer F (2003) Requirements engineering and agile software development. 1–6
[33] Ross JW, Sebastian IM, Beath C, Mocker M, Moloney KG, Fonstad NO (2016) Designing and executing digital strategies. 2016 Int Conf Inf Syst ICIS 2016 1–17
[34] Rudin C, Chen C, Chen Z, Huang H, Semenova L, Zhong C (2021) Interpretable Machine Learning: Fundamental Principles and 10 Grand Challenges. 1–80
[35] Schallmo D, Williams C (2018) Digital Transformation Now! Guiding the Successful Digitalization of Your Business Model
[36] Schuchmann D, Seufert S (2015) Corporate Learning in Times of Digital Transformation: A Conceptual Framework and Service Portfolio for the Learning Function in Banking Organisations. Int J Adv Corp Learn 8:31–39. doi: 10.3991/ijac.v8i1.4440
[37] Silver B (2016) DMN Method and Style
[38] De Smedt J, Hasić F, vanden Broucke SKLM, Vanthienen J (2019) Holistic discovery of decision models from process execution data. Knowledge-Based Syst 183. doi: 10.1016/j.knosys.2019.104866
[39] Taylor J, Fish A, Vanthienen J, Vincent P (2013) Emerging Standards in Decision Modeling—an Introduction to Decision Model & Notation. Intell BPM Syst Impact Oppor 133–146
[40] Vanthienen J (2021) Decisions, advice and explanation: an overview and research agenda. A Res Agenda Knowl Manag Anal
[41] Van Veldhoven Z, Etikala V, Goossens A, Vanthienen J (2021) A Scoping Review of the Digital Transformation Literature using Scientometric Analysis. In: 24th International Conference on Business Information Systems (BIS 2021). p 12
[42] Van Veldhoven Z, Vanthienen J (2021) Digital transformation as an interaction-driven perspective between business, society, and technology. Electron Mark 16. doi: 10.1007/s12525-021-00464-5
[43] Vial G (2019) Understanding digital transformation: A review and a research agenda. J Strateg Inf Syst 28:1–27. doi: 10.1016/j.jsis.2019.01.003
[44] Weill P, Woerner SL (2015) Thriving in an Increasingly Digital Ecosystem. MIT Sloan Manag Rev 56:27–34. doi: 10.1287/isre.1100.0318
[45] Xu F, Uszkoreit H, Du Y, Fan W, Zhao D, Zhu J (2019) Explainable AI: A Brief Survey on History, Research Areas, Approaches and Challenges. Lect Notes Comput Sci

(including Subser Lect Notes Artif Intell Lect Notes Bioinformatics) 11839 LNAI:563–574. doi: 10.1007/978-3-030-32236-6_51

NUTRITION TRACKING AND MANAGING SYSTEM FOR PATIENT NUTRITION

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ABSTRACT

Proper nutrition plays an essential role in disease prevention, recovery from illness, and ongoing good health. However, many patients leave the hospital in a poor nutritional state, and healthcare professionals know very little about their patients' post-discharge nutrition care. This paper develops a nutrition tracking and managing system implemented using the OpenEMR and Apple HealthKit frameworks. The system tracks and manages patients' nutrition, from pregnancy and lactation to patients with diabetic or Inherited Metabolic Disorders (IMD), enabling healthcare professionals to make personalized nutrition treatment plans. The system addresses the shortcomings of the current care workflow in patients' post discharge by collecting and integrating both nutrition information and contextual metrics with the Electronic Medical Record (EMR) system. The system serves as a powerful platform for both patients and healthcare professionals to improve patient health.

INTRODUCTION

Malnutrition is a global problem. There are millions of people are suffering from different forms of malnutrition. Based on the recent reports from the WHO [1], 1.9 billion adults are overweight or obese while 462 million are underweight; among children, 52 million under-fives are suffering from wasting, where they have a low weight for their height. In the U.S., approximately 35% of adults and 17% of youths are obese. The increasing prevalence of obesity and its association with cardiovascular disease, several forms of cancer, diabetes, and other chronic illnesses have prompted interest in identifying effective ways to promote healthy eating and weight control [2].

Proper nutrition plays an essential role in disease prevention, recovery from illness, and ongoing good health. For example, healthy food choices are vital to preventing chronic illnesses such as diabetes and heart disease [3].

In recent years, as smartphone platforms are getting more popular and more powerful, more people are using them in nutrition tracking and managing programs. Smartphone apps provide a useful and low-cost way to disseminate information about proper dieting and nutrition to the general population and in particular to at-risk populations such as cancer survivors and people who are overweight or obese [2]. Smartphone apps have the potential to lower costs, reduce the burden to participants, and overcome some limitations of traditional in-person behavioral programs. However, in a nutrition tracking and managing system, without allowing patients to interact with clinical professionals (such as Registered Dietitians) and integrating with EHRs, smartphone apps cannot work alone to effectively improve patient nutrition.

In this paper, we present our nutrition tracking and managing system to improve patient nutrition. We first review current systems and their shortcomings in the related works section. Next, we describe the design of our nutrition tracking and managing system, which includes the smartphone App function design and the backend EHR function design. After the system design, we will cover the implementation of our system. Finally, the paper ends with a brief discussion and future objectives of our work.

RELATED WORKS

A number of apps have been developed for nutrition tracking and weight control for both iPhone and Android. The functions provided by these apps include feedback, goal-setting for healthy eating, healthy cooking, grocery or restaurant decision making, self-monitoring of energy and nutrient intake, weight tracking, and planning social support and change [4].

Typically, during a patient’s hospital stay, healthcare professionals (physicians, dietitians, nurses and nutrition staff) use the Electronic Medical Record (EMR) to track and manage patient nutrition status. However, many patients leave the hospital in a poor nutritional state, and healthcare professionals know very little about their patients’ post-discharge nutritional care.

The apps currently available on the market do not have the functionalities to facilitate nutrition tracking and manage workflows in post-discharge and

ambulatory patient nutrition care. The shortcomings of these apps make nutrition care challenging for both patients and healthcare professionals, as well as increase healthcare cost and affect patient treatment outcomes. In particular, the shortcomings include:

1. Poor patient education [5]. Since there no NTMS integrated with the EMRs, current workflows do not have the ability to provide a convenient mechanism for patients to obtain comprehensive and customized nutrition knowledge based on their health conditions.

2. No patient engagement. Current workflows do not support any communication between healthcare professionals and patients, such as updating nutrition care plans, monitoring nutrition status, etc. for post-discharge patients.

3. Lack of consistency and accuracy of nutrition data. Patients usually record nutritional data in a journal style (paper) manually. It is very challenging to maintain consistent nutrition logs over a long period [6]; also, it is easy to underestimate and/or overestimate nutritional facts.

4. No contextual data is captured in the current workflow. In order to provide meaningful insights for healthcare professionals, nutritional information needs to be collected along with many other contextual data, such as the heart rate, blood pressure, and fitness data.

SYSTEM DESIGN AND IMPLEMENTATION

Figure 1 illustrates the structure of the nutrition tracking and managing system in this paper. In this setup, Apple HealthKit is the accompanying development Application Programming Interface (API), which is included in the iOS SDK (Software Development Kit). Serving as a core component, HealthKit is used in this system as a bridge between the patient App and OpenEMR. Health data, either collected by other any devices (such as Apple watch, etc.), or manually entered into Apple HealthKit by patients, can be transferred to OpenEMR. OpenEMR has been certified as a complete ambulatory EHR by the Office of the National Coordinator (ONC) for Health Information Technology, and it is the most popular open-source electronic health record system and medical practice management solution. This paper fully integrates the patient nutrition data and other contextual metrics (including patient exercise, hear rate, blood pressure and weight) with clinical workflows, and provides a comprehensive platform for healthcare professionals.

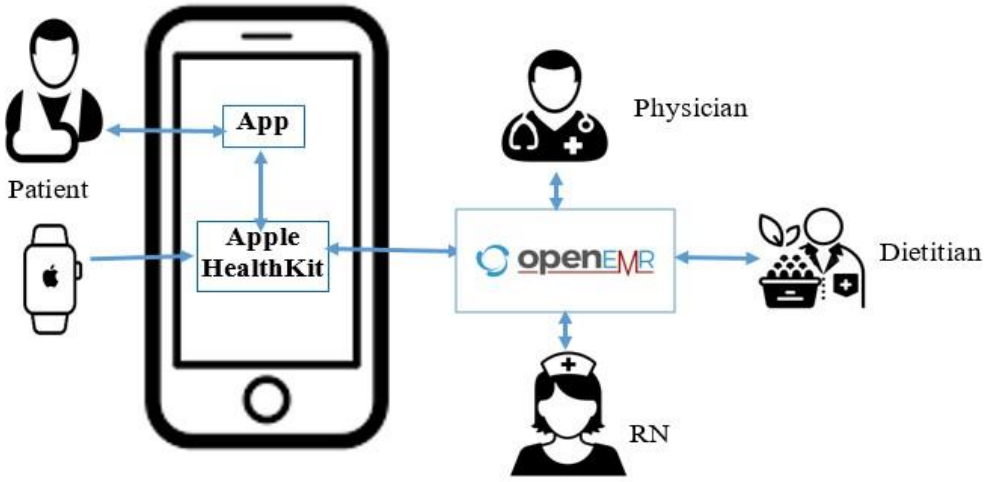

Figure 1. Nutrition Tracking and Managing System Structure

By using the nutrition tracking and managing system, a typical workflow of post-discharge patient nutrition care includes the following steps:

1. The process starts in OpenEMR when physicians and dietitians set up personalized education materials and nutrition care plans during patient clinic visits or hospital stays. Nurses communicate with patients about both documents and send them to the App through Apple HealthKit.

2. After discharge, patients configure contextual data collection strategies through the App. This includes the metrics that will be collected and sent over to OpenEMR and how often they will be sent. Patients also report their daily diet intakes (pictures, notes and estimated nutritional facts) to OpenEMR.

3. Dietitians review nutrition data and other contextual metrics and send patient feedback, which includes adjustments to patient daily diet intakes, updated nutrition care plans, etc.

We have developed the following new functions on OpenEMR to provide:

1. Interfaces for clinicians to review patient nutrition data, define a patient nutrition plan, and communicate with patients.

2. Interfaces for system administrators to define and manage nutrition templates (data fields and data formats) by utilizing OpenEHR Archetypes and Templates [7].

3. Reports on the progress of patient nutrition care.

The Smartphone App provides the following functions:

1. Retrieving the data from the Health data hub (in our case, which is Apple HealthKit).

2. Formalizing and validating the patient nutrition data and other contextual metrics based on nutrition templates.

3. Processing (e.g. summarizing daily intake, etc.) and sending the data to OpenEMR.

4. End user interface for a patient manually entering and reviewing health data.

CONCLUSION AND FUTURE WORK

A nutrition tracking and managing system for patient nutrition has been successfully developed and has served as a central platform for physicians, nurses, registered dietitians and patients working together to manage patient nutrition, such as in disease prevention, recovery from illness, and ongoing good health. We have started the project on the iOS platform because iOS is the No. 1 mobile OS in the American market (56.22% of market share in Jan. 2021) [8]. We are planning to expand the project to the Android platform in the future. As part of our future work, we will also discover the potential of applying this system in clinical trials by tracking other health data, such as patient vitals.

REFERENCES

[1] https://www.who.int/news-room/fact-sheets/detail/malnutrition

[2] Coughlin SS, Whitehead M, Sheats JQ, Mastromonico J, Hardy D, Smith SA. *Smartphone applications for promoting healthy diet and nutrition: a literature review,* Jacobs J Food Nutr. 2015;2:021.

[3] O'Connor D.L., Blake J., Bell R., Bowen A., Callum J., Fenton S., Gray-Donald K., Rossiter M., Adamo K., Brett K., et al. *Canadian consensus on female nutrition: Adolescence, reproduction, menopause, and beyond,* J. Obstet. Gynaecol. Can. 2016; 38:508–554. doi: 0.1016/j.jogc.2016.01.001.

[4] Azar KM, Lesser LI, Laing BY, Stephens J, Aurora MS, et al. *Mobile applications for weight management: theory-based content analysis,* Am J Prev Med. 2013; 45(5):583–589.

[5] Marsha Moore Kenner, Martha L Taylor, P.Carolyn Dunn, Harvey W Gruchow, Kathy Kolasa, *Primary Care Providers Need a Variety of Nutrition and Wellness Patient Education Materials,* Journal of the American Dietetic Association, Volume 99, Issue 4,

[6] Why It's Hard to Track Nutrition, APRIL 3, 2017 https://www.fitnescity.com/blog/2017/3/13/whyits-hard-to-track-nutrition.

[7] https://specifications.openehr.org/releases/AM/Release-2.2.0

[8] https://www.statista.com/statistics/1045192/share-of-mobile-operating-systems-in-north-americaby-month/

Information Privacy, Security and System Resilience, Business Ethics, Business Law - Abstracts

Finding the Emerging Research Agenda: A Systematic Literature Review on Workplace Monitoring and Surveillance

Oral Presentation

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An earlier study predicts that computerized monitoring and surveillance will be the next big brother in a digitized workplace. Virtual workplace monitoring and surveillance have become crucial and challenging because of workplace transformation facilitated by the COVID-19 pandemic. In this review, using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework, we select 68 unique papers on surveillance in organizations for this critical literature review exercise. Our critical literature review reveals four research gaps that further studies can investigate within the context of surveillance and monitoring in the workplace.

Level of Cybersecurity Readiness of Small and Medium Nonprofit Organizations (NPOs) During COVID-19

Oral Presentation

Dr. Natalia Ermicioi [1], ***Dr. Xiang Liu*** [1]

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Abstract— Considering the unprecedented COVID-19 pandemic crisis, many NPOs, like other types of institutions, have migrated their operations to remote, virtual platforms to maintain at least a minimum level of activity. Consequently, the NPOs are experiencing an increased level of online activity during COVID-19. This study assesses the level of NPOs' readiness during COVID-19 through the lens of three components of the ISO 22301:2019 - Business Continuity Management Systems (BCMS) – labeled as 3Ps: Policy, People, and Processes. A survey study using a snowball sampling approach was conducted to examine information security readiness in small and medium-sized NPOs during the COVID-19 Pandemics in D.C., Maryland, and Virginia (DMV) area. Each item in the three aspects of readiness was measured at the level of high, moderate, or low. The findings of the study demonstrate that the NPOs should put more emphasis on developing and implementing cybersecurity policies during crises to increase the level of awareness and preparedness. The empirical results of this study further shed light on the aspects and factors of cybersecurity readiness that are often less prioritized by NPOs senior management but should be taken into more consideration when creating cybersecurity policies and procedures.

Keywords— NPOs, cybersecurity, readiness, crisis, management, COVID-19

SOCIAL MEDIA: FROM AWARENESS TO TRUST

Oral Presentation

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As of July 2021, there were 4.48 billion social media users around the world, approximately 57 percent of the total global population with 9 in 10 users using one or more social media platforms each month [2]. With the rapid increase in usage, privacy concerns, security concerns, and trust on social media remain the biggest challenges for users [1, 4]. Furthermore, awareness may play a significant role in users' security and privacy concerns which in turn may influence their trust. The primary goal of this paper is to propose a research model with four constructs to explore 1) whether awareness influences one's privacy concerns and security concerns, 2) whether security and privacy concerns influence users' trust, and 4) whether security and privacy concerns have any role in mediating between awareness and trust. We used an instrument with four constructs [3]. The instrument was administered electronically to a sample of undergraduate students at a medium-sized university in the USA. We collected 304 completed and usable surveys. Data were analyzed using SmartPLS 3.0, a partial least square structural equation modeling software [5]. In this presentation, we report on our preliminary findings.

REFERENCES

1. Brady, G. M., Truxillo, D. M., Bauer, T. N., & Jones, M. P. (2021). The development and validation of the Privacy and Data Security Concerns Scale (PDSCS). *International Journal of Selection and Assessment*, *29*(1), 100-113.

2. Datareportal (2021). Global social media stats. Available from https://datareportal.com/social-media-users

3. Koohang A., Floyd, K, Yerby, J. & Paliszkiewicz, J (2021). Social media privacy concerns, security concerns, trust, and awareness: empirical validation of an instrument. *Issues in Information Systems*, 22(2), 133-145. https://doi.org/10.48009/2_iis_2021_136-149

4. Koohang, A. & Nord, J. H. (2021). Critical components of data analytics in organizations: A research model. *Expert Systems with Applications, 166.* https://doi.org/10.1016/j.eswa.2020.114118

5. Ringle, C., Wende, S., & Will, A. (2005), SmartPLS 3.0, SmartPLS, Hamburg, available at: www. smartpls.de

THE FUTURE ROLE OF ARTIFICIAL INTELLIGENCE IN SYSTEMS HARDENING

Oral Presentation

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System hardening is a tedious process in which a set of guidelines must be rigorously applied to some combination of operating systems, software, data, and configurations. The goal of hardening is to minimize attack surfaces and maximize control over system resources. Although the importance of hardening cannot be understated, it is also a costly and time-consuming effort. Further, there is every possibility a human could (accidentally or intentionally) overlook important vulnerabilities or change settings which impede a core functionality. Thus, there is a natural case for automating the process of system hardening. Furthermore, artificial intelligence has already been entrusted with the management of many other aspects of cyber security. The purpose of this research is to investigate the efficacy of intelligent software as a surrogate for human cyber analysts. It describes an experiment in which automated hardening solutions are pitted against analysts. It compares and contrasts the relative strengths and weaknesses of each approach and identifies future research directions.

Using Social Engineering to Raise Awareness toward Information Security

Oral Presentation

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The use of technology has become an extremely critical component for organizations in conducting their decision-support, analytical, and operational activities. As the sophistication of modern technology has increased exponentially, so has those of cyber-crimes, which has necessitated continuous enhancements in enterprise-level cyber-security measures. While most of these measures are technical in nature, the use of behavioral ones like social engineering (SE) is gaining importance in recent times.

This phenomenon has evolved primarily in response to the increased use of SE by cyber attackers themselves that targets the human element of organizations to evade established technical safeguards.

This research addresses the use of the SE to raise information security awareness and enhance the security focus of an organization. The research involves analysis of a SE phishing experiment conducted at an organization that supplemented established training measures to raise security awareness with a view to change the entire organizational behavior toward information security. The findings of this experiment show that SE phishing was successful in changing individuals' behavior and perception toward information security.

Managers, information security professionals, trainers and educators can use the findings revealed by this research to understand and implement effective awareness trainings and strategies that focus on information security.

WHEN PENNYMAC, PURSUANT TO 12 C.F.R. § 1024.37(b), TAKES CONTROL OVER REAL ESTATE, FOR WHICH PENNYMAC HAS NO SECURITY INTEREST, HAS PENNYMAC TAKEN THE BORROWER'S REAL ESTATE WITHOUT JUST COMPENSATION?

Oral Presentation

Dr. Brad Johnson [1]

1. *FRANCIS MARION UNIVERSITY*

During the Great Recession, there was a proliferation of real estate foreclosures. As a result, mortgage borrowers lost their jobs, stopped paying their contractually required, mortgage indebtedness payments, including interest, principal, taxes, and property insurance.

In these cases, to protect their security interest in real estate, mortgage lenders, including mortgage indebtedness servicer providers, would (1) obtain force-placed insurance (FPI) on the real estate secured by the Mortgage/Deed of Trust and (2) charge the borrower for the "cost" of such hazard insurance coverage. However, banking practices that arose during this period became abusive (e.g., exorbitant FPI profits, commissions, and kickbacks) and, accordingly, were subject to increased scrutiny.

In response, Congress enacted the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank). The purpose of Dodd-Frank was to "promote financial stability of the United States by improving accountability and transparency in the financial system, to end 'too big to fail,' to protect the American taxpayer by ending bailouts, [and] to protect consumers from abusive financial services practices."

In particular, Title X of Dodd-Frank created the Consumer Financial Protection Bureau ("CFPB") to investigate violations of consumer protection laws and enact rules regarding consumer protection statutes. Moreover, Section 1022(b)(1) of Dodd-Frank, 12 U.S.C. 5512(b)(1), authorizes the CFPB to prescribe rules (e.g., Regulation X) "as may be necessary or appropriate to enable the Bureau to administer and carry out the purposes and objectives of the Federal consumer financial laws, and to prevent evasions thereof."

As an example, in 2013, the Bureau published final rules "that make major changes to the mortgage loan servicing requirements of Regulation X, which includes the provision relating to FPI." In particular, "the term "force-placed insurance" means hazard insurance obtained by a servicer on behalf of the owner or assignee of a mortgage loan that **insures the property securing such loan**." Moreover, " [a] servicer may not assess on a borrower a premium charge or fee related to force-placed insurance unless the servicer has a reasonable basis to believe that the borrower has failed to comply with the mortgage loan contract's requirement to maintain hazard insurance."

As a mortgagee, PennyMac has "in rem rights" in the real estate that is identified as security in a Deed of Trust. However, recently, PennyMac, as a creditor and debt service provider, has used 12 C.F.R. § 1024.37(b) to excuse its abusive actions (e.g., illegal FPI charges, commissions, and kickbacks) in taking control of real estate for which PennyMac has no security interest. *See PennyMac v. Johnson and Wijayaningsih*, 20 CVS 2436 (Superior Court, Forsyth County, NC 2020).

Information Privacy, Security and System Resilience, Business Ethics, Business Law - Papers

Finding the Emerging Research Agenda: A Systematic Literature Review on Workplace Monitoring and Surveillance

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ABSTRACT

An earlier study predicts that computerized monitoring and surveillance will be the next big brother in a digitized workplace. Virtual workplace monitoring and surveillance have become crucial and challenging because of workplace transformation facilitated by the COVID-19 pandemic. In this review, using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework, we select 68 unique papers on surveillance in organizations for this critical literature review exercise. Our critical literature review reveals four research gaps that further studies can investigate within the context of surveillance and monitoring in the workplace.

INTRODUCTION

Attewell [1], in one of their early studies, predicts that computerized monitoring and surveillance will be the next big brother in a digitized workplace. Moreover, they also caution the readers about potential controversies surrounding computerized monitoring and surveillance. Ball [2] defines workplace surveillance as "… management's ability to monitor, record and track employee performance, behaviors and personal characteristics in real-time (for example, Internet or telephone monitoring) or as part of broader organizational processes (for example, drug testing in recruitment)". We can find organizational monitoring and surveillance based on worker productivity [3], internet use [4], video monitoring [5], and computer use [6]. Extant research puts much emphasis on finding the consequences of monitoring and surveillance. The negative consequences or concerns surrounding monitoring and surveillance are privacy invasion [3], legal backlashes because of workplace ethical violation [2], employee health and psychology [7], employee motivation, organizational commitment [8], and data security concerns [9]. Because of workplace transformation facilitated by the COVID-19 pandemic, virtual workplace monitoring, and surveillance have become crucial and challenging. Thus, it is a timely endeavor

to undertake a critical literature review on workplace monitoring and surveillance and to find emerging research agenda for more significant theoretical and managerial impact.

SYSTEMATIC REVIEW METHODOLOGY

PRISMA Framework

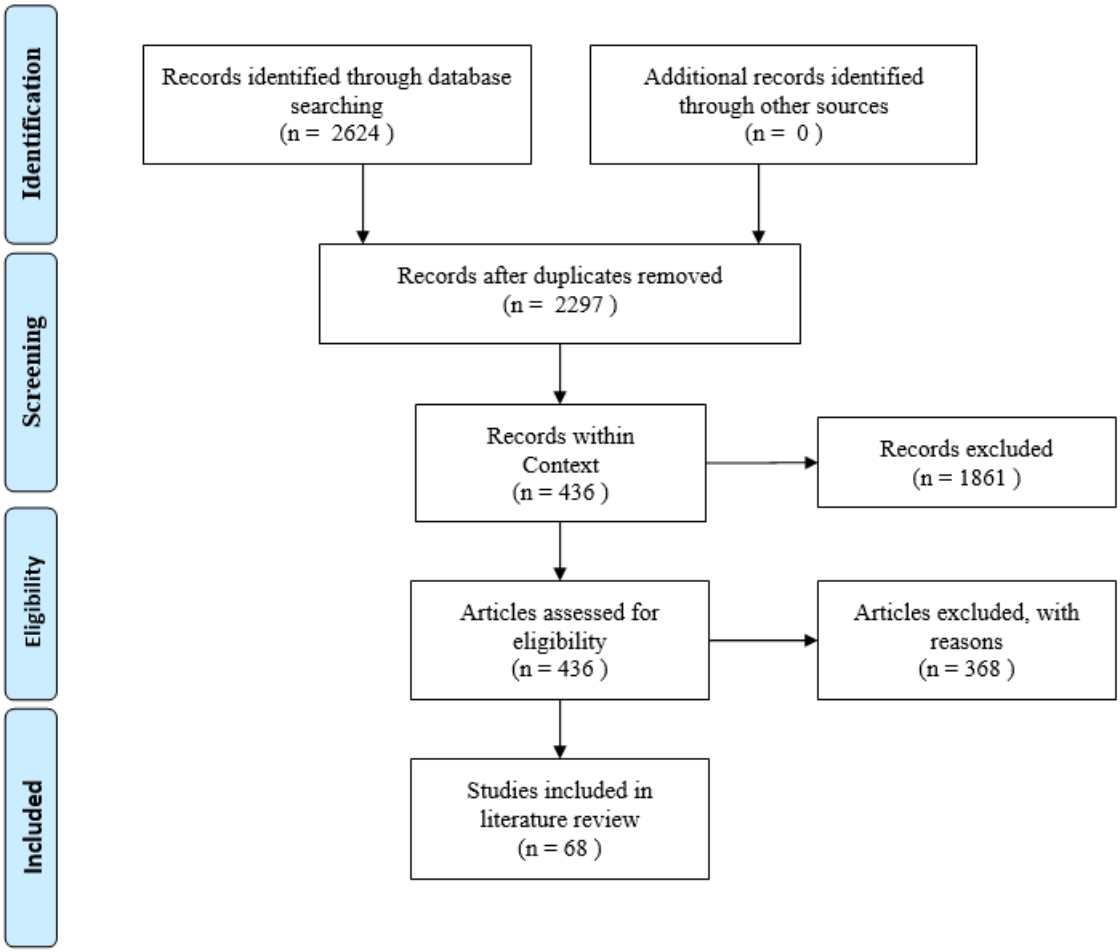
In this critical literature review, we use the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework as the methodology for creating the literature pool [10]. According to this framework, the review or meta-analysis search process has four phases: identification, screening, eligibility, and inclusion. In the identification phase, we use EBSCO Academic Search Complete Databases and search for multiple search terms. We use a preliminary filter of only scholarly peer-reviewed journals and language English. The search terms and results of the searches are summarized in Table 1. We have not used any papers from any other sources; thus, it can be a limitation. However, we intentionally have done that to keep the search scope within a feasible number. In total, we find 2624 articles in this identification phase.

TABLE 1
Keyword-based Database Search Result

Search Number	Search Term (Applied to only English Scholarly Peer-Reviewed Academic Journals)	Search Date (mm/dd/yyyy)	Number of Papers from the Search
1	AB employee AND AB surveillance	06/21/2021	373
2	AB employee AND AB monitoring	07/21/2021	874
3	AB workplace AND AB surveillance	06/21/2021	430
4	AB workplace AND AB monitoring	07/21/2021	949
Total papers from all the searches			2624
AB = Abstract, AND = Logical Connector of Two Terms			

We remove 327 duplicate titles from our preliminary search in the screening phase. After removing these papers, we have 2297 unique titles. Next, we filter the papers that talk about disease surveillance, injury surveillance, cyberspace surveillance, and personal level information surveillance to ensure all the retained papers are within the scope of monitoring and surveillance in an organization. After this filtering process, we are left with 436 unique titles. In the eligibility phase, we have done the screening based on the title, abstract, and introduction section of the paper (if in doubt). We excluded 368 papers as ineligible because of those deemed ineligible because of not closely related to the context of the study. Thus, we select 68 unique papers on surveillance in organizations for this critical literature review exercise. Figure 1 illustrates the PRISMA Flow process of this study.

FIGURE 1
PRISMA Flow Diagram



Before starting the critical literature review on dominant debates and methodology, we would like to summarize some descriptive statistics about the search results. Figure 2 shows the yearly distribution of the 68 papers. We can see a recent surge of surveillance and monitoring papers since the year 2018.

FIGURE 2
Yearly Distribution of Papers

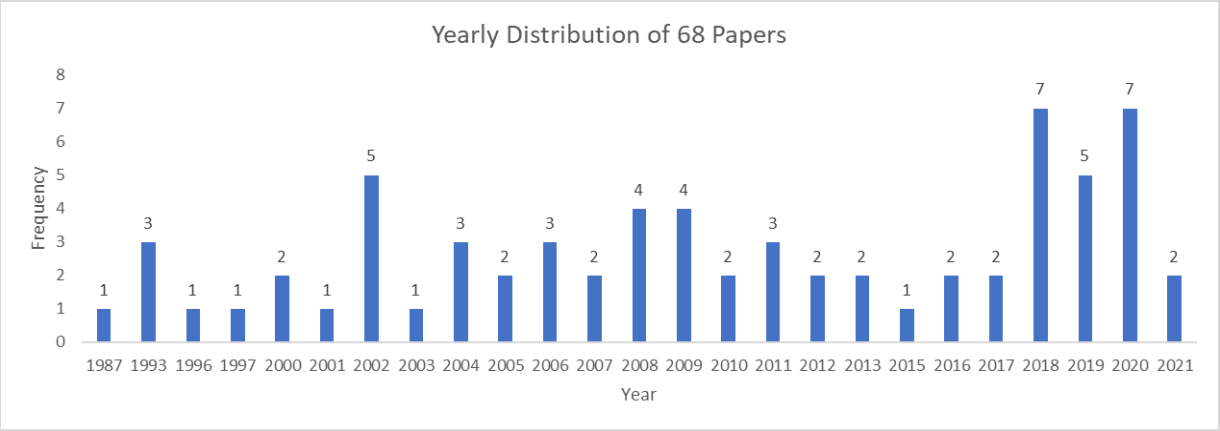
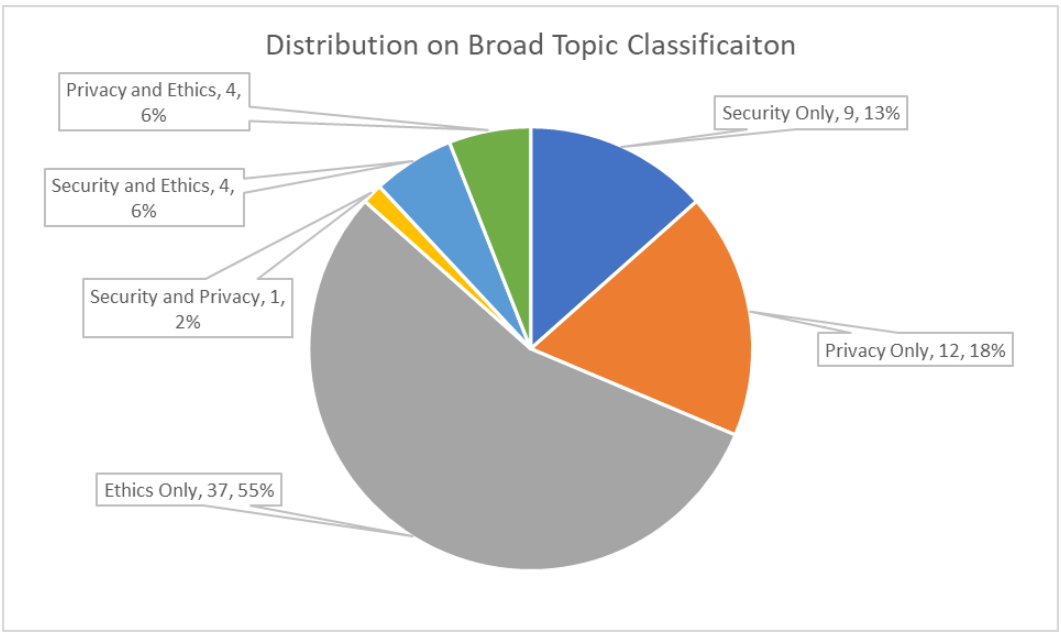


Figure 3 depicts the distribution of papers based on the broad topical classification as per the research scope. We can see ethics as the dominant topic within the papers.

FIGURE 3
Topic Proportions



DOMINANT STREAMS AND DEBATES

The workplace monitoring and surveillance research can be broadly classified into security, privacy, and ethics studies. Moreover, within each of these streams, we find debates about— 1) what information or activity to monitor and surveil, 2) what tool to use in the monitoring and

surveillance, and 3) negative vs. positive consequences of monitoring and surveillance. Thus, this section is going to summarize the finding on the streams and debates within the streams.

Security in Workplace Surveillance

Several primary research objectives within this stream are to develop an RFID based system to monitor organizational attendance [11], to see the impact of surveillance in COVID-19 impacted work-from-home [12], to examine the emergent business practices to reduce and control employee internet misuse [13], to see the impact of surveillance on insider cyber threats [14], to find the impact of surveillance on behavioral risk management [15], to impact of forensic computing surveillance in the workplace [16], to explore the impact of surveillance of human resource information [17], and to find the impact of monitoring on internet abuse by employees [18]. This stream talks about the surveillance of computer use [14], worker productivity [15], employee activity [16], human resource information [17], and internet use [15]. This stream indicates the surveillance tools that are forensic computing tools for employee activity tracking [16], video-recognition tool [9], and facial recognition [19].

In the stream of security in workplace surveillance, we find an emphasis on positive consequences such as computer surveillance reducing insider cyber threats [14], surveillance as part of the employee assistance program can detect unproductivity early and suggest necessary remedial steps to help the employee to be back on track [15], forensic computing reduces the insider threat of cybersecurity breaches [16], and employee surveillance reduces internet abuse by the employees [18]. In this stream, studies also look into the negative consequences that are employee monitoring can deteriorate working relationships and increase security concerns such as data breaches [17], video surveillance increases security concerns [20], and facial recognition increases data breach concerns [19].

Privacy in Workplace Surveillance

Several primary research objectives within this stream are to see whether the productivity monitoring through intelligent wearable technology increases legal controversies surrounding employment and labor law [3], to find the impact of workplace monitoring on the right to private life at work [21], to find the impact of employer's access to employee social media on privacy concerns [22], to find the impact of location-monitoring tools [23], and to find the impact of workplace surveillance on collective bargaining agreements [24]. This stream talks about the surveillance of employee productivity [3, 25], employee activity and social media use [22, 23, 26], computer and e-mail use [6, 27], and video activity [5]. This stream indicates the surveillance tools that are wearable technology [3, 25], social media administrative tools [22], and location-sensors [23].

In the stream of privacy in workplace surveillance, we find emphasize on positive consequences such as the combination of comprehensive omnibus federal information privacy law, a narrower sector-specific employee privacy protection act, information-specific act such as health information act reduces the privacy consequences [25], workplace surveillance's negative impact can be reduced by proper task design, supervisory processes, employee expectation management, and appraisal [2], and employee computer use monitoring increases employee awareness towards

cyber risks [6]. In this stream, studies also look into the negative consequences that are adoption of wearable technology in the workplace increases the changes of legal consequences, namely privacy concerns, unlawful employment discrimination, worker safety, and worker compensation issues [3], workplace monitoring has a detrimental impact on a reasonable expectation of privacy and can increase unfair dismissals [21], workplace surveillance negatively impacts employee well-being, work culture, productivity, creativity, and motivation [2], employee social media surveillance via federal social media regulation such as can lead to gross violation of privacy [22], and the ability to control location-sensing monitoring is related to monitoring fairness through the mediation of privacy invasion [23].

Ethics in Workplace Surveillance

Several primary research objectives within this stream are to explore the effects of general employee attitude towards organizational monitoring [4], to see the impact of surveillance on workplace delinquency [28], to find the impact of workplace surveillance on emotional labor, workplace violence, and depressive symptoms in work [29], to find the impact of surveillance on remote workers [30], and to explore the impact of surveillance during a pandemic [31]. This stream talks about the surveillance of performance and productivity [30-34], computer, e-mail, internet, telecommunication use [4, 7, 35, 36], activity [37, 38], and location [39]. This stream indicates the surveillance tool that are electronic performance management systems [32, 33], machine learning [40], sensor-based monitoring [38], and spying tool [41].

In the stream of ethics in workplace surveillance we find emphasize on positive consequences such as ethical utilitarianism strengthens the positive relationship of positive beliefs about monitoring tools and perceived organizational support, trust in organization, trust in supervisor, and perception on monitoring fairness [4], surveillance is a valuable tool in organizations with prior use of the "Theory X" labor relations, speed up union pressures, in organizations with mature products, in organizations with routine works [1], electronic performance monitoring can increase employee sustained attention and video-based monitoring also has positive impact [42], surveillance plays a deterrence role in reducing workplace delinquency [28], computer monitoring is significantly associated with compliance intention [43], telecommunication monitoring significantly reduces employee telecommunication violation [36], and explanation of electronic performance monitoring is positively associated with perception on informational justice, and justice perception is positively associated with trust in manager, job performance, and job satisfaction [44]. In this stream, studies also look into the negative consequences that are monitoring is negatively associated with lesser intrinsic motivation via less felt trust [45], employee performance monitoring has a negative impact on job design and worker stress [32], electronic monitoring increases stress, job dissatisfaction, and poor quality of work [7], electronic surveillance may increase discriminatory behavior [46], employee surveillances increase the concern for social inequalities [47], employee's feeling of inappropriate e-mail monitoring is associated with the negative response towards top management [48], and surveillance attracts legal consequences [49].

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TABLE 2
Dominant Streams Summary Table

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Ajunwa 2018)	The objective of this research is to see whether the productivity monitoring through smart wearable technology increases legal controversies surrounding employment and labor law.	Privacy & Ethics	Worker productivity	Wearable technology	N/A	N/A	Adoption of wearable technology in the workplace increases the changes of legal consequences namely privacy concerns, unlawful employment discrimination, worker safety, and worker compensation issues.
(Ajunwa et al. 2017)	The objective of this research is to see how existing legal frameworks can be strengthened to minimize the privacy and ethical consequences of productivity monitoring and employee wellness via wearable technologies.	Privacy	Worker productivity, health wellness program	Wearable technology	N/A	Combination of comprehensive omnibus federal information privacy law, a narrower sector-specific employee privacy protection act, information-specific act such as health information act reduces the privacy consequences.	N/A
(Alder et al. 2008)	The objective of this research is to explore the effects of employee general attitude towards organizational monitoring.	Ethics	Internet Use	N/A	Theory of Reasoned Action, Moral Reasoning Theory of Formalism and Utilitarianism	Ethical utilitarianism strengthens the positive relationship of positive beliefs about monitoring tools and perceived organizational support, trust in organization, trust in supervisor, and perception on monitoring fairness.	Ethical formalism strengthens the negative relationship of negative beliefs about monitoring tools and perceived organizational support, trust in organization, trust in supervisor, and perception on monitoring fairness.
(Al-Naima and Ameen 2016)	The objective of this research is to develop a RFID based systems to monitor organizational attendance.	Security	Attendance	RFID-based system	N/A	N/A	N/A
(Atkinson 2018)	The objective of this research is to find the impact of workplace monitoring on the right to private life at work	Privacy	N/A	N/A	N/A	N/A	Workplace monitoring has detrimental impact on reasonable expectation of privacy and can increase unfair dismissals.

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Attewell 1987)	The objective of this research is to develop a integrative conceptual understanding about computer surveillance.	Ethics	N/A	N/A	Corporate culture theory, neo-Marxist theory, product or technological lifecycle theory, contingency theory, industrial sociology.	Surveillance is a useful tool in organizations with prior use of the "Theory X" labor relations, speed up union pressures, in organizations with mature products, in organizations with routine works.	Surveillance generates organized resistance.
(Ball 2002)	The objective of this research is to identify the elements of CCTV monitoring.	Ethics	Video-based activity	CCTV	Socio-technical theory	N/A	N/A
(Ball 2010)	The objective of this research is to review the research findings on workplace surveillance and its consequences.	Privacy & Ethics	N/A	N/A	Socio-technical theory	Workplace surveillance's negative impact can be reduced by proper task design, supervisory processes, employee expectation management, and appraisal.	Workplace surveillance negatively impacts employee well-being, work culture, productivity, creativity, and motivation.
(Bernstrøm and Svare 2017)	The objective of this research is to investigate the impact of monitoring and employee control.	Ethics	N/A	N/A	Self-determination theory	N/A	Monitoring is negatively associated with lesser intrinsic motivation via less felt trust.
(Brown and Dent 2017)	The objective of this research is to find the impact of employer's access to employee social media on privacy concerns.	Privacy	Social media activity	Social media administrative tool	N/A	N/A	Employee social media surveillance via federal social media regulation such as can lead to gross violation of privacy.
(Carayon 1994)	The objective of this research is to design an electronic performance management system	Ethics	Performance	Electronic performance management systems	N/A	N/A	Employee performance management has negative impact on job design and worker stress
(Burrell 2020)	The objective of this research is to see the impact of surveillance in COVID-19 impacted work-from-home team.	Security	Worker productivity	N/A	N/A	Employee engagement, organizational development, virtual team management efforts is required to effectively monitor the work of work-from-home team.	N/A

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Case and Young 2002)	The objective of this research is to examine emergent business practices to reduce and control employee internet misuse.	Security	Internet Use	N/A	N/A	Internet monitoring is required to reduce the employee misuse of electronic mail and internet access to prohibited site from employer network.	N/A
(Chen and Ross 2007)	The objective of this research is to find which individual differences and personality factors impact employee's reaction to surveillance.	Ethics	Performance	Electronic performance management systems	Personality theories	N/A	N/A
(Claypoole and Szalma 2019)	The objective of this research is to see the impact of electronic performance monitoring on sustained employee attention	Ethics	Performance	Electronic performance management systems	N/A	Electronic performance monitoring can increase employee sustained attention and video-based monitoring also has positive impact.	N/A
(Davidson and Henderson 2000)	The objective of this research is to see the impact of electronic performance monitoring on task performance, mood state, and self-reported stress level.	Ethics	Performance	Electronic performance management systems	Social facilitation	Electronic performance monitoring is effective in performing easy task and not so effective in dealing with difficult tasks.	N/A
(De Vries and van Gelder 2015)	The objective of this research is to see the impact of surveillance on workplace delinquency	Ethics	Employee Activity	N/A	Routine Activity Theory	Surveillance plays a deterrence role in reducing workplace delinquency	N/A
(DeTienne and Abbott 1993)	The objective of this research is to establish the importance of electronic monitoring system	Ethics	Employee Activity	Electronic monitoring system	N/A	Employee centric electronic monitoring system brings positive impact in organization	N/A
(Elmuti and Davis 2006)	The objective of this research is to establish the importance of electronic monitoring system	Ethics	Computer use	Electronic monitoring system	N/A	N/A	Electronic monitoring increases stress, job dissatisfaction, and poor quality of work.

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Eivazi 2011)	The objective of this research is to find the justification of employer's decision to implement computer use monitoring	Privacy	Computer use	N/A	N/A	Employee computer use monitoring increases employee awareness towards cyber risks	N/A
(Evans 2007)	The objective of this research is to see how adoption of monitoring technology impacts privacy	Privacy	Employee Activity	N/A	N/A	N/A	Monitoring technology may increase legal backlashes
(Everett et al. 2004)	The objective of this research is to compare countries for e-mail privacy in workplace	Privacy	E-mail	N/A	N/A	N/A	E-mail monitoring in workplace is negatively associated with privacy concern
(Fuchs 2013)	The objective of this research is to integrate existing social science theories to develop a surveillance theory	Ethics	N/A	N/A	Surveillance theory	N/A	Electronic surveillance may increase discriminatory behavior
(Garcia 2020)	The objective of this research is to find the opportunity to build collective action through monitoring technology	Ethics	N/A	N/A	Collective Action	Implementation of surveillance technology increases the opportunity build a more tightly coupled team through collective action.	N/A
(Garden 2018)	The objective of this research is to find the status of labor organizing in the age of technological surveillance	Ethics	Employee Activity	Data analysis and machine learning	N/A	N/A	Implementation of surveillance technology reduces the opportunity of labor organizing.
(George 1996)	The objective of this research is to find the impact of surveillance on work and stress	Ethics	Performance	Electronic performance management systems	N/A	N/A	Computer-based monitoring largely has negative impact on performance and work stress
(Godden 2020)	The objective of this research is to summarize the legal consequences of workplace surveillance	Ethics	N/A	N/A	Legal mobilization theory	N/A	The workplace surveillance has negative group relevant impact such as strike

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Halpern et al. 2008)	The objective of this research is to see the impact of electronic surveillance on management and legal issues in workplace	Privacy	N/A	N/A	N/A	N/A	Organizations doing electronic workplace surveillance needs to take measures to minimize employee surveillance data misuse, unauthorized access, and alteration, thus, they can lessen the reputation damage through legal consequences.
(Hamin 2000)	The objective of this research is to see the impact of surveillance on insider cyberthreats	Security	Computer use	N/A	N/A	Computer surveillance reduces insider cyberthreats	N/A
(Hansen 2004)	The objective of this research is to find the impact of surveillance on behavioral risk management	Security	Worker productivity	N/A	N/A	Surveillance as part of the employee assistance program can detect unproductivity early and suggest necessary remedial steps to help the employee to be back on track	N/A
(Harty-Golder 2006)	The objective of this research is to find the impact of surveillance cameras on workplace privacy	Privacy	CCTV	N/A	N/A	Surveillance cameras must be placed in a manner that does not violate employee privacy	N/A
(Henle et al. 2009)	The objective of this research is to see the impact of surveillance on fairness and cyberloafing	Security & Ethics	Computer use	N/A	Procedural justice theory	Surveillance policy with zero tolerance, progressive discipline, and appeal process leads to higher perception of policy fairness. Periodic monitoring leads to less cyberloafing.	N/A
(Huth 2013)	The objective of this research is to find the impact of surveillance on insider threat and privacy	Security & Privacy	Employee Activity	N/A	N/A	Employee monitoring can reduce insider threat by early detection	Employee monitoring can increase employee privacy concern
(Jiang et al. 2020)	The objective of this research is to examine the side effects of internet monitoring of employees	Ethics	Internet Use	N/A	Self-determination theory, Commitment theory	N/A	Internet monitoring decreases employee satisfaction with internet usage policy, intrinsic motivation to perform a work, and affective work commitment

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Kierkegaard 2005)	The objective of this is to see the ethical implications of e-mail surveillance in workplace	Ethics	E-mail	E-mail interception	N/A	N/A	E-mail monitoring is workplace can increase discriminatory actions
(Kim et al. 2018)	The objective of this research is to find the impact of workplace surveillance on emotional labor, workplace violence, and depressive symptoms in work	Ethics	N/A	N/A	N/A	N/A	Workplace surveillance increases emotional labor, workplace violence, and depressive symptoms in female Bank employees
(Kiss and Mosco 2005)	The objective of this research is to summarize the collective agreements regarding electronic surveillance	Privacy	N/A	N/A	N/A	N/A	Electronic surveillance is associated with a higher privacy related clauses in collective agreements
(Kolb and Aiello 1997)	The objective of this research is to find the impact of computer-based performance monitoring on employee productivity	Ethics	Performance	Electronic performance management systems	N/A	N/A	The employees under computer-based monitoring performance are not faster and more productive than those of whom who are not monitored
(Kuo et al. 2019)	The objective of this study is to explore the possible antecedents of healthcare workers compliance	Ethics	N/A	N/A	N/A	Computer monitoring is significantly associated with compliance intention	N/A
(Leffakis and Doll 2004)	The objective of this research is to find the impact of workplace surveillance on employee telecommunication violation	Ethics	Telecommunication	N/A	Socio-technical theory	Telecommunication monitoring significantly reduces employee telecommunication violation	N/A
(Marchant 2019)	The objective of this research is to explore the ethical standards of sensor-based worker surveillance	Ethics	Employee Activity	Sensor-based worker surveillance	N/A	The sensor-based surveillance can only be successful when the monitoring is fully transparent to the workers	N/A

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Mason et al. 2002)	The objective of this research is to find the impact of technology surveillance on employee responses	Ethics	N/A	N/A	Legitimacy theory	N/A	Technology surveillance in workplace is associated with workplace relations
(McNall and Roch 2009)	The objective of this research is to find the impact of location-monitoring tools	Privacy	Employee Activity	Location-sensing monitoring	N/A	N/A	The ability to control location sensing monitoring is related to monitoring fairness through the mediation of privacy invasion
(McNall and Roch 2011)	The objective of this research is to find the impact of electronic performance monitoring on employee reactions	Ethics	Performance	Electronic performance management systems	Social exchange theory, Justice theory	Explanation of electronic performance monitoring is positively associated with perception on informational justice. Justice perception is positively associated with trust in manager, job performance, and job satisfaction	N/A
(Mika 2012)	The objective of this study is to find the impact of workplace surveillance on collective bargaining agreements	Privacy & Ethics	N/A	N/A	N/A	N/A	Workplace surveillance is negatively related to collection bargaining trust, privacy concern, and reasonable work rules
(Morvan 2009)	The objective of this study is to compare the impact of workplace monitoring on freedom of speech of worker in a two-country comparison	Ethics	N/A	N/A	N/A	N/A	Workplace monitoring has significant legal consequences surrounding freedom of speech in both the US and French legal system
(Nivedita et al. 2021)	The objective of this study is to find machine learning-based solution to transparent workplace surveillance	Security	Video-based activity	Video recognition tools	N/A	N/A	N/A
(Nunn et al. 2002)	The objective of this paper is to find the negative impacts of workplace monitoring	Ethics	N/A	N/A	N/A	N/A	Workplace monitoring can lead to the violation of employee rights

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(O'Rourke et al. 2018)	The objective of this paper is to find the impact of employee social media monitoring on cyberslacking and cyberloafing	Security	Social media activity	N/A	N/A	Employee social media monitoring is associated with a reduction of cyberslacking and cyberloafing and in turn, associated with higher concentration and workplace productivity	N/A
(Posner 2008)	The objective of this research is to see the legal impact of workplace surveillance	Privacy	N/A	N/A	N/A	N/A	Workplace surveillance is associated with higher legal consequences in workplace in terms of privacy invasion
(Raab 2002)	The objective of this paper is to find the impact of workplace surveillance on privacy and trust	Privacy & Ethics	N/A	N/A	N/A	N/A	Workplace surveillance is negatively related to trust in organization via privacy concern
(Rahmanović et al. 2018)	The objective of this paper is to find the impact of video surveillance in productivity	Security & Ethics	Worker productivity	video surveillance	N/A	Video surveillance is positively associated with worker productivity	Video surveillance increases security concern
(Rydzik and Kissoon 2021)	The impact of surveillance of tourism workers during pandemic	Ethics	N/A	N/A	N/A	N/A	Employee surveillances increase the concern for social inequalities
(Sanders et al. 2013)	The impact of workplace surveillance through spying tools	Ethics	Internet Use	Spying tool	N/A	N/A	The usage of spying tool will attack legal consequences via privacy invasion
(Syrek et al. 2021)	The objective of this paper is to explore the impact of surveillance during pandemic	Ethics	Worker productivity	N/A	N/A	N/A	Workplace monitoring without proper supervision is negatively associated with employee well-being
(Snyder and Cornetto 2009)	The objective of this paper is to explore the impact of employee e-mail monitoring	Ethics	E-mail	N/A	Boundary management theory	N/A	Employee's feeling of inappropriate e-mail monitoring is associated with negative response towards top management

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Spitzmüller and Stanton 2006)	The objective of this research is to see the impact of organizational surveillance and monitoring on employee compliance	Ethics	N/A	N/A	Theory of planned behavior	Employee attitude towards workplace surveillance is positively associated with compliance intention	N/A
(Stahl 2008)	The objective of this research is to impact of forensic computing surveillance in workplace	Security	Employee Activity	Forensic computing	Critical theory	Forensic computing reduces the insider threat of cybersecurity breaches	N/A
(Stantont and Weiss 2003)	The objective of this research is to explore the impact of electronic surveillance of human resource information	Ethics	Human resource information	N/A	N/A	N/A	Electronic surveillance is negatively associated with organization trust and work justification
(Stark et al. 2020)	The objective of this research is to find the impact of facial recognition-based surveillance	Security & Ethics	Facial data	Facial recognition technology	N/A	N/A	Facial recognition technology is workplace is negatively associated with privacy concern
(Tataru and Tataru 2020)	The objective of this research is to explore the impact of surveillance of human resource information	Security & Ethics	Human resource information	N/A	N/A	N/A	Employee monitoring can deteriorate working relationship and increase security concern such as data breach
(Valentine 2001)	The objective of this research is to find the relationship between employee monitoring and job satisfaction	Ethics	N/A	N/A	N/A	N/A	Employee monitoring is negatively associated with job satisfaction
(Wallis 2011)	The objective of this paper is to find the impact of employee's official mobile device monitoring	Ethics	Location	Telecommunication monitoring tool	N/A	Mobile device monitoring increases field worker productivity	N/A

Citation	Objective Statement	Topic	What?	How?	Theory	Positive Consequence	Negative Consequence
(Wang et al. 2021)	The objective of this research is to find the impact of surveillance on remote workers	Ethics	Worker productivity	N/A	Personality theories	Social support and monitoring reduced work-for-home challenges , worker performance, and well-being	N/A
(Waxman and Barile 2016)	The objective of this research is to find legal consequences of emerging surveillance techniques such as video and location in public sector	Ethics	Video and location	N/A	N/A	N/A	Surveillance attracts legal consequences
(Webster and Robins 1993)	The objective of this research is to find the	Ethics	N/A	N/A	Social Taylorism	N/A	Employee surveillance impacts long term labor process in the organization
(Yost et al. 2019)	The objective of the research is to find the antecedents and outcome of electronic surveillance	Privacy	N/A	N/A	Organizational citizen theory, psychological reactance theory	N/A	Negative perception on monitoring and surveillance is negatively associated with contextual performance
(Young 2010)	The objective of this study is to find the impact of monitoring on internet abuse by employees	Security	Internet Use	N/A	N/A	Employee surveillance reduces internet abuse by the employees	N/A

DOMINANT METHODS

From our critical review regarding the dominant methods, we have found the qualitative, quantitative, mixed-method study, conceptual, theoretical papers, and design science as the primary classifications. Within the 23 papers under the qualitative method, we find the use of legal document content analysis [41, 49, 50], case study [51], focus group discussion [12], thematic analysis [52], and ethnographic study [39].

Within the 19 papers under the quantitative method, we find the use of longitudinal survey [4], structured equation modeling [45, 48], random co-efficient model [31], multivariate logistic regression [19], logistic regression [29], hierarchical regression [53], and experimental methods [33, 42, 54].

Moreover, we also have found 21 conceptual, theoretical paper that develops understanding about the concepts surrounding security, privacy, and ethics of workplace surveillance [1, 2, 6, 55], four design science papers regarding model and artifact building [9, 11, 20, 32], and one mixed-method study using thematic analysis and survey [30].

Table 3 summarizes the critical review of the methodology.

TABLE 3
Dominant Method Summary Table

Citation	Ontology	Epistemology	Method Type	Specific Method	Setting	Number of Organizations	Number of Respondents
(Ajunwa 2018)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Ajunwa et al. 2017)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Alder et al. 2008)	Realism	Positivist	Quantitative	Longitudinal Survey - Structured Equation Modeling	Employees of sales and service center	Single	186
(Al-Naima and Ameen 2016)	N/A	N/A	Design Science	N/A	N/A	N/A	N/A
(Atkinson 2018)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Attewell 1987)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Ball 2002)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Ball 2010)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Bernstrøm and Svare 2017)	Realism	Positivist	Quantitative	Survey - Structured Equation Modeling	Norwegian employees	Multiple	3015
(Brown and Dent 2017)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Carayon 1994)	N/A	N/A	Design Science	N/A	N/A	N/A	N/A
(Burrell 2020)	Nominalism	Anti-positivist	Qualitative	Focus group discussion	Cybersecurity professional	Multiple	18
(Case and Young 2002)	Realism	Positivist	Quantitative	Survey	Top level executives	Multiple	52

Citation	Ontology	Epistemology	Method Type	Specific Method	Setting	Number of Organizations	Number of Respondents
(Chen and Ross 2007)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Claypoole and Szalma 2019)	Realism	Positivist	Quantitative	Experiment	Student		197
(Davidson and Henderson 2000)	Realism	Positivist	Quantitative	Experiment	Student		48
(De Vries and van Gelder 2015)	Realism	Positivist	Quantitative	Survey	Employees	Multiple	455
(DeTienne and Abbott 1993)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Elmuti and Davis 2006)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Eivazi 2011)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Evans 2007)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Everett et al. 2004)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Fuchs 2013)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Garcia 2020)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Garden 2018)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(George 1996)	Nominalism	Anti-positivist	Qualitative	Case Study	Catalog, utility, communications, and reservations	Multiple	5
(Godden 2020)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A

Citation	Ontology	Epistemology	Method Type	Specific Method	Setting	Number of Organizations	Number of Respondents
(Halpern et al. 2008)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Hamin 2000)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Hansen 2004)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Harty-Golder 2006)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Henle et al. 2009)	Realism	Positivist	Quantitative	Experiment and Survey	Student	N/A	545
(Huth 2013)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Jiang et al. 2020)	Realism	Positivist	Quantitative	Experiment	Software developers	Single	70
(Kierkegaard 2005)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Kim et al. 2018)	Realism	Positivist	Quantitative	Survey - Logistic Regression Analysis	Banking employees in South Korea	Multiple	381
(Kiss and Mosco 2005)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Kolb and Aiello 1997)	Realism	Positivist	Quantitative	Experiment	Student	N/A	124
(Kuo et al. 2019)	Realism	Positivist	Quantitative	Survey - Hierarchical Regression Analysis	Medical workers	Multiple	303
(Leffakis and Doll 2004)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A

Citation	Ontology	Epistemology	Method Type	Specific Method	Setting	Number of Organizations	Number of Respondents
(Marchant 2019)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Mason et al. 2002)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(McNall and Roch 2009)	Realism	Positivist	Quantitative	Experiment - Hierarchical regression	Student		208
(McNall and Roch 2011)	Realism	Positivist	Quantitative	Survey	Call center employees	N/A	257
(Mika 2012)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Morvan 2009)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Nivedita et al. 2021)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Nunn et al. 2002)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(O'Rourke et al. 2018)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Posner 2008)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Raab 2002)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Rahmanović et al. 2018)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Rydzik and Kissoon 2021)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A

Citation	Ontology	Epistemology	Method Type	Specific Method	Setting	Number of Organizations	Number of Respondents
(Sanders et al. 2013)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Syrek et al. 2021)	Realism	Positivist	Quantitative	Survey - Random Coefficient Model	Employee of multinational organization	Single	516
(Snyder and Cornetto 2009)	Realism	Positivist	Quantitative	Survey - Structured Equation Modeling	Full time employees	Multiple	155
(Spitzmüller and Stanton 2006)	Realism	Positivist	Quantitative	Survey - Structured Equation Modeling	Full time employees	Multiple	251
(Stahl 2008)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Stantont and Weiss 2003)	Nominalism	Anti-positivist	Qualitative	Thematic analysis	HR managers and employees	Multiple	20
(Stark et al. 2020)	Realism	Positivist	Quantitative	Survey - Multivariate logistic regression	Full time employees	Multiple	461
(Tataru and Tataru 2020)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Valentine 2001)	Realism	Positivist	Quantitative	Regression analysis	Youth	N/A	2607
(Wallis 2011)	Nominalism	Anti-positivist	Qualitative	Ethnography	Young Employees	Multiple	70
(Wang et al. 2021)	Multiple Ontology	Multiple Epistemology	Mixed-method	Thematic analysis and survey	Full time employees	Multiple	39 for qualitative and 522 for quantitative

Citation	Ontology	Epistemology	Method Type	Specific Method	Setting	Number of Organizations	Number of Respondents
(Waxman and Barile 2016)	Nominalism	Anti-positivist	Qualitative	Content Analysis	Legal document analysis	N/A	N/A
(Webster and Robins 1993)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A
(Yost et al. 2019)	Realism	Positivist	Quantitative	Survey - Structured Equation Modeling	Full time employees	Multiple	231
(Young 2010)	N/A	N/A	Conceptual theoretical paper	N/A	N/A	N/A	N/A

EMERGING RESEARCH AGENDA

First, there is a lack of research in furthering algorithmic fairness in the monitoring and surveillance literature. Current literature investigates security, privacy, and ethical considerations of worker productivity using wearable technology [3], e-mail monitoring using algorithmic approach [27], e-mail monitoring using interception [35], telecommunications monitoring [36], employee activity monitoring using sensor-based tool [38], employee activity monitoring using location-based tool [23], video-recognition surveillance for security [9], worker productivity surveillance using video-recognition [20], and surveillance using facial-recognition [19]. In all these studies, there is a call for further research in machine learning and artificial intelligence use to ease monitoring automation. The negative consequences from these surveillance tools indicate that just making the surveillance automated will not going to minimize the negative consequences. Thus, it is suggested that further research needs to consider how algorithm-based surveillance can be made more transparent and fair in the eye of the employees. This line of research will be practically significant because increasing transparency and fairness will reduce the loss from the legal battle, will increase employee satisfaction, and will uphold the organization's reputation. We also have found only two researches that implement advanced machine learning approaches to handle video recognition-based surveillance [9, 40]. Thus, for this research problem, we are proposing to use a neural network-based advanced machine learning method with the capacity to explain the algorithm for higher transparency and fairness [56].

Second, further research can address the monitoring and surveillance challenges using emerging technologies such as blockchain. Extant literature on security, privacy, and ethics in surveillance investigate the security challenges of RFID-based attendance monitoring [11], CCTV footage monitoring and hacking challenges [57], computer use and insider cyber threats [14], human resource information monitoring and breach [17], internet use and abuse prevention using spying technologies [18]. It is always a concern by the monitoring organization to keep the monitoring data safe from unauthorized use. To keep data safe from breaches, organizations use blockchain technology that gains popularity because of the tamper-proof nature of the system [58]. However, our critical review does not find any studies that integrate blockchain concepts in this context. Thus, we see an opportunity to conduct this research. This proposed line of research will be practically significant because organizations will have another tool that is arguably more secure than any centralized system. From the method review, we identify few research on design science, but none of those design science projects contribute to design science theory as suggested by Baskerville, et al. [59]. Thus, we are proposing a popular design science method by Peffers, et al. [60] to conduct this research and to achieve a more significant theoretical impact.

Third, we call for more multinational and multicultural investigations in monitoring and surveillance research. Current papers mainly cover the security, privacy, and ethical issues of workplace surveillance from a single country perspective. For example, studies are found in the country context of Australia [22], Korea [29], Canada [61], Taiwan [53], and Britain [62]. Few studies try to look into a multicultural perspective, such as surveillance on European Union [3] and country comparison between the U.S. and France [63]. These studies show how cross-country perspective broadens the understanding of country differences, political environment,

and legal frameworks. Thus, more studies of cross-country are needed to enhance our theoretical and practical knowledge in this research domain. From the method review, we find a lack of longitudinal studies. One study we find uses a longitudinal survey that deals with employees' general attitudes toward workplace surveillance [4]. For cross-country studies longtitudinal studies might be able to capture both the country variation and time variation for greater research impact [64].

Fourth, there is a need for more researchers in the group, team, and network context. Extant literature on workplace surveillance heavily focuses on an individual level [2, 4, 30, 43, 45] and organizational level [1, 40] studies. However, group, team, and network are within the individual level and organization level if we consider different blocks that create an organization. Moreover, we do not find much investigation within these levels. The group, team, and network-level investigations will create the opportunity to use more social theories such as social influence and collective impact that we also have found lacking in the current body of knowledge. In terms of practical significance, an organization will better understand the collective thinking of multiple individuals and thus, be able to reduce group-level or team-level security, privacy, and ethical concerns. For this research, we propose social network analysis such as graph analysis of employee perception because no study as of now uses this novel methodological approach [65]. Apart from this method, we can also try to pursue a multi-level study that will be the first of its kind in this research domain [66].

CONCLUSION

Our critical literature review reveals four research gaps that can be investigated by further studies within the context of surveillance and monitoring in the workplace. We also propose suitable research methodologies for each of these researches that cannot only be suitable for the problem but also fill the methodological void identified through the critical review. We expect further studies will continue this line of research following the found emerging themes.

REFERENCES

[1] P. Attewell, "Big Brother and the Sweatshop: Computer Surveillance in the Automated Office," Sociological Theory, Article vol. 5, no. 1, pp. 87-100, Spring87 1987.
[2] K. Ball, "Workplace surveillance: an overview," Labor History, Article vol. 51, no. 1, pp. 87-106, 2010.
[3] I. Ajunwa, "Algorithms at Work: Productivity Monitoring Applications and Wearable Technology as the New Data-Centric Research Agenda for Employment and Labor Law," St. Louis University Law Journal, Article vol. 63, no. 1, pp. 21-53, Fall2018 2018.
[4] G. S. Alder, M. Schminke, T. W. Noel, and M. Kuenzi, "Employee Reactions to Internet Monitoring: The Moderating Role of Ethical Orientation," Journal of Business Ethics, vol. 80, pp. 481-498, 2008.
[5] B. Harty-Golder, "Privacy and surveillance cameras in the workplace," MLO: Medical Laboratory Observer, Article vol. 38, no. 3, pp. 48-48, 2006.
[6] K. Eivazi, "Computer use monitoring and privacy at work," Computer Law & Security Review, Article vol. 27, no. 5, pp. 516-523, 2011.

[7] D. Elmuti and H. H. Davis, "Not Worth the Bad Will," Industrial Management, Article vol. 48, no. 6, pp. 26-30, 2006.
[8] H. Jiang, A. Tsohou, M. Siponen, and Y. Li, "Examining the side effects of organizational Internet monitoring on employees," Internet Research, Article vol. 30, no. 6, pp. 1613-1630, 2020.
[9] M. Nivedita, P. Chandrashekar, S. Mahapatra, Y. A. V. Phamila, and S. K. Selvaperumal, "Image Captioning for Video Surveillance System using Neural Networks," International Journal of Image & Graphics, Article p. 1, 2021.
[10] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement," Annals of internal medicine, vol. 151, no. 4, pp. 264-269, 2009.
[11] F. M. Al-Naima and H. A. Ameen, "Design of an RFID based Students/Employee Attendance System," Majlesi Journal of Electrical Engineering, Article vol. 10, no. 1, pp. 23-33, 2016.
[12] D. N. Burrell, "Understanding the Talent Management Intricacies of Remote Cybersecurity Teams in COVID-19 Induced Telework Organizational Ecosystems," Revista Academiei Fortelor Terestre, Article vol. 25, no. 3, pp. 232-244, 2020.
[13] C. J. Case and K. S. Young, "Employee Internet Management: Current Business Practices and Outcomes," CyberPsychology & Behavior, Article vol. 5, no. 4, pp. 355-361, 2002.
[14] Z. Hamin, "Insider Cyber-threats: Problems and Perspectives," International Review of Law, Computers & Technology, Article vol. 14, no. 1, pp. 105-113, 2000.
[15] S. Hansen, "From 'Common Observation' to Behavioural Risk Management: Workplace Surveillance and Employee Assistance 1914-2003," International Sociology, Article vol. 19, no. 2, pp. 151-171, 2004.
[16] B. C. Stahl, "Forensic Computing in the Workplace: Hegemony, Ideology, and the Perfect Panopticon?," Journal of Workplace Rights, Article vol. 13, no. 2, pp. 167-183, 2008.
[17] G. F. Tataru and Ș. R. Tataru, "Human Resources and Personal Data Protection: An Indissoluble Relationship," Journal of Public Administration, Finance & Law, Article no. 18, pp. 303-311, 2020.
[18] K. Young, "Policies and procedures to manage employee Internet abuse," Computers in Human Behavior, Article vol. 26, no. 6, pp. 1467-1471, 2010.
[19] L. Stark, A. Stanhaus, and D. L. Anthony, ""I Don't Want Someone to Watch Me While I'm Working": Gendered Views of Facial Recognition Technology in Workplace Surveillance," Journal of the Association for Information Science & Technology, Article vol. 71, no. 9, pp. 1074-1088, 2020.
[20] A. Rahmanović, M. Saračević, Ć. Sukić, and M. Mujević, "Possibilities of Applying Video Surveillance and other ICT Tools and Services in the Production Process," TEM Journal, Article vol. 7, no. 1, pp. 128-136, 2018.
[21] J. Atkinson, "Workplace Monitoring and the Right to Private Life at Work," Modern Law Review, Article vol. 81, no. 4, pp. 688-700, 2018.
[22] M. Brown and C. Dent, "Privacy Concerns over Employer Access to Employee Social Media," Monash University Law Review, Article vol. 43, no. 3, pp. 796-827, 2017.
[23] L. McNall and J. Stanton, "Private Eyes Are Watching You: Reactions to Location Sensing Technologies," Journal of Business & Psychology, Article vol. 26, no. 3, pp. 299-309, 2011.

[24] K. Mika, "Privacy in the Workplace: Are Collective Bargaining Agreements a Place to Start Formulating More Uniform Standards?," Willamette Law Review, Article vol. 48, no. 2, pp. 251-274, Winter2012 2012.
[25] I. Ajunwa, K. Crawford, and J. Schultz, "Limitless Worker Surveillance," California Law Review, Article vol. 105, no. 3, pp. 735-776, 2017.
[26] L. Evans, "Monitoring Technology in the American Workplace: Would Adopting English Privacy Standards Better Balance Employee Privacy and Productivity?," California Law Review, Article vol. 95, no. 4, pp. 1115-1149, 2007.
[27] A. M. Everett, Y.-Y. Wong, and J. Paynter, "Balancing Employee and Employer Rights: An International Comparison of E-Mail Privacy in the Workplace," Journal of Individual Employment Rights, Article vol. 11, no. 4, pp. 291-311, 2004.
[28] R. E. De Vries and J.-L. van Gelder, "Explaining workplace delinquency: The role of Honesty–Humility, ethical culture, and employee surveillance," Personality & Individual Differences, Article vol. 86, pp. 112-116, 2015.
[29] G. H. Kim et al., "Emotional labor, workplace violence, and depressive symptoms in female Bank employees: a questionnaire survey using the K-ELS and K-WVS," Annals of Occupational & Environmental Medicine, Article vol. 30, pp. 1-1, 2018.
[30] B. Wang, Y. Liu, J. Qian, and S. K. Parker, "Achieving Effective Remote Working During the COVID-19 Pandemic: A Work Design Perspective," Applied Psychology: An International Review, Article vol. 70, no. 1, pp. 16-59, 2021.
[31] C. Syrek, J. Kühnel, T. Vahle-Hinz, and J. Bloom, "Being an accountant, cook, entertainer and teacher—all at the same time: Changes in employees' work and work-related well-being during the coronavirus (COVID-19) pandemic," International Journal of Psychology, Article p. 1, 2021.
[32] P. Carayon, "Effects of Electronic Performance Monitoring On Job Design and Worker Stress: Results of Two Studies," International Journal of Human-Computer Interaction, Article vol. 6, no. 2, p. 177, 1994.
[33] R. Davidson and R. Henderson, "Electronic Performance Monitoring: A Laboratory Investigation of the Influence of Monitoring and Difficulty on Task Performance, Mood State, and Self-Reported Stress Levels," Journal of Applied Social Psychology, Article vol. 30, no. 5, pp. 906-920, 2000.
[34] K. J. Kolb and J. R. Aiello, "Computer-Based Performance Monitoring and Productivity in a Multiple Task Environment," Journal of Business & Psychology, Article vol. 12, no. 2, pp. 189-204, Winter97 1997.
[35] S. Kierkegaard, "Privacy in electronic communication: Watch your e-mail: Your boss is snooping!," Computer Law & Security Review, Article vol. 21, no. 3, pp. 226-236, 2005.
[36] Z. M. Leffakis and W. J. Doll, "Using High-Performance Work Systems to Support Individual Employment Rights and Decrease Employee Telecommunication Violations in the Workplace," Journal of Individual Employment Rights, Article vol. 11, no. 4, pp. 275-290, 2004.
[37] K. B. DeTienne and N. T. Abbott, "Developing an employee-centered electronic monitoring system," Journal of Systems Management, Article vol. 44, no. 8, p. 12, 1993.
[38] G. E. Marchant, "What Are Best Practices for Ethical Use of Nanosensors for Worker Surveillance?," AMA Journal of Ethics, Article vol. 21, no. 4, pp. 356-362, 2019.
[39] C. Wallis, "Mobile phones without guarantees: The promises of technology and the contingencies of culture," New Media & Society, Article vol. 13, no. 3, pp. 471-485, 2011.

[40] C. Garden, "Labor Organizing in the Age of Surveillance," St. Louis University Law Journal, Article vol. 63, no. 1, pp. 55-68, Fall2018 2018.
[41] D. E. Sanders, J. K. Ross, and P. Pattison, "Electronic Snoops, Spies, and Supervisory Surveillance in the Workplace," Southern Law Journal, Article vol. 23, no. 1, pp. 1-27, Spring2013 2013.
[42] V. L. Claypoole and J. L. Szalma, "Electronic Performance Monitoring and sustained attention: Social facilitation for modern applications," Computers in Human Behavior, Article vol. 94, pp. 25-34, 2019.
[43] C. Spitzmüller and J. M. Stanton, "Examining employee compliance with organizational surveillance and monitoring," Journal of Occupational & Organizational Psychology, Article vol. 79, no. 2, pp. 245-272, 2006.
[44] L. McNall and S. Roch, "A Social Exchange Model of Employee Reactions to Electronic Performance Monitoring," Human Performance, Article vol. 22, no. 3, pp. 204-224, 2009.
[45] V. H. Bernstrøm and H. Svare, "Significance of Monitoring and Control for Employees' Felt Trust, Motivation, and Mastery," Nordic Journal of Working Life Studies, Article vol. 7, no. 4, pp. 29-49, 2017.
[46] C. Fuchs, "Political Economy and Surveillance Theory," Critical Sociology (Sage Publications, Ltd.), Article vol. 39, no. 5, pp. 671-687, 2013.
[47] A. Rydzik and C. S. Kissoon, "Decent work and tourism workers in the age of intelligent automation and digital surveillance," Journal of Sustainable Tourism, Article pp. 1-18, 2021.
[48] J. Snyder and K. Cornetto, "Employee Perceptions of E-mail Monitoring from a Boundary Management Perspective," Communication Studies, Article vol. 60, no. 5, pp. 476-492, 2009.
[49] S. S. Waxman and F. G. Barile, "“Eye in The Sky": Employee Surveillance in the Public Sector," Albany Law Review, Article vol. 79, no. 1, pp. 131-149, 2016.
[50] C. L. Huth, "The insider threat and employee privacy: An overview of recent case law," Computer Law & Security Review, Article vol. 29, no. 4, pp. 368-381, 2013.
[51] J. F. George, "Computer-Based Monitoring: Common Perceptions and Empirical Results," MIS Quarterly, Article vol. 20, no. 4, pp. 459-480, 1996.
[52] J. M. Stantont and E. M. Weiss, "Organisational databases of personnel information: contrasting the concerns of human resource managers and employees," Behaviour & Information Technology, Article vol. 22, no. 5, p. 291, 2003.
[53] K.-M. Kuo, P. C. Talley, and T.-J. Cheng, "Deterrence approach on the compliance with electronic medical records privacy policy: the moderating role of computer monitoring," BMC Medical Informatics & Decision Making, journal article vol. 19, no. 1, pp. N.PAG-N.PAG, 2019.
[54] C. A. Henle, G. Kohut, and R. Booth, "Designing electronic use policies to enhance employee perceptions of fairness and to reduce cyberloafing: An empirical test of justice theory," Computers in Human Behavior, Article vol. 25, no. 4, pp. 902-910, 2009.
[55] J. V. Chen and W. H. Ross, "Individual differences and electronic monitoring at work," Information, Communication & Society, Article vol. 10, no. 4, pp. 488-505, 2007.
[56] A. Chouldechova and A. Roth, "A snapshot of the frontiers of fairness in machine learning," Communications of the ACM, vol. 63, no. 5, pp. 82-89, 2020.
[57] K. Ball, "Elements of Surveillance: A New Framework and Future Direction," Information, Communication & Society, Article vol. 5, no. 4, p. 573, 2002.

[58] X. Pan, X. Pan, M. Song, B. Ai, and Y. Ming, "Blockchain technology and enterprise operational capabilities: An empirical test," International Journal of Information Management, vol. 52, p. 101946, 2020.
[59] R. Baskerville, A. Baiyere, S. Gregor, A. Hevner, and M. Rossi, "Design science research contributions: finding a balance between artifact and theory," Journal of the Association for Information Systems, vol. 19, no. 5, p. 3, 2018.
[60] K. Peffers, T. Tuunanen, M. A. Rothenberger, and S. Chatterjee, "A design science research methodology for information systems research," Journal of Management Information Systems, vol. 24, no. 3, pp. 45-77, 2007.
[61] S. Kiss and V. Mosco, "Negotiating Electronic Surveillance in the Workplace: A Study of Collective Agreements in Canada," Canadian Journal of Communication, Article vol. 30, no. 4, pp. 549-564, 2005.
[62] D. Mason, G. Button, G. Lankshear, S. Coates, and W. Sharrock, "On the Poverty of Apriorism: Technology, Surveillance in the Workplace and Employee Responses," Information, Communication & Society, Article vol. 5, no. 4, p. 555, 2002.
[63] P. Morvan, "A Comparison of the Freedom of Speech of Workers in French and American Law," Indiana Law Journal, Article vol. 84, no. 3, pp. 1015-1046, Summer2009 2009.
[64] J. R. Darling and V. R. Wood, "A longitudinal study comparing perceptions of US and Japanese consumer products in a third/neutral country: Finland 1975 to 1985," Journal of International Business Studies, vol. 21, no. 3, pp. 427-450, 1990.
[65] P. J. Carrington, J. Scott, and S. Wasserman, Models and methods in social network analysis. Cambridge university press, 2005.
[66] T. A. Snijders and R. J. Bosker, Multilevel analysis: An introduction to basic and advanced multilevel modeling. Sage, 2011.

Level of Cybersecurity Readiness of Small and Medium Nonprofit Organizations (NPOs) During COVID-19

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ABSTRACT

Considering the unprecedented COVID-19 pandemic crisis, many NPOs, like other types of institutions, have migrated their operations to remote, virtual platforms to maintain at least a minimum level of activity. Consequently, the NPOs are experiencing an increased level of online activity during COVID-19. This study assesses the level of NPOs' readiness during COVID-19 through the lens of three components of the ISO 22301:2019 - Business Continuity Management Systems (BCMS) – labeled as 3Ps: Policy, People, and Processes. A survey study using a snowball sampling approach was conducted to examine information security readiness in small and medium-sized NPOs during the Covid-19 Pandemics in D.C., Maryland, and Virginia (DMV) area. Each item in the three aspects of readiness was measured at the level of high, moderate, or low. The findings of the study demonstrate that the NPOs should put more emphasis on developing and implementing cybersecurity policies during crises to increase the level of awareness and preparedness. The empirical results of this study further shed light on the aspects and factors of cybersecurity readiness that are often less prioritized by NPOs senior management but should be taken into more consideration when creating cybersecurity policies and procedures.

Keywords— NPOs, cybersecurity, readiness, crisis, management, COVID-19

Introduction

A. Cybersecurity during COVID-19 and NPs

Microsoft's *Nonprofit Guidelines for Cybersecurity and Privacy* highlights that in 2016, nearly one-third of the top fifteen contract recipients of the city of New York were nonprofits, awarded contracts worth a combined total of 404 million dollars [9]. The increasing prevalence of awards such as these have irrevocably altered nonprofit operation and management. Today, NPOs face an ever-changing landscape of technology, economy, and

culture [11]. Therefore, each nonprofit organization's cybersecurity standards should be aligned with its peers in the industry as well as their private counterparts.

These new roles lead to new strategies, like data sharing between various partner-organizations and NPOs' increasing turn to ideas of e-governance and accountability through the Internet [5]. Digital interaction of this kind with donors, beneficiaries, the public, and partners subsequently increases the possibility of NPO data exposure.

Contrary to common perceptions, nonprofit organizations, much the same as for-profit businesses, engage in a variety of activities involving data collection [10]. Despite managing a lot of data, as [12] noted, the technology isn't often a top priority for NPOs, given the required resources and costs. On the other hand, research indicates that the information systems of NPOs are vulnerable to cybercrimes [5]. Moreover, considering the unprecedented COVID-19 pandemic crisis, many NPOs, like other institutions, have migrated their operations onto remote, virtual platforms to maintain at least a minimum level of activity. Consequently, NPOs are experiencing an increased level of online activity during COVID-19. According to [1], although charities face similar kinds of cybersecurity threats as their for-profit counterparts, the NPOs experienced particularly aggressive phishing attacks in the COVID-19 work-from-home setting.

A recent report published by Deloitte [2] that analyzes their Cyber Intelligence Center cases has concluded that while the entire globe has focused on the health, economic, and financial risks that the COVID-19 pandemic has created, cybercriminals have used these circumstances to perform even more illicit activity. [2] recorded a spike in phishing attacks, Malspam, and ransomware attacks since the escalation of the COVID-19 pandemic.

NPOs, now more than ever, can become victims of cyberattacks. Is this circumstance influencing cybersecurity readiness levels within nonprofit organizations? How should the senior management of NPOs adjust the risk control strategies of their organizations to respond? To the best of our knowledge, this is one of the few studies to address both the academic and industry gap in the less-researched field of nonprofit organizations, in conjunction with the unprecedented COVID-19 pandemic crisis.

B. The Business Continuity Management Systems (BCMS) Components: 3Ps - Policy, People, and Processes

ISO (International Organization for Standardization) 22301:2019 (EN) Security and Resilience — Business Continuity Management Systems (BCMS) documents a set of generic requirements that can be adopted by any organization when implementing and maintaining a management system, with the purpose to improve an organization's capability to prepare for, respond to, and recover from disruptions when they arise [7]. Similar to any other management system, a BCMS includes the following components specified by this standard:

a) a policy;

b) competent people with defined responsibilities;

c) management processes; and

d) documented information supporting operational control and enabling performance evaluation [7].

For this project, three (3) components of the BCMS were used as the metrics to estimate the cybersecurity readiness of an organization, each assessing the cybersecurity measures taken by the NPOs from a different perspective, including policy, people, and processes. They are referred to in this project as the 3Ps. Operational control and performance evaluations do not constitute the subject of the current study; therefore, data corresponding to these two aspects was not collected in line with the scope of this study.

Methodology

The present research was conducted initially as part of the author's dissertation work at Marymount University. The current paper represents an extension of Section 1, Chapter 5 of the author's D.Sc. Thesis [3]. The present paper describes only the "readiness" aspect of the findings by using the descriptive analysis to identify the mean value as a measure of the readiness level, following [8] methodology of reporting the Level of Readiness of disaster recovery and information technology security, readiness and awareness levels.

Research Design

The current research study used a postpositivist, quantitative, nonexperimental survey research approach. For this project, a snowball approach was used to collect data. The survey response rate was monitored through a chain of control and custody. Seventy-two (72) responses were recorded, and seven (7) responses were not considered in the data analysis, following the bias-reduction methods. A total of sixty-five (65) valid responses have been used in data analysis. The respondents self-identified as "part of the NPO's leadership team," and through the survey, they expressed their perceptions of their cybersecurity readiness as an organization during COVID-19.

Instrument – Survey

The current research project used an existing, previously utilized instrument – the National Cyber Security Alliance (NCSA) survey for assessing small businesses' cybersecurity practices [14]. This research project's instrument replaced the original instrument's usage of "small business/business" with "nonprofit" and added a time frame statement: "during COVID-19." The original survey instrument was directly collected from the NCSA's website, and no special permission was required as per NCSA's Public License Grant to Use Website Contents. The corresponding Survey Questions for the 3 Ps (BCMS components) are listed in Annex 1.

Population – NPOs in DMV Area

This research project considers nonprofit organizations located in the D.C., Maryland, and Virginia (DMV) area as its target population. More elaborations are provided as follows.

What is "the DMV Area"? The study exclusively considers organizations that are physically located in Washington, DC (full geographical area), Maryland (Prince George's County and Montgomery County) and Virginia (Arlington County, Fairfax County, and Census-designated places in Fairfax County, including Falls Church City, Alexandria City, and Fairfax City (Fairfaxcounty.gov, 2020). The current research study used corresponding ZIP Codes to determine the NPOs located in the designated geographic area.

What are nonprofit organizations (NPOs)? The Internal Revenue Services (IRS) defines nonprofits as charitable organizations that "must not be organized or operated for the benefit of private interests" [6] and fall under section 501(c)(3) of the Internal Revenue Code, which covers the following purposes: "charitable, religious, educational, scientific, literary, testing for public safety, fostering national or international amateur sports competition, and preventing cruelty to children or animals" [6].

According to the current project's research design, the only organizations that have been considered are those that are registered 501(c)(3) organizations that fulfill the following criteria: (1) an annual income of less than $49,999,999; (2) a primary exempt activity serving human beneficiaries; and (3) a number of employees less than 250 [6]. Additionally, only organizations that filed taxes with the IRS in 2019 were considered, as their information is publicly available on the IRS website.

Research Approach

The current research paper used a quantitative method to assess the perception of cybersecurity readiness of the NPOs during Covid-19. The SPSS statistical software was used for data analysis and focused on descriptive statistics to obtain the mean value (Table 1) as a measure of readiness level, following [8] methodology of reporting the Level of Readiness for disaster recovery and information technology security. Readiness and awareness levels can be calculated by taking the highest mean score minus the lowest mean score and dividing it by 3. The result has been added to the minimum and maximum value to create three measurement levels at low, moderate, and high with respective value ranges for each measurement. Although the findings do not represent the Level of Cybersecurity Readiness in absolute terms, the methodology does help in ranking the readiness and awareness levels between the variables and in comparison with the clusters. This allows a better understanding of the level of readiness in relative terms and within the model; therefore, it was considered suitable for the current research paper.

Key Findings

Table 1 presents the Descriptive Statistics information – including the Variable, the Scale, the Mean value, the Standard Deviation, and Minimum & Maximum.

Table 1
Descriptive Statistics

Variable	Scale	Mean	Standard Deviation	Minimum	Maximum
People1	5-Point Likert Scale	2.52	1.348	1	5
People2	5-Point Likert Scale	2.68	1.348	1	5
People3	5-Point Likert Scale	1.92	0.924	1	5
People4	5-Point Likert Scale	1.98	1.431	1	5
Policy1	5-Point Likert Scale	1.6	1.356	1	5
Policy2	5-Point Likert Scale	1.34	1.02	1	5
Policy3	5-Point Likert Scale	1.68	1.239	1	5
Policy4	5-Point Likert Scale	2.00	1.25	1	5
Process1	5-Point Likert Scale	2.38	1.476	1	5
Process2	5-Point Likert Scale	2.38	1.343	1	5
Process3	5-Point Likert Scale	2.63	1.206	1	5
Process4	5-Point Likert Scale	2.94	1.478	1	5

Calculating the Level of Readiness for People Component within its cluster -

Following [8] methodology, the readiness level for the BCMS Component People was calculated by taking the highest mean score (2.68) minus the lowest mean score (1.92) and dividing by 3 (result = 0.25). The resulted ranges for the three measurement levels are the following

- 1.92 - 2.17 - low
- 2.18 - 2.42 - moderate
- 2.43 - 2.68 - high

Table 2
Level of Readiness for People Within Its Cluster

BCMS Component – People	Mean	Level of Readiness
People 1	2.52	High
People 2	2.68	High
People 3	1.92	Low
People 4	1.98	Low

Calculating the Level of Readiness for Process Component within its cluster -

Following [8] methodology, the readiness level for each BCMS Component Process was calculated by taking the highest mean score (2.94) minus the lowest mean score (2.38) and dividing by 3 (result = 0.18). The resulted ranges for the three measurement levels are the following

- 2.38 - 2.56 - low
- 2.57 - 2.75 - moderate
- 2.76 - 2.94 - high

Table 3
Level of Readiness for Process Within Its Cluster

BCMS Component – Process	Mean	Level of Readiness
Process 1	2.38	Low
Process 2	2.38	Low
Process 3	2.63	Moderate
Process 4	2.94	High

Calculating the Level of Readiness for Policy Component within its cluster -

Following [8] methodology, the readiness level for each BCMS Component Policy was calculated by taking the highest mean score (2.00) minus the lowest mean score (1.34) and dividing by 3 (result = 0.22). The resulted ranges for the three measurement levels are the following

- 1.34 - 1.56 - low
- 1.57 - 2.77 - moderate
- 1.78 - 2.00 - high

Table 4
Level of Readiness for Policy Within Its Cluster

BCMS Component – Policy	Mean	Level of Readiness
Policy 1	1.6	Moderate
Policy 2	1.34	Low

Policy 3	1.68	Moderate
Policy 4	2.00	High

A. Comparing the Level of Readiness for all Components within the Same Scalable Measure - 5-Point Likert Scale

Following [8] methodology, the readiness level for BCMS Components was calculated by taking the highest mean score (2.94) minus the lowest mean score (1.34) and dividing by 3 (result = 0.53). The resulted ranges for the three measurement levels are the following

- 1.34 - 1.87 - low
- 1.88 - 2.40 - moderate
- 2.41 - 2.94 - high

Considering the Mean values presented in Table 1, the Level of Readiness for each BCMS has been established. Tables 5, 6, and 7 showed the Level of Readiness for BCMS Components: People, Policy, and Processes of the small and medium-sized NPOs in the DMV Area.

Table 5
Level of Readiness for People

BCMS Component – People	Mean	Level of Readiness
People 1	2.52	High
People 2	2.68	High
People 3	1.92	Moderate
People 4	1.98	Moderate

Table 6
Level of Readiness for Process

BCMS Component – Process	Mean	Level of Readiness
Process 1	2.38	Moderate
Process 2	2.38	Moderate
Process 3	2.63	High
Process 4	2.94	High

Table 7
Level of Readiness Level for Policy

BCMS Component – Policy	Mean	Level of Readiness
Policy 1	1.6	Low
Policy 2	1.34	Low
Policy 3	1.68	Low
Policy 4	2.00	Moderate

The following color-coded rules have been used for the visual representation of the Level of Readiness:

Table 8

Color-codded Rule

Color	Level of Readiness
Red	Low
Yellow	Moderate
Green	High

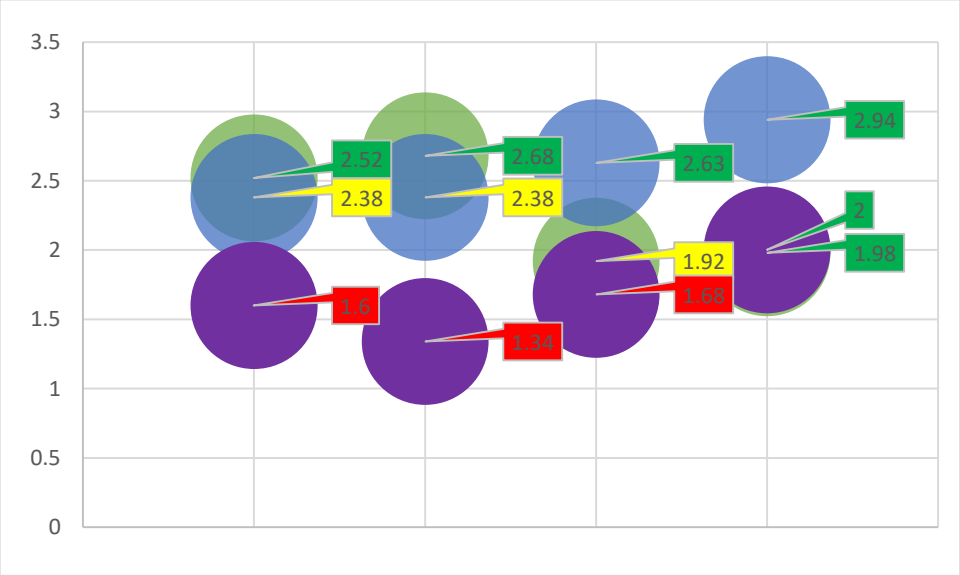
Figure 1 represents a visual color-coded demonstration of the various Levels of Readiness for each BCMS Component. The vertical numeric values represent the ranges for the Mean value. The color-coded squared values represent the actual Mean value for each BCMS Component according to the color-coded Level of Readiness.

Figure 1
Individual Levels of Readiness for People, Policy, and Process

Figure 2 represents the Combined Levels of Readiness for People, Policy, and Process BCMS components with the actual Mean values for each BCMS Component according to the color of Level of Readiness. Figure 2 gives a general perspective of the Level of Readiness of each component, facilitating the visual comparison of the Process BCMS components.

Figure 2

Combined Levels of Readiness Level for People, Policy, and Process



Discussion

According to [4], the readiness level is defined as "the level of an organization's awareness, preparedness, and commitment to prevent and combat cyber-attacks." Therefore, the findings of the current research should serve as proof for senior NPO managers to focus their cybersecurity strategies towards People, Processes, and Policies. NPOs can use existing cybersecurity frameworks like the NIST Risk Management Framework (RMF) to improve their risk management strategies and protect the organizations from cyber threats in such an unprecedented circumstance as COVID-19.

The current paper describes a finding from a more complex study that surveyed 65 NPOs employees, part of the NPOs' leadership, to determine their perceptions of their cybersecurity readiness as an organization.

Data analysis of the current research project showed that within the People component, the NPOs' leaders have a higher perception of readiness when talking about the level of support and emphasis from the senior management, however, their readiness perception is lowest when comes to the ability of the employees to detect spear-phishing (and other types) attacks and given the number of hours of cybersecurity training.

Within the Process component, the NPOs' leaders have a higher perception of readiness if a manual backup procedure would be needed in case of an attack, however, they have a lower perception of readiness regarding a process for employees to report cyber-attacks to

leadership or data and equipment security. A moderate level of readiness is perceived by the NPOs' leaders in regard to the immediate data breach response process.

And finally, within the Policy component, the NPOs' leaders have a moderate perception of readiness when considering a clearly defined cybersecurity policy, business continuity, and disaster recovery policy; high perception of readiness thinking about the escalation of suspicion events; and moderate perception of readiness regarding the knowledge management of cybersecurity policy.

Overall, when comparing the clusters, the perceived Level of Readiness for Policy is considerably lower than the Level of Readiness for People and Processes. This finding suggests that small and medium-sized NPOs should emphasize developing and implementing cybersecurity policies during crises to increase the level of awareness and preparedness among employees.

The authors acknowledged the limitations of this study as per its research design. The nonprobability sampling procedure generally does not control for selection bias and does not permit the calculation of sampling error [13, p.172]. However, two bias reduction methods have been used in this study to alleviate such limitations: chain of control and custody and purposeful sampling. Purposeful nonprobability sampling is an appropriate technique that rejects biases in cases with precise selection criteria in which only qualifying participants will be considered in data collection and analysis. The current project used the following exact criteria for the respondents:

1. Physical location of the NPO (DMV Area)
2. Restricted number of employees (less than 250)
3. Restricted size of the annual budget (less than $50 million)
4. Respondent participant is part of the NPO's leadership team

As the current research project is considered an exploratory study is aiming to enlarge the limited body of knowledge on the topic rather than an in-depth explanatory analysis hence, a nonprobability sampling procedure was selected as it is regarded suitable for the exploratory type of research.

Conclusions and Future Research Directions

The existing literature suggested that three factors influence security preparedness among NPOs: (1) [lack of] information security culture; (2) [lack of] information security awareness; and (3) [lack or misuse of] information security policies [5].

This being said, it is recommended that small NPOs should have higher cybersecurity awareness and establish information security practices to ensure the safeguard of their informational assets. Additionally, these entities should be supported through accessible or affordable cybersecurity programs since they face budget limitations and restrictions as their income is social mission-oriented.

We consider that the findings of the current paper are contributing to the enhancement of business and management practice and also elevating the understanding of the workforce

behavior when evaluating information security: a relatively new priority for businesses and nonprofit entities. Central to the entire discipline of cybersecurity is the concept of the human aspect of information security. As the current study shows, the challenges experienced by nonprofit organizations over the past two years remain unprecedented; therefore, there is an increasing need for entities to introduce new measures and practices that would align with the evolving cybersecurity threats.

To our knowledge, little research has been found that surveyed nonprofit organizations regarding their information security preparedness in conjunction with the unprecedented COVID-19 pandemic crisis. The primary objective of this study was to address both the academic and industry gap in the less-researched field of a nonprofit organization and highlight the evolving necessity of cybersecurity awareness in both for-profit and nonprofit entities.

The current study highlights that cybersecurity awareness must be positioned as urgent when discussing the improvement of business concepts and concrete, practical measures to be implemented (e.g., enforcement of cybersecurity policy and procedures). To increase awareness and shape workforce behavior, cybersecurity needs to be embraced by organizations as an indispensable component in business development and success. This paper has advanced the practice of business management by placing cybersecurity awareness in the top priorities of NPOs and urging nonprofit leaders to take active steps in developing cybersecurity strategies, policies, procedures, and employee training programs, as the cybersecurity threats are evolving and are so dangerous for cyber-vulnerable entities such as nonprofits.

Additionally, the authors identified several future research directions delineated as follows. First, the current study targeted NPOs located in the DMV area with less than 250 employees and an annual budget of less than $50 million. In order to increase the generalizability of the study findings, larger samples from more diverse geographical locations can be recruited for data analysis. Second, the current research project targeted organizations that have primarily human beneficiaries. Therefore, organizations labeled with letter code C: Environmental Quality, Protection and Beautification and D: Animal-Related according to the National Taxonomy of Exempt Entities (NTEE) code [6] have been excluded, as well as other organizations that do not describe themselves as having “human beneficiaries.” A future study may extend the focus to the non-human beneficiaries and compare the findings across different types of beneficiaries. Finally, when taking a closer look at the People component, volunteer participation becomes a unique feature of NPOs. The number of volunteers involved and the level of cybersecurity awareness of those volunteers emerge as interesting variables to examine further.

REFERENCES

[1] Anders, S.B., *Cybersecurity Resources for a remote workforce: Certified public accountant.* The CPA Journal, 2020. **90**(7): p. 72-73.
[2] Deloitte. *Impact of COVID-19 on Cybersecurity*. 2020; Available from: https://www2.deloitte.com/ch/en/pages/risk/articles/impact-covid-cybersecurity.html.
[3] Ermicioi, N., *Factors affecting nonprofits' information security readiness during crises: A study of COVID-19's impact on small and medium nonprofit organizations (NPOS) in the DMV area*, in *School of Technology and Innovation*. 2020, . Marymount University.
[4] Hasan, S., et al., *Evaluating the cyber security readiness of organizations and its influence on performance.* Journal of Information Security and Applications, 2021. **58**: p. 102726.
[5] Imboden, T.R., et al., *How are nonprofit organizations influences to create and adopt information security policies? .* Issues in Information Systems, 2013. **14**(2): p. 166-173.
[6] IRS. *Exempt Purposes - Internal Revenue Code Section 501(c)(3)*. 2019; Available from: https://www.irs.gov/charities-non-profits/charitable-organizations/exemptpurposes-internal-revenue-code-section-501c3.
[7] ISO. *ISO 22301:2019 (EN) Security and Resilience — Business Continuity Management Systems-Requirements*. 2019; Available from: https://www.iso.org/obp/ui/#iso:std:iso:22301:ed-2:v1:en.
[8] Kasim, S.A. and I.B. Mohamed, *Level of Readiness in IT Disaster Recovery Plan*, in *Cyber Resilience Conference (CRC)*. 2018. p. 1-4.
[9] Microsoft Corporation. *Nonprofit Guidelines for Cybersecurity and Privacy*. 2017; Available from: https://download.microsoft.com/download/1/D/4/1D494A7D-D153-40FC-BC18-F4C2F800E752/Nonprofit_Guidelines_for_Cybersecurity_and_Privacy.pdf.
[10] National Council of Nonprofits *Cybersecurity for Nonprofits*. 2019.
[11] Renshaw, S. and G. Krishnaswamy, *Critiquing the Knowledge Management Strategies of Non-Profit Organizations in Australia.* Proceedings of the World Academy of Science, Engineering and Technology (WASET), 2009. **37**: p. 456 – 464.
[12] Rottkamp, D.M., *Reimagining strategic vision for nonprofits: Evaluating everything after COVID-19: Certified public accountant.* The CPA Journal, 2021. **91**(4): p. 22-27.
[13] Singleton, B. and B. Straits, *Approaches to Social Research* 5th ed. 2018: Oxford University Press.
[14] The National Cyber Security Alliance. *A new survey released by the National Cyber Security Alliance (NCSA)*. 2020; Available from: https://staysafeonline.org/small-business-target-survey-data/.

Annex 1

BCMS Components

Statement	Component – People
What level of support do you have for your organization's cybersecurity during COVID-19?	People 1
The organization’s senior management consistently emphasizes the importance of cybersecurity during COVID-19	People 2
Most employees are sophisticated about detecting spear-phishing and other kinds of intrusion attempts during COVID-19	People 3
On average, how many hours of cybersecurity training do you require per employee during COVID-19?	People 4

Statement	Component – Process
Does your organization have a clearly articulated process for employees to report potential cyber threats to leadership during COVID-19?	Process 1
Does your organization have a clearly articulated business process that outlines how employees should securely dispose of equipment and data during COVID-19?	Process 2
If you were to have a data breach or cybersecurity incident during COVID-19, does your organization have a response process you can immediately put into action?	Process 3
If you were to have a data breach or cybersecurity incident during COVID-19 and lose access to your computers and network, do you have a process to initiate manual or backup procedures to continue operating your organization?	Process 4

Statement	Component – Policy

Does your organization have a clearly defined and documented cybersecurity policy during COVID-19?	Policy 1
If the organization had a computer system business continuity or disaster recovery policy before, was it updated in 2020?	Policy 2
Which best describes the knowledge management of cyber security policy in during COVID-19?	Policy 3
The organization has a clear, well-established policy for escalating suspicious events during COVID-19.	Policy 4

Note: Considering the variables' scale, the collected raw data was adjusted, and the values of the corresponding variables received numeric values.

THE FUTURE ROLE OF ARTIFICIAL INTELLIGENCE IN SYSTEMS HARDENING

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ABSTRACT

System hardening is a tedious process in which a set of guidelines must be rigorously applied to some combination of operating systems, software, data, and configurations. The goal of hardening is to minimize attack surfaces and maximize control over system resources. Although the importance of hardening cannot be understated, it is also a costly and time-consuming effort. Further, there is every possibility a human could (accidentally or intentionally) overlook important vulnerabilities or change settings which impede a core functionality. Thus, there is a natural case for automating the process of system hardening. Furthermore, artificial intelligence has already been entrusted with the management of many other aspects of cyber security. The purpose of this research is to investigate the efficacy of intelligent software as a surrogate for human cyber analysts. It describes an experiment in which automated hardening solutions are pitted against analysts. It compares and contrasts the relative strengths and weaknesses of each approach and identifies future research directions.

INTRODUCTION

The purpose system hardening is to minimize vulnerability to cyber-attacks and maximize resource control. This is accomplished by configuring operating systems, software, data, and settings according to security best practices. Once an image is satisfactorily hardened, it can be deconstructed and reduced to a set of instructions. Configuration management tools such as Chef, Puppet, and Ansible can use these instructions to create cloned copies of the original on demand.

Service delivery hinges on the state of security within the original image. Cloud-based systems are typically comprised of many containerized or virtualized workloads. Each instance is a replicant of an original image. Any vulnerabilities left in the original image will multiplied many times over. Hence, properly hardening the original image is essential to system health.

Hardening a system involves reduces the attack surface by eliminating unnecessary programs, applications, and access points. Adding controls for authentication, auditing, and authorization is equally important. Replacing passwords, implementing lockout policies, removing unused accounts, applying patches and updates, logging activity, limiting permissions, and invoking encryption protocols are all examples of actions which may be part of a hardening scheme.

Different industries and fields subscribe to different sets of security policies. For instance, the defense industry and the US federal government references STIGs (Security Technical

Implementation Guides) for hardening their systems. The health care industry uses HIPAA-compliant hardening standards, and the financial field uses the FFIEC IT security Book. Other sectors adhere to the guidance provided by organizations such as the Center for Internet Security (CIS), National Institute of Standards and Technology (NIST), International Standards Organization (ISO), and the SysAdmin, Audit, Network, and Security (SANS) Institute. Each of these authorities provides detailed instructions, checklists, policies, and principles. This is an exhaustive, time consuming activity. The possibility of errors is significant. A cyber analyst could (accidently or intentionally) leave critical vulnerabilities unaddressed and/or derail system functionality.

This creates a natural case for automating the hardening process. Not only would automation save money, cut down on human errors, and save time, but it would also mitigate the impact that a malevolent IT professional could have on organizational resources. Much of the data center is already automated. So there is ample precedence for taking humans even further out of the loop. Furthermore, the rapid advance of artificial intelligence promises even better solutions than those imagined just a few years ago. The diffusion of machine learning into adjacent areas suggests its viability in system hardening. Artificial intelligence is already used in network protection, malware detection, endpoint behavior modeling. Hence, there is every possibility that system hardening could be guided by intelligent software instead of humans.

Unfortunately, the task of hardening is not as straightforward as it may seem. The cyber analyst has to achieve a balance between exhaustively hardening an image while ensuring that key functionality is maintained. It is possible to over-harden an image, leaving it secure but unable to provide the service it was intended to deliver. Conversely, an unhardened image may exhibit high performance but invite penetration attempts. Understanding the purpose of a security guideline and predicting its effects on system functionality is difficult. It requires speculation, experience, and high-level problem solving. To sum, the hardening process is a more difficult task than first appears might suggest.

Despite advances in computational intelligence system hardening is still difficult to automate. The act of balancing system functionality with security policy compliance requires higher-order reasoning that has been difficult to emulate until very recently. So how does intelligent software compare with human cyber analysts? Do humans still outshine automation systems? Or does software result in fewer mistakes?

The purpose of this research is to compare human analysts against automation tools in a controlled laboratory experiment. Across a number of scenarios, a human analyst and software will compete to determine who can best secure an image according to a specified security standard while maintaining require functionality. The results will not only have implications for future software design, but they will also inform decisions makers' understanding of the cyber security space.

The remainder of this paper is organized as follows: the next section is Related Research. It describes related studies on AI and automation, especially those with ties to cyber security. The third section describes the experiment, including the subjects, techniques, measurements, and analysis. The fourth section presents the results. The fifth section provides implications while the sixth section offers concluding comments.

RELATED RESEARCH

The related research is divided into two sections. The first section reviews applications of artificial intelligence in cyber security. The second section investigates uses of artificial intelligence in IT operations.

Artificial Intelligence in Cyber Security

Various forms of artificial intelligence have been used in the cyber security domain for almost two decades. This includes areas such as intrusion detection, malware identification, fraud activity, and spam filtering.

Network intrusion detection systems identify malicious network activity and attempt to parse it from benign traffic. Many intrusion detection systems have implemented machine learning models due to their ability to adapt to new and evolving attacks. One example system (Lu et al., 2013) proposed a unified solution which incorporated genetic algorithms for misuse and anomaly detection. The program sought to improve genetic network programming to hasten rule pruning and merging.

Another a network intrusion detection system achieved a high level of computational intelligence using a combination of learning techniques (Subbulakshmi et al., 2010). The proposed system used artificial neural networks, support vector machines, and regression to detected distributed denial of service attacks. The results indicated that the highest accuracy was obtained when feedback from SVMs was prominently weighted. A third network intrusion detection was developed in 2011 (Sedjelmaci & Feham). It used clustering to reduce the amount of information and organize the data set. It then used support vector machines with misuse detection techniques to identify instances of malfeasance. It was able to detect brute force attacks such as Denial of Service but it could also detect subtle events such as probes.

Malware detection systems are a good application for artificial intelligence. The learning capabilities inherent in artificial intelligence makes it difficult for even the most subtle malware to evade detection. In 2006 Kolter and Maloof determined that breaking data into n-grams and using boosted decision trees to classify malware is more effective than approaches which rely on Naïve Bayes classifiers and support vector machines. Association rules and rule mining was used in another study (Ye et al., 2007). It used automatic extraction of decision rules of execution sequences to distinguish between malware and clean program files. Separately, Hidden Markov Models were used to detect whether a given program file is a variant of a previous program file (Chouchane et al., 2008). The interpretation of the sequence led a proposed system to classify a program as safe or malicious.

The most subtle malware is capable of morphing to evade detection. However, machine learning techniques such as neural networks can be used to detect such activity. This is evidenced in a pattern recognition system (Santamarta, 2006). Virus behavioral patterns were detected using self-organizing maps in another learning system (Yoo, 2004). This malware detection system is unique in that it incorporates visualization into its classification methods.

Artificial Intelligence in IT Operations

Artificial intelligence has figured prominently in IT operations for some time. It is often used to assist in scheduling and load balancing. As far back as the 1990s (Schaerf et al., 1994) systems were developed using reinforced learning to distribute loads across multi-node systems. The systems considered basic behavioral parameters and their effect on system efficiency. The presented significant improvements over naïve approaches.

Another study of load balancing in private cloud environments used Ant Colony Optimization (Nishant et al., 2012) with various machine learning algorithms. It incorporated artificial neural networks to adapt the parameters according to usage patterns. In a more recent study (Xu, et al., 2019) a deep reinforcement learning (DRL) based mobility load balancing algorithm was developed to distribute network traffic loads across ultra-dense networks. The proposed two-layer system had a centralized cluster controller on top and multiple load balancing agents on the bottom layer.

In order to forecast demand for cloud-based services, artificial intelligence is used to monitor consumption patterns, current usage, and growth indications. This increases the likelihood that services will be available when users want them. In one study (Ajila & Bankole, 2013) cloud client prediction models were created using machine learning. This experiment tested the efficacy of support vector machines, neural networks, and linear regression. The aim of this study was to determine how much improvement could be gained with intelligent resource scheduling. The result showed that across the board significant improvements were possible.

Similar findings were reiterated in a more recent study of workload predictions for cloud applications (Kirchoff et al., 2019). This project focused on maintaining service level agreements and sustaining quality of services with minimum resource allocations. It determined that a deep learning approach provides the most utility. Specifically, deep learning does the best job of minimizing resource consumption while maximizing availability.

EXPERIMENTAL EVALUATION

The purpose of this research is to compare the performance of intelligent automation software and cyber analysts at system hardening. It will determine how close the approaches are in terms of effectiveness, performance, and reliability. Given the advances in machine learning and automation, it is possible that computationally intelligent systems have surpassed humans at system hardening. This research investigates how adept such systems are balancing the application of hardening protocols against preservation of system functionality.

Procedure

The experiment compares the performance of software-based and traditional approaches to system hardening. Given the same list of hardening requirements, the intelligent automation

software and the human analyst will harden three unsecured systems. Each system is presented as an independent virtual machine. The goal is to minimize the attack surface and maximize resource control while preserving each system's specified functionality.

Experimental Environment

This experiment uses a private cloud test environment. There are three systems in total – a web server, a file server, and a python/Flask application server (see Table 1). These systems were specifically selected because they represent an increasing degree of complexity. Each system is instantiated as a virtual machine. A separate copy of each instance is allocated to the intelligent automation and manual test groups. Each test group resides on a separate project space within the cloud.

For each system, a corresponding list of hardening requirements are specified. These requirements are used by the United States Department of Defense to assure baseline security. They are known as STIGs (security Technical Implementation Guides). There are specific STIGs for commonly used operating systems, applications, and databases. They are published by the United States Defense Information Systems Agency.

These hardening guidelines were selected because they are well-respected, widely circulated, and openly available. Furthermore, they are very specific. There are a number of software tools (such as SCAP manager) which will automatically determine which requirements have been implemented.

Table 1. Systems Being Hardened

System	*Purpose*	*Base Image*	*Relevant Software*
Web Server	Web content hosting	Centos Server 8	Apache 2.0 Server
File Server	File directory services and networked file shares	Windows Server 2016	MS Server File Services
App Server	Python/Flask web application hosting	Ubuntu Server 20.04 LTS	Python Nginx Uwsgi Flask

Subjects

To represent the intelligent automation group, a software program called ConfigOS is used. ConfigOS is the most advanced hardening tool in a relatively narrow field. Other tools exist but use little or no machine intelligence and have low levels of automation. The ConfigOS platform consists of a cloud backend and an agent which is installed in the system being secured.

The agent conducts an inventory of the image, observes configurations, and reports to the backend. The backend considers each hardening guideline. It uses trained neural networks to

anticipate the configurations needed to achieve the desired outcome. It then recommends remediations in order to comply with STIG requirements. The agent will automatically perform all configurations which do not require human intervention (e.g. providing new or harder passwords).

Metrics

For each system, the software and the human analyst groups are scored according to a percentage of how fully they implemented the hardening requirements without losing functionality. For independent, unbiased scoring, a tool called SCAP Workbench is used. SCAP WorkBench is an open source tool that allows users to evaluate remote images. It automatically scans and assesses a given image's configurations against one more STIG files. It provides a report which indicates the level of compliance with a given hardening protocol.

Hardening performance is calculated in terms of a percent. 100% indicates that every STIG requirement is implemented. STIG guidelines which require user-supplied data (such as a password or IP address) were excluded from scoring. Along with effectiveness, efficiency was also considered. For the present study, efficiency is interpreted as the time taken to harden each image.

To judge functionality, a test script was written for each category of system. The test scripts were executed using Apache JMeter. The web server system test ensures that web pages with multimedia could be loaded from an external peering point. The file server test ensures that a user with active credentials could upload a file to a remote share drive. The python/Flask server test checks that a third party can initiate contact and receive a response from the Flask app. Systems which no longer provided the requisite functionality were deemed a failure and given a score of zero.

RESULTS

The hardening results are depicted in Table 2 (below). The individual analysts and the intelligent software's performance at system hardening was graded using an independent, automatic scoring tool call SCAP Workbench. The results attest to the difficulty of the task. The lowest performance was that of individual 1, who had only six month's work experience. Individual 1 did their strongest work on the File Server. Perhaps this is because the File Server is window based. Much of the hardening work can be performed via GUI features such as configuration wizards and option menus. However, Individual 1 was unable to harden the application server without interfering with its functionality. Individual 2 had approximately 5 years work experience. This individual outperformed the intelligent software on the Linux platforms but was bested by the software when it came to the Microsoft-based file Server. The third individual had 13 years work experience. They did the best job of hardening Linux software while lagging at hardening the Windows operating system. The Intelligent software did the best job of hardening the file server. However, it lagged in Linux OS support. It also lost functionality when hardening the application server.

Table 2. Results

Hardening Agent	*Web Server*	*File Server*	*Application Server*
Individual 1	79% 3 hours 42 minutes	87% 7 hours 27 minutes	Lost functionality 8 hours 54 minutes
Individual 2	83% 4 hours 19 minutes	90% 6 hours 54 minutes	77% 9 hours 33 minutes
Individual 3	94% 3 hours 35 minutes	88% 7 hours 11 minutes	83% 6 hours 19 minutes
Intelligent software	78% 1 minutes	94% 3 minutes	Lost functionality 2 minutes

IMPLICATIONS

This research suggests that while artificial intelligence is gaining ground, it is still not on par with experienced cyber analysts. Clearly, the more experienced individuals do a better job of preserving customized software bindings while achieving higher levels of security. There are two possible explanations:

The first explanation regards technical exposure. The experienced individuals may have more familiarity with the Linux operating and some exposure to the implemented solution stack. If different operating systems were selected that their performance may have suffered. Indeed, information systems professionals tend to gravitate to an operating system in their comfort zone and avoid those which they are unfamiliar with.

The second explanation is that more experienced workers are adept at interpreting system linkages and associating them with changes in system configuration. Over time, analysts become skilled at solving technical problems. This would suggest that troubleshooting / testing experience is more important than experience with a given operating system. Another possible explanation is that the developers of the intelligent software were themselves more familiar with Windows and focused their development around it. This is possible although it is unlikely. It is more likely that the software couldn't account for the interlinks between the app stack components when hardening the system.

The next major step forward in the automation of systems hardening is the development of computational awareness of the impact of reconfigurations on system state (See Figure 1). This will require the ability to reduce system state to a matrix of configurations. The intelligent software would then observe the impact of reconfiguration on functionality. It would attempt a reconfiguration, observe the results on functionality, and then respond accordingly.

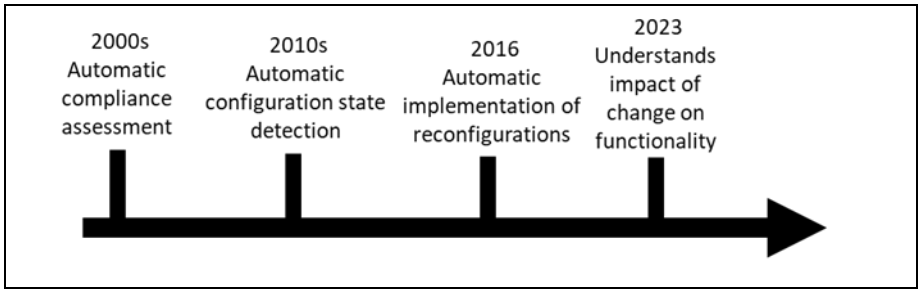

Fig. 1: Progression of intelligent automation software

CONCLUSTION

To curb the growing threat against information resources, more and more organizations are undertaking plans to maintain hardened baselines for their computing images. Their goal is to reduce the attack surface, eliminate vulnerabilities, and more finely control assets. This creates less opportunity for malicious attacks, fewer operational malfunctions, and reduced service interruptions. The task of system hardening is tedious and often error-prone. The individual performing the task must keep track of myriad details. It is also an expensive proposition. Cyber security analysts are in high-demand. The dedication of their time to a singular image requires a significant organizational investment.

There is a good case for automating the process of system hardening. Artificial intelligence has been entrusted with the management of many other aspects of cyber security. Much of the container / virtual machine lifecycle has already been automated. Automation of the hardening process is a logical extension of this trend. However, system hardening is complex and difficult to automate. There is a need to balance adherence to security guidelines against system functionality. If a system is over-tightened it may not work. If it is under-secured it represents a liability.

This research investigated the efficacy of intelligent software as a surrogate for human analysts. It described a controlled laboratory experiment in which cyber analysts are pitted against software for image hardening. In the experiment it was determined that although automation has come a long way, it still lacks the ability to balance security policy compliance against system functionality. This skill is a requisite to achieving a secured, functional system. The problem space is still too unstructured. In the future, software developers should focus restructuring the problem space so that the imputed system goals are formalized.

In some areas, the automation software did shine through. Some of the humans made more mistakes. They all took hours longer to achieve the same level of results. At present, more intelligent software could be incorporated into workflows. The artificial intelligence could perform the initial phases of hardening while leaving higher-order decisions to humans.

REFERENCES

1. Lu, N., Mabu, S., Wang, T., and Hirasawa, k. “An Efficient Class Association Rule-Pruning Method for Unified Intrusion Detection System using Genetic Algorithm”, in IEEJ Transactions on Electrical and Electronic Engineering, Vol. 8, Issue 2. (2013)
2. T. Subbulakshmi, S. M. Shalinie, and A. Ramamoorthi, “Detection and Classification of DDoS Attacks using Machine Learning Algorithms”, European Journal of Scientific Research, Volume 47, No. 3, pp. 334 – 346. (2010)
3. H. Sedjelmaci, and M. Feham, “Novel Hybrid Intrusion Detection System for Clustered Wireless Sensor Network”, International Journal of Network Security & Its Applications (IJNSA), Vol.3, No.4. (2011)
4. J. Z. Kolter and M. A. Maloof, “Learning to detect and classify malicious executables in the wild,” Journal of Machine Learning Research, vol. 7, pp. 2721–2744. (2006)
5. Y. Ye, D. Wang, T. Li, and D. Ye, “Imds: intelligent malware detection system,” in KDD, P. Berkhin, R. Caruana, and X. Wu, Eds. ACM, pp. 1043–1047. (2007)
6. M. R. Chouchane, A. Walenstein, and A. Lakhotia, “Using Markov Chains to filter machine-morphed variants of malicious programs,” 3rd International Conference on MALWARE. (2008)
7. R. Santamarta, “Generic detection and classification of polymorphic malware using neural pattern recognition,” Proceedings of the International Multiconference on Computer Science and Information Technology (2006)
8. I. Yoo, “Visualizing Windows executable viruses using self-organizing maps,” in VizSEC/DMSEC ’04: Proceedings of the 2004 ACM workshop on Visualization and data mining for computer security. (2004)
9. A, Shaerf, Y. Shoham, M. Tennenholtz, “Adaptive Load Balancing: A Study in Multi-Agent Learning” in Journal of Artificial Intelligence Research vol 2, pp. 475-500. (1994)
10. K. Nishant, P. Sharma, V. Krishna, C. Gupta, K. Singh, Nitin, R. Rastogi, "Load Balancing of Nodes in Cloud Using Ant Colony Optimization," 14th International Conference on Computer Modelling and Simulation, Cambridge, UK. (2012)
11. Y. Xu, W. Xu, Z. Wang, J. Lin, S. Cui. “Load Balancing for Ultradense Networks: A Deep Reinforcement Learning-Based Approach” IEEE Internet of Things Journal, vol. 6, No. 6. (2019)
12. S. Ajila, A. Bankole “Cloud Client Prediction Models Using Machine Learning Techniques. IEEE 37th Annual Computer Software and Applications Conference. (2013)
13. D. Kirchoff, M. Xavier, J. Mastella, C. Rose “A preliminary study of machine learning workload prediction techniques for cloud applications” 2019 27th Euromicro International Conference on Parallel, Distributed and Network-Based Processing (PDP). (2019)

Innovative Education, Assessment, Engaged Learning Curriculum, Teaching and Pedagogy - Abstracts

Addressing problems during a merger between management information systems and decision sciences

Oral Presentation

Dr. Gurkan I. Akalin [1]

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In this paper, I will address some of the major obstacles unique to these discipline mergers for creating new majors and how to address them. With the development of majors similar in Business Analytics, these two disciplines may face pressure to be combined to produce a single major. From the perspective of university administrations, this should be an easy process, but in reality it is with multiple issues along the way. These disciplines are however not immiscible as well.

Advocacy for Entrepreneurial People with Autism in Fields of STEM

Oral Presentation

Dr. James Lawler [1]

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ADVOCACY FOR ENTREPRENEURIAL PEOPLE WITH AUTISM IN FIELDS OF STEM

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ABSTRACT

Diversity can enhance the creative process. People with disabilities can exceed in the fields of STEM. However, entrepreneurial students with Autism Spectrum Disorders (ASD) can be denied desirable opportunities in STEM. Though exceptional students with autism can excel in innovations of STEM, higher-functioning students with autism are frequently unemployed or underemployed in industry positions of STEM. Neurodiversity is a competitive advantage for business that is neglected often in industry.

In this anticipated paper, the authors consider how entrepreneurial neuro-divergent students with autism can be better engaged in curricula of schools of STEM and in industry. The authors are designing the methodology as instructors at a school of technology of a leading metropolitan university that is currently engaging students with disabilities. The methodology is in incremental phases of focus grouping instructors and students with autism in STEM at the university, interviewing instructors, staff and students with Autism Spectrum Disorders (ASD) at schools of technology at adjacent regional universities, and surveying industry professionals at adjacent organizations pioneering neurodiversity programs in STEM, such as Google and Microsoft. The authors are desiring to learn participant perceptions of programs of STEM for students with autism. Engagement of local non-profit organizations helping people and students with disabilities is anticipated further by the authors. The authors consider as a goal of this paper a “culture of growth” in a curricular and extra-curriculum model of programs of STEM for neuro-divergent students.

The benefits of this paper are in an advocacy for entrepreneurial people and students with autism in the fields of STEM. The focus is in highlighting present and proposed programs of STEM that are considered to be definitely helping students with Autism Spectrum Disorders (ASD), in the perceptions of the population samples of this study. The eventual focus of this paper is in improving the perceptions of professors and students without disabilities of the potential of STEM students with disabilities. The findings of this paper will be input into involving higher-functioning people and students with disabilities more productively in organizational positions. Overall, this paper posits an enhanced narrative for a neuro-diverse future of work.

Applying SPC to Healthcare Cost Reduction

Oral Presentation

Dr. Kip Pirkle [1]

1. *Southern Wesleyan University*

The goal of this workshop is to provide a practical application of statistics to the ongoing cost issues in US healthcare management. Data has been collected, analyzed, and made transparent over the last couple of decades, but the effectiveness of the US healthcare system has actually lost ground relative to peer countries.

COFFEE, FLAMENCO, AND DRAWN TOGETHER: CREATIVITY EXPERIENCES FROM VCU SCHOOL OF BUSINESS

Oral Presentation

Dr. Elena Olson [1]

1. *Virginia Commonwealth University*

Creativity plays a vital part in our lives, both personal and professional aspects alike. It is true considering the world is spinning in its normal pace. Well, that was not the case since March 2020 when our lives were disrupted by COVID-19. Stay-at-home orders, social distancing, masks, sanitizers, travel bans, and isolation. What role does creativity play then? How do we continue our creative practices and feel connected to our so easily taken for granted workspaces, colleagues, students? How do we pave our ways to 'back to normal'? This report is intended to share some personal experiences in a role of Creativity Tsaritsa at VCU School of Business (Gough, 2020), immediately prior and in times of pandemic.

The report provides an opportunity to examine the role of creativity in supporting the VCU School of Business' strategic plan referred to as EPIC (Experiential Learning, Problem-solving Curricula, Impactful Research, and Creative Culture) (Khan, 2019, 11:30).

CONSTRUCTING LANGUAGE RESOURCES FOR FASHION MERCHANDISING MAJORS FOR A GENERALIZED AI CURRICULUM

Oral Presentation

Dr. Nathan Green [1], ***Dr. Jung-ha Yang*** [1]

1. *Marymount University*

While Artificial Intelligence (AI) has long been the pursuit of Computer Science, Data Science and Mathematics, the use of narrow AI has quickly spread to a variety of industries. The use of Machine learning has transformed various industries including image-driven industries such as the fashion industry. While workers in these industries may not fully understand how the AI tools are created, it is still important for them to know what information is gathered and how they can be utilized to solve specific problems. To help address this growing divide between AI and its industry clientele, we have started to roll out an AI curriculum in different departments at our university, as the understanding of the possible use of AI can be meaningful for college students in making their future career decisions or in developing their career path. To bring AI to our fashion merchandising students, we created a corpus of more than 400 women's athletic shoes from a well-known online retailer. The athletic shoes represented a variety of types and brands. They were harvested via a scrapper written directly for this purpose. The students were able to examine the uses of a dataset in the choices they may make regarding design, color, style, size, and feature descriptions. The curriculum around this module was designed for two 75-minute modules covering AI topics and data analysis using a fashion language resource.

Developing an EXCEL/Analytics “Spine” in the BBA Curriculum

Oral Presentation

Dr. Reza Kheirandish [1]

1. *Clayton State University*

The author of this paper is a faculty at a business school in a metropolitan area and he was asked by the dean of the college of business to form a committee to create a set of deliverable tasks/activities within the current business curriculum, where students are exposed to the Excel based exploration, problem solving, and analytics so that by the time they are graduating they are proficient in Excel. The committee proposed that when possible and in all courses that are applicable, throughout the BBA curriculum, we develop Excel based learning, problem solving, data analysis, and data visualization to achieve proficiency in Excel by the time our students graduate. This article reviews those proposed activities suggested for the specific courses within the BBA program.

Enhancing Workplace Skills and Content Knowledge through ADR: A Multi-Disciplinary Gender Discrimination Simulation

Oral Presentation

Prof. DeShannon McDonald [1], ***Dr. Valentina Iscaro*** [2]

1. *Alabama A & M University,* ***2.*** *Alabama A&M University*

The purpose of the article is to present an innovative active learning simulation to cultivate conflict resolution, problem solving, critical thinking and analysis, decision making, and collaboration skills as well as content knowledge in gender discrimination issues, such as sexual harassment in the workplace. Simulations are commonly utilized in business schools to develop employment skills and foster content retention (Druckman & Ebner, 2013; Page & Mukherjee, 2007; Hartley, Eboch, & Gilberg, 2017). In 2016, the EEOC published a report asserting the ongoing issues of workplace harassment and issued a call for academics, employers, and other stakeholders to assist in efforts to combat gender discrimination. In response to this call and in alignment with AACSB and their college's experiential learning platform, the authors designed a simulation in which learners will use negotiation skills to resolve a sexual harassment case in a conciliation hearing overseen by U.S. Equal Employment Opportunity Commission (EEOC) representatives. The modified simulation content is based on a 2020 EEOC sexual harassment and retaliation case. The following documents were developed for the simulation: a. General Background; b. Three confidential roles; c. Learner Preparation Handout; d. Learner Resource Guide; e. Instructor Resource Guide; and f. Simulation Rubric. The simulation has been administered in four undergraduate and graduate management courses and is ideal for instructors of legal and business courses to team teach concepts in diverse legal and business courses like legal environment, business law, negotiation, entrepreneurship, supply chain, human resource management, and marketing. Learners are assessed based on their level of negotiation skill and proper use of simulation facts, laws, and other guidelines.

Exploring the underlying factors for variations in digital upskilling among business students

Oral Presentation

Dr. Rodney McCrowre [1], ***Dr. Burcu Adivar*** [2], ***Mr. Julius Cook*** [1]

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Both private and government industries face a short supply of digital talent or skill sets needed for digital transformation. Many accredited business schools continue to integrate trainings in disruptive technologies such as cloud computing, IoT, machine learning, artificial intelligence, blockchain, intelligent enterprise solutions upskilling programs into their curriculum. In this study, we plan to assess the impact of a particular business school's curricular and extracurricular activities on gaining new skills to secure future jobs and contribute to the digital workforce.

As a measurement of the digital skills, authors use the digital fitness application developed by a global company leading digital talent transformation. Digital fitness applications continue to expand in technology by casting human behaviors, mindsets, relationships, and skillsets across the world's leading businesses. To meet the demands of a growing labor market and to improve its recruiting process, Price Waterhouse, and Coopers (PwC) had introduced the first Digital Fitness Application in 2017. Upon registration, the app starts with an initial assessment of the user's knowledge and understanding of digital skills, behaviors and assigns an overall Digital Fitness Score broken down to behavior, mindset, relationships, and skills scores. Based on the initial assessment, an individualized learning plan, which includes engaging, bite-sized, sometimes interactive educational content, is created. With weekly short quizzes as reassessments, the goal is to help users fill knowledge gaps and improve their overall scores. Since 2017, PwC has trained 275,000 employees with the Digital Fitness app creating a significant positive impact on the digital readiness of its global workforce.

This study seeks to address the relationship between digital skills, critical thinking skills and the student learning experience in courses with embedded upskilling programs. While digital skills can be assessed using the overall scores of the PwC Digital Fitness App, critical thinking skills can be quantified through external assessments and select quantitative courses. Meanwhile, study presents exploratory research between primary factors such as demographics, class level (graduate vs. undergraduate), transfer vs. first time student status, GPA, earned credit hours and participation in extracurricular activities. With sample size of 400 student records, study findings reveal interesting results and a summary of future research directions.

Gaining Insight Into Student Learning Styles in Decision Sciences Classes

Oral Presentation

Dr. Shona Morgan [1], ***Dr. Sherrie Drye*** [2], ***Dr. Patrick Rogers*** [3]

1. *North Carolina A&T State Univ.,* ***2.*** *North Carolina A&T State Univ,* ***3.*** *North Carolina A&T State Uni*

One of the primary missions of higher education is to ensure that students gain skills and knowledge that will be a foundation for future academic and career success. It is imperative that students persist in college to develop their intellectual aptitude to perform at their highest level in future work endeavors. Our work augments a growing base of literature focused on the use of student learning style data to promote greater student success in collegiate coursework. We specifically, study the impact of learning style data on student success in business courses rooted in the decision sciences. Data was collected over ten semesters beginning in the spring of 2016 up until the fall of 2020 in three different decision science courses in the College of Business and Economics (COBE). There were a total of 431 student responses which were useable. Analysis will be performed to better understand if certain learning styles are advantaged over others in terms of student outcomes.

Increasing Student Awareness of Career Opportunities in the Service Supply Chain Sector

Oral Presentation

Dr. Laquanda Leaven Johnson [1]

1. *North Carolina A&T State Univ.*

The awareness of career opportunities in the service supply chain sector continues to be deficient when compared to the recognition of opportunities experienced in the traditional manufacturing supply chain area. Within the service sector exists three major trends that may be contributing to this decreased awareness. The first trend involves the lack of a standard identity for the service sector. The second trend involves major variances in the education provided to students in preparation for careers in the service supply chain field as compared to the preparation provided for careers in the manufacturing supply chain sector. Furthermore, the third trend focuses on the need for marketing and creation of value. The literature supports the use of innovative strategies and enhanced marketing endeavors to increase the awareness of career paths in the service supply chain sector. The results of this comprehensive study indicate these three trends are major areas of improvement needed to address the impending issue of talent shortages in the service supply chain field.

INTERNSHIP EFFECTIVENESS AND SATISFACTION: AN APPLICATION OF HERZBERG'S THEORY OF MOTIVATION

Oral Presentation

Dr. Ed Showalter [1]***, Dr. Inigo Arroniz*** [2]

1. *Randolph-Macon,* ***2.*** *Randolph-Macon College*

This abstract outlines a continuation of research and data analysis presented at the Southeastern Institute for Operations Research and Management Sciences in September 2021. Specifically, this research extends the previous by focusing on the statements of Interns regarding their positive and negative experiences while in their internships. These statements will be analyzed using Herzberg's Motivation theory (Herzberg 1959,1966,1968.) One of the co-authors used this approach almost two decades ago and found that an analysis of interns' statements supported Herzberg's theory, making the theory applicable with this sample.

Of particular interest in this study is differences between interns whose internships were completely in-person versus those whose internships had a virtual component. The data was collected in August of 2021 in a survey of interns who complete their internships within the last five years. The data set for analysis is comprised of 86 intern's responses of which 29 had a virtual element. The survey also gathered information on Self-Efficacy (Sherere et al. 1982), Growth Need Strength (Hackman & Oldham, 1980), and interns' perceptions of learning based on Gordon (2002).

The data analysis is currently underway, and the full paper is expected to be complete prior to the meeting.

KIT KAT VS. M&Ms: PROCESS CAPABILITY LESSONS USING FUN-SIZED CANDY

Oral Presentation

Dr. Suzie Smith [1]

1. *Presbyterian College*

In the July 2016 *Decision Sciences Journal of Innovative Education* (DSJIE), Ronald Lembke published a Teaching Brief in which he created an in-class activity to help students understand process variability and capability by weighing the contents of fun-sized plain and peanut M&Ms. As peanut M&Ms are chunkier and have higher variability, it is more difficult to keep the actual weights of the fun-sized candy between specification limits. Plain M&Ms also fail to meet specification limits due to the discrete nature of the product. This presentation extends the DSJIE brief by including additional fun-sized candy in the experiment. The classes also tested Take Five, Kit Kat, Peanut Butter M&Ms, and Snickers to see which candies had the best process capability. One brand significantly outperformed the others.

Making Business Analytics More Engaging, a Three-Phase approach

Oral Presentation

Dr. Elham Torabi [1]***, Dr. Hoda Atef Yekta*** [1]

1. *James Madison University*

Despite its usefulness to their careers, business students often consider introductory Business Analytics material difficult, overwhelming, and dry. This lack of interest lowers students' engagement and motivation. When coupled with remote online learning due to COVID, these challenges create a recipe for disaster. We discovered that this new environment required us to design new ways of teaching. Here, we explain how we redesigned the Business Analytics II course in a unique way to increase student engagement. In this course, students are usually stymied by linear programming and mathematical modeling, either because they have never seen it before or get lost partway through. This material makes up a significant part of the course; it is significantly involved and contains various components, and (like accounting and programming concepts) the material cumulatively builds. Therefore, to succeed, students need to understand the big picture and the interrelation among the subtopics while staying engaged with the material throughout the course. Students who miss or misunderstand even one lecture quickly fall behind and end up repeating the course.

As a sticky and ongoing problem, we are always considering how to better support students in this course. Inspired by the Just-in-Time Teaching model (Novak et al 1998) and the continuous improvement cycle of plan-act-assess-reflect (Dahlgaard et al 1995), we present our three-phase structure to improve this course, particularly how we implemented it online during COVID. In this model, we view the learning process as having three distinct phases revolving around class time. The before-class phase introduces students to motivating but simple examples of the topic, guiding students through an independent self-learning process. In this phase, students complete and submit an assignment before class, in which they write about or solve problems related to the day's topic. In the second phase, the instructor reviews and clarifies solutions to the before-class problems and compares everyone's answers. From this exercise, students receive instant feedback and can benchmark their progress against peers, motivating them to focus on what follows. During class, the instructor presents the material with more difficult problems. This phase is a good time to work in breakout rooms to encourage peer interaction. In the final after-class phase, students complete homework problems of intermediate and advanced difficulty.

This recursive, semi-flipped process meant that lecture time was more efficient because we could focus on the challenging parts of problems and still allow time to review basic steps if students struggled with the before-class problems. The frequency and timing of feedback were helpful for both instructors and students to assess their performance and plan adjustments to the process. We implemented this approach using two different technologies: Google Sheets (Google Inc.) and Top Hat (Tophatmonocle Corp.) in five sections of Business Analytics II across two different instructors. We are in the process of analyzing the effectiveness of this approach through pre- and post-course outcomes. This presentation should interest instructors of business analytics looking for ways to make their course more engaging for students.

OVERCOMING KNOWLEDGE RETENTION ISSUES FROM THE FIRST PRINCIPLES COURSE

Oral Presentation

Prof. Rebecca Hutchins [1], ***Dr. Gerald Hutchins*** [1]

1. *Appalachian State University*

This study reports the results of a strategy to improve retention of a specific concept from the first Principles of Accounting course. Following research on the effect of retention from the first course to performance in the second course, we explore the effects of a targeted experimental intervention on performance. In prior published research, we found a student's inability to demonstrate understanding of key concepts from the financial accounting course are significantly related to important learning objectives in the second course. Here we report how students predicted to choose incorrect answers performed after the targeted experimental intervention.

Taking the Mask off Active Learning: Teaching Students to Think Critically & Retain More in a Pandemic World

Oral Presentation

Dr. Jim Mirabella [1]***, Dr. Julius Demps*** [1]

1. *Jacksonville University*

The days of traditional teaching are long gone thanks to a pandemic which forced the change. Many professors made it clear that a student must show up for class or they would miss the lesson, but now there is a need to provide live streaming or at least to have lecture videos in the course room. While there was a strong opposition to change the way we educate, now there is a stronger push for making courses that appeal to those on location, those watching remotely and those who just want to watch the recordings. The setting has been flipped so that the classroom is no longer the only means of learning and participating. Just how effective is the new normal? With detailed statistics of over 1000 courses from the past 30 years, the authors will compare courses in which students just listened to lectures vs. classes in which the students engaged in activities designed to teach the same lessons vs. students watching videos of these activities or lectures from past courses. The activities involved the students making their own decisions and typically leading or working with a team. The lesson for activities came about when the professor debriefed the class on the results, the good and bad decisions, and how the activity & discussion related to the course material. Retention of the material was assessed through exam questions, and since the same or similar questions were used in each of the course settings, the authors will show the value of active learning and how it leads to critical thinking and greater retention of material. The courses that will be used for this analysis include Statistics, Quantitative Analysis, Operations Management, Leadership & Human Resource Management. Has this pandemic opened the door to greater learning or has it just complicated the professor's ability to reach their audience?

TEACHING DURING A PANDEMIC USING ONLINE PLATFORMS AND HOW NOT TO LOSE MOMENTUM

Oral Presentation

Prof. Keely Clay [1]

1. *Kennesaw State University*

TEACHING DURING A PANDEMIC USING ONLINE PLATFORMS AND HOW NOT TO LOSE MOMENTUM

ABSTRACT

March of 2020, academia and, the world found itself in uncharted territory. The uncharted territory was the pandemic itself. According to Merriam-Webster, the word pandemic is defined as “occurring over a wide geographic area (such as multiple countries or continents) and typically affecting a significant proportion of the population”. Online teaching methods, would soon be another, new uncharted territory, for faculty who were not verse in using online teaching platforms. Faculty that had the knowledge of online platforms, in combination with their courses, were able to navigate teaching during a pandemic. The University, and program in which I teach, has all hybrid courses. The hybrid courses meet once a week, face to face. Students are to login into their courses, outside of the face to face meeting time, for all other required information. Each week, as students log into their courses a weekly learning module is shown. Within each weekly module, students will find several items that require viewing. Articles of the subject matter, along with pre-recorded videos, that have been created by the professor, as well as weekly assignments. The courses use D2L Brightspace, this is where students login to find course materials. There are also other online platforms that are used for student faculty meetings that will also be discussed.

When the pandemic shutdown the face to face classroom, the only option was virtual. If professors already instructed their courses virtually then educating during a pandemic would be nothing new to them and their students. However, if a professor was used to only having face to face courses then shifting modalities would become uncharted territory quickly. How can a course be instructed fully online, throughout the duration of a semester and not loose momentum? In this paper, insight will be given on how to use several different online platforms successfully. Faculty can integrate this information into their student’s courses and keep at their disposal for the future. Another insight that will be given in this paper is how faculty can keep students engaged, and inspired while successfully completing the course without losing momentum.

REFRENCES

[1] Merriam-Webster. (n.d.). Pandemic. In Merriam-Webster.com dictionary. Retrieved October 30, 2021, from https://www.merriam-webster.com/dictionary/pandemic

The 2021 Title I Family Engagement Surveys: An Equity of Voice Imperative

Oral Presentation

Dr. Lisa Wills Keister [1], ***Ms. Theresa Dawkins-Smith*** [1], ***Ms. Patrice Barnes*** [1], ***Ms. Reynelle Garcia*** [1]

1. *Prince William County Public Schools*

This paper describes the rigor, innovation, and integrity brought to bear on the survey development process and subsequent data collection to support a Title I program aligned with new equity of voice practices in a large Northern Virginia school division. Discussed are the psychometric properties of the 16- and 18-item surveys, the constructs of interest, and the Family Engagement Sentiment Profiles that will enable the program to longitudinally track progress in Title I elementary and middle school community attitudes and behavior and make more informed data-driven decisions.

The Impact of Globalization and ICT on the Education System and the Role of the Educator

Oral Presentation

Dr. Ramy Rahimi [1]

1. *O'Maley College of Business, Embry-Riddle Aeronautical University*

ABSTRACT

Today, the education system, with all its sectors, is disturbed and disrupted through globalization, the advancement of technology, and the COVID-19 pandemic. In order to advent, reform and expend the education system to align with the decentralization and marketization perspectives of globalization, a fundamental alteration is held necessary at the education system and educator level. The research paper aims is to investigate, and identify the factors that influence the education system reform and subsequently the future role of the educator. The results of this study show that globalization and information and communication technology (ICT) are the main factors that drive the change in the core of education systems and the profession of educator. Additionally, the COVID-19 pandemic has further accelerated the rate of the change as it uncovered the flaws in the education systems throughout the globe. Furthermore, the study recommends the adoption of the 5Cs, critical thinking, creativity, collaboration, communication, and counseling as a fundamental supplement to the core of the education system as well as to the educators' teaching philosophy. Combined, the 5Cs enable and empower students to become a body of experts providing sustainable and resilient solutions to the 21st century problems.

Keywords: Education, Critical Thinking, Creativity, Collaboration, Communication, Counseling

USING EXAM WRAPPERS TO IMPROVE STUDENT SUCCESS IN THE BUSINESS SCHOOL – A QUANTITATIVE COURSE EXPERIMENT

Oral Presentation

Prof. Xu Hartling [1]

1. *Salem State University*

Developed by Lovett, an exam wrapper provides students with a structured reflection opportunity about exam performance [1]. In a quantitative business course at Salem State University, it was frequently and commonly observed that students made mistakes in their previous homework or exams and tended to repeat those mistakes on later exams. This observation raised a lot of questions on how students worked on their homework and how they prepared for the exams. Students may not spend sufficient time in reflecting and improving their mastering of topics covered in previous homework or exams. In order to increase student success in this quantitative business course, exam wrappers were developed and adopted. This paper studies the effectiveness of exam wrappers in student reflection measured by students' exam performance. Preliminary results showed that the majority of students improved their exam performance after implementing exam wrappers. Exam wrappers proved to be a valuable and powerful tool to increase student understanding, confidence, and performance in this quantitative business course.

Using VBA to Grade Student Excel Projects

Oral Presentation

Dr. Cintia Easterwood [1]

1. *Virginia Tech*

Business school faculty are increasingly requiring that students complete Excel assignments in their courses. Grading these assignments can be tedious and time-consuming, especially for faculty who teach large classes. While online learning systems that automatically grade Excel assignments do exist, these systems do not typically allow faculty members to determine how the projects are graded or to create or customize the Excel projects. This workshop will show participants how Visual Basic for Applications (VBA) can be used to automate the grading of Excel projects. The grading program has been used to grade Excel projects completed by students in an Excel class taught at a large public university. Use of the program significantly reduces the amount of time required to grade the projects, eliminates grading errors that occur when assignments are manually graded, and allows the instructor to determine the content of the assignments as well as how they are graded.

WHY AN ACCOUNTING INTERNSHIP

Oral Presentation

Dr. Wanda DeLeo [1]

1. *College of Coastal Georgia*

Internships are a great way for college students to obtain valuable work experience. Accounting internships are based on the concept of service or work-based learning, which can be described as applying the knowledge learned in the classroom to real-world situations. For the student an internship is more than enhancing accounting skills. It is about providing a bridge from the classroom to the workplace and an opportunity to try the career path they are pursuing. A reviews of the literature on internships identified benefits to both students and the employer. For the intern an accounting internship is helpful in clarifying career goals, providing work experience, providing job leads, solidifying accounting principles, acquiring academic credit, reducing tuition and transiting into the work place. For the employer an accounting internship program is a helpful recruitment tool for full time positions, allows for seasonal help at a low cost while providing opportunities for full time employees to foster their leadership skills. The program also provides the firm an opportunity to give back to the community. A survey of students who participated in an accounting internship at one institution showed that a 100% believed that the internship they participated in was beneficial and 98% of the participants would recommend the host employer to other students. These results suggest that work-based/service learning is an important complement to academic programs and classroom teaching.

Innovative Education, Assessment, Engaged Learning Curriculum, Teaching and Pedagogy - Papers

APPLYING SPC TO HEALTHCARE COST REDUCTION

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ABSTRACT

The goal of this workshop is to provide a practical application of statistics to the ongoing cost issues in US healthcare management. Data has been collected, analyzed, and made transparent over the last couple of decades, but the effectiveness of the US healthcare system has actually lost ground relative to peer countries.

Current health expenditure (% of GDP) for the US increased about 35% from 2000-2018. Of course, this was before the COVID pandemic hit.
https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS?locations=US

In 2018, the U.S. spent nearly twice as much on health per person as comparable countries ($10,637 compared to $5,527 per person, on average) and yet has worse health outcomes.

The Peterson Center on Healthcare and KFF (Kaiser Family Foundation)
https://www.healthsystemtracker.org/brief/what-drives-health-spending-in-the-u-s-compared-to-other-countries/

https://worldpopulationreview.com/country-rankings/health-care-costs-by-country
https://www.investopedia.com/articles/personal-finance/072116/us-healthcare-costs-compared-other-countries.asp

Statistical Process Control
https://www.qualitydigest.com/currentmag/articles/03_article.shtml
https://www.researchgate.net/figure/Process-capability-analysis-for-patient-waiting-time_fig4_256835273
https://onlinedegrees.kent.edu/ischool/health-informatics/community/why-is-data-analytics-important-in-healthcare
https://online.shrs.pitt.edu/blog/data-analytics-in-health-care/
https://www.datapine.com/blog/big-data-examples-in-healthcare/#examples
https://www.google.com/search?rlz=1C1GCEA_enUS875US875&sxsrf=ALeKk02PKfTz0WL9eLhMpxRMTc2l5VeDsw:1628454999442&source=univ&tbm=isch&q=example+Healthcare+process+capability+study&sa=X&ved=2ahUKEwis0ZjOo6LyAhXILs0KHeaTCgMQjJkEegQILhAC&biw=1396&bih=685
https://www.healthcatalyst.com/insights/control-charts-healthcare-drive-4-improvement-basics/
https://www.iise.org/uploadedFiles/SHS/Resource_Library/details/26.pdf

The US healthcare system is certainly overdue for improvement. From a statistical perspective, the only way to improve a process is to understand that process, and the US healthcare industry is far from being well understood. To improve the process, data must be collected and analyzed so that the capability of the process is understood. By examining the process, the major causes of variation are isolated and studied further.

One of the most common measures in healthcare is length of stay for a particular procedure. The "specifications" are determined by prior contractual arrangements, then case-by-case modifications are made by a physician and an insurance company. These specifications are based on historical data for a particular procedure, along with input from the medical community. In theory, the contracted coverage should take into account the process capability across the client hospital system.

Example

A patient is admitted to the hospital for a common medical procedure. The procedure is nonlife threatening, and the outcomes are well established across the medical community. Advanced Healthcare System (AHS) has a recently negotiated contract with Blue Cross for insurance coverage for this common procedure.

Assume a patient is admitted to a hospital after a knee replacement. The procedures, cost, length of stay, follow-up complications, recovery, etc. are well known in the US healthcare system. AHS has contracted with Blue Cross for reimbursement of a typical hospital stay. The sake of argument, we will assume three days is the average length of stay for a knee replacement.

We must draw a distinction between the process capability of the hospital system versus the specifications set by the physician and the health insurance company (Lower Control Limit and Upper Control Limit). The control limits are arbitrary stakes in the ground, not necessarily related to the process capability. I will take some license showing you this data on a normal distribution, but remember, the sampling distribution of means will be normally distributed.

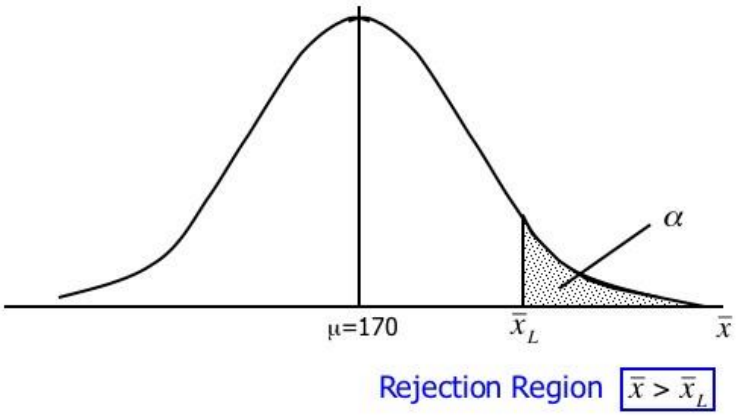
The physician may have a standard policy that an uncomplicated knee replacement requires a minimum one night stay in the hospital. But due to complications, age, pre-existing conditions, etc. the average stay in the hospital is actually three days. The insurance company has negotiated with the hospital system and has agreed to pay up to five nights in the hospital, without an exception order being required by the physician.

We will start with a standard figure of a normal distribution. Then we look at the specific distribution we are describing, centered on three days with a standard deviation of 2/3 of a day. The diagram describes the mean ± 3 sigma, an asymptotic, normal distribution of means. Now, superimpose the control limits described by the physician and the insurance company. Remember, this data assumes that we have done a process capability study and our best description of the underlying distribution is described by this picture.

Let's walk through some scenarios that might occur for an INDIVIDUAL patient admitted to AHS for knee surgery.

Rejection region

It seems reasonable to reject the null hypothesis in favor of the alternative if the value of the sample mean is ***large*** relative to 170, that is if $\bar{X} > \bar{X}_L$.

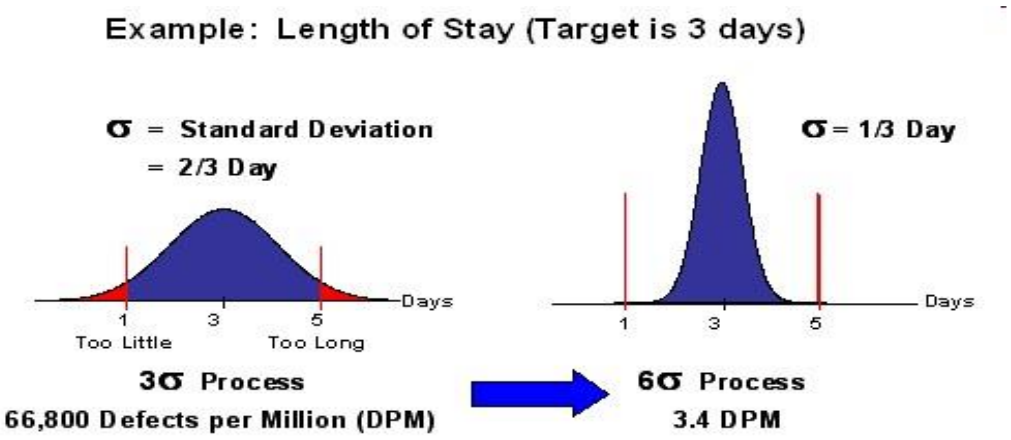


α = P(Type I error)

= P(reject H_0 given that H_0 is true)

$\alpha = P(\bar{X} > \bar{X}_L)$

Goal: reduce variation



CONSTRUCTING LANGUAGE RESOURCES FOR FASHION MERCHANDISING MAJORS FOR A GENERALIZED AI CURRICULUM

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ABSTRACT

While Artificial Intelligence (AI) has long been the pursuit of Computer Science, Data Science and Mathematics, the use of narrow AI has quickly spread to a variety of industries. The use of Machine learning has transformed various industries including image-driven industries such as the fashion industry. While workers in these industries may not fully understand how the AI tools are created, it is still important for them to know what information is gathered and how they can be utilized to solve specific problems. To help address this growing divide between AI and its industry clientele, we have started to roll out an AI curriculum in different departments at our university, as the understanding of the possible use of AI can be meaningful for college students in making their future career decisions or in developing their career path. To bring AI to our fashion merchandising students, we created a corpus of more than 400 women's athletic shoes from a well-known online retailer. The athletic shoes represented a variety of types and brands. They were harvested via a scrapper written directly for this purpose. The students were able to examine the uses of a dataset in the choices they may make regarding design, color, style, size, and feature descriptions. The curriculum around this module was designed for two 75-minute modules covering AI topics and data analysis using a fashion language resource.

INTRODUCTION

In 2017, it was projected that the United States would have a shortfall of 250,000 data scientists within a decade [7]. One way to address the shortfall in
Industry is to inform technical curriculum to be more directed at the needs of jobs. As data science spreads to new industries and domains, the approach is to make experts in new domains aware and capable of consuming data science and AI technologies.

To move forward and address these shortcomings in industry, our university has worked with MITRE Corporation on their GenAI program. The goal of GenAI Program is to create and implement AI curriculum across disciplines. Modules created for this initiative are made available to other partner institutes to be used and modified. This curriculum makes all materials necessary for lesson plans, including course objectives, presentations, AI tools, and datasets available to instructors.

According to MITRE "The Fourth Industrial Age will burn through massive amounts of data, with potentially hundreds of thousands of analysts employing AI tools to make sense

of it all. [4]" This will not be a data science problem alone, as those with domain knowledge will be the analysts in many cases.

BACKGROUND

Fashion products, as one of the major consumer products that retailers strive to make profits from, have been increasingly using AI in the fashion supply chain. In most cases, fashion retailers have been using the various data ranging from scanning the barcodes at the point-of-sales to online product review, to make effective strategies in areas such as predicting consumer demands and making efforts in accurately forecasting trends for product development. Overall, many AI professionals foresee that the use of AI in the fashion industry will increase productivity and efficiency in automated operation and research-based decision making [2]. Though there has been consistent effort in utilizing AI in the fashion retail sector, there needs to be more research on the topics related to fashion and AI. Among the limited number of research regarding the topic,[5] investigated how consumers evaluate the identical product on competing online retailers using AI, specifically sentiment analysis, and found statistically significant differences in how consumer sentiment affected review scores between two major online retailers (i.e., Amazon.com and Macys.com). From a forecasting standpoint, [3] investigated how AI can be used in predicting sales in the specific realm of the fast fashion industry. They developed an algorithm that provides a tool for reasonably accurate forecasting, given the short consumption cycle unique to fast fashion companies.

Data scraping has been done on various Fashion categories from product identification [8] to social media trend detection [6] [9]. Most attempts have been geared towards competitive advantage by targeting the appropriate social space [1] or automatic identification of product features. The importance of image corpora has been seen for these issues with extension annotations done [10]. We have constructed our corpus to be an education tool used by students in the fashion domain. Ours is aimed at store analysis and product description features.

DATA CURATION

A spider and crawler were programmed to follow the links from the default search page given a query. The query for our analysis was "women's shoes." Navigational links were excluded so only the search results were harvested for this data. Restrictions were not applied to the spider, and therefore, we took any result that came back for women's shoes. This included advertisements and sponsored links that may have come up. This has potential for non-related products to infiltrate the dataset. However, we decided to keep them in, since this might be of interest to merchandising students. These extraneous items can also be a valuable learning situation for students who are not familiar with how typical search and information retrieval may yield certain outputs.

Once the URL lists were created via the spider, each one was scrapped using a python script to download and extract relevant information. For each shoe, we gathered:

- *Unique ID*: A code given by the website to identify the product
- *Name*: Full title given to the product
- *Price Range*: Prices come in three forms on this site. A single price may be given if the product does not offer any variations. The product may also have a low and a high price, as a reflection of dynamic pricing. For instance, the price of certain sizes might go up due to low inventory. Some colors have a higher marked price as well. In these situations, the prices on the website are given as low price-high price. In the corpus, both prices are recorded.
- *Category*: Categories are automatically annotated from the directory navigational structure of the website. For instance, Clothing -> Shoes & Jewelry ->Women -> Shoes -> Athletic -> Walking
- *Rating*: This is an average of all customer review scores from 1-5 stars
- *Number of Ratings*: How many customers left a review for this product?
- *Brand*: Brand or store name. This feature has the most empty values due to many products using a graphical image as their brand logo without alt text
- *Colors Available*: a list of all merchant supplied colors. These colors are merchant defined, so it is not a close group of colors.
- *Sizes Available*: a list of all sizes available included variations such as width of the shoes
- *Product Features*: this is a large set of text which includes all text that the merchant added to the description of the shoe. This text may occur anywhere on the page that is not included in the other features.
- *Number of Questions and Answers*: The site includes an ability to ask questions to the merchant or the community at large. This is a count of how many have been asked.

Due to the nature of the website we are scraping, the data lacked consistency and required a few post-processing scripts. The website lets merchants enter in their own data for their products without consistency or accuracy. This, while good for the merchant, can lead to some odd data points. For instance, one merchant put heel size in as a color option. Categorical information also gets sparse at times. This is very apparent for color selections. While some vendors only specify the main color of the shoes, while other merchants put every color that is on the shoes (color1/color2/color3). For both choices, the merchants do not have to pick from a set ontology of colors but
can describe their color however they want. For example, a white shoe may become a pearl shoe, and a black shoe may become a charcoal shoe. Though this adds complexity to the data analysis, it showed the variety in marketing for our intended audience of fashion merchandising students.

Many of the features scrapped from the website were not immediately consumable for data analysis and machine learning. Information that was open to enumeration with custom text such as colors, were better suited to having a count feature such as number of colors. Some information such as sizes available, increased the sparsity of the data by adding in wide sizes of shoes. For information like this, we captured it in Boolean features such as wide_sizes_available.

Data is available in two formats, a comma separated file and a JSON document. Since this is a cross discipline dataset, we wanted to make it usable for those in data science with JSON as well as those who are more practiced with Excel sheets using comma separated files.

CURRICULUM

We had four objectives for this AI and Language Resource Module:

1. Investigate how AI and data science are changing the Fashion Industry
2. Identify possible sources for fashion trend data
3. Create research questions useful for trend forecasting or future product development
4. Recognize the predictive value of data analysis through visualizations

Two 75-minute modules were created for this course. The first module was a general AI in fashion lecture to make the students aware of the direction of AI in the field from the point of view of fashion consumers, product developers, and merchandisers. Students were led in a discussion of different ways AI can be applied to their field. Students brainstormed on possible areas where they thought computers and data could help and where they thought a fashion merchandiser was needed.

The second module dove into the data from the web scrape of shoes. Students were asked to browse the sites, identify what details on a product page were critical to a shoe's success, what would help identify a trendy product, and any fashion specific terminology. Afterwards, students were presented with the results of the data analysis to see if the data matched their intuition.

The lectures were repeated in two semesters. The first semester was pre-Covid19 pandemic and was in person. The second semester was done online via live synchronous zoom sessions. To conduct the group product investigation, we turned to Padlet for brainstorming and documenting the students' intuitions.

DISCUSSION AND FEEDBACK

To help students identify trends in the fashion shoe corpus, we presented them with various scatter plots so that they could analyze their initial thoughts on the products vs the overall trends across 400+ shoes. Much of their intuition was confirmed by the data with a few examples that prompted further class discussion into how AI can be used in the fashion

	product_rating	product_qa	num_colors	show_low_price	show_high_price	num_sizes
product_rating	1	0.115252	0.0536986	0.159727	0.125138	0.0394069
product_qa	0.115252	1	0.252759	-0.0156235	0.115355	0.366884
num_colors	0.0536986	0.252759	1	-0.0762772	0.213955	0.267602
show_low_price	0.159727	-0.0156235	-0.0762772	1	0.512204	0.0480365
show_high_price	0.125138	0.115355	0.213955	0.512204	1	0.284485
num_sizes	0.0394069	0.366884	0.267602	0.0480365	0.284485	1

Figure 1: Correlation Matrix of select features in the corpus

industry. Overall, the dataset was a useful tool in pushing students further to analyze how merchandising decisions are made.

While the students are not statistically trained, we did present them with one correlation matrix seen in Figure 1, along with a simple description of correlation in order to see if the students could identify possible features in the corpus. One correlation noticed by many was the correlation between the num_colors and the num_sizes. Raising both variables brought up a conversation of the management of multiple stock keeping units (SKU)s in an online store. This connection between technical data science and their domain knowledge was the main objective of this pedagogical project.

Students were also shown some simple bag-of-words techniques,
such as frequency charts using word clouds as seen in Figure 2. Following discussion about what can be gathered from a low dimensional word cloud, we went on to other visualizations such as n-gram distributions using bar charts as seen in Figure 3. Students were able to see how the additional context can give a product important selling points and with some changes, unique attributes. Important features of a shoe can be seen in Figure 3,

such as the requirements to indicate if your materials are imported or not and the measurements of the shoe.

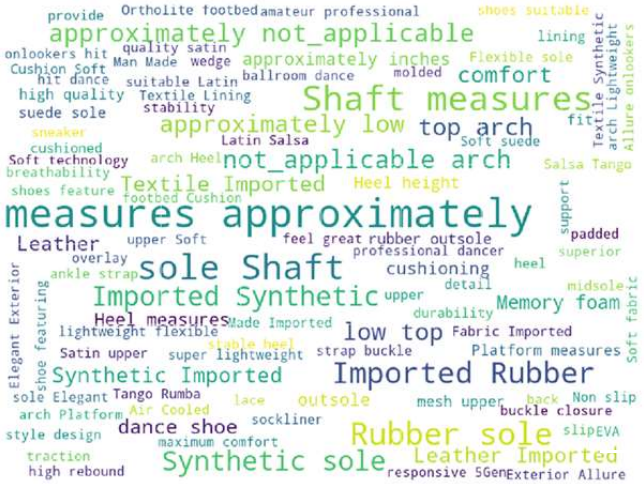

Figure 2: Simple word cloud for unigram frequencies

In the current fashion corpus, we have an aggregation of customer review score and number of reviews. Students brought up interesting points in analyzing the actual customer reviews (e.g., fit, break-in period). In the next iteration of the fashion corpus, we will include access to customer reviews and sentiment scores. This will likely bring up research questions on what to highlight or concentrate on in product descriptions, in order to encourage customers to leave a positive review. For the first pass of using this corpus in a fashion merchandising class, another important objective was to develop visualizations for use with a non-technical audience. In future iterations of the course, we will add course content that enables the student to create faux products and websites that exemplify the results they are seeing in the fashion corpus.

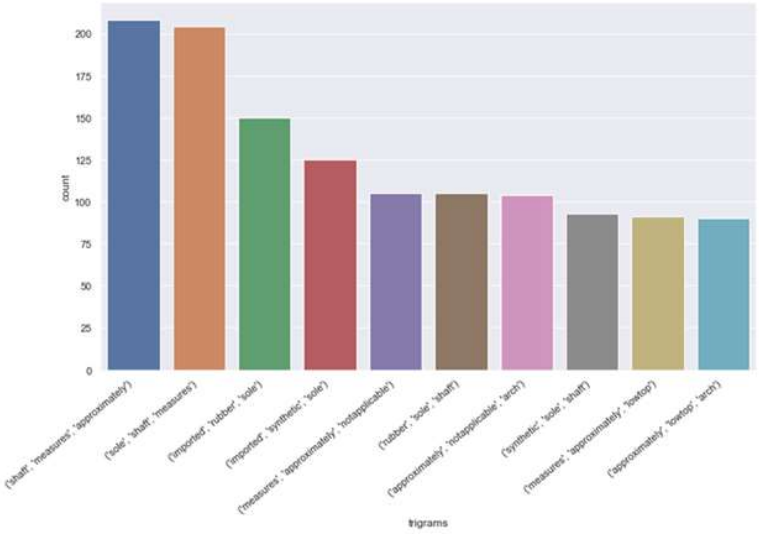

Figure 3: Trigrams across all shoes

CONCLUSION

AI and data analytics have become requirements for more jobs in various domains. Many recruiters are looking for employees who can be cross-trained to make data-driven decisions. Considering such demand from many industries including the fashion industry, we have created a fashion shoe corpus that allows us to teach AI and data analytics to students who major in fashion merchandising, to better prepare them for their future career. This is our first attempt at using a language resource to construct a module for a course outside of Data Science. The curriculum was well received, and it led to an initial entry point to AI for fashion students. Future modifications will be made to the corpus and to the course module learning objectives, to maximize the educational

outcomes from this language resource. The resource is open-source and being made available through MITRE's GenAI program.

REFERENCES

[1] Chakraborty, R., Kundu, S., and Agarwal, P. (2016). Fashioning data - a social media perspective on fast fashion brands. In Proceedings of the 7thWorkshop on Computational Approaches to Subjectivity, Sentiment and Social Media Analysis, pages 26–35, San Diego, California, June. Association for Computational Linguistics.
[2] Chao, G., C. J. H. K. L. J. (2019). The coming ai revolution in retail and consumer products: Intelligent automation is transforming both industries in unexpected ways. https://www.ibm.com/downloads/cas/NDE0G4LA, January.
[3] Choi, T.-M., Hui, C.-L., Liu, N., Ng, S.-F., and Yu, Y. (2014). Fast fashion sales forecasting with limited data and time. Decis. Support Syst., 59:84–92, March.
[4] Eidson, B. (2018). Preparing the next generation for the fourth industrial revolution the mitre corporation, July.
[5] Kang, J. Jang, S. (2016). Iowa state university digital repository - international textile and apparel association (itaa) annual conference proceedings: How do consumers evaluate the identical product on competing online retailers? a big data analysis approach using consumer reviews.
[6] Kushkuley, S. (2012). Trend analysis in harper's bazaar. In CLfL@NAACL-HLT.
[7] Manyika, J. (2017). What's now and next in analytics, ai, and automation | mckinsey, May.
[8] Rubio Romano, A., Yu, L., Simo-Serra, E., and Moreno-Noguer, F. (2017). Multi-modal fashion product retrieval. In Proceedings of the Sixth Workshop on Vision and Language, pages 43–45, Valencia, Spain, April. Association for Computational Linguistics.
[9] Xing, T. (2018). Data modeling and analysis on fashion evolution. In Proceedings of the 11th International Symposium on Visual Information Communication and Interaction, VINCI '18, pages 110–111, New York, NY, USA. ACM.
[10] Zheng, S., Yang, F., Kiapour, M. H., and Piramuthu, R. (2018). Modanet: A large-scale street fashion dataset with polygon annotations. In Proceedings of the 26th ACM International Conference on Multimedia, MM '18, pages 1670–1678, New York, NY, USA. ACM.

OVERCOMING KNOWLEDGE RETENTION ISSUES FROM THE FIRST PRINCIPLES COURSE

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ABSTRACT

This study reports the results of a strategy to improve retention of a specific concept from the first Principles of Accounting course. Following research on the effect of retention from the first course to performance in the second course, we explore the effects of a targeted experimental intervention on performance. In prior published research, we found a student's inability to demonstrate understanding of key concepts from the financial accounting course are significantly related to important learning objectives in the second course. Here we report how students predicted to choose incorrect answers performed after the targeted experimental intervention.

INTRODUCTION

Most University programs offering a major in Business require students take two Accounting Principles classes, most commonly with Financial Accounting the primary content of the first class and Managerial Accounting the second. [4]. Continuing research has connected general academic factors such as prior academic success, often measured using GPA, prior knowledge of accounting [12] [3] [11] [5] and gender on success in accounting courses.[13] [14]. The importance of the first course lies in its ability to both present useful accounting information that can lead to better decision-making for all business majors, and to attract, or discourage, individuals from becoming accounting majors [10]. In this paper we look at how to improve retention of a concept from the first Principles of Accounting course, specifically the ability to identify what is an Asset. The study was conducted over six semesters, all courses taught online, including a total of 428 students. The course is the second in the Principles of Accounting sequence, required of all majors in the College of Business. The class is primarily a Managerial accounting class, with the focus on determination of costs and prediction of costs for budgeting purposes. A review is conducted at the beginning of the class, covering Financial Statements (order of preparation; what each statement includes and how it is used); Account types (asset, liability, equity, revenue, and expense: recognize accounts in each category and on which financial statement each is reported); and the use of debits and credits (which accounts have a debit or credit balance).

PRIOR LITERATURE

Prior literature includes a significant number of studies that have been conducted to address various aspects of the introductory accounting courses [9] and [2] proposed that the content and objectives of the Principles sequence be considered a priority. They ask the question "Have you ever heard anyone describe the **objective** of the elementary accounting sequence?" They propose

that the “elementary accounting courses should be thought of as general education courses, primarily for the business major perhaps, but also of value to a wide variety of students across the campus. We suggest a complete revamping of content and pedagogy to serve the needs of the 80-85% of enrollees that will not become accounting majors, rather than the needs of the 15-20% of students who will.”

The literature is rich in studies on the effect of prior content knowledge and prior academic success on student performance. Tan and Lasward [14] found that prior content knowledge is an important predictor of success. In the context of this study, knowledge from the first principles course would be expected to be a factor in success in the second course. Byrne and Flood [3] also found a positive effect on performance in the first accounting course in University when students had prior accounting content knowledge from pre-University academic courses. Warren andYoung [16] reflect on the tendency of students to lose much of what they learned in the first Principles course before they begin the second Principles course.

The literature on student performance in online principles courses includes the research of Papageorgiou and Halabi [13]. Looking at determinants of student success in online accounting courses, these authors find academic aptitude and prior content knowledge as strong factors in success. The study included eight courses in accounting over the course of earning a degree, and found that as students progressed, the effect of pre-University content knowledge was reduced. The authors did not directly consider the effect of content in one University Accounting class on success in another University Accounting class.

Etter et. al [6] report on the effect of supplemental instruction on performance in Principles of Accounting. Although the intervention here is not a full SI program, the effect of any extra help in preparing students seems to be positive.

METHODOLOGY

Data Sources

This paper uses course performance data from 428 students taking an online managerial accounting course taught by one professor during at a medium size university in the southeastern United States. These students were treated in three distinct subsets: model creation – 231 students from Spring through Summer 2020; model testing – 100 students from Spring and Summer 2021; and Intervention Trial – 97 students from Fall, 2021. The University IRB office treated this as exempt from review because there was minimal student risk and the main intent was to improve instruction. The data include student performance on a Review Quiz, Exam One, Final Exam, and overall course grade. For this study the data on the Final Exam and overall course grade are not analyzed. Nearly all these students received only online instruction. One section of 28 students in the Spring term of 2020 received in-person instruction the first 10 weeks of the term. This section was transitioned to on-line instruction using online lectures and resources in mid-March, 2020 due to university COVID safeguards. These students were not significantly different on key independent variables from those who received only on-line instruction. The exams were all multiple choice and done online with randomized question presentation.

The preliminary findings on knowledge retention from the first course of Accounting Principles were presented at the May, 2021 Southeast Regional meeting of the American Accounting Association. Based on feedback from our presentation, we felt encouraged to integrate more student background data into our research. Our University Institutional Research office generously provided key data including student transfer status, transfer institution, transfer credits, GPA as of the end of the prior term, the grade received in the first principles course, high school GPA, high school graduation date, birth date, and other items. Trowler et.al. [15] extensively review the literature and evidence regarding student engagement generally and Aldamen et.al. [1] explore the relationship of student engagement to student performance specifically in accounting courses. To include elements of student engagement we extracted data from the online course logs for the period prior to Exam One. From these logs, we determined the frequency of accessing the online course materials overall as well as specific aspects of the course for each student.

ANALYSIS

Predicting Knowledge Retention Deficit

The focus of this paper is on the impact of an intervention on knowledge retention. To provide a bit more depth we will discuss the prediction of inadequate knowledge retention. Using the data from the 231 students in the model creation subset, we applied logistic regression to create a predictive model regarding the likelihood a student would respond correctly or incorrectly to the asset question on Exam One. The model was built using data from students in online courses Spring, Summer, and Fall of 2020. These were the same students used in our JHETP paper, [7].

The predictive measure suggested by the initial regression was highly predictive for correct response on the low end of the measure as well as on its high end. On the low end, 94.6% of 148 students were correctly predicted. On the high end, 90.6% of 32 students were correctly predicted to miss the asset question.

The remaining 35 students in the middle range split with about 46% answering correctly and 54% giving an incorrect response. Another logistic regression was conducted on these 35 students. Variables that had low significance to the overall equation were eliminated because there were too many variables to conduct the regression with so few students. For these students, the predicted response from the second regression was substituted for the prediction from the first regression to yield the final predictor. On the final predictor, about 95% of students predicted to respond correctly to the question did in fact respond correctly. The prediction of incorrect responses was also strong with about 94% of students predicted to respond incorrectly being incorrect. The combined correct responses and incorrect responses were correctly predicted for 94.9% of the students.

To test the model, we applied it to students in the model testing subset who took the course during the Spring and Summer terms of 2021. Among the students in model testing subset, 80.3% who were predicted to give a correct response to the asset question, did respond correctly. Of those who were predicted to give an incorrect response to the question, 39.3% were incorrect. This yielded an overall level of 68.1% correct prediction. These results suggest the regression model developed is over specified. However, the prediction still appears to be of value in

distinguishing between those students likely to get the asset question correct without any intervention.

The predictor variables may be categorized according to their conceptual influence on student performance. The categories were developed ad hoc and included academic path, academic success, engagement, knowledge retention, personal, and summary measures. We categorized 14 measures as representing the academic path the student had followed prior to the course. The academic path included measures related to transfer status, transfer institution, the number of days since high school graduation, the days since taking the first accounting course, hours transferred (if any), hours earned prior to the course, and so forth. Academic success included 9 measures such as ACT and SAT scores, high school and college GPA's, and final grade in the first Principles course. Engagement included 10 measures of the frequency with which the student accessed various portions of the online course prior to Exam One. Knowledge retention included 5 measures of correct or incorrect response to specific questions from the review quiz and the overall review quiz percent correct. The personal category included 4 measures including the student's age, gender, the department of their major, and the proximity of the state of their transfer college to the university.

The variables in the regression were all standardized allowing the beta weights to indicate the importance of each measure in the overall prediction [8]. The table below presents the average of the absolute beta weights for each category. The higher the average weight, the more important that category is in predicting knowledge retention. Focusing on the weights from the initial regression, the engagement category had the highest average weight and may reflect the efforts of students to overcome deficiencies they identified from other work in the course. The academic path variables had the next highest average and prior academic success had the lowest average weight. The initial regression was particularly accurate for about 84% of students on either end of the resulting measures.

TABLE ONE
Average Beta Weights

Category	Initial Predictor Equation	Middle Section Predictor Equation
Engagement	**1.286**	**30.608**
Academic Path	**1.132**	**33.026**
Knowledge Retention	**0.976**	**17.026**
Personal	**0.910**	**29.013**
Academic Success	**0.689**	**83.747**

Shifting the focus to the remaining 16% of students, a different pattern emerges. Prior academic success was considerably more important than the other categories with engagement, academic path, and personal variables being roughly equal. Knowledge retention was the least important with these students.

Weaknesses Identified

To help students self-identify possible weaknesses in the knowledge and understandings of important concepts they had retained from basic accounting principles, they were required to complete a Review Quiz of thirty-four questions. After they received their quiz results, online resources were provided to help them better understand the items on which they had difficulty and to overcome deficits in their retention. They were able to retake the quiz a second time to confirm their mastery of the material. Students during 2020 taking the quiz only once had higher scores (median 91.2% correct) than those who retook the quiz. The median correct score for the 56.3% of students who retook the quiz rose from 73.5% on the first try to 97.1% on the second try. This suggests students did benefit from reviewing their errors and used the online resources. A student's highest grade was worth up to 10 points out of 1,000 toward their final course grade.

We found [7] that gaps in concept mastery persisting well into the course reflect negatively on course performance. The inability to give correct responses to review questions on Exam One given in the 5th week of the term suggests that the lack of concept retention has continued beyond any initial time when students might begin to think in accounting terms. Specifically, these results suggest that understanding basic accounting concepts such as "What are assets?", "What are debits and credits?", and "What does an income statement show?" are significantly related to the percentage of correct responses on the comprehensive final and to the final course grade. For example, students able to correctly identify and total asset accounts received final course grades that were two thirds of a letter grade higher than those who were unable to do so correctly.

Can Knowledge Deficits Be Rectified?

Rather than trying to rectify these knowledge deficits through changes in the curriculum preceding the second course, we developed an experiment to provide focused instruction on areas of weakness. During Fall 2021 we provided two PowerPoints on these areas the day before Exam One. Students were encouraged to use the PowerPoints to bolster weaknesses they might have. One PowerPoint was somewhat more focused on identifying assets (a key weakness we had identified) and the other had more content on accounting statements. There was considerable overlap between the two.

The students were randomly assigned to one or the other of the PowerPoints. Students who accessed their assigned PowerPoint and submitted an online statement that they were "DONE" with the assignment were given 5 bonus points toward their 150 point quiz total. Students were able to self-select to forgo the small number of points if they felt confident in their mastery of the material. There was evidence the 25% of students who did not do the PowerPoint were correct in their judgement of mastery. Only 8.7% of them missed the asset question compared to an error rate of 38% for the 58 students who did the PowerPoint before the exam.

Our original intent was to compare students accessing the two PowerPoints. We found there was no significant difference between the two groups. Considering the similarities between the two PowerPoints, we elected to look for effects based on the time spent on the PowerPoints. Using the time and date stamps on the course logs we took the difference between their initial access of

the PowerPoints and the submission of "DONE" as a surrogate for how much time they spent studying the PowerPoint.

Table Two shows the overall impact of the experimental intervention on student response to the asset question on Exam One. Of those who spent two minutes or less on the PowerPoint, 50% missed the asset question. While, of those who spent three or more minutes on it only 26.7% missed the question. Table Three presents the T-Test on these data indicating a significant difference between the two groups and a mean difference of 23.3%.

TABLE TWO
Percent Incorrect Response to Asset Question on Exam One by Time on PowerPoint

		N	Mean	Std. Deviation	Std. Error Mean
Time on PowerPoint	Two Minutes or Less	28	50.0%	0.509	0.096
	Three Minutes or More	30	26.7%	0.450	0.082

TABLE THREE
T-Tests: Asset Question on Exam One
by Two vs. Three Minutes on PowerPoint

		F	Sig.	t	df	One-Sided p	Mean Difference
Identify and Total Assets	Equal variances not assumed	7.527	0.008	1.845	53.988	0.035	23.3%

Tables Two and Three show the overall impact of this intervention. Does the intervention differentially impact the students who we would expect to do well on the question or worse on it? Tables Four through Seven explore these questions. Among students who were predicted to get the asset question correct, there was not a significant difference between their performance based on how much time they spent on the PowerPoint. Conversely, among students who were predicted to get the asset question incorrect, the reverse was true. Those taking three or more minutes on the PowerPoint were significantly more likely to get the asset question correct than those who spent only two or fewer minutes on it. Their mean difference was a substantial 54.9%.

TABLE FOUR
Asset Question by Time on PowerPoint
for Students Predicted to Give the Correct Response

		N	Mean	Std. Deviation	Std. Error Mean
Time on PowerPoint	Two Minutes or Less	15	33.3%	0.488	0.126
	Three Minutes or More	16	37.5%	0.500	0.125

TABLE FIVE
T-Tests: Asset Question on Exam One
by Two vs. Three Minutes on PowerPoint
for Students Predicted to Give the Correct Response

		F	Sig.	t	df	One-Sided p	Mean Difference
Identify and Total Assets	Equal variances assumed	0.219	0.643	-0.235	29	0.408	-4.2%

TABLE SIX
Asset Question by Time on PowerPoint
for Students Predicted to Give the Incorrect Response

		N	Mean	Std. Deviation	Std. Error Mean
Time on PowerPoint	Two Minutes or Less	13	69.2%	0.480	0.133
	Three Minutes or More	14	14.3%	0.363	0.097

TABLE SEVEN
T-Tests: Asset Question on Exam One
by Two vs. Three Minutes on PowerPoint
for Students Predicted to Give the Incorrect Response

		F	Sig.	t	df	One-Sided p	Mean Difference
Identify and Total Assets	Equal variances assumed	4.305	0.048	3.333	22.314	0.001	54.9%

How might these impacts compare with knowledge retention among the prediction groups in the model test subset (Spring or Summer 2021)? Tables Eight and Nine address this question. Students in the test subset who were predicted to give the correct response to the asset question

were not significantly different from Fall 2021 students who spent three minutes or more on the PowerPoint. Conversely, those students in Spring or Summer 2021 who were predicted to give an incorrect response were significantly more likely to miss the asset question than Fall 2021 students who spent three minutes or more on it.

TABLE EIGHT
Asset Question – Fall 2021 Students with Three Minutes or More on PowerPoint vs. Spring or Summer Students Without PowerPoint by Predicted to Give the Correct or Incorrect Response to the Question

Prediction	Term	N	Mean	Std. Deviation	Std. Error Mean
Predicted to be **correct**	Spring Summer 2021	66	19.7%	0.401	0.049
	Fall 2021	16	37.5%	0.500	0.125
Predicted to be **incorrect**	Spring Summer 2021	28	39.3%	0.497	0.094
	Fall 2021	14	14.3%	0.363	0.097

TABLE NINE
T-Tests: Fall 2021 Students with Three Minutes or More on PowerPoint vs. Spring or Summer Students Without PowerPoint by Predicted to Give the Correct or Incorrect Response to the Question

		F	Sig.	t	df	One-Sided p	Mean Difference
Predicted to be **correct**	Equal variances not assumed	5.881	0.018	-1.325	19.924	0.100	-17.8%
Predicted to be **incorrect**	Equal variances not assumed	17.031	0.000	1.850	34.295	0.036	25.0%

DISCUSSION

A student's ability to correctly identify and total the balances of asset accounts is a knowledge and skill which should carry over from an entry accounting course to managerial accounting. W show [7] evidence that students who are unable to demonstrate this skill by the first exam of the managerial course are less successful on their final exam and in their final course grade. To address these deficiencies in knowledge retention we implemented an experimental intervention to bolster their retention. Students who spent at least three minutes on the intervention had improved performance on the asset question on Exam One. Particularly, the intervention appears to have been more helpful for those predicted to miss the question. We also found that of the five categories of predictor variables engagement had the highest beta weights for the first and

most important part of the predictor equation. The measures of knowledge retention were at the middle level of importance.

How might we use these findings to improve student success? Focusing on the introductory course seems unlikely to yield a strong result because of the length of time between courses and the different institutions where the introductory course may have been taken. We believe stronger student performance may come from interventions that increase engagement. (The intervention in our experiment focused more directly on knowledge retention.) Among the intervention possibilities may be small group mentoring sessions, holding required review sessions, and a more extended period for them to work with additional review material.

REFERENCES

[1] Aldamen, H., Duncan, K. & Ziegelmayer, J. L. (2018). Cumulative learning and sustained engagement in an introduction to accounting course, *Asian Review of Accounting*. 26(1), 19-38.

[2] Baldwin, B. A., & Ingram, R. W. (1991). Rethinking the Objectives and Content of Elementary Accounting. *Journal of Accounting Education*, 9(1), 1-14.

[3] Byrne, M., & Flood, B. (2008). Examining the Relationships Among Background Variables and Academic Performance of First Year Accounting Students at an Irish University. *Journal of Accounting Education*, 26(4), 202-212.

[4] Danko, K., Duke, J. C. & Franz, D. P. (1992). Predicting Student Performance in Accounting Classes. *Journal of Education for Business*, 67(5), 270-274.

[5] Doran, B. M. et. al., (1991). Determinants of Student Performance in Accounting Principles I and II. *Issues in Accounting Education*, 6(1), 74-84.

[6] Etter, E.R., Burmeister, S.A. & Elder, R.J. (2000). Improving student performance and retention via supplemental instruction. *Journal of Accounting Education, 18(4), 355-368*

[7] Hutchins, R. and Hutchins, G. (2021) Effect of Retention of Knowledge from the First Principles Course on Performance in the Second Principles Course. *Journal of Higher Education Theory and Practice.* 21(11). https://doi.org/10.33423/jhetp.v21i11.4674

[8] Johnson, J. W. and LeBreton, J. M. (2004). History and Use of Relative Importance Indices in Organizational Research. *Organizational Research Methods.* 7(3), 238-257.

[9] Jordan, E. E. & Samuels, J. A. (2020). Research Initiatives in Accounting Education: Improving Learning Effectiveness. *Issues in Accounting Education*, 35(4), 9-24

[10] Kaenzig, R & Keller, R. (2011). A Comprehensive Effort to Recruit and Retain Accounting Students. *Journal of Accounting Education*, 29, 63-78

[11] Pasewark, W. R. (2020). Research Initiatives in Accounting Education: A Proposed Agenda for Accounting Education Research. *Issues in Accounting Education*, 35(4), 3-7

[12] Papageorgiou, E., & Carpenter, R. (2019). Prior Accounting Knowledge of First-Year Students at Two South African Universities: Contributing Factor to Academic Performance or Not?. *South African Journal of Higher Education*, 33(6), 249-264.

[13] Papageorgiou, K., & Halabi, A. K. (2014). Factors contributing toward student performance in a distance education accounting degree. *Meditari Accountancy Research*, 22(2), 211-223.

[14] Tan, L. M., & Laswad, F. (2008). Impact of Prior Content and Meta-Cognitive Knowledge on Students' Performance in an Introductory Accounting Course. *Pacific Accounting Review,* 63-74.

[15] Trowler, V., Allan, R.L., Bryk, J. & Din, R.R**. (**2021). Pathways to student engagement: beyond triggers and mechanisms at the engagement interface. The Higher Education Academy. https://doi.org/10.1007/s10734-021-00798-1

[16] Warren, D. L. & Young, M. N. (2012). Integrated Accounting Principles: A Best Practices Course for Introductory Accounting. *Issues in Accounting Education.* 27 (1), 247–266.

THE 2021 TITLE I FAMILY ENGAGEMENT SURVEYS: AN EQUITY OF VOICE IMPERATIVE

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ABSTRACT

This paper describes the rigor, innovation, and integrity brought to bear on the survey development process and subsequent data collection to support a Title I program aligned with new equity of voice practices in a large Northern Virginia school division. Discussed are the psychometric properties of the 16- and 18-item surveys, the constructs of interest, and the Family Engagement Sentiment Profiles that will enable the program to longitudinally track progress in Title I elementary and middle school community attitudes and behavior and make more informed data-driven decisions.

INTRODUCTION

At the request of the Title I Office, the Office of Program Evaluation revised the 2021 Title I Family Engagement Survey Elementary School and created the 2021 Title I Family Engagement Survey Middle School with the primary goal of enhancing the Office's reporting on federal grant requirements. The researcher engaged the work to better support the Title I community, a community anecdotally described as underserved, with rigorously obtained data. Also, uppermost in the researcher's mind were questions that guide her practice as an education researcher and program evaluator: What does it mean to focus on equity? How does this work promote, reinforce, or deny equity? And, in what ways do the words in this report convey equity? Meaning, it was imperative to understand the extent to which the Title I Office had been engaged in survey development, how surveys were administered, and how equity was addressed in that process. More importantly, it was necessary to acknowledge any unresolved requirements associated with the prior

year's elementary survey development to address those requirements in this new version and avoid those issues in creating the middle school survey.

Four fundamental changes to survey development and administration dramatically increased Title I Elementary school family data quality and quantity. First, the Family Engagement Committee stakeholder group of Title I Elementary school personnel provided substantive input and iterative feedback on the elementary survey and supported a new survey administration process. Similarly, a Title I teachers and personnel stakeholder group provided substantive input and iterative feedback and supported a new survey administration process for the middle school survey. Second, a week-long survey awareness campaign preceded an electronic survey administration for the first time in Title I survey administration history within the Division. Third, the awareness campaign and survey administrations took place through text message, email, and a new dedicated webpage on the Title I Office website. And finally, the surveys were translated into all nine Division languages.

The main challenge was to produce surveys that would allow the Title I Office to move the needle on how they use survey data to augment federal reporting requirements while also countering negative impressions associated with Title I families and the Title I program. More importantly, our collective, collaborative challenge was to do something new and different for the division Title I Office aligned with the strategic commitments of the new superintendent. Her strategic commitments of Learning and Achievement for All, Positive Climate and Culture, Family and Community Engagement, and Organizational Coherence inspired this innovative and sustainable work. This first administration of the surveys, data collection, and analyses is a foundation for the Title I Office to build upon as they take more and more ownership of this data collection each subsequent year.

The elementary and middle school surveys were composed of 16 and 18 questions, respectively, many of which had a write-in response option. As a best practice in survey development for underrepresented communities, write-in response options provided each family a voice and each school qualitative data to characterize their school-level data. Extending Shafer's use of equity of voice in the classroom, write-in response options ensures that every family that opts to participate in the survey has the chance to be heard by the Title I Office and the Division [2]. Equity of voice augments communication sharing and, most importantly, disrupts historical patterns of inequitable access to school and Division leadership through survey data and reinforces values such as tolerance.

The Title I Family Engagement Survey Elementary is based loosely on a previous survey, newly revised to be a data collection vehicle for the Office. The Title I Family Engagement Survey Middle School is an entirely new survey constructed similarly to the elementary version. The researcher applied factor analysis to identify dimensions in the data and verify scale construction for both surveys [1]. Five subscales were identified within surveys, meaning that despite the item's wording, survey items were grouped according to predominant statistical relationships to one another. Hence, the larger construct of "family engagement" is comprised of the following dimensions that express family perceptions as follows: Awareness of Title I Programming (ES or MS Awareness), Satisfaction with the Title I Reading Program (ES or MS Reading), Satisfaction with the Title I Mathematics Program (ES or MS Math), Perception of Title I School Climate (Elementary or Middle School Climate), and Overall Satisfaction with Title I Programming (Elementary or Middle School Overall Satisfaction).

The Sentiment Profile is meant to support the Title I Office in decision-making and connecting those decisions to engagement levels between Title I families, the Office, and the school division. The Sentiment Profile distills data from the rigorously developed surveys. It allows the Title I Office to longitudinally track strengths and challenges in their family engagement efforts at the elementary and middle school levels.

Considering the novel utility of Title I Family Engagement Sentiment Profiles, the Office of Program Evaluation looks forward to the next iteration of this survey administration and further collaboration with the Title I Office to empower them with rigorously obtained survey data. Translation of the write-in responses into English, the primary language of the Title I Office leadership, is forthcoming.

ELEMENTARY SURVEY EXECUTIVE SUMMARY

- Every elementary school was represented in the data, and between 59 to 156 responses were received per school.
- Of the 2576 families who started the survey, 98.95% (n = 2,549) of families completed the survey.
- The write-in response options captured 1596 responses, with an overwhelming 61.96% of families sharing their voice with the Title I Office and the Division.
- We directed an awareness campaign through email, text message, and a new survey web page on the Division Title I website from May 17 through May 24, 2021.

- Survey reminders were sent via text and email on June 1, June 4, June 8, and June 11, 2021.
- The survey was closed on June 21, 2021, although most responses were received by June 7, 2021.

ELEMENTARY SURVEY SIGNIFICANT FINDINGS & RECOMMENDATIONS

The following findings from the Elementary-level family survey responses are noteworthy:

- Although 28.0% of families didn't know if their child received direct support from a Title I reading teacher, more than half (53.3%) of families were aware of this activity.
- Between 35.1% (Strongly agree) and 53.0% (Agree) of families have a positive sentiment about the support their child receives in reading, but 20.1% (n = 511, N = 2,539) were unaware of what tools are most helpful for their child in reading.
- Lexia was identified by 47.7% of families as being the most helpful tool to their child in reading. Considering last year as a pilot year and this year's ramped-up training and support of teachers and ITC's, it is expected that this response may increase.
- A surprising 28.9% (132) of families didn't know about Curbside Library Pick-up, but 18.6% said they would use it now that they are aware.
    - Recommendation: Since Curbside Library Pick-up checks out books to students, this service may be a conduit for communicating to the unaware parents about enrollment in Reading Strategies and tools that may help their child in reading. For instance, notifications might be auto-printed along with book due dates on the same ticket.
- 76.1 % (n =346, N = 456) of families are aware if their child is enrolled in Math Support, indicating high awareness, yet 65.6% (n = 299) of families are unaware of what tools seem most helpful to their child in mathematics.
    - Recommendation: The disconnect between these two numbers may indicate an opportunity for an explanatory survey question on this year's survey. Perhaps asking parents how often they sit with their child when she/he is doing math homework may further substantiate family indication of a desire for more math family events and the nature of those events.
- Regarding how many school or virtual school events middle school families attended, 64.0% (n = 293, N = 458) responded they did not participate in any events last year. This statistic is not surprising considering pandemic impacts.
    - Recommendation: Next year's survey should follow up with a "Why not?" question to determine the reason: Event timing (to confirm or refute newly implemented consistent scheduling this year), technology challenges, or other write-in explanations.

- Of the 165 families who attended one or more events last year, 90.7% (N = 160, Strongly agree or Agree, n = 145) found the event helpful. Similarly, 85.8% (N = 162, Strongly agree or Agree, n = 139) learned ways to help their child at home.
    - Recommendation: This is a solid descriptive statistic to share with families in communications to bolster attendance this year.
- In equal proportions, the survey data identified Friday, Saturday, and Monday as unequivocally the best days for family events at school-- 23.9% (107), 23.9% (107), and 23.7% (106), N = 448, respectively. The predominant time frames for events were between 5:30 and 7:30pm (62.9%, N = 340, n = 214). For families who selected Saturday as the best day for family events, those respondents identified afternoon between 11 am and 1 pm as the best time frame (43.0%, N = 107, n = 46).
    - Recommendation: The data suggests that event planners adopt alternating schedules between Saturdays (11 am to 1 pm) and a weekday. Implementing such as schedule might provide equitable access to events for all Title I middle school families. And if it is possible to repeat events, offering the same event on a Saturday and during a weekday might maximize attendance and provide equitable access to resources for families.
- Email messages (85.9%, n = 385), report cards (49.3%, 221), and text message (39.5%, n = 177) are the top three ways in which families receive information from teachers.
    - Recommendation: Next All-Title I-school communications could include a question asking the family which mode they received the notification to which they are responding: Email message or text message and compare that to the family information held by the Division. It may be that mobile phone numbers should be updated/confirmed annually.

TITLE I ELEMENTARY SCHOOL FAMILY ENGAGEMENT SENTIMENT PROFILE

The researcher collected and cleaned data and then examined the data with principal component analysis (PCA). The general purpose of PCA is to "identify a relatively small number of themes, dimensions, components or factors underlying a relatively large set of variables" [1]. In this instance, four subscales were identified: Elementary School Awareness of Title I Programming (ES Awareness), Elementary School Satisfaction with the Title I Reading Program (ES Reading), Elementary School Satisfaction with the Title I Mathematics Program (ES Math), and Perception of Title I Elementary School Climate (Elementary School Climate). The researcher constructed an Overall Satisfaction with Elementary School Title I Programming (ES Overall Satisfaction) profile by combining the "satisfaction" question from the ES Reading, ES Math, and Elementary School Climate subscales. Cronbach's alpha was used to estimate internal consistency for each survey and each subscale identified by PCA. The researcher eliminated an item if it had a PCA coefficient below .5. Four of 5 subscales met the Cronbach alpha requirement of .7 or

above. ES Overall Satisfaction had a Cronbach's alpha of .668, which identifies those questions as candidates for revising next year. Reliability statistics are listed below for each sub-scale. See Appendix B for profile score calculations.

The first measures of the Title I Elementary School Family Engagement Sentiment Profile are provided below:

Table 1 Awareness of Title I Programming (ES Awareness)

Q1. ES AWARENESS	>.5	**Descriptive Statistics (α = .713)**		
	PCA Coefficients	**N = 10,141**		**Profile Index**
		Yes	No	
a. Do you know your school receives federal funding under the Title I Program?	0.680	**n = 4883**	**n = 5258**	**48.15%**
b. Do you know about your school's Title I Parent and Family Engagement Policy?	0.820			
c. Do you know about your school's Continuous Improvement Plan?	0.762			
d. Do you receive invitations to Title I division-level meetings and events (e.g., ParentCamp)?	0.621			

Table 2 Satisfaction with the Title I Reading Program (ES Reading)

Q4. ES READING		**Descriptive Statistics (α = .871)**				
	> .5	**N = 10,089**				
	PCA Coefficients	(SD = 0; D = .25; A = .80; SA = 1.00)				**Profile Index**
		SD	D	A	SA	
a. My child has gained self-confidence as a reader.	0.802	**n = 456**	**n = 1247**	**n = 5675**	**n = 2711**	**74.96%**
b. My child reads more on her or his own.	0.787					
c. My child enjoys reading.	0.748					
d. My child understands what she/he reads.	0.749					

Table 3 Satisfaction with the Title I Mathematics Program (ES Math)

Q7. ES Math		**Descriptive Statistics (α = .911)**				
	> .5	**N = 10,061**				
	PCA Coefficients	(SD = 0; D = .25; A = .80; SA = 1.00)				**Profile Index**
		SD	D	A	SA	
a. My child understands math concepts better.	0.773	**n = 339**	**n = 1359**	**n = 6074**	**n = 2289**	**74.43%**
b. My child has gained self-confidence as a math student.	0.811					
c. My child completes math assignments on her or his own.	0.791					
d. My child enjoys math.	0.832					

Table 4 Perception of Title I Elementary School Climate (Elementary School Climate)

Q18. ELEMENTARY SCHOOL CLIMATE		**Descriptive Statistics (α = .848)**				
	> .5	**N = 6,007**				
	PCA Coefficients	(SD = 0; D = .25; A = .80; SA = 1.00)				**Profile Index**
		SD	D	A	SA	
a. I feel welcomed by my child's school community.	0.908	**n = 162**	**n = 271**	**n = 3263**	**n = 2311**	**83.06 %**
b. The communication I receive helps me feel involved in my child's education.	0.798					
c. I feel comfortable contacting my child's school.	0.875					

Table 5 Overall Satisfaction with Elementary School Title I Programming (ES Overall Satisfaction).

ES OVERALL SATISFACTION		**Descriptive Statistics (α = .668)**				
	> .5	**N = 1,341**				
	PCA Coefficients	(SD = 0; D = .25; A = .80; SA = 1.00)				**Profile Index**
		SD	D	A	SA	
Q4e. I am satisfied with the support my child receives in ***reading*** from the school.	.742	**n = 65**	**n = 97**	**n = 841**	**n = 280**	**78.82%**
Q9e. I am satisfied with the support my child receives in ***math*** from the school.	.578					
Q18d. Overall, I am satisfied with ***how Title I funds are used*** to enhance my school's programs.	0.801					

- The individual profiles show a satisfaction rate between 74.43% and 83.06% in the Elementary School Title I program elements.
    - Recommendation: A working group to explore the awareness metric (48.15%) might be a practical approach to exploring potential solutions. The more families are aware of the Title I program, the more they can be engaged in their child's school and Title I offerings.

Table 6 Title I Elementary School Family Engagement Sentiment Profile Benchmarks (100 PT Scale)

TITLE I ELEMENTARY SCHOOL FAMILY ENGAGEMENT SENTIMENT PROFILE BENCHMARKS (100 PT SCALE)	**SY**	
	20-21	**21-22**
Awareness (Yes=100/ N=0)	**48.15**	TBD
Reading (SD = 0, D = .25; A = .8; SA = 1)	**74.96**	TBD
Math (SD = 0, D = .25; A = .8; SA = 1)	**74.43**	TBD
Climate (SD = 0, D = .25; A = .8; SA = 1)	**83.06**	TBD
Overall (SD = 0, D = .25; A = .8; SA = 1)	**78.82**	TBD

MIDDLE SCHOOL SURVEY EXECUTIVE SUMMARY

- Middle school family participation was substantial; between 144 and 165 responses were received per school.
- Of the 465 families who started the survey, 98.1% (n = 456) of families completed the survey.
- The write-in response options captured 386 responses, with an overwhelming 61.96% of families sharing their voice with the Title I Office and the Division.
- We directed an awareness campaign through email, text message, and a new survey web page on the Division Title I website from May 17 through May 24, 2021.
- Survey reminders were sent via text and email on June 1, June 4, June 8, and June 11, 2021.
- The survey was closed on June 21, 2021, although most responses were received by June 7, 2021.

MIDDLE SCHOOL SURVEY SIGNIFICANT FINDINGS & RECOMMENDATIONS

The following findings from the middle-level family survey responses are noteworthy:

- The survey observed approximately equal participation aggregated by middle school. Harmony Middle School saw 31.4% (144) of responding families. United Braddock Middle School had 32.7% (150) of responses. Francis Loren Middle School saw 35.9% (165) of responses.
- Almost 41% (186, N = 456) of families did not know if their child was enrolled in Reading Strategies.
- Between 48% and 63.8% of families have a positive (Agree) sentiment about their child's Title I reading program, but 53.3% (242, N = 454) are unaware of what tools are most helpful for their child in reading.
- A total of 52.5% (N = 457) of families knew about their school's Curbside Library Pick-up service. These same respondents were likely the same respondents mentioned above who had a positive sentiment about their child's Title I reading program and identified the tools most helpful to their child in reading. For instance, 212 families (46.69%) identified Lexia, Epic, MyOn, Newslea, and other (write-in) tools as most helpful.

- A surprising 28.9% (132) of families didn't know about Curbside Library Pick-up, but 18.6% said they would use it now that they are aware.
    - Recommendation: Since Curbside Library Pick-up checks out books to students, this service may be a conduit for communicating to the unaware parents about enrollment in Reading Strategies and tools that may help their child in reading. For instance, notifications might be auto-printed along with book due dates on the same ticket.
- 76.1 % (n =346, N = 456) of families are aware if their child is enrolled in Math Support, indicating high awareness, yet 65.6% (n = 299) of families are not unaware of what tools seem most helpful to their child in mathematics.
    - Recommendation: The disconnect between these two numbers may indicate an opportunity for an explanatory survey question on this year's survey. Perhaps asking parents how often they sit with their child when she/he is doing math homework may further substantiate family indication of a desire for more math family events and the nature of those events.
- Regarding how many school or virtual school events middle school families attended, 64.0% (n = 293, N = 458) responded they did not participate in any events last year. This statistic is not surprising considering pandemic impacts.
    - Recommendation: Next year's survey should follow up with a "Why not?" question to determine the reason: Event timing (to confirm or refute newly implemented consistent scheduling this year), technology challenges, or other write-in explanations.
- Of the 165 families who attended one or more events last year, 90.7% (N = 160, Strongly agree or Agree, n = 145) found the event helpful. Similarly, 85.8% (N = 162, Strongly agree or Agree, n = 139) learned ways to help their child at home.
    - Recommendation: This is a solid descriptive statistic to share with families in communications to bolster attendance this year.
- In equal proportions, the survey data identified Friday, Saturday, and Monday as unequivocally the best days for family events at school-- 23.9% (107), 23.9% (107), and 23.7% (106), N = 448, respectively. The predominant time frames for events were between 5:30 and 7:30pm (62.9%, N = 340, n = 214). For families who selected Saturday as the best day for family events, those respondents identified afternoon between 11 am and 1 pm as the best time frame (43.0%, N = 107, n = 46).
    - Recommendation: The data suggests that event planners adopt alternating schedules between Saturdays (11 am to 1 pm) and a weekday. Implementing such as schedule might provide equitable access to events for all Title I middle school families. And if it is possible to repeat events, offering the same event on a Saturday and during a weekday might maximize attendance and provide equitable access to resources for families.

- Email messages (85.9%, n = 385), report cards (49.3%, 221), and text message (39.5%, n = 177) are the top three ways in which families receive information from teachers.
    - Recommendation: Next, all Title I school communications could include a question asking the family which mode they received the notification to which they are responding--email message or text message--and compare that number to the family information held by the Division. It may be that mobile phone numbers should be updated/confirmed annually.

TITLE I MIDDLE SCHOOL FAMILY ENGAGEMENT SENTIMENT PROFILE

The researcher collected and cleaned data and then examined the data with principal component analysis (PCA). The general purpose of PCA is to "identify a relatively small number of themes, dimensions, components or factors underlying a relatively large set of variables" [1]. In this instance, four subscales were identified: *Middle School Awareness of Title I Programming* (MS Awareness), *Middle School Satisfaction with the Title I Reading Program* (MS Reading), *Middle School Satisfaction with the Title I Mathematics Program* (MS Math), and *Perception of Title I Middle School Climate* (Middle School Climate). The researcher constructed an *Overall Satisfaction with Middle School Title I Programming* (Middle School Overall Satisfaction) profile by combining the "satisfaction" question from the MS Reading, MS Math, and MS School Climate subscales. Cronbach's alpha was used to estimate internal consistency for each survey and each subscale identified by PCA. The researcher eliminated an item if it had a PCA coefficient below .5. Four of 5 subscales met the Cronbach alpha requirement of .7 or above. MS Overall Satisfaction had a Cronbach's alpha of .668, identifying those questions as candidates for revising next year. Reliability statistics are listed below for each sub-scale. See Appendix B for profile score calculations.

- The first measures of the *Title I Middle School Family Engagement Sentiment Profile* are provided below:

Table 7 Awareness of Title I Programming (MS Awareness)

Q1. MS AWARENESS	> .5	**Descriptive Statistics (α = .702)**		
	PCA Coefficients	**N = 1,369**		**Profile Index**
		Yes	No	
a. Do you know your school receives federal funding under the Title I Program?	0.755	**n = 492**	**n = 877**	**35.94%**
b. Do you know about your school's Title I Parent and Family Engagement Policy?	0.822			
c. Do you know about your school's Continuous Improvement Plan?	0.768			

Table 8. Satisfaction with the Title I Reading Program (MS Reading)

Q4. MS READING		**Descriptive Statistics (α = .716)**				
	> .5	**N = 1,348**				
	PCA Coefficients	**(SD = 0; D = .25; A = .80; SA = 1.00)**				**Profile Index**
		SD	D	A	SA	
b. My child has gained self-confidence as a reader.	0.681	**n = 86**	**n = 291**	**n = 745**	**n = 226**	**66.38%**
c. My child reads more on her or his own.	0.864					
d. My child enjoys reading.	0.820					

*****Principal component analysis identified Q4a. as having an unacceptable coefficient, so the question item was omitted.

Table 9. Satisfaction with the Title I Mathematics Program (MS Math)

Q9. MS MATH		**Descriptive Statistics (α = .860)**				
	> .5	**N = 1,797**				
	PCA Coefficients	**(SD = 0; D = .25; A = .80; SA = 1.00)**				**Profile Index**
		SD	D	A	SA	
a. My child understands math concepts better.	0.630	**n = 101**	**n = 330**	**n = 1046**	**n = 325**	**69.24%**
b. My child has gained self-confidence as a math student.	0.904					
c. My child completes math assignments on her or his own.	0.836					
d. My child enjoys math.	0.853					

Table 10. Perception of Title I Middle School Climate (Middle School Climate)

Q18. MIDDLE SCHOOL CLIMATE		**Descriptive Statistics (α = .848)**				
	> .5	**N = 1,345**				
	PCA Coefficients	**(SD = 0; D = .25; A = .80; SA = 1.00)**				**Profile Index**
		SD	D	A	SA	
a. I feel welcomed by my child's school community.	0.908	**n = 43**	**n = 97**	**n = 835**	**n = 370**	**78.98%**
b. The communication I receive helps me feel involved in my child's education.	0.798					
c. I feel comfortable contacting my child's school.	0.875					

Table 11. Overall Satisfaction with Middle School Title I Programming (MS Overall Satisfaction).

MS OVERALL SATISFACTION		**Descriptive Statistics (α = .668)**				
	> .5	**N = 1,341**				
	PCA Coefficients	**(SD = 0; D = .25; A = .80; SA = 1.00)**				**Profile Index**
		SD	D	A	SA	
Q4e. I am satisfied with the support my child receives in ***reading*** from the school.	.742	**n = 65**	**n = 97**	**n = 841**	**n = 280**	**73.94%**
Q9e. I am satisfied with the support my child receives in ***math*** from the school.	.578					
Q18d. Overall, I am satisfied with ***how Title I funds are used*** to enhance my school's programs.	0.801					

- As indicated below, overall satisfaction with their school's Title I Program (73.94%) and perceptions of school climate (78.98%) were the most substantial benchmark measures for this first iteration of the Title I Middle School Family Engagement Sentiment Profile.
    - Recommendation: A working group to explore the awareness metric (35.94%) might be a practical approach to exploring potential solutions. The more families are aware of the Title I program, the more they can be engaged in their child's school and Title I offerings.

Table 12 Title I Middle School Family Engagement Sentiment Profile Benchmarks (100 PT Scale)

TITLE I MIDDLE SCHOOL FAMILY ENGAGEMENT SENTIMENT PROFILE BENCHMARKS (100 PT SCALE)	**SY**	
	20-21	**21-22**
Awareness (Yes=100/ N=0)	**35.94**	TBD
Reading (SD = 0, D = .25; A = .8; SA = 1)	**66.38**	TBD
Math (SD = 0, D = .25; A = .8; SA = 1)	**69.24**	TBD
Climate (SD = 0, D = .25; A = .8; SA = 1)	**78.98**	TBD
Overall (SD = 0, D = .25; A = .8; SA = 1)	**73.94**	TBD

OVERALL RECOMMENDATIONS FOR FUTURE TITLE I FAMILY ENGAGEMENT SURVEY DATA COLLECTIONS

Data collection procedures

Title I teachers administered the Title I Family Engagement survey in past years. Hand-picking families did not reach a representative number of families with elementary-level students. This year's administration relieved them of this burden, allowing them to concentrate on end-of-year processes and procedures. Utilizing an awareness campaign, using multiple survey administration platforms, and translating into all division languages appear to be successful updates to survey administration. This year was a benchmark for survey administration. It is recommended that the Title I Office repeat next year's administration processes to increase response rates further. A survey response rate white paper is in development detailing the successful administration as a Title I Office resource for the 2022 survey administration.

Open-ended questions

Next year, translating write-in responses into English will be included in the request made of the language translation office in a way amenable to all offices involved in this division-level data collection: Translation Services, the Title I Office, and the Office of Program Evaluation. Qualitative data (write-in responses) will be analyzed separately from other survey data using thematic coding, and the results will be shared with Title I and school-level leadership. English is the primary language of administrators who will receive analyses of school-level write-in responses.

Demographic information

A suggestion to make data collection from this survey even more meaningful might be to inquire about the race and ethnicity of family respondents and the number and grade level of children per family. In this way, the data might be analyzed in concert with other division-wide survey data to understand how representative this data is and where the survey administration can be improved.

FOCUS GROUP RECOMMENDATIONS

Ways to improve cognitive validity of underperforming survey items

Cognitive validity means that participants interpret a survey item in the same way the researcher intended [3]. For survey questions that ask parents and families to identify the most helpful reading or math tools, the researcher may improve item function if icons commonly associated with the tools were used to prime each question. The sample graphics and associated priming language below depict how a visual aid might appear before the question.

"The following pictures represent what you might have seen when your child used a particular tool:

EPIC

MyON

Lexia Core5

Lexia PowerUp

Using screenshots more demonstrable of what a student sees or what a parent might see looking over a child's shoulder is another idea posed by the group that the researcher and collaborators will explore later during survey revisions. Meaning, capturing introduction screens representative of the different tools may help families more accurately connect an application to its common name.

Immersive Reader was recommended as a text-to-speech accommodation for English or home language-illiterate respondents. Immersive Reader, a tool to assist with reading and comprehension, might enhance survey readability. In addition to improving understanding of a survey question, a tool like Immersive Reader may improve focus on a text by allowing changes to font size and style, text, line spacing, and background color, all of which can make a document easier to read. It would be helpful to understand the limits of Immersive

Reader, such as available languages, alongside the available functionalities of the survey administration tool. Preliminary investigation suggests that survey administration tool functionality may not accommodate the use of Immersive Reader. However, this idea inspires a workaround: Posted audio recordings of the survey in all nine languages on the official survey website so that families can listen to the audio as they complete the survey.

Equity in computer tool access

To ease the pandemic's negative impact on learning, the Division's central administration supported multiple computer tools in reading and mathematics. Understanding requirements and timelines for implementation for programs such as DreamBox, MyON, and Lexia PowerUp and which Title I schools used those programs would be valuable contextual information for data interpretation next year. Furthermore, the extent to which those programs are available in languages other than English and Spanish and the availability of technology workarounds that increase English Language Learner accessibility to those programs are important factors to consider.

Data interpretation and inclusion

Demographic information such as family race/ethnicity, home language, and child's grade level could enhance the usability of the data. Also, by integrating gender-neutral pronouns, the researcher will be more considerate towards and inclusive of students who might not identify strictly as male or female.

Tapping survey application advanced functionalities

For the 2022 surveys, it might be helpful to integrate skip-logic by school for particular questions. For instance, optimizing survey functionality so that a family only rates the computer applications available to their student's school would require less manipulation by the researcher to disaggregate and thus reduce the possibility of introducing errors into the data.

APPENDIX A

2021 TITLE I ELEMENTARY SCHOOL FAMILY ENGAGEMENT SENTIMENT PROFILE CALCULATIONS

The researcher calculated ES Awareness as an aggregate percentage of families who answered "Yes" to Q2.a, b., c., and d., as follows in Table B1.:

Table B 1. ES Awareness Sentiment Profile Calculation

Q2.a, b., c., and d.
(#Yes / N question responses) (100) = Score
((1152 + 886 + 1054 + 1791) / (10141)) (100) = Score
(4883/10141) (100) = **48.15%**

ES Reading, ES Math, Elementary School Climate, and ES Overall Satisfaction were calculated as weighted percentages, as shown in Tables B2, B3, B4, and B5 below. Weights were applied to minimize the impact of unfavorable responses (SD, D) and maximize the impact of favorable responses (A, SA) on the final percentage score.

Table B 2. ES Reading Sentiment Profile Calculation

Q4a., b., c., and d.		
SD	(132 +97 +126 +101)(0) = 0	
D	(206 +246 +413 +382)(0.25) = 311.75	
A	(1496 + 1449 + 1336 + 1394)(0.8) = 4540 596.0	
SA	(687 + 725 + 648 + 651)(1.0) = 2711	((SD + D + A + SA) /(N responses)) (100)
		((311.75 + 4540 + 2711) / (10089))(100)
		(7562.75 / 10089) (100) = **74.96%**

Table B 3. ES Math Sentiment Profile Calculation

Q7a., b., c., and d.		
SD	(82 + 80 + 90 + 87)(0) = 0	
D	(303 + 342 + 358 + 356)(0.25) = 339.75	
A	(1581 + 1540 + 1467 + 1486)(0.8) = 4859.2	
SA	(548 + 548 + 604 + 589)(1.0) = 2289	((SD + D + A + SA) / (N responses)) (100)
		((339.75 + 4859.2 + 2289) /(10061)) (100)
		(7487.95/ 10061) (100) = **74.43%**

Table B 4. ES Climate Sentiment Profile Calculation

Q16a., b., and c.		
SD	(55 + 55 + 52)(0) = 0	
D	(71 + 138 + 62)(0.25) = 67.75	
A	(1089 + 1146 + 1028)(0.8) = 2610.4	
SA	(787 + 659 + 865)(1.0) = 2311	((SD + D + A + SA) / (N responses)) (100)
		((67.75 + 2610.4 + 2311) / (6007)) (100)
		(4989.15 / 6007) (100) = **83.06%**

Table B 5. MS Overall Satisfaction

Q4e., Q7e., and Q16d.		
SD	(95 + 89 + 51)(0) = 0	
D	(207 + 262 + 137)(0.25) = 151.5	
A	(1337 + 1450 + 1203)(0.8) = 3192	
SA	(886 + 719 + 586)(1.0) = 2191	((SD + D + A + SA) /(N responses)) (100)
		((151.5 + 3192 + 2191) / (7022)) (100)
		(5534.5 / 7022) (100) = **78.82%**

APPENDIX B

2021 TITLE I MIDDLE SCHOOL FAMILY ENGAGEMENT SENTIMENT PROFILE CALCULATIONS

The researcher calculated MS Awareness as an aggregate percentage of families who answered "Yes" to Q2.a, b., and c., as follows in Table B1.:

Table B 6. MS Awareness Sentiment Profile Calculation

Q2.a, b., and c.*
(#Yes / N question responses) (100) = Score
((185 + 139 + 168) / (1369)) (100) = Score
(492/1369) (100) = **35.94%**

MS Reading, MS Math, Middle School Climate, and MS Overall Satisfaction were calculated as weighted percentages, as shown in Tables B2, B3, B4, and B5 below. Weights were applied to minimize the impact of unfavorable responses (SD, D) and maximize the impact of favorable responses (A, SA) on the final percentage score.

Table B 7. MS Reading Sentiment Profile Calculation

Q4b., c., and d.*		
SD	(25 + 31 + 30)(0) = 0	
D	(68 + 115 + 108)(0.25) = 72.75	
A	(285 + 216 + 244)(0.8) = 596.0	
SA	(69 + 88 + 69)(1.0) = 226	((SD + D + A + SA) / (N responses)) (100)
		((72.75 + 596.0 + 226) /(1348)) (100)
		(894.75 / 1348) (100) = **66.38%**

*Principal component analysis identified Q2d. and Q4a. as having unacceptable coefficients, so the question items were omitted.

Table B 8. MS Math Sentiment Profile Calculation

Q9a., b., c., and d.		
SD	(22 + 23 + 21 + 35)(0) = 0	
D	(75 + 89 + 68 + 98)(0.25) = 82.5	
A	(278 + 265 + 261 + 242)(0.8) = 836.8 596.0	
SA	(74 + 72 + 99 + 80)(1.0) = 325	((SD + D + A + SA) / (N responses)) (100)
		((82.5 + 836.8 + 325) / (1797)) (100)
		(1244.3 / 1797) (100) = **69.24%**

Table B 9. MS Climate Sentiment Profile Calculation

Q18a., b., and c.		
SD	(15 + 15 + 13)(0) = 0	
D	(30 + 46 + 21)(0.25) = 24.25	
A	(278 + 288 + 269)(0.8) = 668	
SA	(125 + 199 + 146)(1.0) = 370	((SD + D + A + SA) / (N responses)) (100)
		((24.25 + 668 + 370) /(1345)) (100)
		(1062.25 / 1345) (100) = **78.98%**

Table B 10. MS Overall Satisfaction

Q4e., Q9e., and Q18d.		
SD	(25 + 24 + 16)(0) = 0	
D	(63 + 54 + 38)(0.25) = 38.75	
A	(271 + 270 + 300)(0.8) = 672.8	
SA	(90 + 103 + 87)(1.0) = 280	((SD + D + A + SA) /(N responses)) (100)
		((38.75 + 672.8 + 280) /(1341)) (100)
		(991.55 / 1341) (100) = **73.94%**

REFERENCES

[1]Meyers, L. S., Gamst, G., & Guarino, A. J. (2013). Applied Multivariate Research: Design and Interpretation (2nd ed.). Thousand Oaks, CA: Sage.

[2]Shafer, L. (2017, November 27). Usable Knowledge: How to Have an Equitable Class Discussion. Retrieved from Harvard Graduate School of Education News: https://www.gse.harvard.edu/news/uk/17/11/how-have-equitable-class-discussion

[3]Trenor, J. M., Miller, M. K., & Gipson, K. G. (2011). Utilization of a Think-Aloud Protocol to Cognitively Validate a Survey Instrument Identifying Social Capital Resources of Engineering Undergraduates. 2011 ASEE Annual Conference & Exposition, (pp. 22.1656.1 - 22.1656.15). British Columbia. doi:10.18260/1-2--18492

USING EXAM WRAPPERS TO IMPROVE STUDENT SUCCESS IN THE BUSINESS SCHOOL – A QUANTITATIVE COURSE EXPERIMENT

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Abstract: Developed by Lovett, an exam wrapper provides students with a structured reflection opportunity about exam performance [1]. In a quantitative business course at Salem State University, it was frequently and commonly observed that students made mistakes in their previous homework or exams and tended to repeat those mistakes on later exams. This observation raised a lot of questions on how students worked on their homework and how they prepared for the exams. Students may not spend sufficient time in reflecting and improving their mastering of topics covered in previous homework or exams. In order to increase student success in this quantitative business course, exam wrappers were developed and adopted. This paper studies the effectiveness of exam wrappers in student reflection measured by students' exam performance. Preliminary results showed that the majority of students improved their exam performance after implementing exam wrappers. Exam wrappers proved to be a valuable and powerful tool to increase student understanding, confidence, and performance in this quantitative business course.

1. INTRODUCTION AND LITERATURE

In the Bertolon School of Business at Salem State University, ODS 333 Operations and Logistics Management covers many quantitative topics such as linear programming. ODS 333 is considered as one of the most challenging core courses by both faculty members and students in the business school. In this course, students are typically assessed by various ways including homework, quizzes, and exams. Although similar questions are given in their exams, students often repeat their mistakes made in previous homework or quizzes. This may suggest that students do not spend sufficient time in reflecting and improving their mastering of topics previously covered. It may also suggest that students need to reconsider their study habits and exam preparations.

The ability of thinking about thinking – metacognition has been identified as a key component in teaching and learning. There are many studies emphasizing the importance of raising metacognitive awareness and using metacognitive approach in education [2, 3, 4, 5, 6, 7, 8, 9]. There are many ways to increase students' metacognition at a pedagogical level. Developed by Lovett, an exam wrapper provides students with a structured reflection opportunity about exam performance. It encourages students to look more closely at their returned exams by asking questions about how they prepared, where and why they lost points, and what they planned to do differently for future exams [1].

Exam wrappers were adopted in various engineering courses and found to be highly effective [10]. Especially for students who performed the poorest on the first exam, they improved to nearly achieving the class average on the final exam. In another study, exam wrapper assignments were offered as extra credit after the first three exams in a large introductory Food Science and Human Nutrition course. This study found a modest relationship between use of study strategies and improved exam performance particularly for students with a B exam average, suggesting that students in the middle of the grade distribution may benefit most from this type of intervention [11].

The benefits of using exam wrappers are not only limited to increase exam scores. Exam wrappers prompt students to review their graded assignments and exams and encourage students to reconsider their study habits and preparations thus make an adjustment to study habits. Students who proactively took the steps for adjustment tend to perceive better outcomes [12]. Exam wrappers are also proven to provide information about students' understanding of content and level of skills so that appropriate measures and actions can be taken to help students who are struggling in the course [13].

In fall 2018, the exam wrappers were given to three sections of ODS 333. They were distributed after the first midterm exam. The total number of students in these three sections was 71, out of which 70 students participated. Students' academic performance in terms of exam scores was monitored and tracked before and after using exam wrappers. The results of exam wrappers, Exam 1 (before the exam wrapper) scores, and Exam 2 (after the exam wrapper) scores were analyzed. The preliminary results showed that majority of students improved their exam performance after implementing exam wrappers. Other metrics of assessing the effectiveness of exam wrappers were explored.

2. METHODOLOGY

2.1 Implementation of Exam Wrappers

ODS 333 Operations and Logistics Management is a core course in the Bertolon School of Business curriculum. The class size of ODS 333 is small with a cap of 25 students. The majority of the students enrolled in this course are juniors and seniors. Students attend two 75-minute lectures per week. Since ODS 333 is one of the most challenging courses among all business core courses with high DFW rates, faculty have implemented various evidence-based pedagogy to increase student success. For example, MyLab Operations Management – an online teaching and learning platform by Pearson was adopted in 2017 to engage students with immersive content, tools, and experiences. Additionally, the Bertolon School of Business provides students with various learning resources including the peer tutoring service. Based on faculty members' observation, students often repeat their mistakes made in previous homework and quizzes although similar questions are given in their exams. A reflection activity is needed especially evidence-based and pedagogical approach.

Exam wrappers is an effective tool to increase metacognition and they ensure students to reflect on three important components of learning: what they know, how well they know it, and subsequently make choices about future learning strategies. As a result, an exam wrapper was

developed for ODS 333 to increase students' metacognitive awareness and self-regulated learning. It was used in the fall semester of 2018 in three sections of ODS 333. There were 71 students in three sections combined. Students were given exam wrappers in the following class after taking the first exam. A total of 70 exam wrappers were collected at the end of the class.

2.2 Content of Exam Wrappers

The exam wrapper developed in this study includes three parts. The first part is personal prognosis inventory providing students with a list of behaviors that they should exhibit in order to succeed in ODS 333. Students were asked to check items they had used and write down the percentage of their time spent on them. This part of the exam wrapper gives students a chance to reflect on the efficiency of their exam preparation. Most importantly, the list serves as a guideline of potential learning strategies students could adopt in the future.

The second part of exam wrapper is to ask students to look over their graded exam and categorize what kind of mistakes they made and estimate the respective percentages. Mistakes include trouble with applying the definitions, lack of understanding of the concepts, not knowing how to approach the problem, careless mistakes and so on. By going over a list of mistake types, students got to reflect their exam performance and it was hoped to avoid these mistakes in the future. Additionally, students were asked to enter how many hours they had spent on preparing for the exam.

The last part of exam wrapper contains two open-ended questions. The first question asks students to name at least three things they would do differently in preparing for the next exam. For instance, spending more time, changing a specific study habit, or going to office hours and so on. The second question asks students to make a suggestion to their professor on how to help them learn better and prepare better for the next exam. Both questions were designed to provide students and faculty a path forward making collaborated efforts to achieve academic and teaching excellence.

2.3 Data Collection and Analysis

Data collection was conducted in fall 2018. Students were informed about this research project which uses classroom surveys and their exam performance data via consent approved by IRB. About a week after the first exam, exam questions were gone over in class and students got to look at their exam performance including their scores. On the same day, exam wrappers were distributed and collected. It was well communicated to students that returning exam wrappers was voluntary and it had no impact to their exam scores.

Among all three sections of ODS 333, there were 71 students. A total of 70 exam wrappers were collected, out of which 67 were considered valid data points in this analysis. Student responses and their exam scores were analyzed. Table 1 shows an overview of the analysis. It was noted that the score of Exam 2 (after students were given exam wrappers) did increase slightly compared to Exam 1 (without exam wrappers). More analysis and insights gained are presented in the next section.

Table 1. Overview of the Exam Wrapper Study

Total Students	71
Total Exam Wrappers Distributed	71
Total Exam Wrappers Collected	70
Total Valid Data For Analysis Purpose	67
Exam 1 Average Score	89
Exam 1 Standard Deviation	16
Exam 2 Average Score	91
Exam 1 Standard Deviation	21

3 RESULTS AND INSIGHTS GAINED

In Part One of the exam wrapper, students reflected how they had prepared for the exam by checking recourses they used and providing the percentage of time spent on them. The result is summarized in Table 2. "Use Pearson MyLab 'Question Help' button", "Attend the exam review class", and "Re-do all/some of the homework problems before the exam" were top three resources students used in exam preparation. The relationship of the top three recourses and Exam 1 performance was explored. The coefficients of correlation are $r = -0.11$ (Use Pearson MyLab "Question Help" button), $r = 0.18$ (Attend the exam review class), and $r = 0.1$ (Re-do all/some of the homework problems before the exam) respectively. "Attend the exam review class" and "Re-do all/some of the homework problems before the exam" undoubtedly increased exam performance, however "Use Pearson MyLab 'Question Help' button" had a negative impact on exam performance. This might be because students depended heavily on the "Help" function built in Pearson MyLab Operations Management. Without "Help" function during the exam, students lost both proficiency and confidence.

Table 2. Results of Exam Wrapper Part One

Questions in Part One	**Percentage**
Use Pearson MyLab "Question Help" button	15%
Attend the exam review class	15%
Re-do all/some of the homework problems before the exam	14%
Review the chapter/PowerPoint after the class	12%
Review your own notes after the class	11%
Work the practice exam problems with your notes/textbook	9%
Read the chapter/PowerPoint before coming to class	7%
Ask for help from classmates/friends	6%
Work the practice exam problems w/o looking at your notes/textbook	5%
Use Pearson MyLab other resources	5%
Bring questions you have to class	2%
Post your questions on the discussion board on Canvas	1%
Ask for help from ODS tutors in the Accounting Lab CC-115	0%

Use Facebook or other social media websites study group	0%
Go to your professor's office hours regularly	0%

In Part Two of the exam wrapper, students categorized mistakes they made in the exam based on various reasons given. The result is summarized in Table 3. "Careless mistakes", "Did not have time to work on/complete the problem", and "Did not write notes down on the cheat sheet" were top three mistakes students made in Exam 1. Optimistically, students who made "Careless mistakes" or "Did not write notes down on the cheat sheet" were expected to avoid these mistakes in future exams. Or at least those students were alerted after completing this part of the exam wrapper. Because various factors could contribute to "Did not have time to work on/complete the problem", many learning strategies could improve or even eliminate repeating this mistake in the future.

Table 3. Results of Exam Wrapper Part Two

Questions in Part Two	**Percentage**
Careless mistakes	20.2%
Did not have time to work on/complete the problem	10.1%
Did not write notes down on the cheat sheet	9.4%
Lack of understanding of the concepts	8.5%
Did not review the topics related to the problem	7.2%
Did not solve similar problems in preparing for exam	7.2%
Trouble with applying the definitions	5.9%
Not knowing how to approach the problem	5.6%
Did not bring a calculator	3.4%
Unclear expectation/requirement of the problem	2.8%
Issues with technology (computer, internet, Canvas, etc.)	0.7%

We also gained some insights from the following observations: (1) The top three study habits students showed in exam preparation were: Use Pearson MyLab "Question Help" button, Attend the exam review class, and Re-do all/some of the homework problems before the exam. While the other two study habits correlated to exam performance in a positive way, using Pearson MyLab "Question Help" button too much resulted in dependence and negatively impacted exam performance; (2) The top three mistakes students made in Exam 1 were: Careless mistakes, Did not have time to work on/complete the problem, and Did not write notes down on the cheat sheet. Students were believed to avoid repeating the same mistakes if they learned a lesson. For example, "Careless mistakes" could be easily avoided by changing the attitude and paying attention to details. Increasing proficiency could keep away from making mistakes such as "Did not have time to work on/complete the problem". Finally, "Did not write notes down on the cheat sheet" could be eliminated by attending the exam review class; and (3) The total hours spent on exam preparation and exam score correlated positively although the correlation was not

significantly strong. It suggested that spending more time preparing for the exam might be helpful but it might also require a robust study strategy.

4 CONCLUSIONS AND FUTURE DIRECTIONS

In this paper, the relationship between exam wrappers and exam scores was explored. Exam wrappers were given to three sections of ODS 333 in fall 2018. A total of 70 exam wrappers were collected, out of which 67 were valid data points in this analysis. In each of the three sections, the majority of students improved their exam performance after implementing exam wrappers. This proved the effectiveness of exam wrappers although the improvement was marginal. Although exam wrappers did not seem to increase exam scores significantly, filling out exam wrappers did provide students an opportunity of reflection and adjustment in general. It was noted that exam wrapper was a good exercise to assist students in developing metacognitive skills in this quantitative business course.

There are some limitations of this study. Exam wrappers were only given to students after Exam 1. Further analysis could be done if exam wrappers were given to students after the second exam and additional data was collected. Exam score was the only measurement used in this study to evaluate the effectives of exam wrappers. Other measurements could be used to further assess the effectiveness. For example, metacognition information using Metacognitive Awareness Inventory (MAI) scores might be a good option. This paper was also limited by conducting quantitative analysis only. The effectiveness of exam wrappers could be assessed qualitatively by anonymously surveying students their perceptions at the end of the semester. For example, an exit survey with both likert-scale and open ended comments could be used to collect student satisfaction information. Additionally, this study was a one-course and one-semester effort. Extending the study to a multiple-course and multiple-semester scale would be a future research direction. Introducing demographics data (gender and ethnicity) [14] to the current data collection effort would be another future research direction.

References

[1] M. C. Lovett, "Make exams worth more than the grade: Using exam wrappers to promote metacognition.," in *Reflection and Metacognition in College Teaching*, New York , Stylus Publishing, 2013, pp. 18-52.

[2] T. Djudin, "Using Metacognitive Strategies to Improve Reading Comprehension and Solve a Word Problem," *Journal of Education, Teaching and Learning,* vol. 2, no. 1, pp. 124-129, 2017.

[3] S. M. Poo and P. L. Funn, "Using Metacognitive Awareness in Learning Vocabulary with Cloud-Based Immersive Technology," *International Journal of Information and Education Technology,* vol. 7, no. 2, p. 114, 2017.

[4] B. Breed and R. Bailey, "The influence of a metacognitive approach to cooperative pair problem-solving on self-direction in learning," *The Journal for Transdisciplinary Research in Southern Africa,* 2018.

[5] P. Cunningham, H. M. Matusovich, J. R. Morelock and D.-A. N. Hunter, "Beginning to Understand and Promote Engineering Students' Metacognitive Development," in *2016 ASEE Annual Conference & Exposition*, 2016.

[6] B. J. Millis, "Using Metacognition to Promote Learning," in *IDEA Paper #63*, 2016.

[7] A. Siegesmund, "Using self-assessment to develop metacognition and self-regulated learners," *FEMS Microbiology Letters,* 2017.

[8] B. Batson, "Introducing Metacognition to Sophomores and Juniors and Its Effect on Academic Performance," in *2018 ASEE Annual Conference & Exposition*, 2018.

[9] C. H. Maduabuchi and I. O.-I. Angela, "Teaching Metacognitive Skills for the Promotion of Self-Regulated Learning Among Secondary School Students in Nigeria," *British Journal of Education,* vol. 4, no. 10, 2016.

[10] J. Chen, "Effective and Adoptable Metacognitive Tools," in *2016 ASEE Annual Conference & Exposition*, 2016.

[11] P. G. Gezer-Templeton, E. J. Mayhew, D. S. Korte and S. J. Schmidt, "Use of Exam Wrappers to Enhance Students' Metacognitive Skills in a Large Introductory Food Science and Human Nutrition Course," *Journal of Food Science Education ,* vol. 16, no. 1, 2017.

[12] J. Liao, T. Kunberger, G. I. Papkov, L. D. Nguyen and R. O'Neill , "Exam Wrappers, Reflection, and Student Performance in Engineering Mechanics," in *2018 ASEE Annual Conference & Exposition*, 2018.

[13] K. J. Chew, H. L. Chen, B. Rieken, A. Turpin and S. Sheppard, "Improving Students' Learning in Statics Skills: Using Homework and Exam Wrappers to Strengthen Self-Regulated Learning," in *2016 ASEE Annual Conference & Exposition*, 2016.

[14] K. J. Chew, H. L. Chen, B. Rieken, A. Turpin and S. Sheppard, "Improving Students' Learning in Statics Skills: Using Homework and Exam Wrappers to Strengthen Self-Regulated Learning," in *American Society for Engineering Education (ASEE) 123rd annual conference*, New Orleans, 2016.

[15] R. N. Soicher and R. A. R. Gurung, "Do Exam Wrappers Increase Metacognition and Performance? A Single Course Intervention," *Psychology Learning & Teaching,* vol. 16, no. 1, p. 64–73, 2017.

[16] A. Badir, J. Liao, T. Kunberger, G. I. Papkov, L. D. Nguyen and R. O'Neill, "Exam Wrappers, Reflection and Student Performance in Engineering Mechanics," in *ASEE Annual Conference and Exposition*, 2018.

[17] M. W. Roberts, "Fostering Reflection and Metacognition with Engineering Homework," in *2017 ASEE Rocky Mountain Section Conference*, USA, 2017.

USING VBA TO GRADE STUDENT EXCEL PROJECTS

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ABSTRACT

Business school faculty are increasingly requiring that students complete Excel assignments in their courses. Grading these assignments can be tedious and time-consuming, especially for faculty who teach large classes. While online learning systems that automatically grade Excel assignments do exist, these systems do not typically allow faculty members to determine how the projects are graded or to create or customize the Excel projects. This workshop will show participants how Visual Basic for Applications (VBA) can be used to automate the grading of Excel projects. The grading program has been used to grade Excel projects completed by students in an Excel class taught at a large public university. Use of the program significantly reduces the amount of time required to grade the projects, eliminates grading errors that occur when assignments are manually graded, and allows the instructor to determine the content of the assignments as well as how they are graded.

DISCUSSION OF VBA GRADING PROGRAM

This paper discusses the use of a VBA program to grade student Excel projects. VBA code is included in the paper along with descriptions of how to use the code to grade Excel assignments and how to modify the code for different assignments. This VBA grading program has been used to grade Excel projects completed by students in an Excel class taught at a large public university. Use of the program significantly reduced the amount of time required to grade the projects. Rather than spending 10 minutes manually grading one student's assignment, the program was able to grade 200 assignments in 20 minutes. (The length of time it takes the program to grade assignments will depend on the length and complexity of the assignments.)

Due to the extensive use of Excel in business organizations, knowledge of Excel is an essential skill for many business graduates. Mastery of Excel is considered the most important "application-oriented skill" that students graduating from accounting programs should have.[1] Becoming a proficient user of Excel requires a significant amount of practice. As a result, faculty at one large public institution have increased the number of Excel projects assigned to students in their accounting courses. This increase in the number of Excel assignments is consistent with the requirements of AACSB Standard A5 of the 2018 Standards for Accounting Accreditation which states that students should develop information technology skills.

While students benefit greatly from completing Excel assignments, the assignments can be extremely time-consuming and tedious to grade. Grading these assignments can be an especially difficult task for faculty who teach large lecture sections and do not have teaching assistants that can help with the grading. Even if faculty have teaching assistants, having them manually grade Excel assignments can increase the incidence of grading errors and lead to inconsistencies in grading if multiple teaching assistants are used to grade the same assignment. Depending on the

teaching assistants, faculty may have to spend time supervising their work to ensure that the assignments are graded consistently by all teaching assistants and in accordance with the faculty member's grading rubric. A correctly written VBA program, on the other hand, is not likely to make grading mistakes and will grade every assignment according to the criteria built into the program.

Although online learning platforms that automatically grade Excel assignments do exist, these platforms typically control how the assignments are graded and do not allow faculty to customize the assignments. The platforms are normally associated with specific Excel textbooks and can only be used to grade assignments included in those textbooks. Faculty cannot change the assignments or use the platform to grade assignments they have created. In addition, faculty have little control over the grading criteria used by the platform. The platform may not employ the same grading rubric that a faculty member would choose. For example, the grading platform may deduct points if parentheses are included in a formula even though the formula performs that calculation correctly with or without the parentheses. It may also deduct points if the corners of a chart are not placed exactly within the boundaries of specific cells. The platforms usually do not allow for the fact that Excel formulas can be written in different ways and still be correct. If a student's formula is correct but is not identical to the formula the platform is looking for the student's answer will be marked as incorrect. Using VBA to grade Excel assignments can address these grading issues. The VBA program can be modified to grade a variety of assignments based on the criteria specified by the instructor.

Although the VBA grading program is currently used to grade projects assigned in an Excel class, it can be used to grade Excel projects assigned in a variety of business classes including finance, financial accounting, managerial accounting, marketing, and management classes. The program can be modified to grade different formulas and their resulting values, charts, solver output and PivotTables. It can also check for range names and hyperlinks.

The remaining sections of this paper discuss accessing the VBA code, the grade sheet, the grading program, and how to use the program to grade a formula, a chart, a PivotTable, a Solver analysis and a named range. The last section discusses some of the limitations. The actual VBA code several of the sub procedures is included in the Appendix.

Accessing the VBA Code

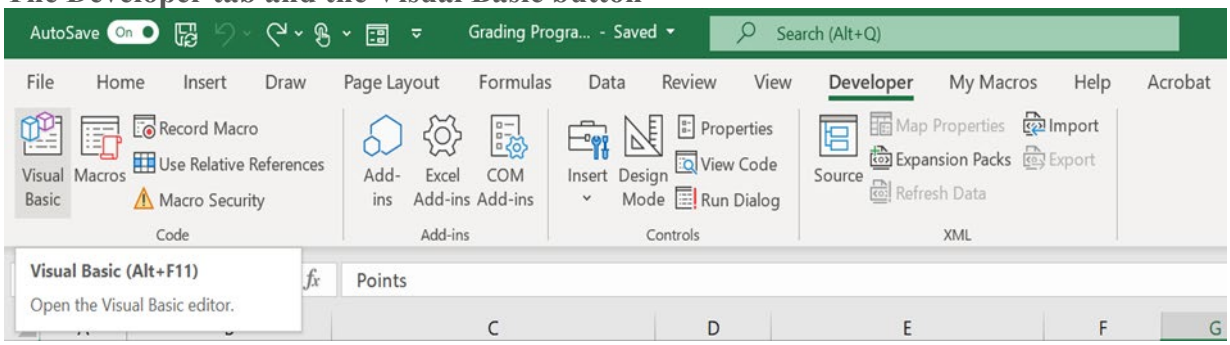
The VBA code is comprised primarily of sub procedures (i.e., macros) and custom functions. The "LoopAndGrade" sub procedure loops through the students' assignments comparing formulas, cell values, and other characteristics to the correct formulas, values, and characteristics listed in the grade sheet. Most of the grading is completed by other macros that are called by the LoopAndGrade macro. The grade sheet is included in the Excel file with the grading macros and functions and the students' files must be saved in a separate folder that only includes assignments to be graded.

The grading sub procedures and custom functions are placed in a module in the Visual Basic Editor of the Excel grading file. To access the Visual Basic Editor, the Developer tab must be enabled within Excel. Once the Developer tab is enabled, the Visual Basic Editor can be opened

by selecting “Visual Basic” on the left side of the Developer tab or pressing Alt-F11. Figure 1 shows the Visual Basic button on the Developer tab.

FIGURE 1

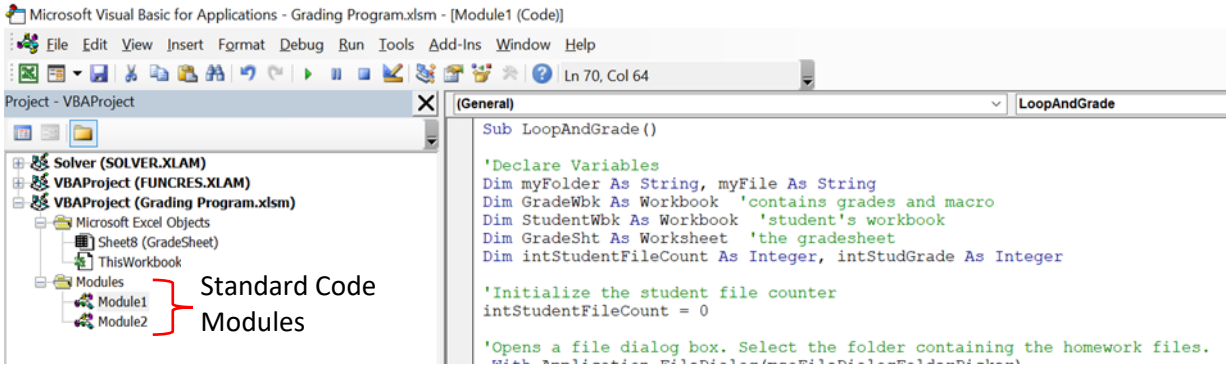
The Developer tab and the Visual Basic button



Once the Visual Basic Editor is accessed a new window appears. Figure 2 shows the Visual Basic Editor window. The left side of the window displays Project Explorer, and the right side displays the Code window. Project Explorer displays a list of the Excel workbooks (referred to as “projects”) that are open and the items such as worksheets and modules contained in the open workbooks. If Project Explorer is not visible when the Visual Basic Editor is opened, it can be displayed by selecting the View button and then selecting Project Explorer. The Code window on the right side of the Visual Basic Editor is used to enter VBA code. If the Code window is not visible, it can be opened by selecting the View button and then selecting Code.

FIGURE 2

The Visual Basic Editor



VBA code must be placed in a “container” called a module. There are different types of modules; however, the different types will not be discussed in this paper. The code to grade the Excel assignments must be placed in a Standard code module. Standard modules appear in the Modules folder of an Excel Project in the Project Explorer window. Figure 2, for example, shows that the Grading Program file contains two Standard modules (Module1 and Module2). A Standard module can be inserted by selecting the Insert button on the ribbon in the Visual Basic Editor and then selecting Module. (Class module should not be selected.) A Standard module can also be inserted by right-clicking within the area of the Project Explorer window relating to the project. After right-clicking in Project Explorer, “Insert” and then “Module” must be selected.

The Grade Sheet

The grade sheet serves two important functions. First, it provides information that the VBA grading program must have in order to grade the assignments. Second, it is used by the grading program to record the points earned by students. The grade sheet must be named "GradeSheet" and it must be set up correctly for the grading program to work properly. Figure 3 displays a sample grade sheet. Columns A through G of the grade sheet provide information related to the steps to be graded. This information must be entered by the instructor. The grading program begins recording student names and points earned in column H. A different column is used for each student. Formulas are used at the bottom of the spreadsheet to sum the points and calculate an overall percentage grade.

FIGURE 3

The grade sheet

	A	B	C	D	E	F	G	H	I	J	S
1	Step No.	Description	Worksheet	Cell to Grade	Value to Grade	StartPosition	Points	Student Points	Student Points	Student Points	S
2	2	Student Name	Honor Code	D5			Solution	Hokie Bird	Lois Lang	Clark Kent	J
3	2	Unique File ID	Honor Code	D7			XXXXX	13183	57641	88592	
4	2	Student Name Points	Honor Code	D5			4	4	4	4	
5	2	Honor Code Points	Honor Code	D16			4	4	4	4	
6	3	Remove extra spaces	Inventory	B6	TRIM	1	0.5	0.5	0.5	0.5	
7	3	Remove non-printable ch	Inventory	B6	CLEAN	5	0.5	0.5	0	0.5	
8	3	Check cell value	Inventory	B6	AT932060/OffICE maCHinES-AT		0.5	0.5	0	0.5	
9	3	Remove extra spaces	Inventory	B20	TRIM	1	0.5	0.5	0.5	0.5	
10	3	Remove non-printable ch	Inventory	B20	CLEAN	5	0.5	0.5	0	0.5	
11	3	Check cell value	Inventory	B20	HAM162110/paPEr-HAM		0.5	0.5	0	0.5	
12	3	Remove extra spaces	Inventory	B38	TRIM	1	0.5	0.5	0.5	0.5	
13	3	Remove non-printable ch	Inventory	B38	CLEAN	5	0.5	0.5	0	0.5	
14	3	Check cell value	Inventory	B38	SCT20743/genERAl oFFice-SCT		0.5	0.5	0	0.5	

The information in columns A and B of the grade sheet is not used by the grading program. Column A lists the number associated with the step to be graded. This number matches the step number in the assignment instructions provided to the students. Column B describes the item to be graded or the task to be performed by the grading program. Since the information in columns A and B is not used by the grading program, any information that is deemed relevant can be placed in these columns.

Unlike columns A and B, columns C through G contain information that the grading program uses to grade the assignments. The information in columns C and D provides the location of the cell or item to be graded. Column C must display the name of the worksheet that contains the item to be graded and column D must display the cell address of the item to be graded. The grading program cannot grade the student's work if the work is not in the sheet and cell specified in the grade sheet. Students must make sure their worksheet names are spelled and capitalized correctly. To help minimize problems associated with worksheet names and cell addresses that do not match the grade sheet, students are provided with a starting file that must be used to complete the assignment. This starting file includes correctly named sheets and cell labels that help students identify where tasks should be completed. Students are also provided with assignment instructions that specify the worksheet names and cell addresses where formulas and other items should be located.

Column E of the grade sheet includes the value the grading program is looking for. This "value" can be a variety of things depending on the task being graded. If a student is asked to enter a

formula in a cell, the “value” graded can be the actual formula itself, part of the formula, or the formula result. The “value” can be a specific function if the student is asked to use one or it can be text that the student was asked to enter in a cell. This “value” can be any of the following: a range name, a chart type, the formula for a data series used to create a chart, the objective cell formula or a constraint formula used in solver, the address for source data used to create a PivotTable or the name of a PivotTable data field.

Column F of the grade sheet displays the “start position”. The start position specifies the position at which to start searching for a string (i.e., text) within another string. This information is not always needed; however, it is needed when the grading program is looking for something specific within a formula. For example, the grading program might be searching for the presence of a specific function within a formula. If the start position is 1, the program begins its search at the first character of the formula (i.e., at the equal sign.) A start position of 1 can be used in many instances; however, it cannot be used when searching for multiple instances of the same function within a formula or when a formula must include more than one function and these functions must be in a specific order. This can be explained with an example. Assume a student is asked to use nested If functions to create a formula that will display “High” if the value in cell J22 is greater than 10,000, display “Medium” if the value is less than or equal to 10,000 and greater than 5,000, and display “Low” if the value is less than or equal to 5,000. The student can enter either one of the following formulas:

=IF(J22>10000,"High",IF(J22>5000,"Medium","Low"))
=IF(J22<=5000,"Low",IF(J22<=10000,"Medium","High"))

Both formulas produce the same results; therefore, either formula is acceptable. The grading program can check to see if the student’s formula contains two IF functions. The program does this by using a VBA function named InStr. InStr searches the formula for an “IF” and returns the character position of the “I” in the first IF that it finds. If the start position for the first IF is specified as 1, the InStr function starts with the first character of the formula, searches for an “IF” and returns a 2. To find the second “IF” in the formula the start position must be greater than 2 because the InStr function must begin its search after the “I” in the first IF. The “I” in the second IF function is the 21st character of the first formula and the 22nd character of the second formula; thus, to search for the second IF function the start position must be greater than two and less than 22. If the InStr function cannot find the string it is looking for, it returns a 0.

Except for cells G1 through G3, the cells in column G must contain the points assigned to each item that is graded. In most cases the points are positive because the student earns points for completing a step correctly; however, negative points can be assigned. Points can be deducted if a student’s formula includes a value, reference, or function that it should not include.

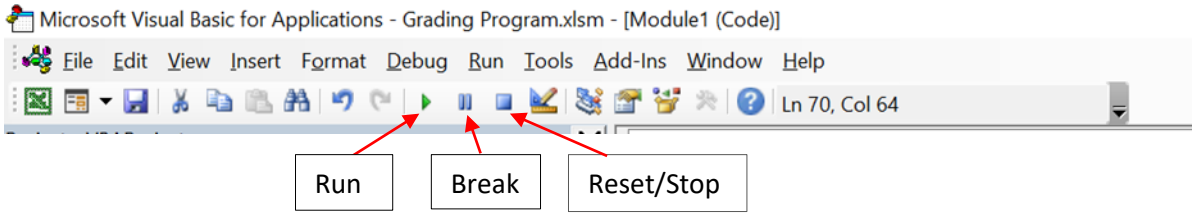
Starting with column H, the remaining columns in the grade sheet are used by the grading program to record points earned by students. Before entering points, the grading program will enter the student’s name and unique file ID. These two items are obtained from cells D5 and D7 of a sheet included in the starting file for the assignment. This sheet is named “Honor Code”. Students are required to enter their name in the sheet, read the Honor Code statement, and enter their initials in cell D16 to confirm they will abide by the Honor Code. Once the students enter their name, a five-digit random number automatically appears in cell D7. This random number or “unique file ID” is generated by a macro included in the starting file. The purpose of the unique

file ID is to discourage students from copying each other's assignments. Each student file must contain a different unique file ID. Once the unique file ID appears in the Honor Code Sheet, it cannot be changed by the student. Changing the original student name entered in cell D5 will not change the unique file ID.

The Grading Program

The LoopAndGrade sub procedure must be run to grade the Excel assignments. The sub procedure can be run by selecting the Macros button on the Developer tab, selecting the macro in the dialog box, and clicking "Run". The sub procedure can also be run from within the Visual Basic editor by placing the cursor anywhere in the code for the sub procedure and clicking the Run button (a green triangle) or pressing F5. If a problem occurs when running the program, execution can be temporarily paused by pressing the Break button or stopped by pressing the Reset button. Figure 4 illustrates the Run, Break and Reset buttons.

FIGURE 4
The Run, Break and Reset buttons in the Visual Basic Editor



After the "Run" button is pressed, the LoopAndGrade sub procedure opens a dialog box. The dialog box is used to browse for and select the folder containing the student files to be graded. Once the folder is selected, the "OK" button must be clicked. The procedure will proceed to loop through all the files in the folder. It will open each file and grade it. As mentioned previously, the procedure will enter the student's name and unique file ID in the grade sheet. After that it will enter points in the grade sheet if the student has entered his/her name in cell D5 of the Honor Code sheet. It will also enter points in the grade sheet if the student placed his/her initials in cell D16 of the Honor Code sheet. Recall that the purpose of entering initials in the Honor Code sheet is to confirm that the student will abide by the Honor Code statement. If the student did not complete these steps, 0 points will be entered in the grade sheet.

The LoopAndGrade sub procedure will then proceed to call (i.e., execute) other procedures that grade the steps in the assignment. Another procedure must be called for each step or range name to be graded and the instructor must add the code that calls the procedures to the LoopAndGrade sub procedure. Figure 5 shows a portion of the LoopAndGrade sub procedure. Any text displayed in green represents a comment and does not execute. Comments are created by preceding the text with an apostrophe. The code to call the procedures must be placed in between the comments "Call Grading Procedures Here" and "End of Grading Procedures that are Called".

FIGURE 5

Portion of the LoopAndGrade sub procedure

```
'Activate the first sheet in the student's workbook
StudentWbk.Sheets("Honor Code").Activate

'intStudGrade represents the column in the GradeSheet where the student's grades should be entered.
'The first 7 columns of the GradeSheet describe the step that is graded.
intStudGrade = intStudentFileCount + 7
'Copy the student's name and unique ID to the grading sheet
GradeSht.Cells(2, intStudGrade).Value = StudentWbk.Sheets("Honor Code").Range("D5").Value
GradeSht.Cells(3, intStudGrade).Value = StudentWbk.Sheets("Honor Code").Range("D7").Value
'If student entered name in Honor Code sheet, then assign points
If Not IsEmpty(StudentWbk.Sheets("Honor Code").Range("D5").Value) Then
    GradeSht.Cells(4, intStudGrade).Value = GradeSht.Cells(4, 7).Value
Else
    GradeSht.Cells(4, intStudGrade).Value = 0
End If
'If student entered honor code initials, the assign points
If Not IsEmpty(StudentWbk.Sheets("Honor Code").Range("D16").Value) Then
  GradeSht.Cells(5, intStudGrade).Value = GradeSht.Cells(5, 7).Value
Else
  GradeSht.Cells(5, intStudGrade).Value = 0
End If
'*************************************************************
'Call Grading Procedures Here
GradeStep GradeWbk, StudentWbk, GradeSht, intStudGrade, 6, 3, 2, 0 'Step 3
GradeStep GradeWbk, StudentWbk, GradeSht, intStudGrade, 15, 3, 3, 0 'Step 4
GradeStep GradeWbk, StudentWbk, GradeSht, intStudGrade, 27, 3, 4, 0 'Step 5
GradeStep GradeWbk, StudentWbk, GradeSht, intStudGrade, 125, 4, 3, 2 'Step 15
GradeChart GradeWbk, StudentWbk, GradeSht, intStudGrade, 227, 2 'Step 22
GradeSolver GradeWbk, StudentWbk, GradeSht, intStudGrade, 231, 5, 14 'Step 23
GradePivot GradeWbk, StudentWbk, GradeSht, intStudGrade, 245, 2, 1, 17 'Step 24
'*************************************************************
'Close student's homework file without saving changes
StudentWbk.Close savechanges:=False
myFile = Dir
Loop
```

Instructor enters this code

Different procedures must be called depending on the item that is graded. Table 1 includes a list of the sub procedures that can be called along with an explanation of their purpose and a list of their parameters. Parameters represent the data that the sub procedures need in order to run. Five sub procedures are listed in Table 1. The GradeStep sub procedure is used to grade formulas in cells while the GradeChart sub procedure grades charts. The GradePivot sub procedure grades PivotTables, the GradeSolver sub procedure grades a Solver analysis and the CheckRngName sub procedure grades a named range. Two of the sub procedures call custom functions. The GradePivot sub procedure calls the CountDecimalPlaces function and the CheckRngName sub procedure calls the NamedRangeExists and the RangeIsCorrect functions. The custom functions are listed in Table 2.

TABLE 1

Sub procedures that can be called

Sub Procedure Name	Purpose	Parameters
GradeStep	Grades a formula in a cell	wbk1 wbk2, grs, intGradeColumn, intRowNum, intNumCells, intNumParts, intNumDig
GradeChart	Grades a chart	wbk1, wbk2, grs, intGradeColumn, intRowNum, intNumDSeries
GradePivot	Grades a PivotTable	wbk1, wbk2, grs, intGradeColumn, intRowNum, intNumFields, intCalcField, intNumRows

GradeSolver	Grades a solver analysis	wbk1, wbk2, grs, intGradeColumn, intRowNum, intNumConstraints, intNumRows
CheckRngName	Grades a range name	wbk2, grs, intGradeColumn, intRowNum

TABLE 2

Custom functions called by sub procedures

Function Name	Purpose	Called By
CountDecimalPlaces	Counts the number of decimals places in the value displayed in the gradesheet	GradePivot
NamedRangeExists	Checks to see if the student's file contains a range with the specified name	CheckRngName
RangeIsCorrect	Checks to see if the cell range for a particular range name is correct	CheckRngName

Table 3 lists the parameters used in the sub procedures that are called. The table also includes a definition of each parameter and a list of the sub procedures each parameter is used in. Four of the first five parameters in the table are required by all five sub procedures called and the first parameter in the table is required by four of the sub procedures called. The first two parameters, wbk1 and wbk2, are workbooks accessed by the LoopAndGrade sub procedure prior to calling the other procedures. The parameter wbk1 is the workbook that contains the grade sheet and the grading program. The workbook is referred to as GradeWbk in the LoopAndGrade sub procedure; therefore, GradeWbk is passed to the sub procedures as the argument or value corresponding to wbk1. The parameter wbk2 is the student workbook that is open and being graded. The LoopAndGrade sub procedure refers to the student workbook as StudentWbk. The LoopAndGrade sub procedure opens StudentWbk and begins to grade it prior to calling another sub procedure; thus, StudentWbk is passed to the other sub procedures as the argument corresponding to wbk2.

TABLE 3

Parameters used in sub procedures

Parameter	Definition	Sub Procedure Used In
wbk1	The workbook that contains the grade sheet and the grading program	GradeStep, GradeChart, GradePivot, GradeSolver
wbk2	The student workbook that is open and being graded	GradeStep, GradeChart, GradePivot, GradeSolver, CheckRngName
grs	The grade sheet	GradeStep, GradeChart, GradePivot, GradeSolver, CheckRngName

intGradeColumn	The column in the grade sheet where the points for a particular student will be entered	GradeStep, GradeChart, GradePivot, GradeSolver, CheckRngName
intRowNum	The first row of the grade sheet that relates to the step graded by the sub procedure	GradeStep, GradeChart, GradePivot, GradeSolver, CheckRngName
intNumCells	The number of cells in the student's workbook that the procedure grades	GradeStep
intNumParts	The number of parts or components of the student's formula that must be graded. It excludes the ending cell/formula value.	GradeStep
intNumDig	The number of decimal places the student's cell value must be rounded to. Must match the number of decimals in the grade sheet value.	GradeStep
intNumDSeries	The number of data series in the chart	GradeChart
intNumFields	The number of data fields in the PivotTable	GradePivot
intCalcField	The number of calculated fields in the PivotTable	GradePivot
intNumRows	The total number of rows in the grade sheet related to the PivotTable or Solver analysis graded	GradePivot, GradeSolver
intNumConstraints	The number of constraints in the Solver model	GradeSolver

The third and fourth parameters in Table 3 are also accessed or calculated by the LoopAndGrade sub procedure prior to calling the other sub procedures. The parameter grs is the grade sheet which is referred to as GradeSht in the LoopAndGrade sub procedure. The LoopAndGrade sub procedure enters the student's name and unique file ID in GradeSht and also records some points in GradeSht prior to calling other sub procedures. Consequently, GradeSht must be passed to the other sub procedures as the argument corresponding to grs. The parameter intGradeColumn represents the column in the grade sheet where the points for a particular student are recorded. The LoopAndGrade sub procedure calculates intGradeColumn as it loops through and opens the student files. Points recorded for the first student file opened are entered in the eighth column (i.e., column H) of the grade sheet. Points for the second student file opened are entered in the nineth column; points for the third student file opened are entered in the tenth column, etc. Since the LoopAndGrade sub procedure refers to intGradeColumn as intStudGrade, intStudGrade must be passed to the other sub procedures as the argument corresponding to intGradeColumn.

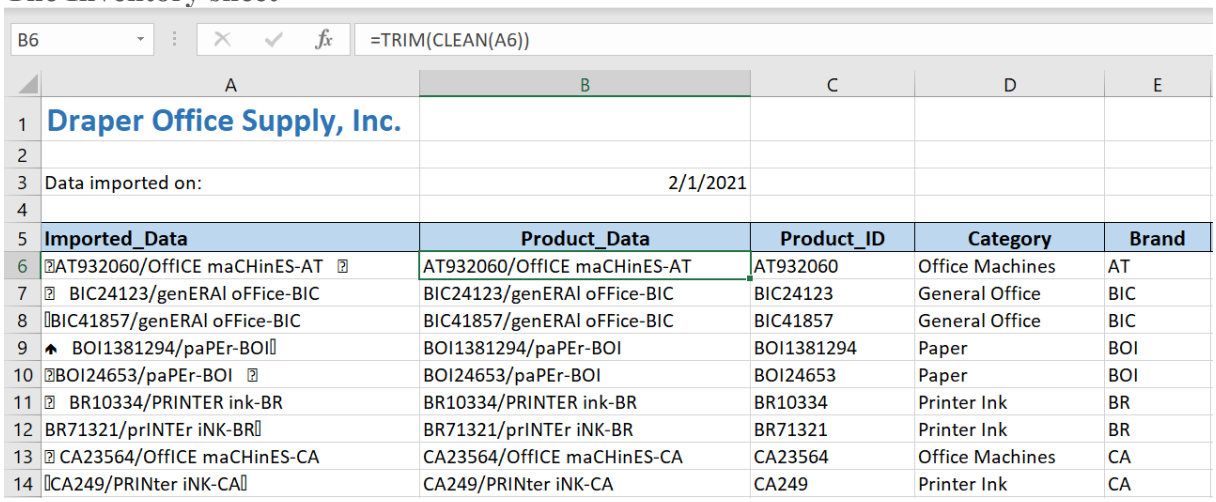
Grading a Formula

To grade a formula in a student's file, certain information must be entered in the grade sheet and a line of code must be added to the appropriate section of the LoopAndGrade sub procedure. The line of code must call the GradeStep sub procedure and must include the correct arguments. The

steps to grade a formula are explained using an example. Assume that students are given a starting file containing a worksheet with a list of imported inventory data. Figure 6 shows a portion of the worksheet which includes data for 39 different inventory items. Cell range A6:A44 contains the imported data. Students are required to use specific functions to clean and re-format the data. Step 3 of the assignment instructions states that students must enter a formula in cell B6 of the spreadsheet that uses the TRIM and CLEAN functions to remove the extra spaces and the non-printable characters from cell A6. The formula entered in cell B6 must be copied down the column to the last item in the list. The correct formula is displayed in the formula bar in Figure 6.

FIGURE 6

The Inventory sheet



B6 =TRIM(CLEAN(A6))

	A	B	C	D	E
1	**Draper Office Supply, Inc.**				
2					
3	Data imported on:	2/1/2021			
4					
5	**Imported_Data**	**Product_Data**	**Product_ID**	**Category**	**Brand**
6	AT932060/OffICE maCHinES-AT	AT932060/OffICE maCHinES-AT	AT932060	Office Machines	AT
7	BIC24123/genERAl oFFice-BIC	BIC24123/genERAl oFFice-BIC	BIC24123	General Office	BIC
8	BIC41857/genERAl oFFice-BIC	BIC41857/genERAl oFFice-BIC	BIC41857	General Office	BIC
9	BOI1381294/paPEr-BOI	BOI1381294/paPEr-BOI	BOI1381294	Paper	BOI
10	BOI24653/paPEr-BOI	BOI24653/paPEr-BOI	BOI24653	Paper	BOI
11	BR10334/PRINTER ink-BR	BR10334/PRINTER ink-BR	BR10334	Printer Ink	BR
12	BR71321/prINTEr iNK-BR	BR71321/prINTEr iNK-BR	BR71321	Printer Ink	BR
13	CA23564/OffICE maCHinES-CA	CA23564/OffICE maCHinES-CA	CA23564	Office Machines	CA
14	CA249/PRINter iNK-CA	CA249/PRINter iNK-CA	CA249	Printer Ink	CA

Prior to entering information in the grade sheet, the instructor must decide how many and which cells in range B6:B44 will be graded. The grading program can loop through and grade every cell in the range; however, this would increase the time required to grade each student's file. Grading the first cell in the column, one cell towards the end of the column, and one additional cell is sufficient to ascertain whether the step was completed correctly. For this example, the following three cells have been selected for grading: B6 (the first cell), B20 and B38.

Figure 7 displays a portion of a grade sheet. Nine rows in the grade sheet relate to step 3. The first three rows in the grade sheet are used to grade the formula in cell B6 of the student's file. The second three rows are used to grade the formula in cell B20, and the last three rows are used to grade the formula in cell B38. Cell range A6:A14 of the grade sheet displays a 3 for the step number. The first row in the grade sheet related to step 3 includes the following description of the step to be graded: "Remove extra spaces". As mentioned previously, the step number and description are not used by the grading program and can contain any information considered relevant. Cell C6 includes the name of the sheet ("Inventory") containing the formula to be graded and cell D6 includes the cell reference for the cell to be graded ("B6"). Cell E6 of the grade sheet displays the word "TRIM" because the grading program must search for the word "TRIM" in each student's formula. Cell F6 displays a start position of 1. This means the grading program starts searching for "TRIM" at character position 1 in the student's formula. Cell G6 displays the points earned by the student if the TRIM function is included in the student's formula.

FIGURE 7

The grade sheet for a formula

	A	B	C	D	E	F	G	H	I
1	Step No.	Description	Worksheet	Cell to Grade	Value to Grade	StartPosition	Points	Student Points	Student
2	2	Student Name	Honor Code	D5			Solution	Hokie Bird	Lois Lan
3	2	Unique File ID	Honor Code	D7			XXXXX	13183	
4	2	Student Name Points	Honor Code	D5			4	4	
5	2	Honor Code Points	Honor Code	D16			4	4	
6	3	Remove extra spaces	Inventory	B6	TRIM	1	0.5	0.5	
7	3	Remove non-printable characters	Inventory	B6	CLEAN	5	0.5	0.5	
8	3	Check cell value	Inventory	B6	AT932060/OffICE maCHinES-AT		0.5	0.5	
9	3	Remove extra spaces	Inventory	B20	TRIM	1	0.5	0.5	
10	3	Remove non-printable characters	Inventory	B20	CLEAN	5	0.5	0.5	
11	3	Check cell value	Inventory	B20	HAM162110/paPEr-HAM		0.5	0.5	
12	3	Remove extra spaces	Inventory	B38	TRIM	1	0.5	0.5	
13	3	Remove non-printable characters	Inventory	B38	CLEAN	5	0.5	0.5	
14	3	Check cell value	Inventory	B38	SCT20743/genERAl oFFice-SCT		0.5	0.5	

Row 7, the second row in the grade sheet related to step 3, has a description of “Remove non-printable characters” because students must include the CLEAN function in their formula. The worksheet, cell to grade and points in cells C7, D7 and G7 are the same as those in C6, D6, and G6. The value to grade in cell E7 is “CLEAN” and the start position in cell F7 is 5. The start position is 5 because the CLEAN function must appear in the formula after the TRIM function. “Cleaning” a cell can leave blank spaces in the place of non-printable characters. A value must be trimmed after it is cleaned so that the TRIM function can remove spaces left by the CLEAN function.

Row 8, the third row in the grade sheet related to step 3, has information related to the formula’s ending value. The description in cell B8 is: “Check cell value”. The worksheet and cell to grade have not changed. They are still “Inventory” and “B6”. The value to grade is the formula’s correct ending value of: “AT932060/OffICE maCHinES-AT”. There is no start position because the grading program is grading an ending formula value and not searching for specific text within the formula. Points earned by students for having the correct ending formula value are displayed in cell G16 of the grade sheet; however, points cannot be earned for a correct ending value if there is no formula in the cell graded.

The information in cell range A9:G11 of the grade sheet is similar to the information in cell range A6:G8; however, the cell to grade in cells D9:D11 is B20 instead of B6. The value to grade in cell E11 of the grade sheet is the correct ending formula value for cell B20.

The information in cell range A12:G14 of the grade sheet is also similar to the information in cell range A6:G8; however, the cell to grade in cells D12:D14 is B38 instead of B6. The value to grade in cell E14 of the grade sheet is the correct ending formula value for cell B38.

After entering the information in the grade sheet, code to call the GradeStep sub procedure must be added to the appropriate section of the LoopAndGrade sub procedure. The code begins with the name of the sub procedure and is followed by arguments corresponding to each of the parameters. The arguments must be in the correct order. (The order is shown in Table 1.) Following is the line of code added to the LoopAndGrade sub procedure to grade step 3:

```
GradeStep GradeWbk, StudentWbk, GradeSht, intStudGrade, 6, 3, 2, 0
```

The first four arguments are explained in the previous section of the paper that discusses the grading program. The fifth argument which has a value of 6 corresponds to the parameter intRowNum. This parameter is the first row of the grade sheet related to the step graded. The first row of the grade sheet related to step 3 is row 6. The sixth argument has a value of 3 and corresponds to the parameter intNumCells. This parameter is the number of cells in the student's workbook that the procedure grades. Step 3 grades three cells: B6, B20 and B38. The seventh argument which has a value of 2 corresponds to the parameter intNumParts. This parameter represents the number of parts or components of the student's formula that must be graded. It does not include the ending cell/formula value. Two parts of the formula in step 3 are graded. These parts are "TRIM" and "CLEAN". A part can be anything included in a formula such as a function, a number, a cell reference, an operator, or other symbol. The last argument is a 0 which corresponds to the parameter intNumDig. This parameter represents the number of decimal places the student's cell value must be rounded to. When the result of a formula that is graded is a number, the ending value in the student's file must be rounded to the same number of decimal places entered in the grade sheet for value to grade. Since the value to grade for step 3 is not a number, the argument is a 0. (If the value to grade is a number and is entered in the grade sheet as an integer, then the value of intNumDig would also be a 0.)

Grading a Chart

The first step in grading a chart consists of entering information related to the chart in the grade sheet. The first row in the grade sheet related to the chart is used to grade the chart type. VBA code numbers for the chart type must be used. Table 4 displays some common chart types and their VBA code numbers. The second row in the grade sheet is used to grade the chart title. The third and subsequent rows are used to grade the data series included in the chart.

TABLE 4
VBA code numbers for chart types

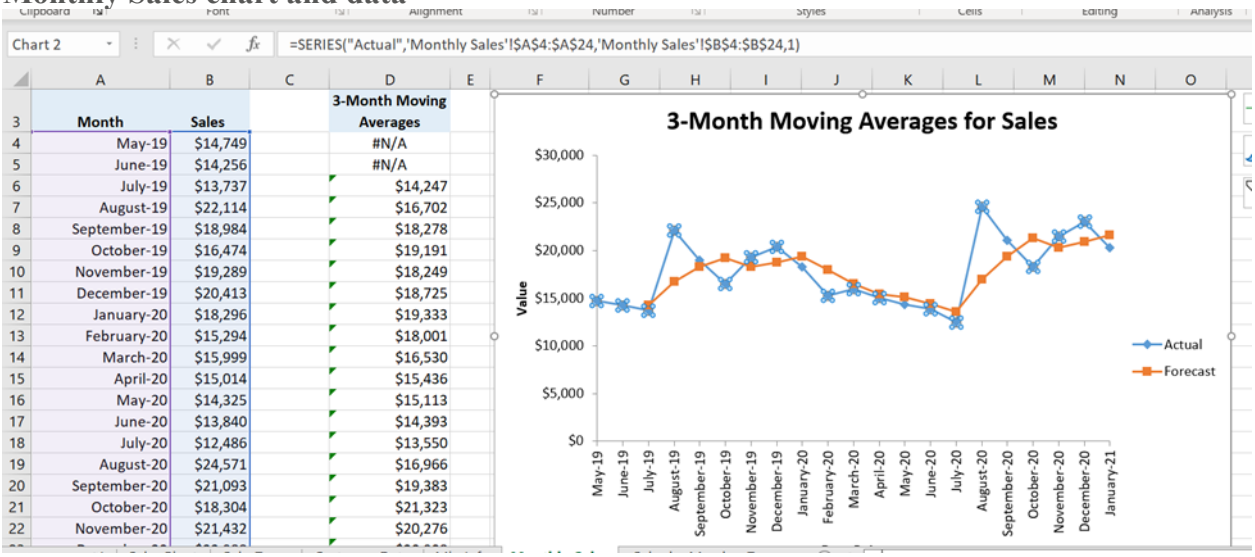
Chart Description	Chart Type – VBA Code
Clustered Bar	57
Clustered Column	51
Line	4
Line with Markers	65
Pie	5
Scatter	-4169
Stacked Bar	58
Stacked Column	52

An example is used to illustrate grading a chart. Assume that step 22 of an assignment requires that students create a line chart with markers on a sheet named Monthly Sales. Figure 8 displays an image of the chart and data. The chart title must be "3-Month Moving Averages for Sales" and two data series must be used to create the chart. The two data series which are also on the Monthly Sales sheet include data for actual and forecasted monthly sales. Figure 9 shows the portion of a grade sheet containing data related to the chart. Row 228 is the first row in the grade sheet corresponding to the chart. Cell A228 includes the step number based on the assignment

instructions. Cell B228 displays a description of: “Chart type”. Cell C228 displays “Monthly Sales”. This is the name of the worksheet containing the chart. The cell to grade is blank because the program is not grading the contents of a specific cell. The value to grade in cell E228 is 65. This represents the VBA code for a line chart with markers. Cell F228 for start position is blank because the grading program is not searching for specific text within a cell. Cell G228 displays the points earned by a student for creating a chart with the correct chart type.

FIGURE 8

Monthly Sales chart and data



	Month	Sales	3-Month Moving Averages
4	May-19	$14,749	#N/A
5	June-19	$14,256	#N/A
6	July-19	$13,737	$14,247
7	August-19	$22,114	$16,702
8	September-19	$18,984	$18,278
9	October-19	$16,474	$19,191
10	November-19	$19,289	$18,249
11	December-19	$20,413	$18,725
12	January-20	$18,296	$19,333
13	February-20	$15,294	$18,001
14	March-20	$15,999	$16,530
15	April-20	$15,014	$15,436
16	May-20	$14,325	$15,113
17	June-20	$13,840	$14,393
18	July-20	$12,486	$13,550
19	August-20	$24,571	$16,966
20	September-20	$21,093	$19,383
21	October-20	$18,304	$21,323
22	November-20	$21,432	$20,276

FIGURE 9

The grade sheet for a chart

	Step No.	Description	Worksheet	Cell to Grade	Value to Grade	StartPosition	Points	Stu
2	2	Student Name	Honor Code	D5			Solution	Hol
228	22	Chart type	Monthly Sales		65		1	
229	22	Chart title	Monthly Sales		3-Month Moving Averages for Sales		0.5	
230	22	Data series	Monthly Sales		=SERIES("Actual",'Monthly Sales'!$A$4:$A$24,'Monthly Sales'!$B$4:$B$24,1)		1	
231	22	Data series	Monthly Sales		=SERIES("Forecast",'Monthly Sales'!$A$4:$A$24,'Monthly Sales'!$D$4:$D$24,2)		1	

The second row of the grade sheet related to the chart is used to grade the chart title; therefore, the description in cell B229 is “Chart title”. The worksheet name in cell C229 is “Monthly Sales”. The cell to grade in cell D229 is blank. The value to grade in cell E229 contains the chart title. The start position in cell F229 is blank. The points earned by students for placing the correct title in the chart are shown in cell G229.

Rows 230 and 231 of the grade sheet contain information used by the GradeChart sub procedure to verify that the correct data series were plotted on the chart. The description in cells B230 and 231 is “Data series” and the worksheet name in cells C230 and C231 is “Monthly Sales”. Cell to grade in cells D230 and D231 is blank because the contents of a specific cell is not graded. Cells E230 and E231 must contain the formulas for the data series that are plotted. These formulas can be obtained by clicking on the symbol (line, column, etc.) representing the data series in the chart. The series formula will appear in the formula bar. (The formula bar in Figure 8 shows the series formula for the actual monthly sales data.) Start position in cells F230 and F231 is blank

and cells G230 and G231 include the points earned by students for plotting the correct data series.

After the appropriate information is entered in the grade sheet, a line of code calling the GradeChart sub procedure is added to the LoopAndGrade sub procedure. Following is the line of code:

```
GradeChart GradeWbk, StudentWbk, GradeSht, intStudGrade, 228, 2
```

The first four arguments are explained in the previous section of the paper that discusses the grading program. The fifth argument corresponds to the intRowNum parameter which is also used in the GradeStep sub procedure. This parameter is the first row of the grade sheet related to the step graded. The first row of the grade sheet related to the chart is row 228. The last parameter is intNumDSerie which represents the number of data series plotted in the chart. The chart in the example includes two data series.

Grading a PivotTable

To grade a PivotTable, information related to the PivotTable must first be entered in the grade sheet rows. The value to grade must include the following items listed in the order shown:

1. The PivotTable cell range
2. The address for the source data in R1C1 notation
3. The data fields in the PivotTable with each data field on a separate row of the grade sheet
4. The number formats for the data fields with the number formats for different data fields on separate rows
5. The calculated fields in the PivotTable with each calculated field on a separate row of the grade sheet
6. PivotTable values to be graded with each value on a separate row of the grade sheet

An example is used to illustrate completing a grade sheet for a PivotTable. Assume that, in step 24 of an assignment, students are asked to create a PivotTable using data on customer sales transactions. This PivotTable must be placed on a sheet named Sales Pivot. Figure 10 displays an image of the PivotTable. The PivotTable must show the total due from customers and total sales net of taxes categorized by membership type. Date must be in the filters area of the PivotTable. Sales net of taxes is a calculated field. A member type of “N/A” is used for customers who have not purchased a store membership. Customers can purchase one of three membership types. Purchasing a membership allows a customer to receive a discount on products purchased. The amount of the discount depends on the type of membership.

FIGURE 10
A PivotTable on the Sales Pivot sheet

	A	B	C
1	Date	(All)	
2			
3	**Member Type**	**Sum of Total_Due**	**Sum of Sales net Taxes**
4	Basic	$3,634.57	$3,632.86
5	Elite	$11,048.15	$11,041.15
6	Elite Plus	$2,838.25	$2,835.81
7	N/A	$4,147.71	$4,140.25
8	**Grand Total**	**$21,668.67**	**$21,650.07**
9			

Figure 11 shows the portion of the grade sheet related to the PivotTable. Row 246, the first row related to the PivotTable, includes a description of "PivotTable range" because the grading program will check to see if the student's PivotTable is in the correct cell range. Cell C246 of the grade sheet displays a worksheet name of "Sales Pivot". Cell D246 is blank because cell to grade is not needed. The value to grade in cell E246 is "$A$1:$C$8". This is the cell range of the PivotTable. A start position is not needed, and students earn 1 point if the PivotTable is in the correct cell range.

FIGURE 11
The grade sheet for a PivotTable

	A	B	C	D	E	F	G	
1	**Step No.**	**Description**	**Worksheet**	**Cell to Grade**	**Value to Grade**	**StartPosition**	**Points**	**St**
2	2	Student Name	Honor Code	D5			Solution	H
246	24	PivotTable range	Sales Pivot		$A$1:$C$8		1	
247	24	PivotTable source data (R1C1 notation)	Sales Pivot		SalesTrans!R4C1:R82C15		1	
248	24	Datafield	Sales Pivot		Sum of Total_Due		1	
249	24	Datafield	Sales Pivot		Sum of Sales net Taxes		1	
250	24	Number format for Datafield	Sales Pivot		$#,##0.00		0.5	
251	24	Number format for Datafield	Sales Pivot		$#,##0.00		0.5	
252	24	Calculated Field	Sales Pivot		Sales net Taxes		1	
253	24	Cell value	Sales Pivot	A1	Date		1	
254	24	Cell value	Sales Pivot	B1	(All)		1	
255	24	Cell value	Sales Pivot	A3	Member Type		1	
256	24	Cell value	Sales Pivot	A4	Basic		1	
257	24	Cell value	Sales Pivot	A5	Elite		1	
258	24	Cell value	Sales Pivot	A6	Elite Plus		1	
259	24	Cell value	Sales Pivot	A7	N/A		1	
260	24	Cell value	Sales Pivot	A8	Grand Total		1	
261	24	Cell value	Sales Pivot	B8	21668.67		1	
262	24	Cell value	Sales Pivot	C8	21650.07		1	

Row 247, the second row in the grade sheet related to the PivotTable, has a description of "PivotTable source data (R1C1 notation)". Cell to grade and start position are not needed. The value to grade is: "SalesTrans!R4C1:R82C15". This is the address for the PivotTable source data in R1C1 notation. R1C1 notation refers to a cell's address using numbers for both the rows and columns. The "R" stands for row and the "C" stands for column; thus, R4C1 is referring to the cell in the fourth row and first column (i.e., cell A4). The cell with an address of R82C15 is O82.

The data fields in the PivotTable must be listed in the grade sheet after the source data. The PivotTable contains two data fields. Cell E248 displays the name of one data field – "Sum of Total_Due" and cell E249 displays the name of the other data field – "Sum of Sales net Taxes".

Cell to grade and start position are not needed; however, points in cells G248 and G249 must be entered.

Number formats for the data fields must follow the data fields in the grade sheet. The value to grade in cell E250 must be the format for the first data field listed and the value to grade in cell E251 must be the format for the second data field listed. Both data fields use a currency format with two decimal places; therefore, the value to grade in cells E250 and E251 is "$#,##0.00". Cell to grade and start position are not needed; however, points in cells G250 and G251 must be entered.

If a PivotTable has one or more calculated fields, they are listed after number formats in the grade sheet. The PivotTable in the current example has one calculated field named "Sales net Taxes". This name is the value to grade in cell E252 of the grade sheet. Cell to grade and start position are not needed; however, a value for points earned if the student's PivotTable has the correct calculated field must be entered in cell G252.

If any values or text in specific cells of the PivotTable are to be graded, they are listed after the calculated field(s) in the grade sheet. Each cell graded is listed on a separate row of the grade sheet. Rows 253 to 262 of the grade sheet are used to grade values in specific cells of the PivotTable. The cell address of the specific cells graded is entered as "Cell to grade" in cells D253:D262. The text or numeric value that should be in the specific PivotTable cell is entered as "Value to grade" in cells E253:E262 of the grade sheet. Points earned for each correct PivotTable value are entered in cells G253:G262 of the grade sheet. Start position is not needed.

After the grade sheet is completed, a line of code that calls the GradePivot sub procedure is added to the LoopAndGrade sub procedure. Following is the line of code for the example PivotTable:

```
GradePivot GradeWbk, StudentWbk, GradeSht, intStudGrade, 246, 2, 1, 17
```

The fifth argument in the code corresponds to the parameter intRowNum which is used in all the sub procedures called by the LoopAndGrade sub procedure. The argument value is 246 because the first row of the grade sheet that relates to the PivotTable is row 246. The sixth argument corresponds to the parameter intNumFields. This parameter represents the number of data fields in the PivotTable. The example PivotTable has two data fields. The seventh argument corresponds to the parameter intCalcField that represents the number of calculated fields in the PivotTable. The example PivotTable has one calculated field. The last argument in the line of code corresponds to the parameter intNumRows. This is the total number of rows in the grade sheet related to the PivotTable. In this example, 17 rows of the grade sheet relate to the PivotTable graded.

Grading a Solver Analysis

To grade a Solver analysis, specific information related to the analysis must be entered in the grade sheet rows. The value to grade must include the following items listed in the order shown:

1. The correct value for objective cell
2. The number of changing cells

3. The formula for the objective cell that appears in the Solver model
4. The formula for the changing cells that appears in the Solver model
5. The formulas for the constraints with each different formula entered on a separate row of the grade sheet
6. The optimal values for the changing cells with each different value entered on a separate row of the grade sheet
7. The cell reference for the cell in the Answer Report that displays the value for the objective cell

An example is used to illustrate completing a grade sheet for a Solver analysis. Assume that, in step 23 of an assignment, students are asked to complete a Solver analysis for a small business that sells office supplies. Due to the increased number of people working at home, business owner would like to start selling four new types of home office workstations. Students must use Solver to determine how many of each type of workstation must be sold to maximize gross profit. The Solver analysis must be completed using information on a worksheet named "Home Office Workstations". Figure 12 displays an image of the "Home Office Workstations" sheet provided to students. The worksheet shows the selling price and cost for the four new workstations. It also shows the amount of space required to store each workstation in the warehouse. The small business, named Draper Office Supply, has a limited amount of warehouse space to store inventory. Students are provided with the following instructions:

> Use Total Gross Profit (cell G15) as the objective cell in the Solver model, with the goal of determining the maximum value for that cell. Use the number of workstations to order (range B15:E15) as the changing variable cells. Enter the constraints based on the information provided in the table below.

Constraint	*Cells or Range*
The total cost of the workstations must be less than or equal to $5,000.	**G6, H6**
The total storage space required must be less than or equal to 420 square feet.	**G10, H10**
The number of workstations ordered must be an integer	**B15:E15**
The number of workstations ordered must be greater than or equal to a specific value	**B15:E15 and B12:E12**
The number of workstations ordered must be less than or equal to a specific value	**B15:E15 and B13:E13**

> Use Simplex LP as the solving method to find an optimal solution. Save the Solver model in cell M3. Solve the model, keeping the Solver solution and produce an Answer report. Rename the Answer Report sheet as follows: *Workstation Report*.

Note that the instructions given to the student require that the Solver model be saved in the Home Office Workstations sheet. This must be done to enable the grading program to grade the formulas for the objective cell, the changing cells, and the constraints.

FIGURE 12
A Solver Analysis on the Home Office Workstations sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Draper Office Supply, Inc.											
2													Solver Model
3		Product ID											$ 2,924.43
4		RBS57392	ELL52106	HIL56287	SST53984								4
5	Selling Price per Home Office Workstation	$284.95	$367.99	$459.99	$680.95		Total Cost	Maximum Cost that can be Incurred					TRUE
6	Cost per Workstation	$179.23	$231.46	$289.33	$428.32		$ 4,957.92	$ 5,000.00					TRUE
7	Gross Profit	$105.72	$136.53	$170.66	$252.63								TRUE
8													TRUE
9	Storage space requirements (in Square Feet):						Total Storage	Maximum Storage					TRUE
10	Storage Space Required per Workstation	15	18	24	36		405	420					32767
11													0
12	Minimum Number of Workstations to Order	3	3	2	2								
13	Maximum Number of Workstations to Order	9	8	8	7								
14							Total Gross Profit						
15	Number of Workstations to Order	9	7	3	2		$ 2,924.43						
16													

Figure 13 displays an image of the completed grade sheet section related to the Solver analysis. The first row related to the Solver analysis, row 232, displays a description of "Correct value for objective cells". It also displays the worksheet name as "Home Office Workstations" and the cell to be graded is cell M3. The value to grade is the optimal value for the objective cell which is 2924.83. A start position is not needed for any of the Solver analysis values graded because the grading program is either grading a cell value or the entire formula within a cell. Values for points earned by students are entered in the grade sheet.

FIGURE 13
The grade sheet for Solver

	A	B	C	D	E	F	G	
1	Step No.	Description	Worksheet	Cell to Grade	Value to Grade	StartPosition	Points	St
2	2	Student Name	Honor Code	D5			Solution	Hc
232	23	Correct value for objective cell	Home Office Workstations	M3	2924.43		1	
233	23	Number of changing cells	Home Office Workstations	M4	4		1	
234	23	Objective cell formula	Home Office Workstations	M3	=MAX($G$15)		1	
235	23	Formula that counts changing cells	Home Office Workstations	M4	=COUNT($B$15:$E$15)		1	
236	23	Constraint	Home Office Workstations	M5	=$B$15:$E$15<=$B$13:$E$13		1	
237	23	Constraint	Home Office Workstations	M6	=$B$15:$E$15=INT($B$15:$E$15)		1	
238	23	Constraint	Home Office Workstations	M7	=$B$15:$E$15>=$B$12:$E$12		1	
239	23	Constraint	Home Office Workstations	M8	=$G$10<=$H$10		1	
240	23	Constraint	Home Office Workstations	M9	=$G$6<=$H$6		1	
241	23	Optimal value for changing cell	Home Office Workstations	B15	9		1	
242	23	Optimal value for changing cell	Home Office Workstations	C15	7		1	
243	23	Optimal value for changing cell	Home Office Workstations	D15	3		1	
244	23	Optimal value for changing cell	Home Office Workstations	E15	2		1	
245	23	Compare objective cell value to answer report	Home Office	E16	G15		1	

The second row of the grade sheet related to the Solver analysis is row 233. This row contains information that enables the grading program to grade the resulting value for the formula in cell M4. The formula in cell M4 counts the number of changing cells. Since the changing cells are cells B15 to E15, the value to grade is 4.

Rows 234 through 240 of the grade sheet contain information that is used to grade the formulas in the Solver model. The first formula in the model is the objective cell formula. The second formula is the formula that counts the changing cells. The next five formulas are the constraint formulas. The cells to grade displayed in rows 234 through 240 of the grade sheet correspond to cells M3 through M9 in the Solver model and the values to grade in the grade sheet correspond to the formulas in cells M3 through M9 of the Solver model.

Rows 241 through 244 of the grade sheet contain information that is used to grade the optimal values for the changing cells. The cells to grade in rows 241 through 244 correspond to cells B15 through E15 of the Home Office Workstations sheet. The values to grade in those same rows equal the optimal values displayed in cells B15 through E15 of the Solver analysis.

The final row of the grade sheet related to the Solver analysis (i.e., row 245) is used to verify that the objective cell value displayed in the Answer Report is equal to the objective cell value in the Home Office Workstations sheet. The worksheet name in cell C245 of the gradesheet is "Home Office" instead of "Home Office Workstations" because the assignment instructions provided to the students require that the name of the Answer Report sheet be changed to "Home Office". The cell to grade is cell E16. Cell E16 is the cell in the Home Office Workstations sheet containing the formula that calculates the value to be maximized. The value to grade is the cell reference for the cell in the Home Office sheet that displays the value for the objective cell.

After entering the required information in the grade sheet, a line of code that calls the GradeSolver sub procedure is added to the appropriate section of the LoopAndGrade sub procedure. Following is the line of code:

```
GradeSolver GradeWbk, StudentWbk, GradeSht, intStudGrade, 232, 5, 14
```

The first four arguments in the code are explained in the previous section of the paper that discusses the grading program. The fifth argument corresponds to the parameter intRowNum which is also included in the other sub procedures that can be called. The argument value for intRowNum is 232 because that is the first row of the grade sheet containing information about the Solver example graded. The sixth argument corresponds to the parameter intNumConstraints. This parameter represents the number of constraints in the Solver model. The Solver analysis example includes 5 constraints. The last argument corresponds to the parameter intNumRows. This parameter is also used in the GradePivot sub procedure. The argument value for intNumRows is 14 because the total number of rows in the grade sheet containing information related to the Solver analysis is 14.

Grading a range name

The CheckRngName sub procedure is used to verify that a student has named a range and the range is correct. The range can consist of one or more cells. Assume that, in step 10 of an assignment, students are asked to name a cell in the starting file. The cell is B8 in the sheet named MiscInfo. The cell contains the sales tax rate and should be named SalesTaxRate. Figure 14 displays an image of the row in the grade sheet related to step 10.

FIGURE 14

The grade sheet for a range name

	A	B	C	D	E	F	G	
1	**Step No.**	**Description**	**Worksheet**	**Cell to Grade**	**Value to Grade**	**StartPosition**	**Points**	**St**
2	2	Student Name	Honor Code	D5			Solution	H
88	10	Range name	MiscInfo	B8	SalesTaxRate		1	

The worksheet name in cell C88 of the grade sheet is “MiscInfo”. The cell to grade is B8 which is the cell in the student file that must be named. (Cell to grade can include a range of cells if the range name applies to more than one cell.) The value to grade in cell E88 is “SalesTaxRate”, the name of the range. A start position is not needed. The value in cell G88 is 1; thus, students earn 1 point for naming the cell correctly.

The following line of code is added to the LoopAndGrade sub procedure:

```
CheckRngName StudentWbk, GradeSht, intStudGrade, 88
```

Unlike the other sub procedures that are called, the CheckRngName sub procedure does not require GradeWbk as the first argument. The fourth and final argument of the sub procedure corresponds to the parameter intRowNum. The argument for this parameter has a value of 88 because row 88 in the grade sheet relates to the range name that is graded.

Limitations

The VBA program has limitations. To use the program, students must place their formulas and values in specific cells. Charts, PivotTables, and Solver analyses must be on specific sheets and sheet names must be identical to the sheet names in the solution file. No more than one PivotTable or chart can be placed on a sheet. The program works best when students are provided with a blank template and instructions indicating where their work must be placed. As a result, students are not able to design their own spreadsheets. Students benefit greatly from having to think about where to put formulas, values, etc. in a workbook. Unfortunately, an automated grading system relies on finding those formulas, values, etc. in specific places in a workbook. Another limitation of the VBA grading program is that it cannot grade macros.

Despite its limitations, the VBA program is useful for grading Excel assignments in large classes and/or classes where multiple Excel projects are assigned. Assignments can be graded quickly. Grading errors that occur due to manually grading assignments are eliminated. Faculty who are fortunate enough to have one or more teaching assistants do not have to spend time supervising them to ensure that assignments are graded consistently and in accordance with the instructor’s grading rubric. In addition, the instructor can assign projects that he/she has created and is able to control how the assignments are graded.

APPENDIX

The following code is for the LoopAndGrade sub procedure

```
Sub LoopAndGrade()
'Declare Variables
Dim myFolder As String, myFile As String
Dim GradeWbk As Workbook  'contains grades and macro
Dim StudentWbk As Workbook  'student's workbook
Dim GradeSht As Worksheet  'the grade sheet
Dim intStudentFileCount As Integer, intStudGrade As Integer
'Initialize the student file counter
intStudentFileCount = 0
```

```
'Opens a file dialog box. Select the folder containing the students' files.
 With Application.FileDialog(msoFileDialogFolderPicker)
      .AllowMultiSelect = False
      .Show
      myFolder = .SelectedItems(1)
      Err.Clear
 End With

'Stop screen updating and status bar updates so the code runs faster
 Application.ScreenUpdating = False
 Application.DisplayStatusBar = False

'Loop through all the students' files in the folder containing the students' Excel files.
myFile = Dir(myFolder & "\", vbReadOnly)

Do While myFile <> ""
'Open the student's file
Workbooks.Open Filename:=myFolder & "\" & myFile, UpdateLinks:=False
'Add 1 to the student file counter
intStudentFileCount = intStudentFileCount + 1

'GradeWbk is the workbook with the grades and the grading macro
'StudentWbk is the student's workbook
Set GradeWbk = ThisWorkbook
Set StudentWbk = ActiveWorkbook
Set GradeSht = GradeWbk.Sheets("GradeSheet") 'the gradesheet
'Activate the first sheet in the student's workbook
StudentWbk.Sheets("Honor Code").Activate

'intStudGrade represents the column in the GradeSheet where the student's points are entered.
'The first 7 columns of the GradeSheet describe the step that is graded.
intStudGrade = intStudentFileCount + 7
'Copy the student's name and unique ID to the grading sheet
GradeSht.Cells(2, intStudGrade).Value = StudentWbk.Sheets("Honor
Code").Range("D5").Value
GradeSht.Cells(3, intStudGrade).Value = StudentWbk.Sheets("Honor
Code").Range("D7").Value
'If student entered name in Honor Code sheet, then assign points
If Not IsEmpty(StudentWbk.Sheets("Honor Code").Range("D5").Value) Then
   GradeSht.Cells(4, intStudGrade).Value = GradeSht.Cells(4, 7).Value
Else
   GradeSht.Cells(4, intStudGrade).Value = 0
End If
'If student entered honor code initials, the assign points
If Not IsEmpty(StudentWbk.Sheets("Honor Code").Range("D16").Value) Then
  GradeSht.Cells(5, intStudGrade).Value = GradeSht.Cells(5, 7).Value
```

```
Else
  GradeSht.Cells(5, intStudGrade).Value = 0
End If
'************************************************************
'Call Grading Procedures Here


'End of Grading Procedures that are Called
'************************************************************
'Close student's file without saving changes
StudentWbk.Close savechanges:=False
myFile = Dir
Loop

'Turn screen updating and status bar updates back on
 Application.ScreenUpdating = True
 Application.DisplayStatusBar = True
End Sub
```

The following code is for the GradeStep sub procedure

```
Sub GradeStep(wbk1 As Workbook, wbk2 As Workbook, grs As Worksheet, _
intGradeColumn As Integer, intRowNum As Integer, intNumCells As Integer, _
intNumParts As Integer, intNumDig As Integer)
'wbk1 is the workbook with the grades and grading macro
'wbk2 is the student's workbook
'grs is the GradeSheet in the workbook with the grading macro
'intGradeColumn is the column in the GradeSheet where the points will be entered
'intRowNum is the first row of the GradeSheet that relates to the step graded by this procedure
'intNumCells is the number of cells in the student's spreadsheet that this procedure grades
'intNumParts is the number of parts or components of the student's formula that must be graded.
'intNumParts excludes the cell/formula value.
'intNumDig is the number of decimal places the student's cell value must be rounded to.
'intNumDig must match the number of decimals shown for the value to grade in the grade sheet
'Declare variables
Dim n As Integer, w As Integer, x As Integer, y As Integer
Dim Points As Single
Dim rng As Range
Dim wsName As String

'Grade the specific step
'Declare variables and arrays specific to this step
Dim GradeRange() As String 'Cells to be graded
Dim GradeValue() 'Correct cell values
Dim PointCellValue() As Single 'Points assigned to correct cell value
Dim RowNum() As Integer 'First row in GradeSheet related to cell
Dim PartValue() 'Values of parts to be graded
```

```
Dim StartPosition() As Integer 'Starting position to search for the part
Dim PointValue() As Single 'Points assigned to the part
Dim PartPos() As Integer 'Position of part in cell
'Set size of arrays
ReDim GradeRange(intNumCells)
ReDim GradeValue(intNumCells)
ReDim PointCellValue(intNumCells)
ReDim RowNum(intNumCells)
ReDim PartValue(intNumParts)
ReDim StartPosition(intNumParts)
ReDim PointValue(intNumParts)
ReDim PartPos(intNumParts)
'Set array values and specify cells to be graded and their values
intNumRows = intNumParts + 1 'intNumRows is the number of rows in the gradesheet related to
a cell
For n = 1 To intNumCells
   RowNum(n) = intRowNum + (intNumRows * (n - 1))  'First row in GradeSheet related to cell
   GradeRange(n) = grs.Cells(RowNum(n), 4).Value 'Cell to be graded
   GradeValue(n) = grs.Cells(RowNum(n) + intNumParts, 5).Value 'Correct cell value
   PointCellValue(n) = grs.Cells(RowNum(n) + intNumParts, 7).Value 'Points assigned to
         'correct cell value
Next n
'Sheet in student's workbook containing formula to be graded
wsName = grs.Cells(intRowNum, 3).Value
'Loop through cells in student's file and check formula
For x = 1 To intNumCells
  Set rng = wbk2.Sheets(wsName).Range(GradeRange(x)) 'rng is the cell to be graded
  'Initialize variables and fill arrays
  Points = 0
  'Loop through the parts to be graded and fill the arrays
  For y = 1 To intNumParts
    PartValue(y) = grs.Cells(RowNum(x) + (y - 1), 5).Value 'The part to be graded
    StartPosition(y) = grs.Cells(RowNum(x) + (y - 1), 6).Value 'Where to start looking for the part
    PointValue(y) = grs.Cells(RowNum(x) + (y - 1), 7).Value 'Points assigned to part
  Next y
  'Loop to determine if parts are in the student's formula and assign a point value
  For w = 1 To intNumParts
    'The InStr function returns the position of the first occurrence of a substring in a string.
    'The first argument tells VBA where to start looking for the substring.
    'The second argument is the string.
    'The third is the substring.
    PartPos(w) = InStr(StartPosition(w), rng.Formula, PartValue(w))
    'If PartPos > 0 then the part was used in the formula
    If PartPos(w) > 0 Then
       grs.Cells(RowNum(x) + (w - 1), intGradeColumn).Value = PointValue(w)
       Points = Points + PointValue(w) 'Add up points earned
```

```
    Else
      grs.Cells(RowNum(x) + (w - 1), intGradeColumn).Value = 0
    End If
  Next w
  'Check to see if cell displays error message.  If it does not, then grade value in cell.
  If VarType(rng.Value) = vbError Then
    grs.Cells(RowNum(x) + intNumParts, intGradeColumn).Value = 0
  Else 'If points earned for parts and student's value is correct, add points to GradeSheet
    'If the values to be compared are numbers (but not dates), round the value in the student's
    'file to the number of decimal places
    If WorksheetFunction.IsNumber(GradeValue(x)) = True And IsDate(GradeValue(x)) = False
And _
       WorksheetFunction.IsNumber(rng) = True And IsDate(rng) = False Then
       If Points > 0 And Round(rng.Value, intNumDig) = GradeValue(x) Then
          grs.Cells(RowNum(x) + intNumParts, intGradeColumn).Value = PointCellValue(x)
       Else
          grs.Cells(RowNum(x) + intNumParts, intGradeColumn).Value = 0
       End If
    Else
       If Points > 0 And rng.Value = GradeValue(x) Then
          grs.Cells(RowNum(x) + intNumParts, intGradeColumn).Value = PointCellValue(x)
       Else
          grs.Cells(RowNum(x) + intNumParts, intGradeColumn).Value = 0
       End If
    End If
  End If
Next x

End Sub
```

The following code is for the GradePivot sub procedure

```
Sub GradePivot(wbk1 As Workbook, wbk2 As Workbook, grs As Worksheet, _
intGradeColumn As Integer, intRowNum As Integer, intNumFields As Integer, _
intCalcField As Integer, intNumRows As Integer)
'wbk1 is the workbook with the grades and grading macro
'wbk2 is the student's workbook
'grs is the GradeSheet in the workbook with the grading macro
'intGradeColumn is the column in the GradeSheet where the points will be entered
'intRowNum is the first row of the GradeSheet that relates to the step graded by this procedure
'intNumFields is the number of data fields in the PivotTable
'intCalcField is the number of calculated fields in the PivotTable
'intNumRows is the number of rows in the gradesheet related to the step.
'Declare variables
Dim n As Integer, x As Integer, y As Integer, intEndRow As Integer, intNumDFields As Integer
Dim LastDField As Integer, FirstFormat As Integer, LastFormat As Integer, FirstCalcField As
Integer
```

```
Dim LastCalcField As Integer, intNumPTFields As Integer, FirstCellRow As Integer
Dim wsName As String
Dim rng As Range
Dim pvt As PivotTable
Dim ws As Worksheet 'Worksheet with PivotTable

'Declare arrays specific to this step
Dim GradeRange() As String 'Addresses of cells to be graded
Dim GradeValue() 'Values in the solution
Dim PointCellValue() As Single 'Points assigned to correct cell values
Dim RowNum() As Integer 'Rows in GradeSheet
Dim studentDFields(10) 'Array that contains student's data fields
ReDim GradeRange(intNumRows)
ReDim GradeValue(intNumRows)
ReDim PointCellValue(intNumRows)
ReDim RowNum(intNumRows)
intEndRow = intRowNum + (intNumRows - 1) 'Last row in grade sheet that relates to PivotTable
'wsName is the name of the sheet in the student's workbook that contains the PivotTable
wsName = grs.Cells(intRowNum, 3).Value
'firstCell is the first cell in the top left corner of the PivotTable
firstCell = Left(grs.Cells(intRowNum, 5).Value, 4)
Set ws = wbk2.Sheets(wsName) 'ws is sheet in student's file that contains PivotTable
On Error Resume Next 'If PivotTable does not exist, skip the next line
Set pvt = ws.Range(firstCell).PivotTable
If pvt Is Nothing Then 'PivotTable does not exist, loop through grade sheet
  For x = intRowNum To intEndRow
    grs.Cells(x, intGradeColumn).Value = 0 'Enter 0 for points
  Next x
  Exit Sub 'Exit the procedure
End If

'Set array values
'Specify cells to be graded, their correct values and their point values
For n = 1 To intNumRows
    RowNum(n) = intRowNum + (n - 1) 'Rows in GradeSheet
    GradeRange(n) = grs.Cells(intRowNum + (n - 1), 4).Value 'Cell to be graded
    GradeValue(n) = grs.Cells(intRowNum + (n - 1), 5).Value 'Correct cell value
    PointCellValue(n) = grs.Cells(intRowNum + (n - 1), 7).Value 'Points assigned to cell value
Next n
'Grade the PivotTable range
If pvt.TableRange2.Address = GradeValue(1) Then
    grs.Cells(RowNum(1), intGradeColumn).Value = PointCellValue(1)
Else
    grs.Cells(RowNum(1), intGradeColumn).Value = 0
End If
'Grade the PivotTable source data
```

```
If pvt.SourceData = GradeValue(2) Then
   grs.Cells(RowNum(2), intGradeColumn).Value = PointCellValue(2)
Else
   grs.Cells(RowNum(2), intGradeColumn).Value = 0
End If
'Count the number of data fields in the student's PivotTable
intNumDFields = pvt.DataFields.count

'lastDField depends on number of data fields in solution
LastDField = 3 + (intNumFields - 1) 'Last array index in grade sheet for data field
FirstFormat = LastDField + 1 'First array index in grade sheet for Format
LastFormat = FirstFormat + (intNumFields - 1) 'Last array index for Format
'Loop through the data fields in the PivotTable and grade
For x = 3 To LastDField
  For y = 1 To intNumDFields
   If pvt.DataFields(y).Name = GradeValue(x) Then
     grs.Cells(RowNum(x), intGradeColumn) = PointCellValue(x)
     'If the data field is in the PivotTable, grade the numberformat
     If pvt.DataFields(y).NumberFormat = GradeValue(x + intNumFields) Then
      grs.Cells(RowNum(x + intNumFields), intGradeColumn).Value = PointCellValue(x + intNumFields)
       Exit For
     End If
   End If
   Next y
Next x

'Determine if calculated fields exist
FirstCalcField = LastFormat + 1 'First array index in grade sheet for calculated field
LastCalcField = FirstCalcField + (intCalcField - 1) 'Last array index for calculated field
intNumPTFields = pvt.PivotFields.count 'The number of PivotTable fields in student's table
'If there are 1 or more calculated fields in the solution, loop through the student's
'PivotTable fields to find the calculated fields
If intCalcField > 0 Then
   For x = FirstCalcField To LastCalcField
      For y = 1 To intNumPTFields
         If pvt.PivotFields(y) = GradeValue(x) Then
            If pvt.PivotFields(GradeValue(x)).IsCalculated = True Then
               grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
            Else
               grs.Cells(RowNum(x), intGradeColumn).Value = 0
            End If
         End If
      Next y
   Next x
End If
'Loop through GradeSheet cells for datafields, formats and calculated fields.
'Enter 0 points in cells that are blank. Cell is blank if fields are missing from
```

```
'student's PivotTable and/or numberformat is incorrect
For x = 3 To LastCalcField
   If grs.Cells(RowNum(x), intGradeColumn).Value = "" Then
      grs.Cells(RowNum(x), intGradeColumn).Value = 0
   End If
Next x
'Loop through cells in student's PivotTable and grade values
'FirstCellRow is the first array index for cell values to be graded
If intCalcField > 0 Then
   FirstCellRow = LastCalcField + 1
Else
   FirstCellRow = LastFormat + 1
End If
For x = FirstCellRow To intNumRows
   'Assign points if the cell value in the student's worksheet equals the solution
   'If the values to be compared are numbers (but not dates), determine the
   'number of decimals places in the solution. Round the value in the student's
   'file to the number of decimal places in the solution
   If WorksheetFunction.IsNumber(GradeValue(x)) = True And IsDate(GradeValue(x)) = False And _
     WorksheetFunction.IsNumber(ws.Range(GradeRange(x))) = True And _
        IsDate(ws.Range(GradeRange(x))) = False Then
        numDecimals = CountDecimalPlaces(grs.Range("E" & CStr(RowNum(x))))
        If Round(ws.Range(GradeRange(x)).Value, numDecimals) = GradeValue(x) Then
           grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
        Else
           grs.Cells(RowNum(x), intGradeColumn).Value = 0
        End If
   Else
      If ws.Range(GradeRange(x)).Value = GradeValue(x) Then
         grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
      Else
         grs.Cells(RowNum(x), intGradeColumn).Value = 0
      End If
   End If
Next x
End Sub
```

The following code is for the CountDecimalPlaces function called by GradePivot

```
Function CountDecimalPlaces(InputCell As Range) As Integer
'Counts the number of decimal places in a cell
Dim StringConvert As String
StringConvert = InputCell.Value 'Converts cell value to a string

If InStr(1, StringConvert, ".") = 0 Then 'InStr = 0 if there is no "."
   CountDecimalPlaces = 0
Else
   'Number of decimals = length of string - number of characters up to "."
   CountDecimalPlaces = Len(StringConvert) - InStr(1, StringConvert, ".")
```

```
End If

End Function
```

The following code is for the GradeSolver sub procedure

```
Sub GradeSolver(wbk1 As Workbook, wbk2 As Workbook, grs As Worksheet,
_intGradeColumn As Integer, intRowNum As Integer, intNumConstraints As Integer, _
intNumRows As Integer)
'wbk1 is the workbook with the grades and grading macro
'wbk2 is the student's workbook
'grs is the GradeSheet in the workbook with the grading macro
'intGradeColumn is the column in the GradeSheet where the points will be entered
'intRowNum is the first row of the GradeSheet that relates to the step graded by this procedure
'intNumConstraints is the number of constraints in the solver model
'intNumRows is the total number of rows in the grade sheet related to the step.
'Declare variables
Dim n As Integer, x As Integer, y As Integer, intCount As Integer, endConstraint As Integer
Dim lastConstraintRow As Integer, firstRow As Integer, lastRow As Integer
Dim rng As Range
Dim wsName As String, wsName2 As String
Dim ws As Worksheet 'Worksheet with Solver Model
Dim ws2 As Worksheet 'Worksheet with Answer Report
'ws is the worksheet in the student's workbook that contains the Solver model
'ws2 is the worksheet in the student's workbook that contains the Answer Report

'Declare variables and arrays specific to this step
Dim GradeRange() As String 'Addresses of cells to be graded
Dim GradeValue() 'Values in the solution
Dim PointCellValue() As Single 'Points assigned to correct cell values
Dim RowNum() As Integer 'Rows in GradeSheet
Dim StudentConstraint(10) 'Array that will contain student's constraints
ReDim GradeRange(intNumRows)
ReDim GradeValue(intNumRows)
ReDim PointCellValue(intNumRows)
ReDim RowNum(intNumRows)
'Set array values
'Specify cells to be graded, their correct values and their point values
For n = 1 To intNumRows
   RowNum(n) = intRowNum + (n - 1) 'Rows in GradeSheet
   GradeRange(n) = grs.Cells(intRowNum + (n - 1), 4).Value 'Cell to be graded
   GradeValue(n) = grs.Cells(intRowNum + (n - 1), 5).Value 'Correct cell value
   PointCellValue(n) = grs.Cells(intRowNum + (n - 1), 7).Value 'Points assigned to cell value
Next n
'wsName is the name of the sheet in the student's workbook that contains the solver model
wsName = grs.Cells(intRowNum, 3).Value
Set ws = wbk2.Sheets(wsName) 'ws is sheet in student's file that contains solver model
```

```
'Loop through first two cells in student's solver model and grade values
For x = 1 To 2
  If ws.Range(GradeRange(x)) = GradeValue(x) Then
    grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
  Else
    grs.Cells(RowNum(x), intGradeColumn).Value = 0
  End If
Next x
'Loop through first two cells in student's solver model and grade formulas
For x = 3 To 4
  If ws.Range(GradeRange(x)).Formula = GradeValue(x) Then
    grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
  Else
    grs.Cells(RowNum(x), intGradeColumn).Value = 0
  End If
Next x
'Count the number of constraints in the student's model
endConstraint = 0 'Determines when to stop counting constraints
intCount = 0 'The number of constraints in the student's model
'The range in the student's file with the first constraint:
Set rng = ws.Range(grs.Cells(intRowNum + 4, 4).Value)
Do While endConstraint = 0
    If rng.Value = "True" Or rng.Value = "False" Then
        intCount = intCount + 1
        StudentConstraint(intCount) = rng.Formula
        Set rng = rng.Offset(1, 0)
    Else
        endConstraint = 1
    End If
Loop
'lastConstraintRow depends on number of constraints in solution
lastConstraintRow = 5 + (intNumConstraints - 1)
'Loop through the constraints in the model and grade
For x = 5 To lastConstraintRow
   For y = 1 To intCount
    If StudentConstraint(y) = GradeValue(x) Then
      grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
      Exit For
    End If
    Next y
Next x
'Loop through GradeSheet cells for constraints and enter 0 points in cells that are blank
'Cell is blank if constraint is missing from student's model
For x = 5 To lastConstraintRow
    If grs.Cells(RowNum(x), intGradeColumn).Value = "" Then
        grs.Cells(RowNum(x), intGradeColumn).Value = 0
```

```
    End If
Next x
'Grade changing cells. Must loop from firstRow with changing value to lastRow
firstRow = lastConstraintRow + 1
lastRow = lastConstraintRow + GradeValue(2)
For x = firstRow To lastRow
    'Assign points if the cell value in the student's worksheet equals the solution
    If ws.Range(GradeRange(x)).Value = GradeValue(x) Then
        grs.Cells(RowNum(x), intGradeColumn).Value = PointCellValue(x)
    Else
        grs.Cells(RowNum(x), intGradeColumn).Value = 0
    End If
Next x
'wsName2 is the name of the sheet in the student's workbook that contains the answer report
wsName2 = grs.Cells(RowNum(intNumRows), 3).Value
On Error Resume Next
Set ws2 = wbk2.Sheets(wsName2) 'ws2 is sheet in student's file that contains answer report
'If there is no error then Answer Report exists and sheet is named correctly.
'Assign points if objective cell final value shown in Answer Report equals objective cell final
'value shown in sheet with Solver Model
If Err = 0 Then
    If ws2.Range(GradeRange(intNumRows)).Value =
ws.Range(GradeValue(intNumRows)).Value Then
        grs.Cells(RowNum(intNumRows), intGradeColumn).Value =
PointCellValue(intNumRows)
    Else
        grs.Cells(RowNum(intNumRows), intGradeColumn).Value = 0
    End If
    Exit Sub
Else
    'Clear the error
    Err.Clear
    grs.Cells(RowNum(intNumRows), intGradeColumn).Value = 0
End If
End Sub
```

REFERENCES

[1] Brink, W.D. & Stoel, M.D. Chapter 2, Analytics Knowledge, Skills, and Abilities for Accounting Graduates, *Advances in Accounting Education: Teaching and Curriculum Innovations*, 2019, Volume 22, 23-43, Emerald Publishing Limited.

Management, Marketing, Accounting, Economics and Finance, Strategy, Organizational Behavior Organizational Theory, Human Resource Management, Consumer Behavior, International Business - Abstracts

A COMPARATIVE STUDY OF DIFFERENCE AND UNIQUENESS IN E-BUSINESS

Oral Presentation

Dr. Jiaqin Yang [1], ***Ms. Tianshu Ren*** [2]

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E-Business can be broadly defined as the application of information and communication technology by commercial firms to facilitate the exchange and services between businesses, groups and individuals. Amazon was one of the firms established at very early stage and eventually becomes the most successful one today. TaoBao (TB) is the most successful Asian e-business firm which was started ten year later after Amazon. The initial public offering of Alibaba Group on 2014 attracted many attentions toward TB, one of the main branches of Alibaba Group. As the two biggest online retailers in the world, Amazon and TB share lots of similarities and remain their own uniqueness at the same time. While TB is looking for worldwide market, at the same time, Amazon, as the most successful E-business in United States, owns the largest market share around the world. This paper presents the comparisons of these two giants from developments, marketing, price, delivery, payments, customer service and performance. These differences will be investigated from the following dimensions: culture, customer habit, regulation system and development of retailer industry. Specifically, this paper focuses on the comparison of the two businesses from various aspects such as history, marketing strategies, web design etc.

Advance Rewards: a New Motivational Practice through Emotional Booster and Cognitive Strengths

Oral Presentation

Dr. Shanggeun Rhee [1], ***Dr. Silvana Trimi*** [2], ***Dr. Gail Fraser*** [1], ***Dr. Nevila Baci*** [3]

1. *Kean University,* ***2.*** *University of Nebraska-Lincoln,* ***3.*** *University of Tirana*

With the advancement of new technology and new generation in the workforce, acquiring and retaining talents is getting more challenging. Two types of work motivation, intrinsic and extrinsic motivation, have provided theoretical foundations for the practitioners looking to implement management practices to help keep the top talents. Being regarded as a true source of work motivation, intrinsic motivation has been the major target of motivation research and it is believed that feelings of competence and self-determination determine the level of intrinsic motivation. The effects of extrinsic rewards, practical tools for practitioners, on the intrinsic motivation have been mixed. Whereas a research stream contends that extrinsic rewards reduce intrinsic motivation, other streams argue that extrinsic rewards can be added to strengthen the level of motivation without undermining intrinsic motivation. The proponents of the latter have focused on proposing ideas to reward in workplaces but they revolve around the traditional approach that rewards are given after work performances are identified. This approach has not only failed to produce a motivational power that sustains over time but it fails to appeal to the new generation in the workplace. This study proposes a revolutionary rewards practice rooted in intrinsic motivation that sustains a practical motivational power that is believed to produce a series of positive organizational and personal outcomes. We call it “advance rewards” or “upfront rewards” that a certain amount of desired rewards are awarded in advance before actual work is performed by the job holder. This practice has a strong motivational power by tackling two critical areas in work motivation; emotional and cognitive aspects. By instilling trust in employers, feelings of recognition and support, and providing a sense of ownership, this practice boosts a positive emotional state for the employee. On the cognitive side, it elevates the level of self-competence and self-determination and generates a strong responsibility to accomplish the task. Boosted emotional state and elevated cognitive strengths will combine to form a strong motivational power that will lead to positive outcomes for the organization and the employee.

AN EXPLORATORY INVESTIGATION OF THE EFFECTIVENESS OF DIGITAL MARKETING CHANNELS FOR UTILITARIAN VERSUS HEDONIC PRODUCTS

Oral Presentation

Dr. Richard Heiens [1]***, Dr. Ravi Narayanaswamy*** [2]

1. *University of South Carolina Beaufort,* ***2.*** *University of South Carolina Aiken*

In the current study, we examine the relative effectiveness of digital marketing practices between online marketers of utilitarian products versus hedonic products. These digital marketing practices include direct click-through links to the marketer's transactional website, as well as links connected through display ads, email marketing, organic search engine results, paid search engine results, referrals from other sites, and social media sites. Using secondary data that tracks web sales by retailer category, our findings indicate that all seven digital marketing channels are more effective for marketers of utilitarian products. One possible explanation is that while utilitarian products are more likely to be evaluated in a logical and rational manner utilizing objective product information, there is a greater need for personal interaction, inspection, and direct experience with hedonic products. Therefore, although marketers of hedonic products can generate sales through digital marketing channels, the return on investment is likely to be relatively greater for utilitarian products.

Key words: digital marketing, utilitarian products, hedonic products, web sales, ecommerce

Comparison of the latent Mean Differences of Attitudes toward Online Advertising and Intent to Purchase between College Students and General Public in China

Oral Presentation

Dr. Yuyun Zhong [1], ***Dr. Ping Wang*** [1]

1. *James Madison University*

The relationship of online advertising and the intent of purchasing behavior has drawn increasing attention due to the rapid acceptance of online shopping. Grounded on Ducoffe's theory about the attitudes toward internet advertising, this study uses the multiple groups of structural equation modeling to compare the latent mean differences of factors about the attitudes toward online advertising and the intent to purchase between college students and non-college students in China. These factors include users' beliefs of entertainment, informativeness, irritation, creditability/trustworthiness, attitudes toward online advertising, and intent of purchasing behavior. The study sheds light on the understanding of the value of advertising and the impact of online advertising towards intent of purchasing between college students and non-college students in China.

Determinants of Small Bank Failure Post-Financial Crisis

Oral Presentation

Dr. John Downs [1]

1. *Lander University*

This study identifies the determinants of small bank failure after the Financial Crisis using annual financial statement categories and bank compliance ratios in contrasting economic conditions. Bank failures are usually a gradual process because of the slow absorption of economic data into their balance sheets. However, the Financial Crisis was an economic shock that created drastic sustained changes to monetary policy, regulation, and compliance requirements. These changes were designed to monitor the fiscal health of the largest banks that had unintended consequences for small bank stability. The downward economic pressure created by these factors accelerated the increase in small bank failure as they struggled against competing with larger banks with strengthening comparative advantages. The findings of the study establish that failed small banks in the Post-Crisis period experienced higher mortgage default losses and lower bank profitability. The effect of increased compliance requirements during the period were explored and determined to not be a significant indicator of failed small banks.

Do Married Managers Produce More Corporate Innovation?

Oral Presentation

Dr. Joey Choi [1]

1. *Louisiana State University Shreveport*

We study how married managers value corporate innovation. Using the panel data of US publicly held firms from 1993 to 2007, we find that firms with married senior executives increase the levels of innovation, measured by the number of patents and citations. In addition, these firms tend to feature better employee relations. Results suggest married managers foster a positive work environment that is more conducive to innovation. Our findings extend the literature on CEO personal traits and corporate policies and outcomes.

Empirical Investigation of the Differences in Job Expectations between Brazil and the US

Oral Presentation

Dr. Cody Logan Chullen [1], ***Dr. Dennis Barber*** [1], ***Dr. Tope Adeyemi-Bello*** [1], ***Dr. Flavia Cavazotte*** [2]

1. *East Carolina University,* ***2.*** *Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio)*

The US and Brazil are the biggest economies in the Western Hemisphere. Both economies also have global significance in that they are in the Top 10 of the largest nominal Gross Domestic Product (GDP) in the world. Given their strategic significance, it is imperative that the labor forces in both nations excel. It is within the framework of national productivity that we explore the similarities and differences in job expectation within the two nations. Our results indicate that job security is far more important to US workers than their Brazilian counterparts. In addition, while a job that provides a sense of accomplishment is highly valued in both cultures, one with supervisory capacity is less so in both nations. The most significant difference between the two countries is consistent with Hofstede's individualism (US) and collectivism (Brazil) typology with Brazilians valuing work with congenial others more so than their counterparts in the US.

Employment and prescription drug utilization in the U.S.

Oral Presentation

Dr. Xiaohui You [1], ***Dr. Cyril Chang*** [2]

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This paper examines the interlocking relationships among gaining employment, individual health status, and changes in prescription drug utilization in the US. Two- and three-stage least squares models based on the Grossman framework was applied to the Medical Expenditure Panel Survey data for 2007-2016. Results confirmed that an individual's drug utilization was positively associated with gaining employment and the resulting improved health status, controlling for confounding factors such as age, wages, education, and uninsured status. Thus, results suggest both a policy-relevant role of gaining employment as a path to greater prescription drug access and utilization and, by implication, the benefit of insurance coverage expansion.

Essential Keywords: Age-Neutral Workplace

Oral Presentation

Dr. Inessa Korovyakovskaya [1]

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In the light of recent historic events, diversity and inclusion are the crux of organizational management in workplaces across the United States. With four to five generations currently actively participating in the labor force, one issue becomes more apparent: Subtle age discrimination. According to the U.S. Bureau of Labor Statistics, the labor force participation rate is expected to increase significantly for individuals ages 65 to 74 and the group of 75 and older through 2024. Other age groups in the labor force are not projected to noticeably change much during these years. In the Covid-19 pandemic reality, employers are focused on minimizing healthcare and life insurance costs, which suggests there may be a general bias against lower paid older workers and minorities due to a rapid rise in healthcare costs for these workforce groups. Employees with less education earn lower wages and may not afford to retire early at age 62 due to the inability to sustain their standards of living (Munnell, 2019).

This study is seeking to answer the following research questions: Does a subtle age discrimination or hiring bias toward Baby Boomers generation currently exist in organizations across the United States? How education level, gender, industry, and job type affect current workforce composition in the United States? How long these trends are projected to exist? When moderated by diversity management policies and practices, do organizations create age-neutral workplaces? We propose a new model that dissects above-mentioned variables to help managers at all leadership levels create an all-inclusive age-neutral organizational environment. An effective way to go forward.

EVALUATING THE OPERATING EFFICIENCY OF HEALTHCARE REAL ESTATE INVESTMENT TRUSTS

Oral Presentation

Dr. Rashmi Malhotra [1], ***Dr. Davinder Malhotra*** [2]

1. *Saint Joseph's University,* ***2.*** *Thomas Jefferson University*

Healthcare specialty real estate investment trusts (REITs) enable an investor to focus on high total return, income, and further diversity within a certain area. COVID-19 has several unique, and at times conflicting, consequences on the healthcare industry. Although significant research has been conducted on the success of REITs and other specialty mutual funds, less study has been conducted on the relative performance of healthcare REITs and how COVID 19 influenced their performance in contrast to past years. This research looks at the performance of healthcare REITs from 2015 through 2020. We also evaluate a REIT's performance to that of its peers as well as its own past performance. We found that the most efficient REITs have been LTC, UHT, and VTR, because they a performance index score of 0, which means they have consistently performed 100% efficient relative to their peers.

Examining the Effects of Alternative Income Measures on Housing Affordability in the Federal Reserve's Sixth District

Oral Presentation

Mr. Doug White [1]

1. *Louisiana State University Shreveport*

The Department of Housing and Urban Development's (HUD) methodology for evaluating housing affordability uses family income to calculate area median income (AMI). This AMI is used to determine rental housing affordability. This paper expands on research that looked at how changing this methodology affected the profile of housing affordability for the state of Louisiana by expanding the analysis to the entire Federal Reserve's Sixth District. By comparing HUD's methodology to three other methods of determining AMI, we determine the effect on rental housing affordability and rental housing availability for the six states found in the Federal Reserve's Sixth District. By using 2019 American Community Survey, we are able to generate the deficit or surplus in rental units that are both available and affordable to households at different income levels and measure the effect of using different methodologies to determine AMI. Included are figures for Alabama, Florida, Georgia, Louisiana, Mississippi, and Tennessee and the Metropolitan and Micropololitan statistical areas that compose each state.

Explaining Corporate Competitiveness via Cognitive Conflict and Environmental Munificence

Oral Presentation

Dr. O. Volkan Ozbek [1]

1. *Trinity University*

Corporate competitiveness refers to the firm's ability to create and sustain competitive advantage against its industry rivals. This construct basically shows whether a firm can efficiently utilize its resources and capabilities to compete other firms effectively. It is very critical for companies to possess competitive posture so that they can survive in the long run. In this paper, we argue that top management team cognitive conflict will positively affect firm's corporate competitiveness and this relationship is positively moderated by environmental munificence. Grounded on resource dependence and upper echelons theories, this study contributes to the literature by explaining how corporations can become more competitive in the industry.

Exploring Small Business Strategy: Does Supply Chain Orientation and Knowledge Sharing Improve Performance?

Oral Presentation

Dr. Mark Heileman [1], ***Dr. Kip Kiefer*** [2], ***Dr. Timothy Pett*** [1], ***Dr. Laurent Sie*** [3]

1. *Rollins College,* ***2.*** *Southern Wesleyan University,* ***3.*** *ESC-PAU*

Since the early 1990s, supply chain management has focused on just-in-time delivery and maximizing efficiency. For decades, nations, companies, managers, and consumers have all operated under the assumption that necessities like food, cleaning supplies, and medical devices will always be readily available to purchase when needed. However, the recent global pandemic has changed these misconceptions and now there are concerns that supply chains have become a source of vulnerability. Many industries have been shocked by COVID-19 conditions and supply chain resiliency has been significantly challenged. This study examines the relationship between supply chain orientation (SCO) and knowledge sharing (KS) on small business strategy and firm performance. It also explores potential differences that may exist internationally regarding the influence of supply chain and knowledge sharing activities for small firms. 392 surveys were administered to managing directors of small enterprises in the United States, France, and India and explored how managerial practices may impact firm's financial and non-financial performance outcomes. The SCO construct involves the attributes: reliability, responsiveness, agility, cost, and asset management efficiency. Included in the KS measure are items related to both operations management and customer relationship management and, therefore, addresses both upstream and downstream aspects of the firm in the supply chain. We employ regression analysis and mean difference comparisons to analyze the data. Findings indicate that, generally, positive and differential relationships exist between SCO, KS, their interaction, and firm performance, as realized by the profit, people and planet assessments of the triple bottom line. Interestingly, the findings also suggest that differences in managerial practices for business strategy exist across the three countries and these variances are associated with differentiated firm performance outcomes. Theoretically, we examine the influence of the recent COVID shock and how it created obstacles to supply chains such as access to materials, inadequate shipping capabilities, and labor shortages. These obstacles significantly disrupted supply chain coordination and operations and prior efficiency-based models. Practically, this study is important to management professionals because it highlights the positive relationship between a small firm's SCO and KS and the firm's triple bottom line. As such, a focus on SCO and KS is a prudent measure for small firm managers who want to get a leg up on their competition. Furthermore, this study indicates that country and cultural contexts matter such that managers should consider country and cultural aspects in determining the appropriate emphasis on SCO and KS.

Exploring the Factors of Satisfaction and Dissatisfaction with a Fitness Mobile Application

Oral Presentation

Mr. Inje Cho [1], ***Dr. Minseong Kim*** [2], ***Dr. Hyung-Min Kim*** [3]

1. *University of Florida,* ***2.*** *Louisiana State University Shreveport,* ***3.*** *Korea University*

This study classified attributes of fitness apps into satisfiers and dissatisfiers through a text-mining approach based on Herzberg's two-factor model. With Python, this study crawled 100,000 Fitbit app downloaders' English reviews from the Google Play Store, the Android operating system users' app store. By applying the content analysis technique, this study identified three satisfiers – self-regulation, self-monitoring and gratification – and three dissatisfiers – paid service attribute, compatibility attribute and functional attribute – consisting of 25 attributes of a wearable device app experience. The empirical findings provide information for health and fitness mobile app developers to maximize satisfaction and minimize dissatisfaction among users who regularly work out via a fitness app.

Exports Networks and Patterns of Economic Integration: New insight from China-Africa context

Oral Presentation

Mr. Dumor koffi [1]***, Dr. Komlan Gbongli*** [2]

1. *University of Electronic Science and Technology of China,* ***2.*** *Faculty of Economics, University of Miskolc, 3515 Miskolc-Egyetemvaros*

This paper contributes to the analysis of the effect of China's Belt and Road Initiative(BRI) on African countries by inspecting the impact of the economic integration on bilateral trade flows. The empirical analysis extensively uses network analytical methods to characterize SSA countries' trading as a component of the BRI trading network. The study uses IMF dataset from the period 2000–2018 to examine how the topology of the trading network has changed as a result of the initiative. Our results show that the degree of centrality, average node intensity, and density are slightly increasing, with China occupying the network's core position. Additionally, intra-regional trading in East Africa is more intensively integrated under the BRI. This indicates that the BRI members have witnessed an increase in intra-regional trade at a range of economic development levels. Therefore, Policy recommendations are provided in line with the implementation of BRI's important role in changing trade policies in an attempt to develop a sustainable and inclusive African economy.

Gender Diversity and Leadership Lessons From the Biblical Era

Poster

Dr. Hershey H. Friedman [1], ***Dr. Toby Birnbaum*** [1], ***Dr. Robert Fireworker*** [2]

1. *Brooklyn College, CUNY,* ***2.*** *St. John's University*

This paper examines the role of gender diversity in Biblical Leadership as experienced through Miriam, one of the great prophetesses and leaders in Biblical times. Miriam was a sister of Moses and of Aaron. Much has been written about her brothers and their Leadership roles.

However, little is known about the leadership role of Miriam. While some attribute this to a lesser degree of gender diversity in the Biblical era, the thrust of our research in this paper shows how influential she really was in the sojourn of the Israelites in the desert after the Israelites left Egypt.

We aim to study some of her leadership attributes and learn lessons in Leadership that resonate as forcefully today as they did in the Biblical era.

GENDER GAPS IN RANKS AND SALARY OF US SCIENCE FACULTY

Oral Presentation

Dr. Brigid Appiah Otoo [1], ***Dr. Kaye McKinzie*** [1], ***Dr. Samira Nichols*** [1]

1. *University of Central Arkansas*

Despite significant efforts by the US government to achieve gender equality, gender-based differences in worker compensation persist. Women tend to make less money than their male colleagues in most work places. This study explores the existence of rank and/or salary disparities by gender in public universities. We further investigate if these possible disparities are impacted by the affiliation (department) being predominantly male/female/neutral. We discuss the existing trends in depth and offer some thoughts on the prospects for the future. Findings from our study could inform decision making and have policy implications for public universities and individual states in the US.

The existing literature on gender pay gap in the USA fall under two themes. The first focuses on increasing the understanding of existing gender pay gaps while the second focuses on the impact of research methodological choices. We contribute to the first theme by studying the trends in faculty ranks and remuneration in the science fields of US universities. We base our empirical analysis on data gathered from the faculty of 4-year public universities in a South-Central state in the US. Controlling for faculty heterogeneity, we utilize hierarchical linear modelling (HLM) and multiple linear regression (MLR) methods for our analysis.

Government Stimulus and Mortgage Payments During COVID-19: Evidence from the US Census Household Pulse Survey

Oral Presentation

Dr. Florence Neymotin [1], ***Dr. Fred Forgey*** [1]

1. *Nova Southeastern University*

We investigated the impact of governmental stimulus payments and how they were employed by individuals—whether saved, spent, or used to pay down debt—on mortgage repayment. We determined that there was a positive effect for individuals who were eligible for the Economic Impact Payment (EIP) Stimulus and used it to increase their ability to make their next mortgage payment. However, this did not affect their overall likelihood of having paid off their mortgage. These findings held after various demographic controls were employed, as well as after controlling for alternative measures of spending meant to disentangle the EIP from other long-term patterns of saving and spending. Differences by Race and Socioeconomic status were also explored. Our results provide preliminary evidence that the EIP had a positive effect on mortgage payments during the COVID-19 pandemic, and show that a path may exist for crafting future government stimulus payments.

IDENTIFYING ORGANIZATIONAL BARRIERS RESULTING FROM ABRUPT CHANGES TO SPACE POLICY WITHIN THE UNITED STATES

Oral Presentation

Dr. Angela Cheatham [1]

1. *Embry-Riddle Aeronautical University*

In 2010, National Space Policy was updated to encourage private enterprise in space activities and laid the foundation for a fundamental shift in how space exploration would proceed in the United States. These changes to policy re-directed the space industry and encouraged the private sector to compete and collaborate. The purpose of this study was to identify perceived barriers resulting from the abrupt changes to U.S. National Space Policy that occurred for purposes of privatizing outer space activities. The qualitative study focused on the organizational perceptions of changes resulting from government and private company collaboration. Results indicated that changes to organizational policies necessitated cultural adjustments within the organizations; changes to policy also imposed barriers including the use of physical space, transparency among organizations, and cultural adjustments to processes.

Future research should focus on the conditions that led to policy change, the implementation of the changes, and the conditions that preceded the changes which have potential to facilitate organizational success.

IMO 2020: The assessment of investment decisions and financial risks

Oral Presentation

Dr. Mazen Brho [1], ***Dr. Divine Livingstone Caesar*** [2], ***Dr. Amer Jazairy*** [1], ***Prof. Joan Mileski*** [3]

1. *Texas A&M,* ***2.*** *Maritime Business Administration Dept., Texas A&M University at Galveston,* ***3.*** *Texas A&M University*

In 2016, the International Maritime Organization (IMO) limited the sulphur allowed in fuel used on board ships from 3.5% to 0.5% mass-by-mass, starting on January 1st, 2020. This regulation necessitates either a considerable capital investment (e.g., scrubber) or a substantial increase in operational cost in the maritime business. Most importantly, each strategy is associated with financial risk of future uncertainty. However, the financial implications of these two strategies, risk and its hedging tools have received limited attention in the extant literature. Thus, this research aims to (1) outline and investigate the financial strategies for these two IMO 2020 decisions; (2) identify the potential risk associate with each decision; and (3) propose financial hedging products to control the future uncertainty. This research utilizes General Equilibrium Theory to quantitatively demonstrate the management of these risks through financial hedging derivatives. This research contributes by filling a gap in the academic literature and industry practices. It can guide industry practitioners to precisely assess these financial strategies and realize its hedging tools. Academically, this paper initiates a much-needed step for scholars to introduce financial applications and tools to the domain of maritime business.

Incentive for Investment Hurting Growth? – An Analysis on Section 179 Expensing and The Impact on Job Growth from Related Capital Investment

Oral Presentation

Dr. Furkan Oztanriseven [1], ***Mr. Marcus Grabowski*** [2], ***Dr. Mitchell Franklin*** [1]

1. *Le Moyne College,* ***2.*** *EY*

This paper aims to examine the economic impacts resulting from the Section 179 Expensing of the Federal Tax Code. More specifically, it examines the impact of this incentive on automation and technological unemployment through System Dynamics Simulation on the Professional industry, Manufacturing industry, and the rest of the United States economy. It also provides an overview on current trends towards automation along with responsive tax policies to potentially combat the issues that will arise. Based on the model results and the current trends, both the Professional and Manufacturing industries are at risk of automation potential due to an increase of the Section 179 allowance, but the economy benefits as a whole.

Is Grounded Theory a Research Methodology or a Theory Per se? The Case of Project Management Research

Oral Presentation

Dr. Erastus Karanja [1]

1. *NCCU*

Project management, as an academic discipline continues to grow and is characterized by various paradigms and journal outlets. A review of project management research published in the leading journals (Project Management Journal, International Journal of Project Management, and International Journal of Managing Projects in Business) within the last 20 years reveals a heterogeneous mix of research topics, research methods, and theoretical orientations. The review also reveals that several theories are commonly used in PM research namely agency theory, contingency theory, stakeholder theory, and grounded theory. Although widely used in project management research, the nature and boundaries of grounded theory continues to elicit a lot of debate. The goal of this research is to review the manuscripts in the three aforementioned journals and evaluate how they follow(ed) the tenets of grounded theory namely theory development, constant comparison, iterative coding, theoretical sampling, linkage between data collection and analysis among others. This research is driven by the fact that research that is theory oriented is useful in advancing a body of knowledge, adding value to the discipline, and enhancing credibility to the discipline's body of works. As such, the appropriate use of theory or methodologies in a field is a sign of research rigor.

Keywords. Grounded theory, Project management, Content analysis

Is it costly to reduce pollution in response to non-prescriptive regulation? Evidence from China's CSR reporting mandate

Oral Presentation

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Conventional wisdom (the "Traditional View") argues that pollution reductions cannot be achieved without sacrifice of profit. The Porter Hypothesis counters that non-prescriptive regulations can incite innovation that improves process efficiency which simultaneously reduces pollution and benefits shareholders. We employ China's mandatory CSR reporting requirement as a natural experiment to consider these propositions since under the rule some, but not all, of China's public firms were required to issue CSR reports starting in 2008. Our difference-in-differences (DID) analyses apply to a balanced sample of firm-year observations of financial and Trucost pollution-emission data (i.e., all sample firms have complete data for three years before and three years after 2008). This firm-level evidence indicates that firms required to issue CSR reports decreased overall pollution levels after the mandate relative to unaffected control firms, consistent with prior research. Consistent with prior research, we find decreased profit margins among firms subject to the CSR reporting mandate. But, as predicted by the Porter Hypothesis, asset efficiency also improved, which prevents significant reductions in asset returns. Mediation analysis indicates that mandate-related pollution reductions occurred through efficiency improvements, in particular through more efficient use of long-term physical operating assets, which supports the Porter Hypothesis.

Is Materialism a Precursor to Compulsive Buying?

Oral Presentation

Dr. Aadel Darrat [1]

1. *Louisiana State University Shreveport*

This research sheds some light on the grave danger of the normalization of materialistic values in today's society. More specifically, the nature of the relationship between materialism and compulsive buying is examined via structural equation modeling. Results suggest that materialistic consumers are at high risk for developing depression. Interestingly enough, there is no evidence for a direct link between depressed consumers and compulsive buying, yet results indicate that this particular relationship is fully mediated by obsessive-compulsive behavior and low self-esteem. That is, the resulting depressive feelings of materialistic consumers leads to increased risks of exhibiting obsessive-compulsive behaviors and experiencing lower self-esteem, which, in turn, manifests into compulsive buying addiction. Managerial and societal implications are discussed.

Japanese SMEs: A systematic literature review

Oral Presentation

Dr. Said Elbanna [1], ***Ms. Fareed Begum*** [1]

1. *Qatar University*

Japanese management has always been unique and examining what is special about them will have immense implications for SMEs worldwide. Given this, this study aims to review the Japanese SMEs literature to identify research arenas that have been explored in the past and aids in classifying the factors that make Japanese SMEs unique and successful. Using a systematic review approach, 63 studies were identified and analyzed which helped to identify seven themes associated with Japanese SMEs. This review points out a few methodological shortcomings in the literature, identifies gaps and recommends several avenues for future research. It also highlights several implications for both practitioners and policy makers.

Justice and Loneliness in Remote Workplace

Oral Presentation

Dr. Baiyun Gong [1], ***Dr. Xiaochuan Song*** [1]

1. *Nova Southeastern University*

In response to the COVID-19 pandemic, organizations sent employees to work from home. The abrupt change may amplify some previously neglected issues. For example, workplace loneliness became salient to many young employees when they found no chance to interact with others in person. On the other hand, employee perception of organizational justice can also be challenged, due to the lack of social cues when evaluation decisions were delivered. This theoretical paper investigates the dynamics involving workplace loneliness and organizational justice, predicts the consequences of the interplay between the two factors, and discusses possible boundary conditions.

We propose that the feelings of loneliness and the perception of organizational injustice may feed each other and form a vicious cycle, which eventually leads to enhanced intention to quit, jeopardized satisfaction to remote work style, and a preference to work collocated. Specifically, when employees feel they are lonely in the workplace, their trust in the evaluation system can be attenuated, which leads to suspicion of injustice in performance evaluation, as well as decisions derived from it. Such perceived injustice, in turn, makes the employees feel that they are outcast and thus even more lonely at work. Overall, there is a mutual causality between workplace loneliness and injustice perceptions, and the lack of belongingness and perceived injustice may jointly affect the employee's satisfaction toward the remote work style, whereas the employee may prefer to change their work environment or want to quit the job. The sudden switch to the remote workplace may profoundly shake the status quo of perceived justice on all dimensions (i.e., distributive, procedural, interpersonal, and informational justice) of the construct and its relationship with workplace loneliness and intention to quit, job satisfaction to remote work style, and a preference to work collectedly.

Further, we propose that employees' knowledge of their hiring organization's job performance evaluation system can moderate the effect of workplace loneliness on organizational justice perceptions, such that employees who experience workplace loneliness are less likely to feel organizational injustice when their knowledge of the evaluation system is relatively higher, whereas employees who experience workplace loneliness are more likely to feel organizational injustice when their knowledge of the evaluation system is relatively lower. Thus, there is a potential that ample knowledge of the evaluation system helps weaken the vicious cycle of workplace loneliness and organization injustice.

Taken together, seeing through the lenses of organizational justice, we propose a novel mechanism that connects workplace loneliness and employees' responses in turnover, job satisfaction, and collocated work, in the remote work context, and emphasize the importance of employees' understanding of performance evaluation system.

Month of the Year Anomalies in US Equity Market Return

Oral Presentation

Prof. Fatollah Salimian [1], ***Dr. Herman Manakyan*** [1]

1. *Perdue School of Business, Salisbury University*

Numerous studies have been performed to investigate month of the year anomalies in the equity markets all around the world. Many of these studies have utilized arithmetic means to compute average daily returns. Additionally, they don't reflect the contemporary patterns that exist in modern equity markets structure. This study aims to portray differences in US equity market monthly returns during 2001-2020, based on both arithmetic and geometric means. The study further computes seasonal indexes for the twelve different months during the period of study. The results of this research mainly reveal that Septembers are least pleasing to the general equity investors, as the average monthly return on stocks as represented by S&P 500 was actually negative. Additionally, the standard deviation of daily returns was the highest in September. Aprils, on the other hands, were the most favorable month of the year on the grounds of the highest monthly return.

NEW PRODUCT DEVELOPMENT CREATIVITY, A DATA ENVELOPMENT ANALYSIS APPROACH

Oral Presentation

Dr. Felix Flores [1], ***Dr. Viktor Kiss*** [1], ***Dr. Abel Moreno*** [1]

1. *Metropolitan State University of Denver*

Innovation is critical for firm competitiveness and survival. A key part of innovation is team brainstorming and idea generation. Using a sample of one hundred and fifty new product development managers in the United States, we examine factors that support the highest levels of efficiency for generating novel, useful, and manufacturable ideas during the initiation stage of the new product development process. The efficiency of new product development managers in achieving desirable creativity levels when considering various factors is assessed with Data Envelopment Analysis. We provide practical recommendations to enhance team creative output.

Predicting Employee Risk of Attrition in the Tech Sector to Maximize Retention

Oral Presentation

Dr. Jim Mirabella [1], ***Mr. Ambrose Yufanyi Akiim*** [2], ***Mr. Michael Bowe*** [2]

1. *Jacksonville University,* ***2.*** *University of Fredericton*

According to recent research, the technology sector (software) is plagued with high rates of attrition; this has a heavy impact on the bottom line of many organizations, as it is disruptive, expensive, and detrimental to productivity to lose high-performing employees. Tech employees are increasingly seen as valuable assets by organizations, and so employers must begin to take corrective action to motivate and retain their talent amidst the fierce competition. Using a data analytics approach to predicting employee attrition can help to determine which employees are at risk so corporations can make informed and targeted decisions. We analyzed a data set of 8000 observations with 40 variables (features) relating to an employee's personal and demographic information, his / her experiences & performance, as well as information about the risk and impact of loss. A few exploratory and confirmatory statistical analyses were applied to the data, along with the gradient boosting machine learning algorithm; this algorithm trains and validates a predictive classification model to predict an employee's probability of attrition. The resulting classification model portrayed a prediction accuracy and robustness of 62.59% and 80.22%, respectively. Its ability to accurately distinguish between the classes of employees at risk of attrition vs. those not at risk were confirmed by a high AUC (Area under ROC Curve) value of 0.813. These results validate the predictive model, which we could then apply to new employee data. Based on this output and the insights delivered from the model, an organization can leverage the probability of an employee leaving to tailor their retention efforts. The implications of this model are tremendous.

Race and Income Inequality: A Case for the U.S.A

Oral Presentation

Dr. Fadi Fawaz [1]

1. *LSUS*

This paper examines income distribution among races in the United States. Using income data from the U. S. census statistics for Caucasian, Black, Asian-Pacific Islander, and Hispanic families for the years 1947-2018, the paper first determines whether the income diversity among race groups is statistically significant. Finally, some conclusions are drawn based on the empirical results of the study.

Regime-Switching Tempered Stable Structural Model

Oral Presentation

Dr. Sung Kim [1]

1. *Louisiana State University Shreveport*

This study proposes a regime-switching normal tempered stable (NTS) structural model for the pricing of default risk, the model that is based on structural model considering an N-state continuous Markov chain where the underlying firm value process is NTS process. I first derive the characteristic function of a Markov chain modulated NTS process and then use it for closed-form expressions to calculate the corporate bond credit spreads. The novelty of this model is that those closed-form expressions can be obtained by replacing the characteristic function on NTS structural model to the one I derive. I assume that the use of regime-switching NTS process on structural model makes it possible to capture the impact of hidden factors on the pricing of default risk. With the calibration for the term structures of US corporate industrial credit spread, I find that regime-switching NTS structural model provides better fit for all credit ratings than NTS as well as Merton structural model.

Specifics of socio-economic development in Scandinavian countries

Oral Presentation

Dr. Alexander Mechitov [1], ***Dr. Helen Moshkovich*** [1]

1. *University of Montevallo*

The presentation discusses the peculiarities of the socio-economic development in Scandinavian countries, including egalitarian educational system, hi-tech economy, effective healthcare, high level of social protection, and stable political systems. The authors pay special attention to cultural differences, including gender policy and attitude to nature. They also discuss the way Nordic countries combine elements of free market economy with high level of social protection.

Strategies for Filling the Workforce Void

Oral Presentation

Dr. Shirl Donaldson [1], ***Dr. Edie Schmidt*** [2], ***Dr. Regena Scott*** [3]

1. *University of Michigan Flint,* ***2.*** *Nova Southeastern University,* ***3.*** *Purdue University*

An exploratory study investigates strategies to fill the voids created by supply professionals leaving industrial and corporate positions during the great resignation in the post pandemic era. Over 3 million people permanently left US labor force during the COVID 19 pandemic, April 2020 – April 2021) with no plans to return. During this same period over a half million people perished, leaving jobs unfilled. Almost one million individuals opted for early retirement. Self-employment (gig economy) or other creative ways to avoid the traditional work world has attracted the next largest groups of skilled workers. A critical examination of current processes, procedures, and the supplementation of technology to bridge the talent gap until future workers can be trained will be conducted. The US Department of Labor is touting apprenticeships as a means to develop capacity. Concurrently, an evaluation of matching supply to demand in critical sectors by enhancing manufacturing will also be facilitated. The “make or buy” decision is entering into a new realm and the requirements are changing.

Sustainability reporting standards, standardization and standard ideologies in multinational contexts

Oral Presentation

Dr. Kameleddine Benameur [1], ***Mrs. Soukaina Mzoughi*** [2]

1. *Gulf University for Science and Technology,* ***2.*** *GUST*

This essay examines the development of the field of sustainability reporting standardization in recent decades. First, it notes the change in focus occasioned by drawing on the notion of accounting theories, especially those resting on the IFRS and FASB and the emergence of ISSB. That theory reveals the eagerness of financial markets for a common language, a mono-language, similar to the observed dominance of the English language in the business world. I argue that we must consider other standards, being multilingual, when we seek sustainability reporting standardization: 1. Understand the nature of polycentric standards; 2. Appreciate the key role of other standards; 3. And trace the transmission of standards across borders. The paper gives examples of the ways in which our research can be unwittingly mono-standardish in its concepts and methods, and examines the role of the concepts of heterogeneity of standards in challenging the homogenization of the standards. It concludes by setting the agenda for sustainability reporting standardization studies, with a call for standardization studies that are enriched by both the consolidation of existing standards and leaving room for the expression of multi-standards.

Symposium: THE FORMATION AND CONSEQUENCES OF FIRM AND BRAND IDENTITIES: NOVEL RESEARCH PERSPECTIVES FROM MULTIPLE BUSINESS DISCIPLINES

Oral Presentation

Prof. Marko Grunhagen [1], ***Prof. Nan (Tina) Wang*** [1], ***Prof. Trang Doan*** [1]

1. *Eastern Illinois University*

The goal of this Symposium is to offer novel perspectives on the broad theme of 'formation and consequences of firm and brand identities' through three different, yet related lenses across business disciplines. The Symposium aims to facilitate a broad cross-disciplinary discussion of the formation and consequences of firm and brand identities as key research constructs among various business fields. The three presenters hail from the disciplines of marketing, finance, and management information systems and bring their respective unique expertise to bear as they triangulate the theme of the session.

The Application of the Kelly Criterion to Personal Financial Statements and Investments

Oral Presentation

Mr. Ashwin Mahadevan [1], ***Dr. Joshua Brooks*** [2]

1. *Georgia Tech,* ***2.*** *Columbus State University*

A number of studies and popular attention have been devoted to the idea of the "disappearing" middle class. In this study, we use a Kelly Criterion to examine how the allocation of investible funds between the stock market and "riskless" investments explains some of these effects. Kelly Criteria are a class of mathematical models in continuous time and continuous state-space that identify the maximum level of risk one can take in order to have a long-term, zero probability of ruin or bankruptcy. In our application of this model, we use data published by the Federal Reserve and US Census Bureau to create four different representative personal financial statements. These groups are based on household income reflecting the national average, bottom 20%, middle 60%, and top 10% of American households. We find that based on the median financial statements for these groups, the recommended allocation to risky assets for groups other than the top 10% of households is minimal.

The Entrepreneurship-Law Project

Oral Presentation

Dr. Valentina Iscaro [1], ***Prof. DeShannon McDonald*** [2]

1. *Alabama A&M University,* ***2.*** *Alabama A and M University*

Studies have demonstrated that to sustain the acquisition of entrepreneurial competencies, Entrepreneurship Education (EE) needs to adopt approaches that are different from traditional teaching. There is a need for more interactive, learning by doing approaches, whereby teachers should act as mentors in a cooperative and interdisciplinary learning process characterized by creativity, meaning making and interactivity (Lackéus, 2015), and where specific business skills and knowledge of how to start a company and run it are successfully transmitted (Wahid et al., 2017). To provide such an innovative learning experience, we propose *The Entrepreneurship-Law Project* based on the literature about practice-oriented EE and competency-based learning CBL. The project has been designed to offer an interdisciplinary, experiential learning process that incentivize students' acquisition of entrepreneurial competencies by identifying a business idea, assessing its feasibly and developing a new venture action plan to launch it in the American city and state of their choice.

The project is built on a Stage-Gate® model revised and adapted to the defined educational purpose and includes six stages and related gates to validate the process output: 1) Business Idea Proposal; 2) Industry and Market analysis; 3) Business Form/Liability Assessment; 4) Intellectual Property Protection; 5) Start-up capital requirement and 6) Final Presentation.

The educational effectiveness of the project is measured via pre-post test administered to students to self-assess the acquisition of entrepreneurial competencies as defined in the EE literature and including among others locus of control, tolerance to ambiguity, tolerance to risk, creativity, ambitiousness.

THE IDEA MARKET AND THE FEAR OF IDEA THEFT

Oral Presentation

Dr. Justin R. Hall [1]***, Dr. Selen Savas-Hall*** [1]***, Dr. Irina Toteva*** [2]

1. *Jacksonville University,* ***2.*** *Georgia Southwestern State University*

This research examines potential antecedents that lead to a nascent entrepreneur's apprehension to disclose new venture ideas. This research argues that an "Idea Market" exists within the entrepreneurial environment; and within this market, there are entrepreneurs (sellers) with ideas and investors (buyers) with resources. Both the entrepreneurs and investors participate in this market to satisfy a need. Entrepreneurs need resources to exploit their ideas, and investors need ideas to invest resources. An exchange of ideas for resources is often needed for the new venture creation process to take place (Douglas and Shepherd, 2002; Maxwell and Lévesque, 2014). However, this exchange (ideas for resources) has a peculiar characteristic. Ideas are information and information is generally considered a public or free good. Hence, to better understand the antecedents of the fear of idea theft, this research examines two antecedents to information exchange in this entrepreneurial context: (1) the characteristics of the exchange and (2) the quality characteristics of the information being exchanged (Moberg et al., 2002). As it relates to these antecedents, this research investigates the impact of transactions costs, power-dependency, and relationship quality as well as the entrepreneur's perception about the quality of their idea on the entrepreneur's apprehension to disclose their idea. We will collect our data through surveys distributed to nascent entrepreneurs with ideas that are currently searching for potential investors of those ideas and test our hypotheses by conducting analysis using structural equation modeling. Although it is beneficial to thoroughly understand when, how and to what extent entrepreneurs protect their ideas (e.g. Ragatz, Handfield, and Thomas, 1997; Cable and Shane, 1997; Fanimokun, Castrogiovanni, and Peterson, 2012), it may also be beneficial to understand why the fear of idea theft exists. With this understanding, researchers could begin to examine potential mechanisms that could help control or mitigate this fear, allowing for more idea exchanges to occur.

The Impact of Covid-19 and Other Factors on Riverboat Gaming in Louisiana: A Preliminary Analysis

Oral Presentation

Dr. Mary Lois White [1], ***Mr. Doug White*** [1], ***Dr. Tim Vines*** [1]

1. *Louisiana State University Shreveport*

One industry directly affected by the Covid-19 pandemic is legal gaming. In addition to the reluctance of patrons to return to public spaces for such non-essential activities, gaming has been prominently included in local government's public health measures. Louisiana has a long tradition of legalized gambling, primarily on river boats, with important economic impacts in the state, including direct government revenue. In 2019, Louisiana collected as much as 8% of total state revenue from gaming and amusements.

All casinos in Louisiana were temporarily closed by order of the Governor in March 2020 but were gradually allowed to reopen over time. Using monthly data from the Louisiana Gaming Control Board we compare revenues and admissions in each market for full gaming casinos, excluding video poker or slots only properties. The paired t-tests covered the months preceding the pandemic shut down (May 2019-February 2020), and the corresponding months after reopening (May 2020-Feburary 2021). In every market, mean monthly revenue is lower post-reopening than pre-shutdown. Three of the four markets show statistically significant differences at the 0.01 level of significance. In all four markets, mean admissions are lower post-reopening, with statistically significant differences at the 0.01 level.

The Influence of CEO Origin on the Market Valuation of Spun-off Subsidiaries: The Moderating Effect of Firm Capital Intensity

Oral Presentation

Dr. O. Volkan Ozbek [1]

1. *Trinity University*

Corporate spin-offs aim to maximize the shareholder value of both the divesting firm (parent firm) and its spun-off subsidiary (child firm). We argue that appointing a CEO who has previously worked in the parent firm ("insider") will negatively influence the market valuation of spun-off subsidiary. After looking at the first two-year market valuation of 128 completed U.S. spin-offs for a 14-year time span, we found that having an "insider" CEO in the child firm is negatively and significantly related to the firm's market valuation. In addition, we have examined the contingency effect of firm capital intensity on this relationship and found a significant positive effect. Thus, our findings reveal that both CEO origin and capital intensity significantly influence spun-off subsidiaries' market value after becoming independent entities.

The Legitimization of Corporate Entrepreneurship

Oral Presentation

Dr. Latoya Newell Burke [1], ***Dr. Yvette Holmes*** [1]

1. *Bethune-Cookman University*

This paper explores and analyzes the legitimacy of corporate entrepreneurship as a form of entrepreneurship. The study begins with defining entrepreneurship and identifying the commonalities among the definitions of entrepreneurship. By using these commonalities, a synthesized definition of entrepreneurship is presented. The developed definition then creates a checklist for the requirements of entrepreneurship. The paper then defines corporate entrepreneurship by starting with the origin of this term. An analysis of the aspects of the various definitions of corporate entrepreneurship will lead to a developed definition of corporate entrepreneurship. The practice, forms, and models of corporate entrepreneurship are analyzed by applying the definition and tenets of entrepreneurship. This meta-analysis suggests that corporate entrepreneurship meets the requirements of entrepreneurship to legitimize its place as true entrepreneurship.

Who's Auditing the Auditors? Prevention Based on Theories of Fraud and Crime

Oral Presentation

Dr. Leisa Marshall [1], ***Ms. Kayla Byrd*** [1]

1. *Southeast Missouri State University*

The purpose of this study is to evaluate various theories of crime as related to auditors with a focus on fraud prevention. The fraud triangle suggests auditors might commit fraud if the auditor has a perceived pressure, perceived opportunity, and the ability to rationalize the offense. While the fraud triangle describes the motivation, it does not explain the decision to commit the crime. Deterrence theory suggests auditors will not commit fraud because of the fear of punishment. The Sarbanes-Oxley Act of 2002 adds elements of punishment as a deterrent to committing fraud. Rational choice theory (RCT) suggests auditors weigh the costs and benefits of committing fraud and will commit the crime if the benefit outweighs the cost. If the penalty is not high enough, auditors might commit the crime. Missing in the theories is the cost and benefit analysis of not committing the offense. This side of the RCT coin suggests auditors will commit the offense when the costs of not going along with management outweigh the benefits; that is, the cost of losing the client might induce one to commit the fraud. Licensed certified public accountants (CPA) are bound by the AICPAs Code of Professional Conduct (Code). The Code requires a set of behaviors that do not comport with committing fraud. However, CPAs are cited by the Securities and Exchange Commission (SEC) for fraud. A review of the SEC's Accounting and Auditing Enforcement Releases (AAER) between the second quarter of 2018 and 2020 resulted in 100 (of 271) AAERs that cited CPAs. Approximately 40 percent of these CPAs worked as auditors and were cited for audit work deficiencies, failing to meet PCAOB and AICPA auditing standards, ignoring red flags of fraud, and/or other related charges. Each theory is evaluated from the perspective of auditors cited in AAERs to derive prevention controls.

WHY DO YOU WORKOUT? AN EXPLORATION OF FACTORS THAT IMPACT PEOPLE'S REASONS FOR EXERCISE

Oral Presentation

Ms. salma kennouda [1], ***Dr. Sameh Shamroukh*** [1]

1. *Harrisburg University*

People exercise for either health or appearance reasons, we believe that exercise environment could influence reasons for exercise. Understanding the relationship between these two variables is crucial in informing the direction to be taken by the fitness industry to nudge the public towards adopting exercise for long-term health reasons instead of short-term appearance goals.

We hypothesize that there are aspects in the delivery of physical exercise that can impact reasons for exercise, thus harming the individual's self-perception and overall quality of life. This survey was distributed online through LinkedIn, Facebook, and Instagram, anonymity was highlighted. This analysis has an exploratory nature with survey items ordered as follows: Exercise behavior, Reasons for exercise, Exercise environment, Self-objectification, Drive for Thinness then demographics. Final data (n=181) included respondents from three main countries (USA, France, and Morocco) and revealed, through an Exploratory Factor Analysis (EFA), 7 relationships to exercise: "The weight Focused", "The social athlete", "Self-Worth Exerciser", The "Fit-spired", "Clarity Seeker", "The "Bro"", and "Body Ideal Internalizer" that support the importance of viewing exercise as an integral part of a healthy lifestyle instead of a mean to reach peer appreciation or a certain body type.

Keywords: body image, eating disorder, reasons for exercise, self-objectification, body ideal internalization.

Management, Marketing, Accounting, Economics and Finance, Strategy, Organizational Behavior Organizational Theory, Human Resource Management, Consumer Behavior, International Business - Papers

AN EXPLORATORY INVESTIGATION OF THE EFFECTIVENESS OF DIGITAL MARKETING CHANNELS FOR UTILITARIAN VERSUS HEDONIC PRODUCTS

Dr. Richard Heiens, University of South Carolina Beaufort

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AN EXPLORATORY INVESTIGATION OF THE EFFECTIVENESS OF DIGITAL MARKETING CHANNELS FOR UTILITARIAN VERSUS HEDONIC PRODUCTS

ABSTRACT

In the current study, we examine the relative effectiveness of digital marketing practices between online marketers of utilitarian products versus hedonic products. These digital marketing practices include direct click-through links to the marketer's transactional website, as well as links connected through display ads, email marketing, organic search engine results, paid search engine results, referrals from other sites, and social media sites. Using secondary data that tracks web sales by retailer category, our findings indicate that all seven digital marketing channels are more effective for marketers of utilitarian products. One possible explanation is that while utilitarian products are more likely to be evaluated in a logical and rational manner utilizing objective product information, there is a greater need for personal interaction, inspection, and direct experience with hedonic products. Therefore, although marketers of hedonic products can generate sales through digital marketing channels, the return on investment is likely to be relatively greater for utilitarian products.

Key words: digital marketing, utilitarian products, hedonic products, web sales, e-commerce

INTRODUCTION

In recent years, traditional physical retailers have faced dramatic challenges as the industry has undergone rapid and unprecedented transformations. Sometimes referred to as the "retail apocalypse", traditional brick-and-mortar retailing has seen large-scale store closures. At the same time, online shopping has grown exponentially. For example, in 2020 alone, more than 8,300 brick-and-mortar retail stores closed in the U.S., following the closure of 9,300 stores in 2019 [21]. Meanwhile, spurred on by the COVID-19 pandemic, U.S. online retail sales increased by 21.9 percent in 2020, with an additional projected increase of 18 to 23 percent for 2021 [22]. As a reflection of what may be an enduring modification in buyer behavior, these changes probably represent a "tipping point" towards a permanent restructuring of the retail landscape from which many traditional physical retailers are unlikely to recover [7].

Findings from studies on social psychology, including the well-documented Elaboration Likelihood Model, suggest that consumer information processing is likely to vary by product type [26]. One popular approach that recognizes the essential differences between product types is to classify products into utilitarian and hedonic categories. Primarily utilitarian products offer straightforward functional or utilitarian benefits. On the other hand, hedonic products are primarily fun, exciting, and enjoyable, and their appeal is often

enhanced through direct contact and personal examination; the elements that best characterize the traditional physical retail store environment. Unfortunately, e-commerce retailers may have difficulty translating the in-store experience to the online environment [4]. This problem may be particularly acute for hedonic-type products that may require more personal inspection and direct interaction [35].

Nevertheless, as the retail marketplace has inexorably gravitated into the digital arena, retailers have necessarily begun to develop and emphasize new strategies. For example, many online retailers spend a considerable amount of time and money on digital marketing practices designed to lure customers to their retail websites [31]. Prominent examples of the strategies used to establish click-through links to the marketer's transactional website include display ads, email marketing, using search engine optimization tools to enhance organic search engine results, paid search engine results, referrals from other sites, and social media links [24]. Considering the fundamental differences between utilitarian and hedonic products, the purpose of the current study is to examine the relative effectiveness of the various sources of online traffic by product type. In other words, are the new digital marketing channels more effective for utilitarian or hedonic products? Can both categories of products equally benefit from the increased efficiencies associated with digital marketing or is there still a role for traditional brick-and-mortar retailing for hedonic-type products? We begin by reviewing the literature on utilitarian and hedonic products. We then go on to present a series of hypotheses on the relative effectiveness of digital marketing channels for utilitarian versus hedonic type products. We analyze those hypotheses through the use of secondary data on U.S. e-commerce sales, and we conclude by considering the implications of our results.

LITERATURE REVIEW AND HYPOTHESES

One increasingly popular approach used to classify product categories is on what might be considered the emotional spectrum. Using this approach, products on the extreme ends of this spectrum can be classified as either utilitarian or hedonic [16]. On the "thinking" or "cognitive" end of this spectrum are the utilitarian products. Rather than being desired for their emotional, sensory, or psychologically arousing characteristics, utilitarian products simply allow the customer to fulfil a basic need [29]. A product may be classified as utilitarian if its main purpose is to be functional and practical [33]. Hirschman and Holbrook [14] were among the first to make the distinction between utilitarian products and hedonic products, and subsequent studies soon identified the cognitively based utilitarian product categories to include items such as automotive parts and accessories, electronics, hardware, home improvement products, and frequently purchased convenience products [28].

Because selecting the appropriate course of action for utilitarian products is related to actual need and function, consumers are likely to screen, inspect, and logically process all available information prior to purchase [20]. For these shoppers, purchasing is a problem-solving activity rather than a deeply satisfying experience. As such, decisions regarding utilitarian products tend to be cognitively based [30]. In contrast, hedonic products include those which address the multisensory, fantasy, and emotional aspects of product use [14].

Unlike the purchase of functional necessities, many discretionary purchases fall under the category of hedonic consumption. These include the consumption of luxuries, non-necessities, or even frivolous purchases which can be described as exciting, delightful, thrilling, and enjoyable [15]. For example, products with primarily hedonic benefits include apparel [17], books, music, and movies [6], flowers [13] and jewelry [19].

Unfortunately, these hedonic-type some product categories may have difficulty adjusting to the digital realm. For example, as an indulgence rather than a necessity, it is often more difficult for consumers to rationalize and justify hedonic purchases, making persuasion at the point-of-sale of paramount importance [11]. This means that hedonic products may particularly benefit from personal interactions with salespeople. In addition, because hedonic shopping is driven by our desire for fun, entertainment, and emotional arousal, hedonic products are not subject to extensive information processing [16]. Instead, consumers tend to evaluate them more holistically based on the psychological sense of relief or fulfilment that they evoke, which may be easier to communicate via direct interaction [32].

Unlike hedonic products, "spending money on utilitarian products and services has a natural justification: one simply cannot do without such items" [15, p. 60). Consequently, utilitarian shopping can be characterized as efficient and rational, with a focus on rational decision-making and task completion [32]. Therefore, with logical and information processing guiding the decision, consumers of utilitarian products are better able to make a purchase decision without the need for multisensory stimulation, making the online environment perfectly suitable for the sale of the more rational utilitarian products. Thus, although many hedonic products are successfully sold on e-commerce sites, we are likely to see a marked advantage in the effectiveness of the various digital marketing channels for utilitarian products. This is expressed in our hypotheses below:

H1: Digital marketing channels are more effective for utilitarian products than for hedonic products

- H1a: Direct traffic will be more effective for utilitarian products than for hedonic products
- H1b: Display ads will be more effective for utilitarian products than for hedonic products
- H1c: Email marketing will be more effective for utilitarian products than for hedonic products
- H1d: Organic search marketing will be more effective for utilitarian products than for hedonic products
- H1e: Paid search marketing will be more effective for utilitarian products than for hedonic products
- H1f: Referrals will be more effective for utilitarian products than for hedonic products
- H1g: Social media marketing will be more effective for utilitarian products than for hedonic products

DATA AND ANALYSIS

The data for our study were obtained from an e-commerce database provided by Vertical Web Media. This syndicated research firm collects information from global e-commerce retailers on an annual basis. For the current study, we used their "2020 Top 500 E-commerce Retailers in the U.S." database. The database provides a total of 251 metrics for each e-commerce firm, including financial, operational, customer service, and marketing information. The e-commerce retailers are ranked based on their annual web sales and are organized using product categories and business models. Several previous academic research studies have relied on similar data sets, with excellent results [1] [12].

We further broke the database into two categories based on the utilitarian versus hedonic dichotomy. Because general merchandise retailers sell products across multiple product categories, we restricted our analysis to online retailers with a dedicated focus on either utilitarian or hedonic products. As previously described, utilitarian products offer functional value while hedonic products provide primarily pleasure and recreational benefits [32]. Consistent with these definitions and with the approach taken in a previous study [23], consumer electronics, hardware/home improvement, food/beverage, automotive parts/accessories, and office supplies were included in the utilitarian product category. On the other hand, flowers/gifts, jewelry, sporting goods, toys/hobbies, and home furnishings were identified as representative of the hedonic product category.

For the digital marketing channels, the database provides information on the percent of a retailer's traffic from seven different sources: direct traffic, display ads, email, organic search, paid search, referrals, and social media. As previously mentioned, the main objective of this study is to compare the efficacy of the seven sales channels for generating web sales for utilitarian versus hedonic products. Accordingly, web sales serves as the performance measure while average ticket value is used as the control variable. Controlling for average ticket value is necessary to negate any possible external influences imposed by the product's cost. Table 1 provides descriptions of all the research variables.

Table 1: Description of Research Variables

Variable	**Description**
Direct	The percentage of traffic from direct channel
Display Ads	The percentage of traffic from display ads channel
Email	The percentage of traffic from email channel.
Organic Search	The percentage of traffic from internet search engines.
Paid Search	The percentage of traffic from paid links on search engines.
Referrals	The percentage of traffic from other sites.
Social Media	The percentage of traffic from social media.
Web Sales	The net revenue transacted annually by the retailer on the internet.
Average Ticket	The average dollar amount of an order placed on the web.

The identified sample was scanned for missing values. A listwise deletion was used to omit the data points. Specifically, to be considered for analysis, the values for each of the seven channels must be reported. The final sample size for each channel is shown in Table 2 along with the age and gender characteristics of consumers in each category.

Table 2. Sample Characteristics

	Utilitarian	**Hedonic**
	N_U	N_H
Direct	139	134
Display Ads	123	118
Email	137	133
Organic Search	139	134
Paid Search	136	123
Referrals	139	134
Social Media	138	134
Gender	**Percent**	**Percent**
Male	63	51
Female	37	49
Age (years)		
18 - 24	15	16
25 – 34	23	27
35 – 44	22	20
45 – 54	17	16
55 – 64	14	12
65 +	9	9

As shown in Table 2, the gender representation among the e-commerce retailers shows that for the digital marketing channels examined, male shoppers outnumber female shoppers in both categories of products. However, as one might expect from observation and anecdotal evidence alone, the difference is more prominent for utilitarian products in comparison to hedonic products, with males favoring utilitarian products and females favoring hedonic products. With regard to age distribution, the most dominant group of digital marketing channel shoppers were adults in the 25-44 age ranges.

Table 3. Descriptive Statistics of Research Variables

	Minimum		**Maximum**		**Average**		**Standard Deviation**	
	U	**H**	**U**	**H**	**U**	**H**	**U**	**H**
Web Sales ($)	6933215	6937247	3414280683	757356166	96020473	31980330	344931732	73319071
Direct	1289	10852	374397839	51705929	7710010	1712870	37819367	4878404

Display Ads	99.68	186	67792201	8528813	847876	237307	6154120	839975
Email	71	591	18597492	2798516	333879	101232	1715823	294986
Organic Search	1805	26	483789800	36780506	9129986	1827646	47910711	4074424
Paid Search	29	203	137125134	20122668	1854517	701194	11945730	2162030
Referrals	165	235	426782721	3065042	3684598	99113	36323163	307558
Social Media	365	26	49303419	10527753	673008	188715	4441046	918377
Average Ticket Value ($)	25	35	1667	12000	278	675	248	1449

Descriptive statistics for the data set are summarized in Table 3. The descriptive values indicate that each channel has considerable representation. The size of the average purchase (Average Ticket) varies across online retailers depending on the product/service being sold. Also, consistent with the idea that hedonic purchases often involve discretionary luxury-type goods while utilitarian products are generally more practical and functional, the mean of Average Ticket value is significantly higher for hedonic products ($675) as compared to utilitarian products ($278). This disparity also justifies controlling for Average Ticket value, as it enables us to explain the effect of the independent variables on the dependent variable without any possible external influences imposed by a product's cost.

Another key point to note is that the range of values and standard deviations shown in Table 3 imply possible skewness in the data. Previous studies recommend using standardization and logarithmic transformation to normalize skewness [2] [12]. Logarithmic transformation can help convert a highly skewed variable into one that is more approximately normal [3] [5]. More specifically, a common approach proposed in the fields of business and econometrics is to use a natural logarithm with a base *e* (value approximately equal to 2.71828) [34]. Consistent with this approach, all the values were logarithmically transformed, which resulted in a normal distribution for all variables. Thus, the analysis was conducted using logistic regression, with the log-log regression model equation as follows:

$$\text{Log}_e(Y_i) = \alpha + \beta \, \text{Log}_e(X_i) + \epsilon_i$$

where,
Y_i represents the i^{th} predicted variable
X_i represents the i^{th} predictor variable
ϵ_i represents the residual error for the i^{th} variable.

The interpretation of the regression model is given as the expected percentage change in Y when X increases by some percentage. The relationship between X and Y and the coefficient

of Log_e (X) is considered to be elastic [3]. Thus, the effect of any changes in X on the Y variable can be described as follows.

- Multiplying X by e (2.178) will multiply the expected value of Y by $e^{\widehat{\beta}}$
- The proportional change in Y associated with a p percent increase in X is given by $e^{a\widehat{\beta}}$

  where, $a = log([100 + p]/100)$

RESULTS

The correlation scores for all of the variables are provided in Tables 4 and 5. All the predictors show strong association with the dependent variable, Web Sales, indicating significant influence.

Table 4. Correlations Among Utilitarian Research Variables

	Web Sales	Direct	Display Ads	Email	Organic Search	Paid Search	Referrals
Direct	.646**	1					
Display Ads	.657**	.867**	1				
Email	.583**	.955**	.849**	1			
Organic Search	.589**	.939**	.821**	.875**	1		
Paid Search	.575**	.836**	.846**	.812**	.825**	1	
Referrals	.649**	.917**	.855**	.874**	.892**	.791**	1
Social Media	.590**	.924**	.814**	.887**	.870**	.758**	.878**

**Correlation is significant at the 0.01 level (2-tailed)

Table 5. Correlations Among Hedonic Research Variables

	Web Sales	Direct	Display Ads	Email	Organic Search	Paid Search	Referrals
Direct	.588**	1					
Display Ads	.554**	.763**	1				
Email	.542**	.938**	.766**	1			
Organic Search	.503**	.870**	.714**	.823**	1		
Paid Search	.514**	.771**	.842**	.789**	.762**	1	
Referrals	.606**	.813**	.794**	.799**	.809**	.695**	1
Social Media	.496**	.819**	.764**	.797**	.838**	.681**	.765**

**Correlation is significant at the 0.01 level (2-tailed)

For every digital marketing channel, the correlations with Web Sales are higher for utilitarian products than they are for hedonic products. In other words, all seven digital marketing channels are more closely associated with sales for utilitarian products than

they are for hedonic products. While correlation helps provide some preliminary evidence, validating a causal relationship requires more complex analysis [10] [25]. Therefore, the next step was to conduct regression analysis to more conclusively determine the relationship between each digital marketing channel and web sales [9]. The regression procedure was implemented using SPSS v 26. With seven independent variables for each product category, a total of fourteen individual bi-variate regression analyses were conducted. The results are summarized in Tables 6 and 7.

Table 6. Simple Bi-Variate Regression Results for Utilitarian Products

Predictor	R^2	N	B	P-value	e^{β}
Direct	47.00%	138	.700	.000	2.013
Display Ads	44.10%	122	.661	.000	1.937
Email	39.20%	136	.583	.000	1.791
Organic Search	37.30%	138	.614	.000	1.847
Paid Search	35.10%	135	.600	.000	1.822
Referrals	44.60%	138	.670	.000	1.954
Social Media	38.80%	137	.633	.000	1.883

Table 7. Simple Bi-Variate Regression Results for Hedonic Products

Predictor	R^2	N	B	P-value	e^{β}
Direct	39.20%	133	0.588	.000	1.800
Display Ads	30.80%	117	0.562	.000	1.754
Email	32.30%	132	0.629	.000	1.875
Organic Search	26.50%	133	0.549	.000	1.732
Paid Search	26.70%	122	0.532	.000	1.702
Referrals	37.00%	133	0.620	.000	1.859
Social Media	25.00%	133	0.519	.000	1.680

The results of the regression analyses show that each digital marketing channel is significantly related to the dependent variable, Web Sales, for both product categories. In fact, the regression coefficients for all digital marketing channels were significant for both product categories. As indicated previously, this study used log-log models in which both the dependent variable and the independent variables are log-transformed. Thus, the relationship between the dependent variable and each of the independent variables is elastic and the coefficient (β) of the Log_e(predictor) operates as an elasticity [3]. Accordingly, the results should be interpreted as if we multiply a predictor by e (2.718), then the expected value of the Web Sales variable will multiply by e^{β} units, holding Average Ticket value constant.

It was hypothesized that the digital marketing channels will be more effective for utilitarian products than for hedonic products. Another analytical technique that can be used as a test of this hypothesis is to compare the proportion of variance explained by the predictor variables in each product category. The R-sq values in Tables 6 and 7 all show strong fit. Nevertheless, each of the seven the digital marketing channels included in the regression

equations as independent variables appear to explain a greater percentage of variance in the dependent measure for utilitarian products.

Finally, to conclusively demonstrate that there is a significant difference in the impact of digital marketing channels between the two product categories, it is vital to determine if the regression coefficients are statistically different. In order to do so, this study applies the Chow test, which is a classic econometric method to test for equality between two sets of regression coefficients [8]. The technique involves splitting the sample into two sub-groups, estimating the parameters for each of the sub-groups, and then testing to see if the regression coefficients are equal between the two subgroups [18]. The equation used in the Chow test is shown below -

$$F^* = \{[\sum e_c^2 - (\sum e_U^2 + \sum e_H^2)]/k\}/\{(\sum e_U^2 + \sum e_H^2)/(n_u + n_H - 2k)\}$$

where
e_c = Estimated error term for the combined categories
e_u = Estimated error term for the utilitarian category
e_H = Estimated error term for the hedonic category
n_u = The total number of observations in the utilitarian category
n_H = The total number of observations in the hedonic category
k = The total number of parameters in the model

Table 8. Chow Test for Equality

	e_u	e_H	e_c	Chow Stat
Direct	120.965	64.421	191.573	4.489***
Display Ads	106.049	60.77	180.367	9.624***
Email	128.551	69.493	204.812	4.545***
Organic Search	135.675	73.504	215.36	3.974**
Paid Search	136.238	65.518	209.074	4.625***
Referrals	120.321	62.272	187.023	3.264**
Social Media	134.554	74.236	221.037	7.860***

** <.05, ***<.01

Consistent with our hypotheses, the Chow test results provided in Table 8 do in fact indicate that the regression coefficients are not statistically equivalent. This means that the impact of digital marketing channels on sales varies depending on the product category. Comparing these findings with the R-sq values shown in Tables 6 and 7, it is logical to conclude that, despite their overall effectiveness for both product categories, digital marketing channels are relatively more effective for utilitarian products than they are for hedonic products. Thus, our hypotheses are fully supported.

DISCUSSION

Our study provides value to practitioners and researchers in several ways. First, we emphasize the fact that product categories may possess underlying differences that could affect consumer decision processes and purchase patterns. Specifically, one important differentiating characteristic is the position of a particular product on the emotional spectrum ranging from the relatively dispassionate and objective utilitarian products to the more emotionally engaging and psychologically arousing hedonic products. Practitioners should recognize that this fundamental difference may dictate distinctive and dissimilar marketing strategies. Secondly, we examine the use of the most recent digital marketing practices designed to provide consumers access to e-commerce transactional websites. These include direct click-through links to the marketer's transactional website, as well as links connected through display ads, email marketing, organic search engine results, paid search engine results, referrals from other sites, and social media sites. Finally, we examine the effectiveness of the various digital marketing channels for both utilitarian and hedonic products.

Our findings indicate that all seven digital marketing channels are more effective for marketers of utilitarian products. One possible explanation is that there is a greater need for personal interaction, inspection, and direct experience with hedonic products, in comparison to utilitarian products which are more likely to be evaluated in a logical and rational manner. However, that is not to say that marketers of hedonic products cannot successfully utilize these channels nor does it suggest that marketers of hedonic-type products need to abandon the e-commerce environment. Rather, it suggests that the return on investment is likely to be relatively greater for online retailers of utilitarian products that invest in digital marketing channels in comparison to their hedonic product counterparts. The findings also suggest that marketers of hedonic-type products may experience greater relative success through other strategies and tactics. For example, the brick-and-mortar retail apocalypse may not impact all marketers in the same way. In fact, physical retail stores are still the most effective way to create an engaging brand experience and a sense of excitement that can help differentiate brands from the competition [27]. Therefore, despite the ability of digital marketing strategies to drive online sales overall, some types of products may still find success in the physical store environment.

As an exploratory study, our findings may be used as a guide towards conducting additional research and analysis in the field of retailing. For example, because our analysis was restricted to only the largest online retailers with a dedicated focus on either utilitarian or hedonic products, our study does not include the total sales achieved within each of these product categories. In fact, disaggregating the product sales from general merchandise retailers would provide a more complete picture of the totality of sales in each category and could potentially yield different results. In addition, it would be interesting to examine the brick-and-mortar sales patterns for the same product categories. If our findings hold true, the reverse pattern should be observed for brick-and-mortar retailers. In particular, when controlling for average ticket value, we would expect to see dedicated retailers of hedonic products dominating the traditional sales channels. Finally, future research could be conducted to understand the various psychological mechanisms

that may be driving the observable sales patterns in the online environment. Moreover, those studies may seek to examine additional variables not included in our analysis. For example, conversion rates could also be examined alongside sales results.

REFERENCES

[1] Ayanso, A. and Yoogalingam, R. (2009) 'Profiling retail website functionalities and conversion rates: A cluster analysis,' *International Journal of Electronic Commerce*, 14(1), 79-113.

[2] Beauchamp, J.J. and Olson, S.J. (1973) 'Corrections for bias in regression estimates after logarithmic transformation', *Ecology*, 54[6], 1403-1407.

[3] Benoit, K. (2011), 'Linear regression models with logarithmic transformations', *Paper, London School of Economics*, London, Retrieved February 04, 2021 from www.kenbenoit.net/courses/ME104/logmodels2.pdf.

[4] Blázquez, M. (2014) 'Fashion shopping in multichannel retail: The role of technology in enhancing the customer experience', *International Journal of Electronic Commerce*, 18(4), 97-116.

[5] Box, G.E.P. and Cox, R.D. (1964) 'An analysis of transformations', *Journal of the Royal Statistical Society. Series B (Methodological)*, 26(2), 211-252.

[6] Cheema, A. and Papatla, P. (2010) 'Relative importance of online versus offline information for internet purchases: product category and internet experience effects', *Journal of Business Research*, 63(9/10), 9709-9985.

[7] Childs, M., Blanchflower, T., Hur, S., and Matthews, D. (2020) 'Non-traditional marketplaces in the retail apocalypse: Investigating consumers' buying behaviours', *International Journal of Retail & Distribution Management*, 48(3), 262-286.

[8] Chow, G. (1960) 'Tests of equality between sets of coefficients in two linear regressions', *Econometrica,* 28(3), 591-605.

[9] Cohen, J. (1968) 'Multiple regression as a general data-analytic system', *Psychological Bulletin*, 70, 426-443.

[10] Cohen, J. Cohen, P., West, S. Aiken, S. (2003) *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences (Third Edition)*, Mahwah, New Jersey: Lawrence Erlbaum Associates.

[11] Dhar, R. and Wertenbroch, K. (2012) 'Self-signaling and the costs and benefits of temptation in consumer choice', *Journal of Marketing Research*, 49(1), 15-25.

[12] Gudigantala, N., Bicen, P., and Eom, M. (2016) 'An examination of antecedents of conversion rates of e-commerce retailers,' *Management Research Review*, 39(1), 82-114.

[13] Guéguen, N. (2012) 'Say it…near the flower shop: Further evidence of the effect of flowers on mating', *The Journal of Social Psychology*, 152(5), 529-532.

[14] Hirschman, E. C. and Holbrook, M. B. (1982) 'Hedonic consumption: Emerging concepts, methods and propositions', *Journal of Marketing*, 46(3), 92–101.

[15] Kivetz, R. and Zheng, Y (2017) 'The effects of promotions on hedonic versus utilitarian purchases', *Journal of Consumer Psychology*, 27(1), 59-68.

[16] Klein, K. and Melnyk, V. (2016) 'Speaking to the mind or the heart: Effects of matching hedonic versus utilitarian arguments and products', *Marketing Letters*, 84(4), 127-146.

[17] Lahiri, I. and Siddika, H. (2014) 'Fashion behavior: Entangling promotional factors', *Globsyn Management Journal*, 8(1/2), 64-76.

[18] Lee, H. (2008) 'Using the Chow test to analyze regression discontinuities', *Tutorials in Quantitative Methods for Psychology*, 4(2), 46-50.

[19] Lee, J.A., Caudill, S.B., and Mixon Jr., F.G. (2014) 'Shine bright like a diamond: A hedonic model of grading and pricing an experience good, *Applied Economics*, 46(16), 1829-1838.

[20] Lu, J., Liu, Z. and Fang, Z. (2016) 'Hedonic products for you, utilitarian products for me', *Judgment and Decision Making*, 11(4), 332-341.

[21] Meisenzahl, M. (2021) 'Nearly 3000 stores are closing in 2021as the retail apocalypse drags on. Here's the full list', *Business Insider,* Retrieved September 04, 2021 from https://www.businessinsider.com/stores-closing-in-2021-list-2021-3.

[22] Mongelluzzo, B. (2021) 'Expecting record sales, US retailers up import projections', *JoC Online*, Retrieved September 04, 2021 from https://www.joc.com/maritime-news/container-lines/expecting-record-sales-us-retailers-import-projections_20210308.html.

[23] Narayanaswamy, R. and Heiens, R.A. (2018) 'An examination of online sales promotion practices in hedonic versus utilitarian product categories: Evidence from America's largest online retailers', *International Journal of Electronic Marketing and Retailing*. 9(1), 77-88.

[24] Narayanaswamy, R. and Heiens, R.A. (2021) 'The impact of digital sales channels on Web sales: Evidence from the USA's largest online retailers', *International Journal of Electronic Marketing and Retailing*, 12(3), 306-322.

[25] Pedhazur, E. J. (1997) *Multiple regression in behavioral research (Third ed.)*, Fort Worth, TX: Harcourt Brace College Publishers.

[26] Petty, R.E. and Briñol, P. (2012) 'The elaboration likelihood model', in P.A.M. Van Lange, A.W. Kruglanski and E.T. Higgins (Eds.), *Handbook of theories of social psychology*, 1, 224-245, Sage Publications Ltd.

[27] Pezzini, G. (2021) 'Why physical sores are still vital for retail', *LSRetail.com*, Retrieved September 24, 2021 from https://www.lsretail.com/resources/why-physical-stores-are still-vital-for-retail

[28] Ratchford, B.T. (1987) 'New insights about the FCB grid', *Journal of Advertising Research*, 27(4), 24-38.

[29] Roggeveen, A.L., Grewal, D., Townsend, C., and Krishnan, R. (2015) 'The impact of dynamic presentation format on consumer preferences for hedonic products and services', *Journal of Marketing*, 79(6), 34-49.

[30] Schulze, C. Schöler, L. and Skiera, B. (2014) 'Not all fun and games: viral marketing for utilitarian products', *Journal of Marketing*, 78(1), 1-19.

[31] Sohrabi, B., Mahmoudian, P., and Raessi, I. (2012) 'A framework for improving e-commerce websites' usability using a hybrid genetic algorithm and neural network system', *Neural Computing and Applications*, 21(5), 1017–1029.

[32] Vieira, V., Santini, F.O., and Araujo, C.F. (2018) A meta-analytic review of hedonic and utilitarian shopping values', *Journal of Consumer Marketing*, 35(No. 4), 426-437.

[33] Voss, K.E., Spangenberg, E.R., and Grohmann, B. (2003) 'Measuring the hedonic and utilitarian dimensions of consumer attitude', *Journal of Marketing Research*, 40(3), 310-320.

[34] Wooldridge, J. (2012) *Introductory Econometrics: A Modern Approach*, Cengage Learning.

[35] Yu, S., Hudders, L. and Cauberghe, V. (2018) 'Selling luxury products online: The effect of a quality label on risk perception, purchase intention and attitude toward the brand', *Journal of Electronic Commerce Research*, 19(1), 16-35.

EMPIRICAL INVESTIGATION OF THE DIFFERENCES IN JOB EXPECTATIONS BETWEEN BRAZIL AND THE US

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ABSTRACT

The US and Brazil are the biggest economies in the Western Hemisphere. Both economies also have global significance in that they are in the Top 10 of the largest nominal Gross Domestic Product (GDP) in the world. Given their strategic significance, it is imperative that the labor forces in both nations excel. It is within the framework of national productivity that we explore the similarities and differences in job expectation within the two nations. Our results indicate that job security is far more important to US workers than their Brazilian counterparts. In addition, while a job that provides a sense of accomplishment is highly valued in both cultures, one with supervisory capacity is less so in both nations. The most significant difference between the two countries is consistent with Hofstede's individualism (US) and collectivism (Brazil) typology with Brazilians valuing work with congenial others more so than their counterparts in the US.

INTRODUCTION

The United States (U.S.) and Brazil comprise the largest two economies in the Western Hemisphere. Historically, these two countries have maintained constructive, interdependent political and economic relations. As such, cooperation in business ventures between these nations date back more than 100 years. Still today, each remains an attractive source for foreign direct investment (FDI) from the other. Indeed, in 2021 alone the U.S. witnessed its largest number of Brazilian IPO's to date. And in the preceding 5-year period, Brazilian companies raised nearly $9B USD through IPO's across 13 different companies [23]. This trend is nothing new. For instance, in 2015, 50 Brazilian companies launched start-up operations in Pompano Beach, FL [29]. Interest in such enterprises is mutual. Many major U.S. companies have operated successfully in Brazil for several generations including those from the gas and oil industries (e.g., Exxon Mobil and Chevon) and the automotive industries (e.g., General Motors and Ford), just to name a few [47]. Moreover, according to the U.S. Department of State's 2021 [50] Investment Climate Statement on Brazil, the U.S. maintains the second largest single-country stock of FDI by final ownership, accounting for 18 percent of all FDI in the country ($117B USD).

As bilateral interest in foreign business enterprises rises between the U.S. and Brazil, companies have encountered added challenges in the areas of recruitment and selection. For instance, for the 50 Brazilian companies that launched start-up operations in FL referenced above, only a handful sent staff from Brazil to live in the U.S. to build sales. These expatriates were then tasked with hiring U.S. workers to staff remaining openings [29]. Similarly, when the U.S. Olympic Committee once opened a Team USA store in Rio de Janeiro, Brazil, they were obligated under local rules to staff the position with a Brazilian president. Additionally, they were required to maintain a strict ratio of local to foreign employees [47]. U.S. and Brazilian companies are faced with difficult decisions when it comes to staffing their business operations located outside their own country's borders. Careful and thoughtful consideration must be given to whether hiring locally (i.e. host country nationals), deploying expatriates, or some combination thereof is best. One effective way these organizations can greatly aide their staffing decisions is to consider the job expectations of potential new hires or prospective expatriate candidates.

Bartol [2, p. 368] defined job expectations as the "values that individuals place on various potential job rewards, including both intrinsic and extrinsic types of remunerations." A firm understanding of candidate job expectations allows U.S. and Brazilian companies to determine how well an individual's work-related goals, interests, and preferences align with the characteristics/nature of the positions needing staffed [11] [21]. Therefore, employers knowledgeable about candidate job expectations can make informed hiring decisions that place the right person in the right job. Moreover, an understanding of candidate job expectations allows U.S. and Brazilian companies to integrate this knowledge into their recruitment efforts. U.S and Brazilian companies can highlight key aspects of positions that candidates desire while also modeling realistic expectations about the true nature of the work to be performed. This latter strategy is akin to a realistic job preview which has the added benefit of reducing turnover.

At this same time in which FDI between the U.S. and Brazil is growing, both countries have committed to reducing gender inequality within their workforces. Brazil's government has indicated its intention to reduce gender inequality in its workforce by 25% by the year 2025. Brazil has also indicated its intentions to achieve equal pay by 2030 [12]. Similarly, the U.S. has made several commitments to strengthen women's economic security for the future. For example, the U.S. has indicated its intention to strengthen the workforce pipeline for women, including investments in both apprenticeship programs and workforce development programs such as "Women in Apprenticeship and Non-Traditional Occupations." The U.S. has also indicated its interest in minimizing inequities and inequalities faced by female health workers globally [46]. In the same way that knowledge of job expectations across cultures may inform companies in their staffing decisions, such knowledge across gender may also assist in furthering the gender-focused aims highlighted by the U.S. and Brazilian governments.

Thus, this paper seeks to contribute to the literature in two ways. First, by highlighting the role of job expectations across cultures (U.S. vs. Brazil) this paper aims to inform companies on important recruiting and hiring decisions. With a better understanding of job expectations across cultures, companies operating outside their own borders will be better educated as to the suitability of hiring host-country nationals, deploying expatriates, or utilizing a combination of both. Second, by highlighting the role of job expectations across gender (male vs. female) this paper aims to inform companies about male and female candidates that may not only assist them

in their recruiting and hiring decisions, but also help them in addressing gender inequity and inequality issues noted by the U.S. and Brazil government.

THEORY

It is difficult to place the discussion of gender and intercultural differences in work values and job expectations into a particular theoretical framework [5]. The early findings of no differences between genders in job orientation [10] [13] made theoretical explanations of findings difficult to ascertain. Herzberg, Mausner, & Snyderman's [31] two factor theory from the theory of motivation identified two underlying motivations for work. Example of motivating factors are achievement, recognition, and advancement; hygiene factors include supervision, relationships, and work conditions. These factors provide the basis for later empirical and theoretical work differentiating intrinsic and extrinsic job orientations. As such, Manhardt [38] explored job expectations and developed a measure using a less theory connected approach.

Holland's [33] theory of vocational choice implies that individuals will choose occupations which are congruent with their personalities. The original theory did not provide explicit guidance for testing differences between genders in job expectations, work values or occupational choice. Others expanded on this theory by dividing the original six categories into three masculine and three feminine categories [18]. Gender is a strongly protected view of oneself and one's occupation is a public facing representation which may influence occupational choice [27] and reported job expectations. For example, a male may want to become a nurse but chooses not to pursue it out of the pressure of gender roles and identity [27]. Men prefer stereotypically masculine occupations, and women prefer stereotypical feminine jobs [18]. Men place more value on achievement, competition, advancement, and prestige, while women value social interactions, relations, routine, and aesthetics [41].

With the weak theoretical foundations for explaining gender differences in work orientation and job expectations, a more socially comprehensive model which includes education, age, class, and religion can better generate an understanding of work value and job expectations differences. De Vaus and McAllister [19] incorporate a social characteristics model to investigate the theoretical and empirical nature of the differences in work values, job satisfaction, and work orientation. This work is based on earlier theoretical and empirical work of [36]. Loscocco breaks down previous industrial work orientations into the structuralists' [6], rooted in Marxist theory, and the individualists' [20] approaches. Drawing from both approaches, the proposition is that work value and reward structures are a function of personal characteristics (age, gender, family roles, etc.) and job features (complexity, autonomy, promotion, etc.) [36]. A final note on the theoretical exploration is that there is a lack of discussion about how preferences change over time throughout various career and personal developmental stages. Some temporal effects have been empirically noted particularly in gender differences considering the impact of parenthood and career development stages [24].

Gender influence

Early literature provides mixed results for job expectations and differences in orientations between genders where some researchers found disparities in job orientations [10] [13] and others did not [38]. The competing findings can sometimes be explained through research

design. Other factors, such as age, industry, and work context can partially address the conflicting results. When using students as the sample, the variance can be explained by simply looking at different majors [2], suggesting that professional training may be a significant control variable when studying gender differences in job orientation. When controlling for occupational differences, results suggest no pattern of difference between genders exist [8]. de Vaus & McAllister [19] added to the discussion by testing three different models (job, family, and social characteristics) to address gender differences and the data suggest the existence of gender differences in work values is doubtful. Using an ordinal regression analysis, Neil & Snizek [42] conducted a study that controlled for organizational variables. The results suggest that studying an array of occupations could remedy and explain the conflicting findings in the literature. The underlying structure of the work-values domain may also explain the inconsistent results [22].

Throughout the seventies, it was suggested that as more women were joining the workforce and participating in the labor market across various industries that the differences in job expectations and orientations may be disappearing. A convergence of job outcome preferences over a nine-year span between men and women existed on the measures where there were significant differences [3]. Using the Manhardt [38] scale, Brenner & Tomkiewicz [7] found men and women still differed on nearly one-third of the job characteristics. Men, at that time, may have still seen themselves as breadwinners and felt more of a responsibility to be leaders and women may not have yet considered a career as the most important factor in their lives.

Women rate comfortable work environment and congenial associates [5] as more important and career objectives and income as less important [3] consistently in the early studies. Work that offers a feeling of accomplishment ranked high for men and women [5] [7] [38]. Job security ranked in the top-third of job expectations for men and women [5] [7]. Men typically rank pay higher, while women rank benefits higher [22]. These early studies helped inform later research in work-life balance though few men and women, in the Beutell & Brenner [5] study, reported that career was a primary source of life satisfaction. This may have been an American phenomenon, where results in China suggest there is no difference between men and women rankings for job orientation items [48]. Though just a few years later, Chullen, Adeyemi-Bello, & Xi [14], found that men and women Chinese students differed on 23 of the 25 items of the Manhardt [38] scale. Further investigation shows agreement in the mutual ranking of men and women for the very important and important items with the highest rated being intrinsic [35].

Race and ethnicity influence

Ethnicity is significantly related to job attribute preferences and is mediated by cultural influences such as collectivism [16] and differences in values exist between countries [22]. Some of the gender differences remain small within sample; however, when conducting a cross-country analysis, the differences between samples is larger [22]. Care must be taken when generalizing results of job satisfaction from single-country studies due to inconsistent findings cross-country where different country findings reflect both cultural and structural differences [19].

When comparing Russian and Polish responses, Sagan, Tomkiewicz, Adeyemi-Bello, & Frankel [44], found that within sample differences were less pronounced than between sample. Polish men and women did not rank the intrinsic Manhardt [38] items significantly differently, and the

same results were found for Russians. For both countries, there was a difference between extrinsic items with women ranking them higher. In Israel, findings suggest a more androgynous preference of work values [1].

Using the smallest space analysis approach to the ratings of 24 work-value items conceptualized by a double-ordered system, Elizer [22] compared samples from Hungary, Israel, and the Netherlands. The between sample differences suggest that advancement was very important to a larger percentage of Israeli respondents and few of the Hungarian sample. The Dutch did not consider convenient hours, pay and supervision as important when compared to Hungarians and Israelis [22]. Another cross-country study focused on work orientations from nine western European countries [19].

Job satisfaction and expectations differs between countries and within countries. This requires a nuanced approach to job expectations research and careful extrapolations from the results. When compared to white workers, Asian and black workers report much lower level of job satisfaction, and this cannot be explained by immigrant status, job match, or other job characteristics [30]. Black women, in particular, report being unsatisfied with many aspects of their jobs [30]. Blacks report that working conditions, recognition, personal contacts, and nine other items on Manhardt's scale as more important than whites [49], and the authors suggest that business efforts to address inequity have done little to impact these differences. Just as gender differences in job preference or occupational choice may exist, the same has been found for various ethnicities [49]. A much higher percentage of black professionals work in government positions, nongovernmental agencies, and social welfare, whereas the representation for white professionals remains might in the private sector [9]. Ethnicity is normally included in research as a categorical variable leading to all individuals in that category to be treated equally. Though, there is evidence of variation of identities within ethnic groups [43]. When also controlling for race, ethnic identities are associated with differences in job preferences more strongly than race [16].

Professional and educational influence

Work values research cannot simply focus on background variables such as gender and ethnicity. This may be one of the reasons for the divergent findings in previous research. Field of study, occupation and professional experience as controls provides more robust results [1]. Researchers have investigated job expectations within industries and occupations, including prison wardens [45], social workers [34], marine pilots [4] and teachers [37], which provide specific guidance for employers in those particular sectors and industries. These sector and occupation investigations do not allow for generalizability between industries or offer insight into the nuanced differences between occupations. Using occupation, age, experience, education, etc. as a control variable would provide results useful in a variety of industries. As of now, there is much to be desired in the literature in this regard. Work has been done to explore generational differences specifically to job satisfaction [51], but this study is focused on a specific industry, leisure, and recreation. Exposure to education may [26] or may not [39] lead to differences in job satisfaction. Research on the differences between industries tends to focus more on job satisfaction as opposed to job expectations. Extrinsic sources of job satisfaction is more important among unskilled, semiskilled and clerical workers, but intrinsic satisfaction is powerful in all occupational groups [28].

Based on the previous research and theoretical discussions, the current paper aims to address the following research questions:

RQ1a: How important do Americans and Brazilians rate various aspects of their work environment (i.e. job expectations)?

RQ1b: Does the importance assigned to various aspects of the work environment (i.e. job expectations) differ between Americans and Brazilians

RQ2a: How important do males and females rate various aspects of their work environment (i.e. job expectations)?

RQ2b: Does the importance assigned to various aspects of the work environment (i.e. job expectations) differ between males and females?

RQ3a: How important do males and females within the U.S. and Brazil rate various aspects of their work environment (i.e. job expectations)?

RQ3b: Does the importance assigned to various aspects of the work environment (i.e. job expectations) in these countries differ between males and females?

METHODS

Procedure

The data examined in this study were collected through opinion survey. Prospective participants received an email invitation to take part in the study. The invitation briefly described the study (noting that its purpose was to better understand participants' job-related attitudes to help improve the quality of their future work life), encouraged them to participate, assured them their responses would be kept completely confidential, that the data would go directly to the researchers, and that no one would have access to individual responses. Surveys were completed electronically through Qualtrics.

Sample

Responses for this study consisted of 1056 U.S. participants (511 males, 543 females) and 375 Brazilian participants (174 males, 204 females). Participants were drawn from two sources: (1) a large, public university located in the Southeastern United States and (2) a large, private university located in Southeast Brazil. For U.S. participants, approximately 51.7% were enrolled

at the undergraduate level while 48.3% were enrolled in graduate school. For Brazilian participants, approximately 87% were enrolled at the undergraduate level while 13% were enrolled in graduate school. Business represented the most common program of study for participants at both institutions (i.e. 85.6% of all U.S. participants and 35.2% of all Brazilian participants).

The average age reported for U.S. participants was 28.13 years (28.90 years for males, 27.42 years for females) and 25.49 years for Brazilian participants (25.58 years for males, 25.33 years for females). U.S. participants reported being 76.1% Caucasian, 12.3% African/African American, 4.3 % Hispanic or Latino, and 7.4% other. Brazilian participants reported being 76.3% branco (white), 13.4% pardo (brown), 6.7% preto (black), and 3.7% other. Because they represent the emerging workforce, students in general serve as a useful sample characteristic of both the culture and managers within organizations in their countries [17]. Still, it is important to note that more than 98% of the U.S. participants in this study indicated they were currently employed (43.5% in entry level positions, 38.9% in supervisor or manager positions, 2.7% in executive positions, and 15% in other positions) whereas 64% of Brazilian participants indicated they were presently working. Moreover, U.S. participants were drawn from academic programs where there is significant non-traditional undergraduate enrollment (i.e. students which have extensive work histories).

Measure

Participants were asked to rate the importance of 25 job characteristics on a 5-point Likert scale (5=Very Important to 1=Very Unimportant) using Manhardt's [38] job expectations questionnaire. Participants were asked to indicate how important it was for them to have a job which "provides job security…," "provides a feeling of accomplishment…," and/or "encourages continued development of knowledge and skills…", etc. A complete list of all 25 questionnaire items is available in this study's tables. To ensure conceptual correspondence of questionnaire items across cultures, a regimented process of forward-translation and back-translation was followed using multiple bilingual translators. After several reviews/iterations, researchers were satisfied with the correspondence between the English and Portuguese-based versions of the questionnaire. This measure demonstrated satisfactory reliability overall (α=.87), as well as for U.S. (α=.88) and Brazilian (α=.83) participants independently.

Analytical Approach

This study examined and tested its data in a manner consistent with previous research in the job expectations literature ([38]; [2]; Brenner and Tomkiewicz 1979; [14]; [25]; [48]; [44]). First, as noted above, participants were asked to rate 25 job characteristics from Manhardt's [38] scale using a 5-point Likert scale (5=Very Important to 1=Very Unimportant). Mean scores for responses on each of the job characteristics were calculated separately for U.S. and Brazilian participants.

First, in order to answer the research question "How important do Americans and Brazilians rate various aspects of their work environment (i.e. job expectations)?;" the mean scores for each of the 25 job characteristics were rank ordered for each country separately. For example, the job characteristic that received the highest mean score from U.S. participants was ranked #1 (the most important). Similarly, the job characteristic that received the lowest mean score from U.S. participants was ranked #25 (the least important). This process was then repeated for Brazilian participants. In order to answer the research question "Does the importance assigned to various aspects of the work environment (i.e. job expectations) differ between Americans and Brazilians?" an analysis of variance (ANOVA) was performed, comparing the mean scores between U.S. and Brazilian participants overall on each of the 25 job characteristics individually. This step addresses whether a statistically significant difference exists between U.S. and Brazilian participants on the importance of, for example, having a job which "provides job security."

Second, in order answer the research question "How important do males and females rate various aspects of their work environment (i.e. job expectations)?," the mean scores for each of the 25 job characteristics were rank ordered for each gender and country separately in the same manner described above. In order to answer the research question "Does the importance assigned to various aspects of the work environment (i.e. job expectations) differ between males and females?" an analysis of variance (ANOVA) was performed, comparing the mean scores between males and females overall on each of the 25 job characteristics individually in the same manner described above.

Lastly, in order answer the research question "How important do males and females within the U.S. and Brazil rate various aspects of their work environment (i.e. job expectations)"?, the mean scores for each of the 25 job characteristics were rank ordered for each gender and country separately in the same manner described above. In order to answer the research question "Does the importance assigned to various aspects of the work environment (i.e. job expectations) in these countries differ between males and females?" an analysis of variance (ANOVA) was performed, comparing the mean scores between males and females in both the U.S. and Brazil on each of the 25 job characteristics individually in the same manner described above.

A Spearman rank correlation was also performed on each group (country and gender) to determine whether a similar rank order of importance was assigned to each job characteristic across participants (e.g. Was the job characteristic ranked #1 for Americans also ranked #1 for Brazilians?; Was the job characteristic ranked #1 for U.S. males also ranked #1 for Brazilian females, etc.?). Higher scores indicate greater similarity.

RESULTS

General Comparison of Americans and Brazilians Overall

Table 1 illustrates the ranks, means, and standard deviations for American (n = 1056) and Brazilian (n = 375) participants across all twenty-five job expectation questionnaire items.

Insert Table 1 about here

Mean scores were calculated for each of the 25 questionnaire items and rank ordered separately for participants from each country. The Spearman rank correlation coefficient between the rank orders of American and Brazilian participants was .79 ($p < .01$), indicating that the order of importance which Americans and Brazilians placed on job characteristics was similar. Significant differences between male and female respondents on the job expectations questionnaire were tested using ANOVA. Significant differences ($p < .05$ or better) were found on 14 of the 25 items. Brazilians reported higher average scores on 13 of these 14 items. Mean American standard deviations were .86 and mean Brazilian standard deviations were .83, suggesting that Brazilians were slightly more homogenous than Americans with respect to job expectations. However, a paired t-test ($p > .05$) for these standard deviations failed to confirm Brazilians as a group are slightly more homogeneous than are the Americans.

Americans (mean = 4.56) indicated that having a job which "provides job security" was of the highest importance to them (i.e. ranked #1/25). However, "provides job security" was only ranked #10 in terms of importance to Brazilians (mean = 4.19). Rather, Brazilians (mean = 4.73) indicated that having a job which "provides a feeling of accomplishment" was of the highest importance to them (i.e. ranked #1/25). "Provides a feeling of accomplishment" was ranked #2 in terms of importance to Americans (mean = 4.55). On the other hand, both Americans (mean = 3.10) and Brazilians (mean = 3.20) reported having a job which "requires supervising others" to be of the lowest importance to them (i.e. ranked #25/25). Interestingly, the job characteristic "involves working with congenial associates" demonstrated the largest mean difference between Americans (mean = 3.60) and Brazilians (mean = 4.41) while the job characteristic "provides an opportunity to earn a high income" demonstrated the smallest mean difference between Americans (mean = 4.42) and Brazilians (mean = 4.39).

General Comparison of Males and Females Overall

Table 2 illustrates the ranks, means, and standard deviations for Males (n = 681) and Brazilian (n = 750) participants across all twenty-five job expectation questionnaire items.

Insert Table 2 about here

Mean scores were calculated for each of the 25 questionnaire items and rank ordered separately for participants from each country. The Spearman rank correlation coefficient between the rank

orders of Males and Females was .92 ($p < .001$), indicating that the order of importance which Americans and Brazilians placed on job characteristics was very similar. Significant differences between male and female participants on the job expectations questionnaire were tested using ANOVA. Significant differences ($p < .05$ or better) were found on 18 of the 25 items. Females reported higher average scores on all 18 of these items. Mean male standard deviations were .88 and mean female standard deviations were .83, suggesting that females were slightly more homogenous than males with respect to job expectations. A paired t-test ($p < .001$) for these standard deviations confirmed that females as a group are more homogeneous than are males.

Both males (mean = 4.49) and females (mean = 4.69) indicated that having a job which "provides a sense of accomplishment" was of the highest importance to them (i.e. ranked #1/25). On the other hand, both males (mean = 3.15) and females (mean = 3.11) reported having a job which "requires supervising others" to be of the lowest importance to them (i.e. ranked #25/25). Interestingly, the job characteristic "makes a social contribution by the work you do" demonstrated the largest mean difference between males (mean = 3.76) and females (mean = 4.13) while the job characteristic "requires originality" demonstrated the smallest mean difference between males (mean = 3.78) and females (mean = 3.79).

Comparison of Males and Females within the U.S. and Brazil

In addition to comparing the U.S. and Brazil overall and males and females overall, further analysis was performed comparing males and females within each country. Table 2 illustrates the ranks, means, and standard deviations for U.S. males (n = 511), U.S. females (n = 545), Brazilian males (n = 204), and Brazilian females (n = 171) across all twenty-five job expectation questionnaire items.

Insert Table 3 about here

An omnibus test for significant differences between these groups on items in the job expectations questionnaire was performed using ANOVA. Follow-up post-hoc tests were then performed to determine which groups differed from one another. The omnibus test revealed there were statistically significant ($p < .05$) differences between groups on 22 of the 25 items. Post-hoc tests revealed there were statistically significant differences ($p. < .05$) on 16 items between U.S. males and U.S. females (with U.S. females reporting higher average scores on all 16 items), on 11 items between U.S. males and Brazilian males (with Brazilian males reporting higher average scores on 10 of these items), on 19 items between U.S. males and Brazilian females (with Brazilian females reporting higher average scores on all 19 of these items), on 9 items between U.S. females and Brazilian males (with U.S. females reporting higher average scores on 5 of these items), 10 items between U.S. females and Brazilian females (with Brazilian females reporting higher average scores on 9 of these items), and on 10 items between Brazilian males

and Brazilian females (with Brazilian females reporting higher average scores on 8 of these items).

Insert Table 4 about here

The Spearman rank correlation coefficient between the rank orders: of U.S. males and U.S. females was .94, of U.S. males and Brazilian females was .79, of U.S. males and Brazilian females was .80, of U.S. females and Brazilian males was .69, of U.S. females and Brazilian females was .79., and of Brazilian males and Brazilian females was .86. The mean standard deviation for U.S. males was .87, for U.S. females was .84, for Brazilian males was .89, and for Brazilian females was .76. Paired t-tests were performed for each group with these standard deviations. Results were statistically significant between U.S. males and U.S. females ($p < .05$), U.S. males and Brazilian females ($p < .001$), U.S. females and Brazilian males ($p < .001$), and Brazilian males and Brazilian females ($p < .001$). These results mean that U.S. females are slightly more homogenous than U.S. males, Brazilian females are more homogenous than U.S. males, U.S. females are slightly more homogenous than Brazilian males, and that Brazilian females are more homogenous than Brazilian males with respect to job expectations.

Intrinsic and extrinsic perspective of the survey items.

Manhardt's (1972) 25-item survey instrument can also be dichotomized into intrinsic and extrinsic factors based on the locus of incentive from the participants' perspective. Intrinsic motivation occurs when an individual derives an internal pleasure or enjoyment from engaging is a task and where no obvious external incentives are present (e.g. sense of accomplishment). In contrast, extrinsic motivation occurs when an individual engages in behaviors for express external rewards, whether they be tangible (e.g. pay) or intangible (e.g. praise). 13 items (#1, 2, 3, 4, 7, 8, 9, 15, 16, 18, 21, 24, and 25) comprise the intrinsic factor, whereas 12 items (#5, 6, 10, 11, 12, 13, 14, 17, 19, 20, 22, 23) comprise the extrinsic factor. Mean scores for the 13 intrinsic and 12 extrinsic job characteristics were calculated and compared between Americans and Brazilians overall, between males and females overall, and between males and females within the U.S. and Brazil using ANOVA.

First, significant differences between Americans and Brazilians overall were found on both the intrinsic factor (mean = 4.04 for Americans vs. mean = 4.17 for Brazilians) and the extrinsic factor (mean = 3.84 for Americans vs. 3.96 for Brazilians). Next, significant differences between males and females overall were found on both the intrinsic factor (mean = 3.99 for Americans vs. mean = 4.15 for Brazilians) and the extrinsic factor (mean = 3.77 for Americans vs. 3.96 for Brazilians). Lastly, an omnibus test in ANOVA indicated there were differences between U.S males, U.S. females, Brazilian males, and Brazilian females on both the intrinsic and extrinsic factor. Post-hoc tests revealed statistically significant differences for all pairwise comparisons with two exceptions: there was no difference found between U.S. males and

Brazilian females on the extrinsic factor and there no differences found between U.S. females and Brazilian males on either factor.

DISCUSSION AND CONCLUSION

Consistent with Monnot's [40] findings, managers in multinational corporations need to be aware of the impact of culture on the success of their organizations. In this study, we found that the differences in job expectations between Brazil and the US are dictated by cultural values. Using Hofstede's [32] landmark research, there are important differences between the US and Brazil on the four original dimensions of power distance (PD), masculinity versus femininity (MF), uncertainty avoidance (UA), and individualism versus collectivism (IC). While the US is relatively low on power distance and relatively strong on uncertainty avoidance, Brazil is relatively high on power distance and relatively weak on uncertainty avoidance. On the other two dimensions of IC and MF, the cultural distance between the US and Brazil is less pronounced.

Given the small absolute differences in the means of the job expectations questionnaire items, we focused on their rankings instead. In particular, we focused on the items with similar (i.e., minimal absolute differences) or divergent rankings. The closest cultural value similarity on the job expectations questionnaire between the US and Brazil was 'a job that that provides a feeling of accomplishment'. In fact, this questionnaire item was rated first by US males, Brazilian males and females and second overall by US females. Conversely, 'a job that requires supervising others' was unanimously ranked lowest by all subgroups of US males and females and Brazilian males and females. The implications are that jobs that 'provide a feeling of accomplishment' are highly valued in both cultures while those providing supervision are considered less so.

A job that makes a social contribution by the work you do had the same rankings for Brazilian and US males and the same rankings for US and Brazilian females. Since Brazilian culture is considered more collectivist, the mean score for the Brazilian males was higher than US males even with the same ranking. Similarly, the mean score for Brazilian females was higher than the mean score for US females. More importantly, a job that 'involves working with congenial associates' had the highest divergent ranking for US versus the Brazilian sample. The implication of this finding is that in the context of work, the Hofstede's dimension of 'individualist-collectivist' appears to be the most discriminating factor for managers in Brazil and the US.

The second most divergent variable was employment that provides job security. This item was ranked second by US males and first by US females. Conversely, the Brazilian males ranked it twelfth and Brazilian females ranked it tenth. In essence, job security appears to be more important to US workers than their Brazilian counterparts. This could be explained in part along the individualist-collectivist dimension.

The current study offers evidence that global managers should be more concerned with cultural rather national borders when designing incentive systems. Therefore, it is regional cultural variation instead of national borders that play a more important role in effecting the motivational antecedents of job satisfaction and commitment.

REFERENCES

[1] Abu-Saad, I., & Isralowitz, R. E. (1997). Gender as a determinant of work values among university students in Israel. The Journal of Social Psychology, 137(6), 749-763.

[2] Bartol, K. M. (1976). Relationship of sex and professional training area to job orientation. Journal of Applied Psychology, 61(3), 368-370.

[3] Bartol, K. M., & Manhardt, P. J. (1979). Sex differences in job oucome preferences: Trends among newly hired college graduates. Journal of Applied Psychology, 64(5), 477-482.

[4] Bernthal, J. P. (2020). A qualitative descriptive study of job expectations, job satisfaction, and retention among fixed-wing marine pilots. ProQuest Dissertations & Theses Global. Retrieved from https://search.proquest.com/dissertations-theses/qualitative-descriptive-study-job-expectations/docview/2478088593/se-2?accountid=10639

[5] Beutell, N. J., & Brenner, O. C. (1986). Sex differences in work values. Journal of Vocational Behavior, 28, 29-41.

[6] Blauner, R. (1964). Alienation and freedom: The factory worker and his industry. Chicago: University of Chicago Press.

[7] Brenner, O. C., & Tomkiewicz, J. (1979). Job orientation of males and females: Are sex differences declining. Personnel Psychology, 32, 741-750.

[8] Brief, A. P., Rose, G. L., & Aldag, R. J. (1977). Sex differences in preferences for job attributes revisited. Journal of Applied Psychology, 62(5), 645-646.

[9] Burbridge, L. (1994). The glass ceiling in different sectors of the economy: Differences between government, non-profit and for-profit organizations. Wellesley, MA: Wellesley College Center for Research on Women.

[10] Burke, R. J. (1966). Differences in perception of desired job characteristics of the opposite sex. Journal of Genetic Psychology, 109, 27-36.

[11] Cable, D.M. and DeRue, D.S. (2002). The convergent and discriminant validity of subjective fit perceptions. Journal of Applied Psychology, 87(5), 875-884.

[12] Canineu, M. L., & Carvalho A. (2018, March 8). Working for Less in Brazil: Brazil Moves at Snail Pace to Bridge the Gender Wage Gap. Human Rights Watch. https://www.hrw.org/news/2018/03/08/working-less-brazil#

[13] Centers, R., & Bugental, D. E. (1966). Intrinsic and extrinsic job motivators among different segments of the working population. Journal of Applied Psychology, 50, 193-197.

[14] Chullen, C. L., Adeyemi-Bello, T., & Xi, X.-Y. (2015). Job expectations of Chinese college students: re-examining gender differences. Equality, Diversity and Inclusion: An International Journal, 34(8), 742-763.

[15] CIA World Fact Book (2021). Available from: https://www.cia.gov/the-world-factbook/ (accessed October 12, 2021).

[16] Combs, G. M., Milosevic, I., Jeung, W., & Griffith, J. (2012). Ethnic identity and job attribute preferences: The role of collectivism and pyschological capital. Journal of Leadership & Organizational Studies, 19(1), 5-16.

[17] Cordano, M., Scherer, R. F., & Owen, C. L. (2002). Attitudes toward women as managers: sex versus culture. Women in Management Review, 17(2), 51-60. https://doi.org/10.1108/09649420210421754

[18] Costa, P. T., McCrae, R. R., & Holland, J. L. (1984). Personality and vocational interests in an adult sample. Journal of Applied Psychology, 69(3), 390-400.

[19] de Vaus, D., & McAllister, I. (1991). Gender and work orientation: Values and satisfaction in western Europe. Work and Occupations, 18(1), 72-93.

[20] Dubin, R. (1956). Industrial workers' worlds: A study of the central life interests of industrial workers. Social Problems, 3(3), 131-142.

[21] Edwards, J. R. (1991). Person-job fit: A conceptual integration, literature review, and methodological critique. In C. L. Cooper & I. T. Robertson (Eds.), International review of industrial and organizational psychology, 1991, Vol. 6, pp. 283–357). John Wiley & Sons.

[22] Elizer, D. (1994). Gender and work values: A comparative analysis. The Journal of Social Psychology, 134(2), 201-212.

[23] Fereirra, M. (2021, August 27). Brazilian companies breaking records in the American stock market. Drummond Advisors. https://drummondadvisors.com/en/2021/08/27/brazilian-companies-breaking-records-in-the-american-stock-market/

[24] Ferriman, K., Lubinski, D., & Benbow, C. P. (2009). Work preferences, life values, and personal views of top math/science graduate students and profoundly gifted: Developmental changes and gender differences during emerging adulthood and parenthood. Journal of Personality and Social Psychology, 97(3), 517-532.

[25] Frankel, R., Tomkiewicz, J., Adeyemi-Bello, T., & Sagan, M. (2006). Gender differences in job orientation: The case of Poland. Cross Cultural Management: An International Journal, 13(3), 193-203. https://doi.org/10.1108/13527600610683345

[26] Glenn, N., & Weaver, C. N. (1982). Further evidence on education and job satisfaction. Social Forces, 61, 46-55.

[27] Gottfredson, L. S. (1981). Circumscription and compromise: A development theory of occupational aspirations. Journal of Counseling Psychology, 28(6), 545-579.

[28] Gruenberg, B. (1980). The happy worker: An analysis of educational and occupational differences in determinants of job satisfaction. American Journal of Sociology, 86(23), 247-271.

[29] Hemlock, D. (2015, September 4). 50 companies from Brazil start U.S. operations from Pompano Beach. South Florida Sun Sentinal. https://www.sun-sentinel.com/business/jobs/fl-brazilian-startups-20150904-story.html

[30] Hersch, J., & Xiao, J. (2016). Sex, race, and job satisfaction among highly educated workers. Southern Economic Journal, 83(1), 1-24.

[31] Herzberg, F., Mausner, B., & Snyderman, B. (1959). The Motivation to Work. Wiley.

[32] Hofstede, G. (1977). Cultures and Organizations: Software of the mind. The McGraw-Hill Companies. New York, NY

[33] Holland, J. L. (1973). Making vocational choices: A theory of careers. Englewood Cliffs, NJ: Prentice-Hall.

[34] Jacquet, S. E., & Hermon, S. R. (2018). Job expectations and career goals of Title IV-E child welfare social workers with varying levels of work experience: How do they differ. Journal of Public Child Welfare, 12(1), 42-59.

[35] Karriker, J. H., Chullen, C. L., Adeyemi-Bello, T., & Xi, X.-Y. (2021). Gender and Generation: Job expectations of Chinese professionals and students amid complexity and change. Journal of Applied Business and Economics, 23(2), 196-209.

[36] Loscocoo, K. A. (1989). The instrumentally oriented factory worker. Work and Occupations, 16(1), 3-25.

[37] Low, M. (2012). The effects of job expectations and colleagues on new teachers' commitment levels. ProQuest Dissertations & Theses Global. Retrieved from https://search.proquest.com/dissertations-theses/effects-job-expectations-colleagues-on-new/docview/1024565771/se-2?accountid=10639

[38] Manhardt, P. J. (1972). Job orientation of male and female college graduates in business. Personnel Psychology, 25, 361-368.

[39] Martin, J. K., & Shehan, C. L. (1989). Education and job satisfaction: The influences of gender, wage-earning status, and job values. Work and Occupations, 16(2), 184-199.

[40] Monnot, M.J. (2016). The effect of incentives on intrinsic motivation and employee attitudes: A multilevel study across nations and cultural clusters. Thunderbird International Business Review, 60(4), 675–689.

[41] Moore, H. A., & Ollenburger, J. C. (1986). What is your sex parachute? Interest inventory/counseling models and the perpetuation of the sex/wage segregation of the labor market. Work and Ocuupations, 13, 511-531.

[42] Neil, C. C., & Snizek, W. E. (1987). Work values, job characteristics and gender. Sociological Perspectives, 30(3), 245-265.

[43] Phinney, J. S. (1992). The multigroup ethnic identity measure: A new scale for use with diverse groups. Journal of Adolescent Research, 7, 156-176.

[44] Sagan, M., Tomkiewicz, J., Adeyemi-Bello, T., & Frankel, R. (2008). Importance of job characteristics among future businesspersons: A comparative study of Russian and Polish students. International Journal of Management, 25(3), 641-653.

[45] Schiff, M., & Leip, L. (2018). The impact of job expectations, workload, and autonomy on work-related stress among prison wardens in the United States. Criminal Justice and Behavior, 46(1), 136-153.

[46] The White House. (2021). Fact Sheet: United States to Announce Commitments to the Generation Equality Forum. https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/30/fact-sheet-united-states-to-announce-commitments-to-the-generation-equality-forum/

[47] TMF Group. (2018). US companies doing business in Brazil: what you should know. https://www.tmf-group.com/en/news-insights/articles/2018/april/us-companies-doing-business-in-brazil/

[48] Tomkiewicz, J., Frankel, R., Sagan, M., & Wang, C. (2011). Comparing job expectations of Chinese male and female students. Chinese Management Studies, 5(1), 111-120.

[49] Tomkiewicz, J., Johnson, M., & Brenner, O. C. (1997). Comparing job orientations of black and white college graduates in business. Journal of Social Behavior and Personality, 12(3), 699-708.

[50] U.S. Department of State. (2021). 2021 Investment Climate Statements: Brazil. https://www.state.gov/reports/2021-investment-climate-statements/brazil/

[51] Young, S. J., Sturts, J. R., Ross, C. M., & Kim, K. T. (2013). Generational differences and job satisfaction in leisure services. Managing Leisure, 18(2), 152-170.

Table 1
Mean Ratings on Job Expectations Questionnaire by Culture

	Job Expectations Scale Item Please circle either a 1, 2, 3, 4, or 5 concerning importance on a continuum which ranges from very important (=5) on the high end to very unimportant (=1) on the low end.	U.S. (n = 1056)			Brazil (n = 375)			**Significant difference between group means**
		Rank	Mean	SD	Rank	Mean	SD	
1.	requires originality…	18	3.71	.87	12	4.01	.81	***
2.	makes use of your specific educational background…	17	3.76	.94	19	3.83	.87	n.s
3.	encourages continued development of knowledge and skills…	3	4.47	.71	2	4.66	.64	***
4.	is respected by other people…	7	4.23	.88	6	4.42	.84	***
5.	provides job security…	1	4.56	.65	10	4.19	.87	***
6.	provides the opportunity to earn a high income…	4	4.42	.72	8	4.39	.64	n.s.
7.	makes a social contribution by work you do…	13	3.90	.89	11	4.10	.93	***
8.	gives you the responsibility for taking risks…	19	3.64	.91	20	3.78	.80	**
9.	requires working on problems of central importance to the organization…	11	3.93	.81	13	3.98	.82	n.s.
10.	involves working with congenial associates…	23	3.60	.89	7	4.41	.78	***
11.	provides ample leisure time off the job…	15	3.83	.90	17	3.91	.92	n.s.
12.	provides change and variety in duties and activities…	16	3.81	.89	14	3.97	.85	**
13.	provides comfortable working conditions…	6	4.28	.80	4	4.55	.64	***
14.	permits advancement to high administrative responsibility…	5	4.30	.79	9	4.35	.81	n.s.
15.	permits working independently…	14	3.89	.89	18	3.84	.94	n.s.
16.	rewards good performance with recognition…	7	4.23	.82	3	4.57	.66	***
17.	requires supervising others…	25	3.10	.99	25	3.20	.86	n.s.
18.	is intellectually stimulating…	9	4.21	.82	5	4.44	.69	***
19.	satisfies your cultural and aesthetic interests…	20	3.64	1.01	22	3.74	1.05	n.s.
20.	has clear cut rules and procedures to follow…	21	3.63	.97	21	3.76	.97	*
21.	permits you to work for superiors you admire and respect…	10	4.02	.88	16	3.94	.94	n.s.
22.	permits a regular routine in time and place of work…	21	3.63	.97	24	3.54	1.09	n.s.
23.	requires meeting and speaking with many other people…	24	3.25	1.03	23	3.56	1.03	***
24.	permits you to develop your own methods of doing work…	12	3.91	.86	15	3.95	.78	n.s.
25.	provides a feeling of accomplishment…	2	4.55	.64	1	4.73	.55	***
-	Intrinsic Motivation	-	4.04	.48	-	4.17	.39	***
-	Extrinsic Motivation	-	3.84	.48	-	3.96	.43	***

* p < .05, ** p < .01, *** p < .001

Table 2
Mean Ratings on Job Expectations Questionnaire by Gender

	Job Expectations Scale Item Please circle either a 1, 2, 3, 4, or 5 concerning importance on a continuum which ranges from very important (=5) on the high end to very unimportant (=1) on the low end.	Males (n = 681)			Females (n = 750)			**Significant difference between group means**
		Rank	Mean	SD	Rank	Mean	SD	
1.	requires originality…	15	3.78	.86	21	3.79	.87	n.s.
2.	makes use of your specific educational background…	20	3.69	.95	18	3.86	.89	***
3.	encourages continued development of knowledge and skills…	2	4.43	.73	3	4.60	.66	***
4.	is respected by other people…	9	4.12	.92	5	4.43	.80	***
5.	provides job security…	4	4.30	.80	2	4.61	.62	***
6.	provides the opportunity to earn a high income…	3	4.38	.70	5	4.43	.71	n.s.
7.	makes a social contribution by work you do…	17	3.76	.92	11	4.13	.85	***
8.	gives you the responsibility for taking risks…	18	3.72	.86	23	3.64	.91	n.s.
9.	requires working on problems of central importance to the organization…	10	3.92	.83	13	3.97	.79	n.s.
10.	involves working with congenial associates…	19	3.70	.94	15	3.91	.91	***
11.	provides ample leisure time off the job…	13	3.80	.91	17	3.89	.89	n.s.
12.	provides change and variety in duties and activities…	14	3.79	.87	15	3.91	.89	**
13.	provides comfortable working conditions…	8	4.16	.84	4	4.52	.65	***
14.	permits advancement to high administrative responsibility…	6	4.21	.83	7	4.41	.75	***
15.	permits working independently…	16	3.77	.92	13	3.97	.88	***
16.	rewards good performance with recognition…	5	4.28	.80	8	4.35	.79	n.s.
17.	requires supervising others…	25	3.15	.97	25	3.11	.95	n.s.
18.	is intellectually stimulating…	7	4.20	.81	9	4.33	.76	**
19.	satisfies your cultural and aesthetic interests…	22	3.49	1.06	19	3.82	.96	***
20.	has clear cut rules and procedures to follow…	21	3.51	1.00	20	3.80	.92	***
21.	permits you to work for superiors you admire and respect…	12	3.83	.94	10	4.15	.83	***
22.	permits a regular routine in time and place of work…	23	3.45	1.01	22	3.75	.98	**
23.	requires meeting and speaking with many other people…	24	3.26	1.00	24	3.40	1.06	***
24.	permits you to develop your own methods of doing work…	11	3.84	.86	12	3.99	.81	***
25.	provides a feeling of accomplishment…	1	4.49	.66	1	4.69	.57	***
-	Intrinsic Motivation	-	3.99	.48	-	4.15	.44	***
-	Extrinsic Motivation	-	3.77	.47	-	3.96	.45	***

* p < .05, ** p < .01, *** p < .001

Table 3
Mean Ratings on Job Expectations Questionnaire by Culture & Gender

	Job Expectations Scale Item Please circle either a 1, 2, 3, 4, or 5 concerning importance on a continuum which ranges from very important (=5) on the high end to very unimportant (=1) on the low end.	U.S. Males (n = 511)			U.S. Females (n = 545)			Brazilian Males (n = 204)			Brazilian Females (n = 171)			**Omnibus Test for Group Mean Comparisons**
		Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	
1.	requires originality…	17	3.68	.85	21	3.72	.89	10	4.06	.83	17	3.96	.80	***
2.	makes use of your specific educational background…	17	3.68	.96	17	3.84	.91	19	3.73	.93	19	3.91	.81	**
3.	encourages continued development of knowledge and skills…	3	4.39	.72	3	4.55	.70	2	4.58	.75	2	4.72	.52	***
4.	is respected by other people…	8	4.06	.91	7	4.39	.81	7	4.29	.92	5	4.53	.75	***
5.	provides job security…	2	4.41	.70	1	4.69	.57	12	3.95	.99	10	4.40	.68	***
6.	provides the opportunity to earn a high income…	3	4.39	.71	5	4.44	.74	6	4.37	.67	9	4.42	.61	n.s
7.	makes a social contribution by work you do…	16	3.73	.90	11	4.06	.85	16	3.83	1.01	11	4.33	.80	***
8.	gives you the responsibility for taking risks…	19	3.65	.87	23	3.63	.95	13	3.91	.79	24	3.67	.79	**
9.	requires working on problems of central importance to the organization…	10	3.90	.81	14	3.96	.81	11	3.97	.89	15	4.00	.75	n.s.
10.	involves working with congenial associates…	20	3.51	.89	22	3.68	.88	8	4.26	.88	5	4.53	.67	***
11.	provides ample leisure time off the job…	13	3.80	.90	16	3.85	.90	17	3.79	1.00	14	4.01	.84	**
12.	provides change and variety in duties and activities…	15	3.75	.88	15	3.87	.90	13	3.91	.84	13	4.02	.86	***
13.	provides comfortable working conditions…	8	4.06	.85	4	4.48	.69	4	4.46	.74	3	4.62	.53	***
14.	permits advancement to high administrative responsibility…	5	4.19	.81	6	4.40	.76	8	4.26	.90	8	4.44	.72	***
15.	permits working independently…	14	3.77	.89	12	4.01	.87	17	3.79	.99	20	3.89	.89	***

16.	rewards good performance with recognition…	5	4.19	.82	9	4.27	.83	3	4.56	.67	4	4.58	.65	***
17.	requires supervising others…	25	3.12	.99	25	3.08	1.00	25	3.23	.93	25	3.18	.80	n.s.
18.	is intellectually stimulating…	7	4.13	.84	8	4.28	.79	5	4.40	.70	7	4.48	.68	***
19.	satisfies your cultural and aesthetic interests…	22	3.47	1.03	19	3.79	.96	22	3.52	1.14	18	3.93	.92	***
20.	has clear cut rules and procedures to follow…	23	3.44	.98	18	3.80	.92	20	3.71	1.02	21	3.79	.92	***
21.	permits you to work for superiors you admire and respect…	11	3.87	.91	10	4.16	.84	21	3.68	1.03	12	4.15	.79	***
22.	permits a regular routine in time and place of work…	21	3.50	.96	20	3.76	.96	24	3.31	1.14	22	3.73	1.01	***
23.	requires meeting and speaking with many other people…	24	3.20	.99	24	3.29	1.06	23	3.40	1.05	23	3.69	1.00	***
24.	permits you to develop your own methods of doing work…	12	3.83	.87	13	3.99	.84	15	3.89	.83	15	4.00	.74	**
25.	provides a feeling of accomplishment…	1	4.44	.67	2	4.65	.59	1	4.62	.66	1	4.82	.41	***
-	Intrinsic Motivation	-	3.95	.48	-	4.12	.46	-	4.10	.44	-	4.23	.34	***
-	Extrinsic Motivation	-	3.73	.46	-	3.92	.47	-	3.85	.47	-	4.06	.37	***

* p < .05, ** p < .01, *** p < .001

Table 4
Post Hoc Tests for Significant Differences Between Groups

Item	Job Expectations Scale	U.S Males *vs.* U.S Females	U.S. Males *vs.* Brazilian Males	U.S. Males *vs.* Brazilian Females	U.S. Females *vs.* Brazilian Males	U.S. Females *vs.* Brazilian Females	Brazilian Males *vs.* Brazilian Females
1.	requires originality…	n.s	***	***	***	**	n.s
2.	makes use of your specific educational background…	*	n.s	*	n.s	n.s	n.s
3.	encourages continued development of knowledge and skills…	***	*	***	n.s	**	n.s
4.	is respected by other people…	***	*	***	n.s	n.s	*
5.	provides job security…	***	***	n.s	***	***	***
6.	provides the opportunity to earn a high income…	n.s	n.s	n.s	n.s	n.s	n.s
7.	makes a social contribution by work you do…	***	n.s	***	*	***	***
8.	gives you the responsibility for taking risks…	n.s.	***	n.s	***	n.s	*
9.	requires working on problems of central importance to the organization…	n.s	n.s	n.s	n.s	n.s	n.s
10.	involves working with congenial associates…	**	***	***	***	***	**
11.	provides ample leisure time off the job…	n.s.	n.s	*	n.s	n.s	n.s
12.	provides change and variety in duties and activities…	n.s.	n.s	***	n.s	n.s	n.s
13.	provides comfortable working conditions…	***	***	***	n.s	*	n.s
14.	permits advancement to high administrative responsibility…	***	n.s	***	n.s	n.s	n.s
15.	permits working independently…	***	n.s	n.s	n.s	n.s	n.s
16.	rewards good performance with recognition…	n.s.	***	***	***	***	n.s
17.	requires supervising others…	n.s.	n.s	n.s	n.s	n.s	n.s
18.	is intellectually stimulating…	*	***	***	n.s	**	n.s
19.	satisfies your cultural and aesthetic interests…	***	n.s	***	*	n.s	***
20.	has clear cut rules and procedures to follow…	***	*	***	n.s	n.s	n.s

21.	permits you to work for superiors you admire and respect…	***	n.s	***	***	n.s	***
22.	permits a regular routine in time and place of work…	***	n.s	*	***	n.s	***
23.	requires meeting and speaking with many other people…	n.s.	n.s	***	n.s	***	*
24.	permits you to develop your own methods of doing work…	**	n.s	*	n.s	n.s	n.s
25.	provides a feeling of accomplishment…	***	*	***	n.s	***	**
-	Intrinsic Motivation	***	***	***	n.s.	***	**
-	Extrinsic Motivation	***	*	n.s.	n.s.	***	***

EMPLOYMENT AND PRESCRIPTION DRUG UTILIZATION IN THE U.S.

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ABSTRACT

This paper examines the interlocking relationships among gaining employment, individual health status, and changes in prescription drug utilization in the US. Two- and three-stage least squares models based on the Grossman framework were applied to the Medical Expenditure Panel Survey data for 2007-2016. Results confirmed that an individual's drug utilization was positively associated with gaining employment and the resulting improved health status, controlling for confounding factors such as age, wages, education, and uninsured status. Results suggest both a policy-relevant role of gaining employment as a path to greater prescription drug access and utilization and, by implication, the benefit of insurance coverage expansion.

KEYWORDS

prescription drug utilization, employment, health status, Grossman model, three stage least squares

INTRODUCTION

Recently, rising prescription drug prices and diminished innovation by major pharmaceutical companies have raised both consumer concerns over prescription drug availability and affordability and demand for government actions. In response, the Trump Administration has announced several drug pricing proposals and taken reform steps to reduce the prescription drug burden for both consumers and the overall health care system.

Several significant factors could influence prescription drug utilization and spending, such as health status, employment status, insurance status, and disposable income. The interrelationships among employment, health status, and healthcare care utilization are complex and have not been sufficiently examined. For example, an individual's employment status, especially the loss of a job, can reduce healthcare use (including prescription drug utilization). On the other hand, the loss of a job might be the result of poor health, which could lead to increased use of healthcare services and prescription drugs. Further complicating the interrelationships is the feedback effect of healthcare and prescription drug uses that can improve health and the likelihood of getting and maintaining a job.

Opportunistically, the severe recession triggered by the 2008 financial crisis and the subsequent slow recovery over the next decade provided a rare opportunity to empirically investigate the complex relationships among employment, individual health, and prescription drug utilization. With the country in a deep recession, the American economy experienced a sudden slowdown in growth and higher unemployment for three long years between 2007 and 2009. According to a 2010 Commonwealth Fund survey, about 9 million working-age adults lost their health insurance in 2008-2010. In addition, 75 million adults did not get needed healthcare with many skipping prescription drugs, doctor visits, and recommended tests and treatments (Theodorou et al. 2011). Researchers have argued that there might have been a fundamental change in Americans' preferences for healthcare and utilization patterns of healthcare because many people became extremely budgeting conscious both during the great recession and the subsequent period of job-less recovery (Fodman and Book 2010).

Another notable research opportunity arose from the great recession which coincided with the beginning of the Obama Administration’s Affordable Care Act (ACA) in 2010. ACA's ambitious goals included an increase in the quality of health care and affordability of health insurance while simultaneously lowering the uninsured rates and costs of healthcare. It is of policy significance to determine whether ACA has achieved the intended effects of reducing the number of uninsured and increasing the use of health care such as prescription drugs.

The purpose of this study therefore is to investigate the association between the interlocking influences of a change in an individual's employment status, personal health, and personal prescription drug utilization. To capture this complicated multifactorial relationship for an empirical investigation, we developed two-stage least squares and three-stage least squares statistical models based on the Grossman theory of healthcare utilization from the health economics literature. The data were from the Medical Expenditure Panel Survey (MEPS), a national representative sample of individual utilization of health services and prescription drugs for 2007-2016, a period spanning from the beginning of the great economic recession, to the slow recovery and the implementation of ACA.

The rest of the paper proceeds as follows. Section II reviews the earlier research about the effects of employment factors on drug utilization. Section III derives the theoretical framework and presents the empirical models. Section IV describes the data and variables used in this study,

and Section V focuses on the empirical results. Finally, Section VI concludes with a reflection of key policy implications of the findings.

LITERATURE REVIEW

The research on employment, health insurance, and prescription drug utilization is not new. For example, Bass and Woodward (1978) conducted a drug treatment experiment to demonstrate the efficacy of pooling community employment-related services to assist clients in drug addiction treatment. In the same vein, Silverman and Robles (1999) suggested that unemployment and prescription drug use were firmly related to observational data from various sources. The Grossman (1972) model of health demand proposed that the changing of employment and health status affecting healthcare utilization (including prescription drug utilization) when outlined the interaction between a demand function for health and a production function for health.

Using logistic regression techniques and controls for differences in socio-economic characteristics, Stronks et al. (1997) found a close association between income and health of individuals. The association was particularly strong due to employment status, especially among men. For women, however, the income was still found to be related to health controlling for employment status. Other researchers have focused on the relationships between unemployment and unhealthy health behaviors. Henkel (2011) summarized the results of a comprehensive review of research findings on the effect of unemployment on such preventive services as alcohol and drug addiction treatment and smoking cessation and found that unemployment increased the risk of relapse after alcohol and drug addiction treatment.

Recently, researchers have investigated the effects of insurance coverage and healthcare access and utilization. Using Census Bureau's Current Population Survey (CPS) data, Holahan (2011) found that the number of uninsured nonelderly Americans increased by 5.6 million, from 45 to 50 million during 2007-2009 employer-sponsored insurance plans experiencing a more considerable drop in the rate of coverage than public insurance programs. Researchers such as Truffer et al. (2010) found out that the rising unemployment rates and the loss of insurance subsidies were responsible for the observed slowing down of the growth of health care spending during the Great Recession.

At the individual level, Lusardi et al. (2010) and Lusardi et al. (2015) pointed out that more than a quarter of Americans had reported reducing their routine healthcare use during the great recession, not only among the unemployed but also the insured were not immune to the harmful effects of the recession. The pressure to cut business expenses had forced employers to raise copays to shift healthcare costs to their employees, thus negatively affecting the prescription drug use of those who remain employed. Based on the patient-level data from a large firm that had increased employee copayments on prescription drugs, Gibson et al. (2005) found that higher copayments were a significant barrier to prescription drug use, especially among employees with an existing chronic condition or a newly diagnosed chronic illness.

Our brief review of the literature shows that a large body of research on prescript drug utilization exists. However, the existing literature suffers from two major interrelated methodological weaknesses. First, most previous studies were empirical did not base on a broad-based conceptual framework (for example, the Grossman model used in this study) describing the interlocking relationships among prescription drug use, employment, and individual health status. Second, most previous studies used a single-equation approach intuitively to determine the effects

of employment and health on drug utilization and thus ignored the likelihood of the mutually dependent nature of the casual relationships. A single equation model can adequately investigate the relationship of association between two variables if the underlying relationship is one way; that is, the independent variable is genuinely independent, not dependent on other variables. In the interrelationship between drug use, employment, and individual health, the single-equation approach violates the underlying assumptions of regression analysis. It gives rise to inefficient and biased estimates.

Therefore, in this study, we use the well-known and empirically tested Medical Expenditure Panel Survey (MEPS) data for 2007-2016 to estimate a simultaneous equation system based on the Grossman theoretical model to address the interlocking effects of an individual's health and employment status on prescription drug uses. Using the Two-Stage Least Squares (2SLS) and Three-Stage Least Squares (3SLS) estimation techniques and controlling for gender, insurance status, wages, and initial incomes, we investigate in a statistically proper way the association among prescription drug utilization, personal health status, and the effect of gaining employment for working-age individuals.

THE EMPIRICAL MODEL AND ESTIMATION STRATEGY

The Conceptual Model

Our Grossman conceptual framework (Grossman 1972; 1999) begins with a health investment function in the Cobb-Douglas form:

$$I_i = EM_i^{1-\alpha} TH_i^{\alpha} X_i^{1-\beta} T_i^{\beta} \qquad (1)$$

where I_i is the gross investment in health of the i^{th} individual and it is posited to be influenced by a combination of exogenous and endogenous variables including: M_i and X_i are, respectively, the health input (prescriptions filled, for example) and all other market-purchased consumer goods; TH_i and T_i are the amount of time allocated for health production and leisure activities, respectively; and E_i is human capital (e.g., education, job training and experiences). Among the right-hand-side variables, E_i is assumed to be exogenous (already given and not to be determined by the i^{th} individual during the study period) while the rest are endogenous (to be determined by the i^{th} individual).

The time constraint facing the individual (24 hours a day, for example) implies that the total time available (Ω) must be allocated across major daily activity categories such as time for work (TW), time for market and nonmarket activities (TL), time invested in the production of health (TH), and time for leisure (T). Since $\Omega = TW_i + TL_i + TH_i + T_i$ in the Grossman framework, we replace T_i of equation (1) by $(\Omega - TW_i - TL_i - TH_i)$ and obtain:

$$I_i = EM_i^{1-\alpha} X_i^{1-\beta} TH_i^{\alpha} (\Omega - TW_i - TL_i - TH_i)^{\beta} \qquad (2)$$

With the elasticity, $\varepsilon = \frac{1}{1+C}$, the basic structural equations with the production function of health, equation (1) becomes,

$$lnH_i = \varepsilon \ln W_i - \varepsilon \ln \pi_i - \varepsilon ln\delta_i \qquad (3)$$

Where W_i represents the wage while employed and π_i is the marginal cost of gross investment in prescription drug spending (RXS) in period i with the rate of depreciation (δ_i). Grossman's notion that health stock as a capital good, enhanced by investment in health and diminishes with age, accidents, and risky behaviors (Grossman 1972; 1999). To be specific, H_i, the i[th] individual's health stock, is a function of wage income, the individual's health expenditures (include spending on prescription drugs), and the rate of health depreciation. H_i varies with age, a variable with direct or indirect effects (through the changing of health status) on health care services expenditures.

Since $\Omega = TW_i + TL_i + TH_i + T_i$, the health gross investment function becomes,

$$\ln I_i \equiv lnH_{i+1} + ln(1 + H_i/\delta_i) = \ln E_i + (1-\alpha)\ln M_i + \alpha \ln TH_i + (1-\beta)\ln X_i + \beta \ln(\Omega - TW_i - TL_i - TH_i) \quad (4)$$

Subtracting equation (3) from equation (4), we now obtain:

$$lnH_{i+1} + ln(1 + H_i/\delta_i) - lnH_i = \ln E_i + (1-\alpha)\ln M_i + \alpha \ln TH_i + (1-\beta)\ln X_i + \beta \ln(\Omega - TW_i - TL_i - TH_i) - \varepsilon \ln W_i + \varepsilon \ln \pi_i + ln\delta_i \quad (5)$$

After rearranging terms, equation (5) becomes,

$$\underbrace{lnH_{i+1} + ln(1 + H_i/\delta_i) - lnH_i}_{\Delta HG} = \ln E_i + (1-\alpha)\ln M_i + (1-\beta)\ln X_i + \varepsilon \ln \pi_i - \varepsilon \ln W_i + ln\delta_i + \underbrace{\alpha \ln TH_i + \beta \ln(\Omega - TW_i - TL_i - TH_i)}_{\Delta UG} \quad (6)$$

where $lnH_{i+1} + ln(1 + H_i/\delta_i) - lnH_i$ is the stock of the health of the i[th] individual which produces a stream of healthy relative to his age depreciation and previous health status in a given two-year period (ΔHG, label as *hg*), which will be the equation (9) below. The last term on the right hand side, $\alpha \ln TH_i + \beta \ln(\Omega - TW_i - TL_i - TH_i)$, in equation (6) is the individual's working time distribution and allocation, which is the gaining of employment process during the five rounds in the two-years (ΔUG, label as *eg*) period. The importance of this equation is that it precisely describes a change in employment status from unemployment to employment. In other words, the leisure time relates to the time with employment and the time under unemployment (Equation (10) below).

The essence of the Grossman model as developed in our study is that it is the change of employment and health status that affects health care utilization (including prescription drugs) rather than the employment and health status. Specifically, how long it takes an individual from unemployment to employment (gaining employment process) and the gaining health status from unhealthy. To date, no study addressing this point, previous literature either focus on employment or unemployment status or unhealthy conditions effects on healthcare utilization. One important reason might be that it is difficult to find such data to address this scenario. This framework's complex nature makes it difficult to empirically model the effects of those changes in employment and health status on health care utilization.

The MEPS Longitudinal Dataset has five rounds every two years, which provided us the necessary information to calculate the gaining of employment (ΔUG, or *eg*) and health status (ΔHG,

or *hg*). We could then capture how the marginal benefits (employment and better health status) equal the marginal cost of capital (prescription drug) in terms of the gross investment. The complicated relationship between drug utilization (*rxq*) and spending (*rxs*) is also a problem. To be specific, drug utilization (rxq) and drug expenditure can affect each other while the same is also true for drug expenditure and *eg* and *hg*. The empirical models of structural prescription drug utilization equations (investment), health and employment production function corresponding to the empirical model in this study are now presented as an equation system:

$$rxq = \beta_0 + \beta_1 hg + \beta_2 eg + \beta_3 age + \beta_4 lw + \beta_5 le + \beta_6 rxs + \beta_7 lnX + \varepsilon \quad (7)$$

$$rxs = \alpha_0 + \alpha_1 hg + \alpha_2 eg + \alpha_3 age + \alpha_4 lw + \alpha_5 le + \alpha_6 lnX + \epsilon \quad (8)$$

$$hg = \gamma_0 + \gamma_1 rx + \gamma_2 le + \gamma_3 age + \gamma_4 X + \mu \quad (9)$$

$$eg = \theta_0 + \theta_1 rx + \theta_2 erg + \theta_3 lw + \theta_4 X + \nu \quad (10)$$

where the lowercase variables are in natural logarithm and all variables have been defined as above. If we replace $\ln M_i$ with *rxq*, after rearranging the terms, equation (6) becomes equation (7), which is the demand for prescription drug equation. Further, if we replace the $\ln \pi_i$ with *rxs*, equation (6) becomes equation (8), the prescription drug spending equation. Equation (9), the gaining of the healthy status equation, derived from the empirical model equation (3) and ΔHG term in equation (6); and equation (10), the gaining of employment status equation, is derived from Equation (6), the corresponding MEC schedule in the Grossman model associated with the changing status from unemployment to employment, ΔUG term, and *erg* (regional employment-population ratio), *lw* (wages), and other variables, such as *linc* (non-wage income). Equation (9) and (10) address the endogeneity problem involving *rxq* and *rxs*.

Estimation Strategy

Since the goal of this study is to address the effects of the changing employment status on prescription drug utilization, estimations are all restricted to individuals age ranging from 18 (at the end of the first year in the two years) to 65 (at the end of the two years). By clustering the dwelling unit ID (DUID) to correct the potential problem of heteroscedasticity, we estimate the empirical models of structural prescription drug utilization and spending equations (7) to (8).

Our empirical estimation of the equation system of equations 7-10) begins with the ordinary least squares (OLS) regression to establish a general, albeit biased, picture of the relationship between the dependent variable (*rxq*, *rxs*) and the independent variables.The OLS estimation will be followed by a Two-Stage Least Squares (2SLS) estimation of the data to obtain unbiased and efficient estimates of structural parameters. Based on the 2SLS results, we finally perform a true simultaneous equation estimation using the Three-Stage Least Squares (3SLS) technique to address the endogeneity of *eg* and *hg* on both *rxq* and *rxs* and correct the duplicates problem from the 2SLS.

In the 2SLS approaches, we high a set of exogenous variables as instruments (wages, *lw*; age, *age*; non-wage income, *linc*; regional employment-population ratio, *erg*, and education, *le*) to handle the endogeneity of the gaining employment and health status variables (*eg* and *hg*). The time that the individual takes to gain employment from unemployment status is relevant to prescription drugs uses; however, the effect is very complicated. On the one hand, the switch from unemployment to employment status might attribute to the consumption of prescription medicines and the increase of human capital. On the other hand, the longer it takes an individual to get a job,

the less the health services the individual might consume because healthcare is a normal good. Besides, people tend to delay health services during the job-seeking process. For the first case, *eg* might have a positive relationship with drug utilization due to *hg*. Since *hg* is also an independent variable here, we expected *eg* to negatively affect drug utilization as the second case. In contrast, the third case would add complexity to the effect on RX (See Figure 3, The Hypothesized Modelling Diagram).

Since there are multiple endogenous variables and numerous instruments, we need to handle the identification problem. Fortunately, with the instrument variables (*lw*, *linc*, *erg*, and *le*) and two endogenous variables (*eg* and *hg*), we are still able to identify the structural equation's coefficients as the instruments are more than endogenous variables. The problem here will be the test of over-identification to the endogenous variable models, i.e., whether at least one of the instruments is wrong. Besides, we employ the Hansen J statistic for the overidentification test of all instrument variables. The Underidentification test (Kleibergen-Paap rk LM statistic) is precise, along with the test of endogeneity.

DATA AND VARIABLES

Data

The data source is the Medical Expenditure Panel Survey (MEPS), a nationally representative survey with rich individual-level data. A longitudinal data 2008-2016, and a two-year specific period with five rounds in each dataset, 2007-2008, 2009-10, 2010-11, and 2011-12 MEPS data used for analysis in depth. Individual patient characteristics include Employment status, Perceived Health Status, Income, Age, Gender, Race, Health insurance status (Uninsured), and the individual's education years. Observations for most of the variables are over 10,000 for each of the three datasets. Variable labels and definitions are in Table 1.

Table 1. Variable definition

Label	Definition
RXQ (rxq)	A count of all prescribed medications purchased during a specific year.
RXS (rxs)	Sums all amounts paid out-of-pocket and by third party payers for each prescription purchased in a specific year.
hg	If the individual has a change of perceived health status from less healthy level to healthier level in 1 to 4 rounds in the specific two-year period, then, hg equals to 1 to 4, respectfully.
eg	If the individual has a change from unemployment to employment status in 1 to 4 rounds in the specific two-year period, then, *eg* equals to 1 to 4, respectfully.
INC (linc)	Person's non-wage income.
UNINSURED	Uninsured=1, otherwise, 0.
FEMALE	Female=1, Male=0.
AGE (age)	Individual age.
E (*le*)	Individual's education years.
W (*lw*)	Individual's wage.
white	Individual's race, White=1, otherwise 0.

asian	Individual's race, Asian=1, otherwise 0.
hisp	Individual's race, Hispanic=1, otherwise 0.
erg	The regional employment to population ratio.

Note: Lowercase variable label, rxq, rxs, linc, age, lw, and le, are in natural logarithm.

The dependent variables in this study are RXQ and RXS (See Table 1). RXQ (RXTOT in MEPS data) is the natural log of Prescribed Medicines, including Refills in 2007-2016, the utilization quantity variable, which is a count (how many prescripts) of all prescribed medications purchased during a specific year (includes initial purchases and refills). RXS (RXEXP in MEPS data) is the natural log of the spending of Prescribed Medicines, including Refills 2007-2016. The expenditure variable sums all amounts paid out-of-pocket and by third-party payers for each prescription purchased in a specific year.

Why we have the two dependent variables in this study is mainly because of the distinctive feature of prescription drug consumption. Most of the medicines in the market have two names, brand name and generics. Unless those insensitive to money, individuals would have the chance to ask the doctor for the generic version instead of the brand name instead of generic drugs and save the amount of money. Therefore, individuals can adjust their consumption of prescription drugs, with a fixed amount of money consuming more with generics or with a fixed count of prescripts consuming less with the brand name. This feature of the consumption gives the individual consumer more choices but makes the prescription drug utilization more complicated. To fully capture the drug utilization, a simultaneous equation of seemly-unrelated regression with two dependent variables should be an excellent method to deal with this problem.

To capture the changes from unemployment to employment and from the less healthy to better status, we use the MEPS Panel sample with detailed information within five rounds in a specific two-year period. The individuals (with person ID: DUPERSID) on this dataset represent those who were in the MEPS population for all or part of 2007-2008, 2009-2010, 2011-12, 2013-14, and 2015-16 (we also have 2010-11 data estimation), which enable me to estimate the switching of employment and Perceived health status in full five rounds in the two years for the same individual. And the Dwelling unit ID, DUID, allows me to correct the potential heteroskedasticity in estimation by clustering the group effects.

To identify how the employment status can influence drug utilization by the individual, we need to figure out the definition and measure of drug utilization. The factors can drive up drug utilization first. Drug utilization research can involve different aspects of drug use, and drug prescribing, such as pattern, quality, determinants, and outcomes of use, the marketing, distribution, prescription drug uses in society, with particular emphasis on the resulting medical, social and economic consequences (Sjoqvist and Birkett, 2003).

According to different types of drug utilization research, the existing literature highlighted the importance of the demographics structure, insurance, race, and gender effects (Svarstad, *et al.*, 1987; Roe, et al., 2002; Simoni-Wastila, *et al.*, 2004; Sznitman, 2007; Han and Rizzo, 2012; Skoog, *et al.*, 2014) on the prescription drugs utilization. The prevalence of prescription drug use varies significantly by sex, age, and region of the country and varies across race race (Fillenbaum *et al.*, 1993). As for stressing the insurance influences on prescription drug spending, Leibowitz *et al*. (1985) and Thomas *et al*. (2002) suggested that individuals with more generous insurance buy more prescription drugs, and with more aggressive cost-sharing have lower total prescription drug spending.

In general, there is a positive relationship between income and healthcare utilization and expenditures (You and Okunade, 2017; Okunade *et al*., 2018); as the increase of the individuals' income (including wages and other income), people have the propensity to use and spend more on healthcare services, including prescription medications. Topically, females and older people use more prescription drugs than males and age groups for every drug benefiter. Besides, insurance status is related to the quantity of prescriptions individuals purchased. Therefore, the independent variables in this study include individual's demographic characteristics, age in years, gender (Female), non-wage income or discounted property income, wages, insurance status (Uninsured), Employment status (Unemployed, Employed), and Perceived health status (Poor, Fair, and Better than Good).

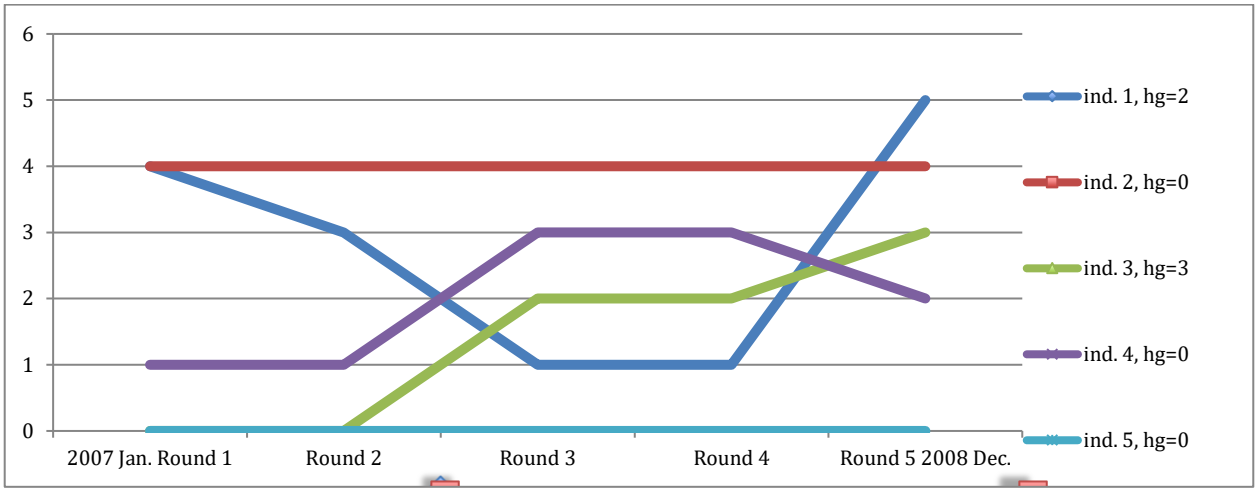
Variables selection and construction

The gaining of health status (ΔHG, or hg)

The two-year longitudinal data with five rounds of Perceived Health Status variables were applied to address the changing and recovery process of an individuals' health status. The variable of changing health status is a process from less healthy (< Good) to healthy (Good, or > Good, such as Very Good and Excellent) status. The Perceived Health Status "Good" is the threshold made to distinguish healthy to unhealthy.

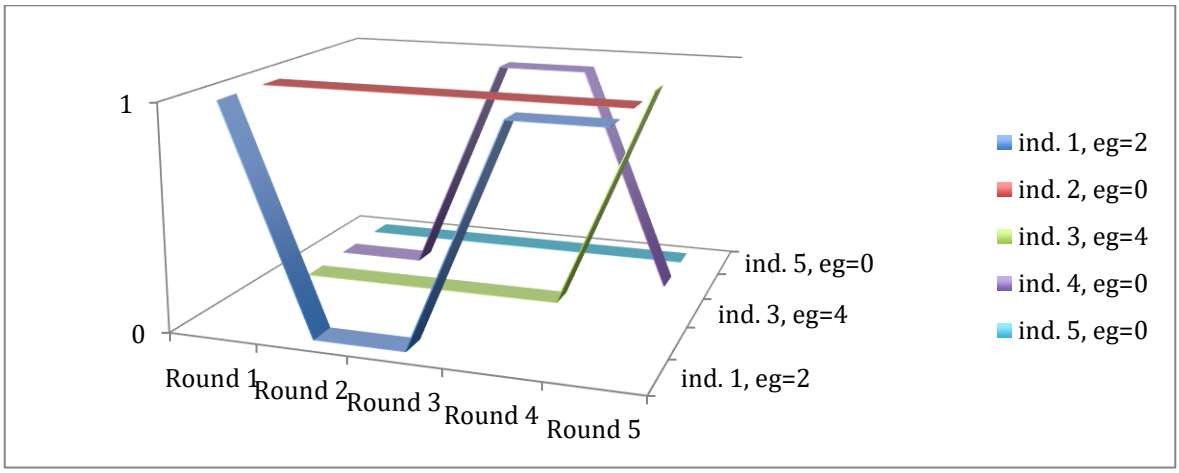
For example, Individual 1 with hg=2, means gaining healthy status (> =Good) in 2 rounds from a less healthy level (< Good). As shown in Graph 1, Individual 1's Perceived Health Status is Very Good (or even better, > Good) at Round 1, falls to Good at Round 2; it does not matter because Good is the threshold made in this study to distinguish healthy to unhealthy. This individual's Perceived Healthy status falls to Fair at Round 3 and 4, then increases to Excellent in Round 5, which means there are two rounds below "Good" before gaining "Good" or better health status; therefore, hg=2. Individual 2 and Individual 5 with hg=0 because their health status with no change though they have entirely different health status, one has been "Excellent" and the other has been "Poor" all the time. Individual 4 also has hg=0; this is because he falls less healthy after gaining a healthy status in 2 rounds. Since the goal in this research is to estimate the changing effects of health status, the hg=0 is not included. The gaining of healthy status will be hg_i, i=1, 2, 3, 4 (See Figure 1).

Figure 1: The gaining health status



Note: 1 to 5 stands for Poor, Fair, Good, Very Good, and Excellent, respectively.

Figure 2: The gaining employment status



Note: 1 stands for employed and 0 for unemployed.

Variables with direct or indirect effects on prescription drug utilization
The gaining employment from unemployment (ΔUG, or eg)

The average length of unemployment changed dramatically about 40 weeks with the 2007-2009 recession from 10 weeks typically. Hence, it would be meaningful to detect if the period from unemployment to employment status for an individual would affect his (her) prescription drug utilization. For the two-year MEPS Longitudinal Data, Δ*UG (eg*) is gaining employment from employment status for working-age individuals age 18-65 in 1 to 4 rounds within the 5-round in the two-year longitudinal period.

Given there are five rounds in each two-year longitudinal data file, the switch of employment status will have four different types, switching in one round, two rounds, three rounds, and four rounds. If the individual only uses one round to gain employment from the unemployment status, then eg=1, if he or she uses two rounds, the eg=2, etc. Again, since no changing on the employment status regardless of being unemployed or employed all the time, eg=0, which is not included in the changing of employment status, hence, eg_i, i=1, 2, 3, 4 (See Figure 2).

Independent variables in this study include individual's demographic characteristics, age in years, gender (Female), non-wage income, wages, insurance status (Uninsured), except the Employment and Perceived health status variables. Thornton and Rice (2011) suggests that insurance has a direct effect on healthcare spending, income, education, and age. It has an indirect impact because these variables are significant determinants of health status, which is an essential factor affecting healthcare spending. Meanwhile, the socio-economic variables, income, and education can have direct and indirect effects (via health status).

In general, the insurance coverage and availability can directly affect healthcare spending by affecting the individual patient's demand for healthcare services and influencing the cost of providing healthcare services to the supply side. The focus in this study is the demand for prescription medicine rather than the supply side given the dataset is the individual level. The insurance factor included here is an individual's Uninsured status to capture the insurance effects on prescription drug utilization, especially targeting the effect of the insurance beneficiary associated with the 2010 Affordable Care Act. Regarding the potential occurrence of adverse selection problems, some healthy people may choose *UNINSURED* under ACA insurance beneficiary because they have good health status. In contrast, the less healthy people may switch to insured (having any insurance), then the effect of *UNINSURED* on drug utilization will be more significant than some other times.

Typically, aging people use more prescription drugs than other age groups for every drug benefiter (Long 1994). Besides, female influences the prescription drug more related to the number of prescriptions purchased than the spending. Hence, female (*FEMALE*) should have been an exogenous variable with a direct effect on the prescription drug utilization from the individual perspective based on the individual-level data. Age (*age*), on the other hand, according to the theoretical model I derived, age (*age*) may have both direct and indirect effects (age depreciation effects, δ_i, on the changing of health status) on prescription drug utilization. Since this research focuses on the changing of employment effects on prescription drug utilization, I restrict the individuals aging from 18 to 65, the number of working-age in the US labor market.

Previous research has mostly stressed the positive relationship between income (total income) and healthcare spending while ignoring the potential indirect effect of income on healthcare spending through the individual patient's employment or health status. Income has a positive relationship with employment status, mainly due to the wage effect. To correct the high correlation between the total income the wage, we separate the individual's total income into the non-wage income (*linc*) and the wage earnings (*lw*). As a result of this variable selection, *linc* becomes an exogenous variable with an indirect effect on prescription drugs. At the same time, *lw* may have direct and indirect effects on drug utilization, which is precisely consistent with the theoretical Grossman framework we derived.

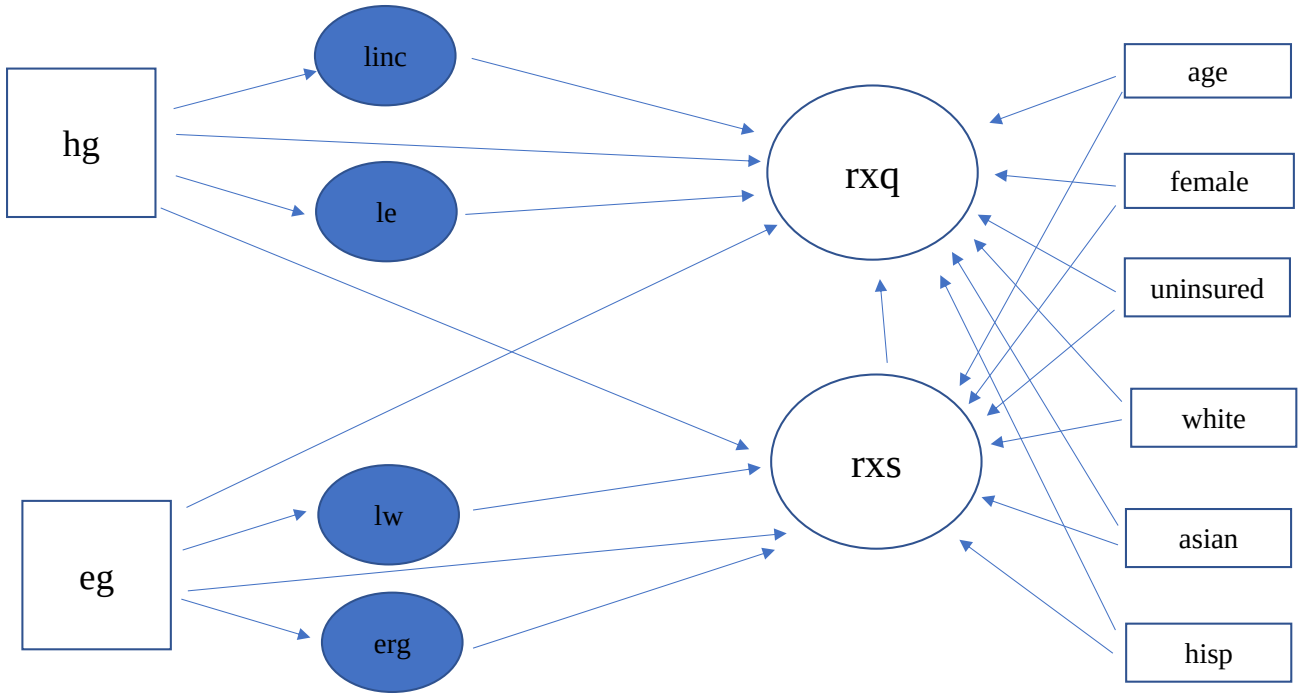
It is well known that years of education are the most critical correlation factors of health, robust to different health health (Grossman, 2000). Rosen and Taubman (1982) and Berger and Leigh (1989) suggests that education directly affects individuals' health status by increasing the

efficiency that individuals produce health. Thus, in this study, we use years of education as the instrument variable to measure the indirect effect of the gaining of healthy status on prescription drug utilization. The regional employment-population ratio, erg, may directly influence the individual's attitude towards actively seeking employment, while may not directly affect the individual's drug utilization, but through the changing process of gaining employment somehow. Therefore, the *erg* is used as an instrumental variable to *eg*. We also include some demographic characteristics, except *age* and *female* we have discussed, there is a group of the race variables, *white* (White), *asian* (Asian), and *hisp* (Hispanics).

Table 2. Descriptive statistics for 2007-2016

Variable	Obs.	Mean	SD	Min.	Max.
RXQ	41855	2.207	1.188	5.866	0.405
RXS	55467	5.052	2.275	12.821	0.405
HG	83666	0.508	0.764	4.000	0.000
EG	83666	0.147	0.580	4.000	0.000
AGE	81256	3.260	0.943	4.443	0.000
FEMALE	83666	0.522	0.500	1.000	0.000
UNINSURED	83666	0.124	0.330	1.000	0.000
LE	75579	1.832	0.882	2.833	0.000
LW	44842	9.880	1.168	12.556	1.504
LINC	32804	7.961	2.326	12.386	-0.693
WHITE	83666	0.613	0.487	1.000	0.000
ASIAN	83666	0.073	0.260	1.000	0.000
HISP	83666	0.317	0.465	1.000	0.000
ERG	83666	0.584	0.082	0.638	0.000

Figure 3: The Hypothesized Modelling Diagram



EMPIRICAL RESULTS

OLS Estimation Results

We begin with the Ordinary Least Squares (OLS) estimation to provide a set of results that serve as the baseline with which the 2SLS and 3SLS results will be compared. Table 3 and Table 4 present the results of OLS estimation for, respectively, the prescription drug utilization and spending equations forthe entire study period of 2007-2016 and Table 5 and Table 6 present the results of OLS estimation for the prescription drug utilization and spending equations for, respectively, the 2007-08, 2009-10, 2010-11, and 2011-12 subperiods. While most parameter estimates have expected signs, apparent magnitudes, and reasonable significance levels, the term variance, R^2 statistics range, is 0.14 -0.72, indicating that the models do not fit the dataset very well. The correlation test shows no high correlation among these variables. The joint effects F-tests (with P-value) of these seven variables are significant for the total dataset, 2007-2016, and separate four datasets as well, indicating that they jointly explain the variation in the drug utilization. Hence, we can use these variables for the simultaneous equation estimations.

Table 3: OLS Prescription Drug Utilization (rxq)
estimation results (t-statistics in parentheses)

	2007-2016		
Variables	Coef.	t	p
rxs	0.454963	178.0323	0.0000
hg	0.001534	0.259645	0.7951
eg	-0.004904	-0.799938	0.4238
age	0.541477	45.3719	0.0000
female	0.079445	9.198272	0.0000
UNINSURED	0.008612	0.565233	0.5719
lw	-0.077286	-20.67367	0.0000
white	-0.015998	-1.674077	0.0941
asian	-0.160569	-8.475633	0.0000
hisp	-0.035107	-3.369512	0.0008
_cons	-1.800636	-32.69811	0.0000
R-squared	0.659798		
Adjusted R-squared	0.659653		

Table 4: OLS Prescription Drug Utilization (RXS) estimation results (t-statistics in parentheses)

	2007-2016		
Variables	Coef.	t	p
hg	-0.025515	-1.596439	0.1104
eg	-0.045249	-2.803192	0.0051
age	2.024408	67.62211	0.0000
female	0.267644	11.63113	0.0000
UNINSURED	-0.890245	-23.68299	0.0000
lw	-0.182675	-17.85705	0.0000
white	0.285762	11.13844	0.0000
asian	-0.311537	-6.303835	0.0000
hisp	-0.575594	-21.1289	0.0000
_cons	-0.719338	-5.08957	0.0000
R-squared	0.178544		
Adjusted R-squared	0.178299		

Table 5: OLS Prescription Drug Utilization (rxq) estimation results (t-statistics in parentheses)

	2007-08		2009-10		2010-11		2011-12	
Variables	Coef.	t	Coef.	t	Coef.	t	Coef.	t
rxs	0.534	[79.55]	0.492	[84.97]	0.461	[67.93]	0.434	[73.58]
hg	0.003	[0.24]	0.005	[0.35]	-0.001	[-0.06]	-0.002	[-0.15]
eg	-0.039	[-2.34]	-0.007	[-0.49]	-0.029	[-1.84]	-0.03	[-2.08]
age	0.378	[10.84]	0.487	[16.1]	0.562	[15.69]	0.569	[17.85]
female	0.095	[4.66]	0.09	[4.64]	0.127	[5.76]	0.077	[3.87]
uninsured	-0.024	[-0.72]	0.03	[0.99]	0.031	[0.88]	-0.077	[-2.23]
lw	-0.089	[-8.15]	-0.096	[-9.56]	-0.097	[-9.14]	-0.1	[-9.53]
white	-0.055	[-0.88]	-0.167	[-2.9]	-0.088	[-1.23]	-0.119	[-2.13]
asian	-0.146	[-1.9]	-0.376	[-5.32]	-0.277	[-3.35]	-0.255	[-3.66]
hisp	0.023	[0.77]	-0.056	[-2.08]	-0.059	[-1.83]	0.004	[0.14]
_cons	-1.563	[-10.54]	-1.453	[-10.23]	-1.606	[-10.64]	-1.415	[-9.66]
R^2	0.717		0.678		0.653		0.62	

Note: Std. Err. adjusted for clusters in DUID.

Table 6: OLS Prescription Drug Utilization (RXS) estimation results (t-statistics in parentheses)

	2007-08		2009-10		2010-11		2011-12	
Variables	Coef.	t	Coef.	t	Coef.	t	Coef.	t
hg	-0.033	[-0.88]	-0.102	[-2.89]	-0.038	[-0.97]	0.02	[0.57]
eg	-0.093	[-2.38]	-0.063	[-1.69]	-0.041	[-1.06]	0.022	[0.61]
age	2.229	[27.05]	1.902	[23.98]	1.979	[22.21]	1.939	[24.48]
female	0.27	[4.8]	0.314	[5.95]	0.275	[4.49]	0.345	[6.52]
uninsured	-0.667	[-8.21]	-0.816	[-11.11]	-0.758	[-9.1]	-0.906	[-11.74]
lw	-0.245	[-8.14]	-0.198	[-7.19]	-0.132	[-4.14]	-0.1	[0]
white	0.031	[0.17]	0.131	[0.84]	0.162	[0.93]	-0.017	[-0.09]
asian	-0.526	[-2.44]	-0.778	[-4.08]	-0.355	[-1.74]	-0.577	[-2.71]
hisp	-0.72	[-8.53]	-0.721	[-9.98]	-0.626	[-7.58]	-0.639	[-9.62]
_cons	-0.442	[-1.13]	0.086	[0.23]	-0.987	[-2.34]	-1.092	[-2.74]
R^2	0.184		0.157		0.14		0.147	

Note: Std. Err. adjusted for clusters in DUID.

Since OLS estimations are likely to be bias and inconsistent because of the endogeneity, 2SLS estimations are employed to handle this problem. Using two successive applications of the OLS estimation, the 2SLS approach is a particular type of IV estimation and the default method for regressing over-identified models. After running an IV (using *le* to instrument *hg*, and *linc* and *erg* to instrument *eg*) regression, we check the weak Instrument Diagnostics, under-identification (Kleibergen-Paap rk LM statistic), and Over-identifying (Hansen J statistic overidentification) test of all instruments. Using the Endogenous test, we check the hypothesis that the endogenous variables are exogenous based on orthogonality conditions. Finally, we use the Hausman command to perform the Hausman Specification test to compare the IV regression performances to the OLS regression.

2SLS Results

To assess the pathways through which the changing of employment and health factors affect prescription drug utilization, we estimate the structural utilization and spending equations and the employment and health equation separately using the 2SLS approach. Table 7 presents the Structural Prescription Drug Utilization (*rxq*) estimation results (2SLS), and Table 8 shows the results from the Structural Prescription Spending (*rxs*) estimations (2SLS) for the total dataset, 2007-2016. And Table 9 presents the Structural Prescription Drug Utilization (*rxq*) estimation results (2SLS), and Table 10 shows the results from the Structural Prescription Spending (*rxs*) estimations (2SLS) for separate datasets, 2007-08, 2009-10, 2010-11, and 2011-12. The first stage estimations show the direct effect of wages (*lw*), income (*linc*), age (*age*), regional employment-population ratio (*erg*), and education on the endogenous variables, the gaining of employment (wages and non-wage income effects), and health status (education, age, and wages effects). And the 2SLS estimations suggest the indirect effects of the instrumental variables, *le*, *lw*, and *erg,* on the drug utilization and spending and the direct effects of other independent variables.

For the total data 2007-2016, according to the result in Table 7, the utilization of prescription drugs has a negative relationship with the changing of health status from bad to good, and a positive relationship with the changes of employment status from unemployment to employment. The total effects of the changing health status on drug utilization (*rxq*) are significant with a value, -0.918. The overall effects of the gaining employment status on drug utilization are positive but insignificant with a value, 0.202. Results in Table 8 shows that there are negative effects (statistically significant) of both gaining healthy status and the changing employment status (*eg*) on prescription drug spending (*rxs*) for all the period, 2007-2016, with values -10.143 and -22.045, respectively.

According to Table 9 results, prescription drugs' utilization has a positive relationship with the changing of health status and the changes in employment status from unemployment to employment most of the time. The total effects of the changing health status on drug utilization (rxq) are significant with values, 0.779, 0.775, 0.281, and -2.191 (insignificant), for 2007-08, 2009-10, 2010-11, and 2011-12, respectfully. The total effects of the changing health status on drug utilization (rxq) are significant with values, 0.779, 0.775, 0.281, and -2.191 (insignificant), for 2007-08, 2009-10, 2010-11, and 2011-12, respectfully. The total effects of the gaining employment status on drug utilization are positive but insignificant at 0.228, -0.122, 0.224, and 1.309, for 2007-08, 2009-10, 2010-11, and 2011-12, respectfully. Results in Table 10 show that the effects of gaining healthy status on prescription drug spending are insignificant for all four periods. The total effects of the changing employment status (eg) are also insignificant on rxs, only significant with 1.377 for 2009-10. The significant effect of eg in 2009-10 suggests that the longer time the individual to get employment, the more he/ she spends on drugs during the launch of the Affordable Care Act (ACA).

There are four instrument variables, education (for hg), erg (for eg), linc (for eg) and lw (for both hg and eg) for both drug utilization and expenditure estimations. For the total data, 2007-2016, education (le) has a significantly positive effect, 0.059, on gaining healthy status; wages (lw) has both direct and indirect effects on drug utilization, with negative effects on gaining employment status, (eg), -0.16, statistically significant. The non-wage income has significantly positive effects on eg, 0.012, which make sense that people may spend a long time finding a high pay job, while with a higher non-wage income.

For the separate datasets, education (le) has a negative effect (le, -0.138, -0.149, -0.109, and -0.012, for 2007-08, 2009-10, 2010-11, and 2011-12, respectively) on gaining healthy status, statistically significant for three out of four estimations. While wages (lw) has negative effects on gaining employment status, (eg), -0.157, -0.159, -0.158, and -0.185, for 2007-08, 2009-10, 2010-11, and 2011-12, respectively. And the non-wage income has positive effects on eg (0.013, 0.018, 0.02, and 0.015, for 2007-08, 2009-10, 2010-11, and 2011-12, respectively), again, which makes sense people may spend a long time to find a high pay job. The higher the wage, the faster the individual wants to get a job; people tend to be more sensitive to wages.

The regional employment-population ratio (erg) has a positive relationship with the gaining of employment status (eg) for all datasets. This result suggests that, with a higher erg, individuals in the area tend to have a relatively longer time gaining employment. Why? On the one hand, the higher erg, the hard to find a job; on the other hand, the higher the erg, the more confidence the individuals will have on finding a high-pay job (with longer seeking time).

Age (age) has a negative relationship with the gaining of health status and gaining employment, except for 2007-2008 (positive but insignificant). As age increases, people tend to have less recovery time from less healthy to healthy status and less time on gaining employment.

Table 7: Structural Prescription Drug Utilization (rxq) estimation results (t-stat in parentheses)

	2007-2016	
	First-stage regressions	
hg	Coef.	p-value
rxs	-0.007	0.087
age	-0.043	0.082
female	-0.024	0.084
uninsured	0.089	0.003
lw	-0.012	0.070
white	0.018	0.278
asian	0.022	0.446
hisp	0.067	0.000
linc	0.001	0.843
le	0.069	0.000
erg	0.199	0.409
_cons	0.499	0.005
	F value	P-value
Excluded instruments F test	12.16	0.000
	First-stage regressions	
eg	Coef.	p-value
rxs	-0.010	0.020
age	-0.263	0.000
female	0.008	0.569
uninsured	0.051	0.143
lw	-0.155	0.000
white	0.031	0.077
asian	-0.005	0.841
hisp	-0.011	0.601
linc	0.014	0.000
le	-0.028	0.048
erg	0.086	0.053
_cons	2.737	0.000
	F value	P-value
Excluded instruments F test	12.820	0.000
	Instrumental variables (2SLS) regression	
rxq	Coef.	p-value
hg	-0.918	0.000
eg	0.202	0.445
rxs	0.462	0.000
age	0.529	0.000
female	0.045	0.016
uninsured	0.054	0.270
lw	-0.066	0.141
white	-0.014	0.568
asian	-0.181	0.000
hisp	-0.037	0.190
_cons	-1.51	0.073

Test of joint significance of endogenous Statistics	Chi2 (1)	P-value
Anderson-Rubin Wald test	F value: 14.81	0.000
Anderson-Rubin Wald test	44.47	0.000
Stock-Wright LM S stat.	43.16	0.000
Underidentification test (Kleibergen-Paap rk LM statistic)	23.107	0.000
Hansen J statistic (overidentification test of all instruments)	2.761	0.090
Hausman test	40.41	0.000

Note: OLS regression with robust standard errors and clusters (DUID)

Table 8: Structural Prescription Drug Spending (rxs) estimation results (t-stat in parentheses)

	2007-2016	
	First-stage regressions	
hg	Coef.	p-value
age	-0.022	0.319
female	-0.016	0.186
uninsured	0.067	0.009
lw	-0.014	0.021
white	0.008	0.583
asian	-0.008	0.749
hisp	0.061	0.001
linc	0.001	0.809
le	0.059	0.000
erg	0.351	0.056
_cons	0.347	0.012
	F value	P-value
Excluded instruments F test	9.62	0.000
	First-stage regressions	
eg	Coef.	p-value
age	-0.261	0.000
female	0.014	0.248
uninsured	0.036	0.219
lw	-0.160	0.000
white	0.018	0.257
asian	-0.006	0.794
hisp	0.004	0.808
linc	0.012	0.000
le	-0.027	0.025
erg	0.203	0.040
_cons	2.717	0.000
	F value	P-value
Excluded instruments F test	10.740	0.000

	Instrumental variables (2SLS) regression	
rxs	Coef.	p-value
hg	-10.143	0.021
eg	-22.045	0.000
age	-3.726	0.001
female	0.361	0.227
uninsured	0.654	0.407
lw	-3.977	0.000
white	0.610	0.129
asian	-0.691	0.236
hisp	-0.120	0.805
_cons	-69.116	0.000
Test of joint significance of endogenous Statistics	Chi2 (1)	P-value
Anderson-Rubin Wald test	F value: 16.02	0.000
Anderson-Rubin Wald test	48.1	0.000
Stock-Wright LM S stat.	4238.66	0.000
Underidentification test (Kleibergen-Paap rk LM statistic)	28.522	0.000
Hansen J statistic (overidentification test of all instruments)	151.168	0.000
Hausman test	27.30	0.001

Note: OLS regression with robust standard errors and clusters (DUID)

Table 9: Structural Prescription Drug Utilization (rxq) estimation results (t-stat in parentheses)

	2007-08		2009-10		2010-11		2011-12	
	First-stage regressions							
hg	Coef.	t	Coef.	t	Coef.	t	Coef.	t
rxs	-0.023	[-2.07]	-0.026	[-2.81]	-0.016	[-1.53]	-0.01	[-1.03]
age	0.004	[0.06]	-0.057	[-1.02]	-0.083	[-1.35]	-0.057	[-1.05]
female	0.004	[0.11]	0.007	[0.25]	0.01	[0.28]	-0.055	[-1.77]
uninsured	-0.039	[-0.6]	-0.025	[-0.47]	0.107	[1.84]	-0.023	[-0.34]
lw	-0.022	[-1.13]	-0.026	[-1.7]	0.008	[0.45]	-0.003	[-0.17]
white	0.08	[1.68]	0.016	[0.32]	0.035	[0.74]	-0.015	[-0.35]
asian	0.235	[2.6]	-0.09	[-1.32]	-0.015	[-0.19]	-0.05	[-0.68]
hisp	-0.105	[-1.78]	0.007	[0.14]	-0.04	[-0.71]	0.091	[1.78]
linc	0.004	[0.55]	0.007	[1.04]	0	[0.03]	0.01	[1.47]
le	-0.194	[-2.27]	-0.122	[-1.36]	-0.112	[-1.22]	0.038	[0.45]
erg	1.051	[5.23]	0.938	[0.11]	-1.72	[-1.29]	0.514	[2.03]
_cons	0.612	[1.89]	0.798	[2.86]	2.12	[3.73]	0.39	[1.2]
Test Statistics	F	P-value	F	P-value	F	P-value	F	P-value
Excluded instruments F test	7.57	0.000	2.85	0.036	5.88	0.000	2.43	0.06

Angrist-Pischke multivariate excluded F test	7.96	0.000	3.36	0.035	4.06	0.007	19.5	0.000
eg	Coef.	t	Coef.	t	Coef.	t	Coef.	t
rxs	-0.027	[-3.03]	-0.011	[-1.14]	-0.01	[-0.95]	-0.009	[-1.01]
age	-0.135	[-2.01]	-0.196	[-3.32]	-0.262	[-3.64]	-0.347	[-5.67]
female	0.058	[2.34]	-0.032	[-1.17]	-0.049	[-1.44]	-0.014	[-0.45]
uninsured	0.08	[1.2]	0.145	[2.31]	0.052	[0.73]	0.108	[1.51]
lw	-0.14	[-5.58]	-0.135	[-6.25]	-0.161	[-6.54]	-0.178	[-7.48]
white	0.006	[0.14]	0.052	[1.32]	-0.032	[-0.65]	-0.051	[-1.11]
asian	0.02	[0.3]	0.007	[0.12]	-0.021	[-0.27]	0.039	[0.53]
hisp	0.066	[1.08]	-0.059	[-1.47]	0.055	[0.94]	-0.045	[-0.94]
linc	0.012	[2.3]	0.018	[3.08]	0.019	[2.77]	0.016	[3.31]
le	0.089	[1.05]	0.069	[0.97]	0.041	[0.33]	0.004	[0.04]
erg	0.299	[1.78]	0.364	[2.59]	0.477	[2.6]	0.431	[1.97]
_cons	1.731	[4.92]	1.831	[5.68]	2.444	[5.33]	3.075	[7.73]
Test Statistics	F	P-value	F	P-value	F	P-value	F	P-value
Excluded instruments F test	5.99	0.000	11.86	0.000	2.71	0.029	4.85	0.002
Angrist-Pischke multivariate excluded F test	7.91	0.000	15.47	0.000	2.67	0.046	6	0.0005
	Instrumental variables (2SLS) regression							
rxq	Coef.	t	Coef.	t	Coef.	t	Coef.	t
hg	0.779	[2.64]	0.775	[1.87]	0.281	[0.82]	-2.191	[-0.63]
eg	0.228	[0.45]	-0.122	[-0.28]	0.224	[0.6]	1.309	[0.49]
rxs	0.575	[30.09]	0.525	[38.94]	0.476	[37.47]	0.435	[14.88]
age	0.364	[3.97]	0.458	[5.25]	0.66	[5.95]	0.86	[1.21]
female	0.102	[2.06]	0.089	[2.34]	0.155	[4.1]	-0.046	[-0.26]
uninsured	-0.052	[-0.58]	0.144	[1.6]	-0.064	[-0.79]	-0.22	[-0.52]
lw	-0.031	[-0.45]	-0.081	[-1.41]	-0.06	[-0.91]	0.122	[0.25]
white	-0.141	[-2.58]	-0.066	[-1.28]	-0.024	[-0.5]	-0.042	[-0.28]
asian	-2.269	[-2.32]	-0.172	[-1.85]	-0.167	[-2.14]	-0.339	[-1.04]
hisp	0.118	[1.66]	-0.032	[-0.5]	-0.006	[-0.11]	0.31	[0.72]
_cons	-2.732	[-2.47]	-2.163	[-2.42]	-2.762	[-2.22]	-3.992	[-0.61]
Test Statistics	Chi2 (1)	P-value	Chi2 (1)	P-value	Chi2 (1)	P-value	Chi2 (1)	P-value
Test of endogeneity	77.832	0.000	19.026	0.000	111.027	0.000	210.921	0.000
Underidentification test (Kleibergen-Paap rk LM statistic)	19.801	0.000	6.995	0.030	7.133	0.068	45.263	0.000
Hansen J Overidentifying restrictions	32.419	0.000	0.221	0.639	25.192	0.000	1147.72	0.000

Note: OLS regression with robust standard errors and clusters (DUID)

Table 10: Structural Prescription Drug Spending (rxs) estimation results (t-statistics in parentheses)

	2007-08		2009-10		2010-11		2011-12	
	First-stage regressions							
hg	Coef.	t	Coef.	t	Coef.	t	Coef.	t
age	-0.037	[-0.71]	-0.05	[-1.05]	-0.06	[-1.12]	-0.041	[-0.88]
female	0.019	[0.65]	-0.003	[-0.1]	0.002	[0.06]	-0.051	[-1.81]
uninsured	-0.016	[-0.3]	0.039	[0.82]	0.03	[0.63]	0.022	[0.38]
lw	-0.023	[-1.31]	-0.011	[-0.79]	0.003	[0.17]	-0.015	[-0.98]
white	0.061	[1.41]	-0.02	[-0.52]	0.018	[0.42]	0.002	[0.06]
asian	0.156	[2.09]	-0.038	[-0.6]	-0.036	[-0.5]	0.006	[0.08]
hisp	-0.064	[-1.25]	0.04	[0.91]	-0.042	[-0.83]	0.085	[1.89]
linc	0.005	[0.82]	0.003	[0.44]	-0.002	[-0.24]	0.008	[1.37]
le	-0.138	[-1.85]	-0.149	[-1.91]	-0.109	[-1.34]	-0.012	[-0.15]
erg	0.945	[5.6]	0.877	[0.96]	-1.811	[-1.41]	0.364	[1.27]
_cons	0.545	[1.94]	0.624	[2.45]	2.066	[3.81]	0.589	[1.86]
Test Statistics	F	P-value	F	P-value	F	P-value	F	P-value
Excluded instruments F test	7.57	0.000	2.86	0.036	5.86	0.000	1.24	0.294
Angrist-Pischke multivariate excluded F test	7.96	0.000	3.38	0.034	4.03	0.007	19.5	0.000
eg	Coef.	t	Coef.	t	Coef.	t	Coef.	t
age	-0.188	[-3.37]	-0.182	[-3.64]	-0.278	[-4.52]	-0.371	[-6.82]
female	0.05	[2.09]	-0.04	[-1.55]	-0.031	[-1.01]	-0.026	[-0.95]
uninsured	0.083	[1.43]	0.174	[3.11]	0.036	[0.58]	0.082	[1.29]
lw	-0.157	[-6.58]	-0.159	[-7.7]	-0.158	[-6.95]	-0.185	[-8.38]
white	-0.003	[-0.08]	0.047	[1.27]	-0.085	[-1.81]	-0.052	[-1.26]
asian	0.042	[0.64]	0.052	[0.91]	-0.057	[-0.86]	0.018	[0.29]
hisp	0.087	[1.65]	-0.062	[-1.63]	0.033	[0.63]	-0.028	[-0.65]
linc	0.013	[2.61]	0.018	[3.17]	0.02	[3.41]	0.015	[3.24]
le	0.134	[1.73]	0.132	[2.09]	0.021	[0.2]	-0.015	[-0.2]
erg	0.374	[2.27]	0.355	[2.54]	0.477	[2.55]	0.319	[2.36]
_cons	1.786	[5.7]	1.813	[6.23]	2.501	[5.95]	3.318	[9.13]
Test Statistics	F	P-value	F	P-value	F	P-value	F	P-value
Excluded instruments F test	5.99	0.000	11.85	0.000	2.71	0.029	4.12	0.006
Angrist-Pischke multivariate excluded F test	7.91	0.000	15.5	0.000	2.67	0.046	6	0.0005
	Instrumental variables (2SLS) regression							
rxs	Coef.	t	Coef.	t	Coef.	t	Coef.	t
hg	-0.133	[-0.16]	-0.424	[-0.63]	0.199	[0.24]	3.554	[0.49]
eg	1.207	[1.27]	1.377	[1.75]	0.709	[0.74]	0.608	[0.13]
age	2.431	[11.27]	2.145	[11.57]	2.299	[7.94]	2.373	[1.59]
female	0.123	[1.27]	0.329	[3.84]	0.258	[2.7]	0.512	[1.84]
uninsured	-0.705	[-4.19]	-1.07	[-5.1]	-0.877	[-5.8]	-1.037	[-2.9]

lw	-0.094	[-0.63]	0.035	[0.27]	-0.055	[-0.33]	0.029	[0.04]
white	0.225	[1.72]	0.204	[1.69]	0.308	[2.18]	0.449	[1.43]
asian	-0.405	[-1.7]	-0.715	[-3.5]	-0.337	[-1.66]	-0.013	[-0.04]
hisp	-0.641	[-4.08]	-0.35	[-2.32]	-0.55	[-4.21]	-0.705	[-0.92]
_cons	-3.034	[-1.29]	-3.394	[-1.69]	-3.306	[-1.04]	-6.415	[-0.54]
Test Statistics	Chi2 (1)	P-value	Chi2 (1)	P-value	Chi2 (1)	P-value	Chi2 (1)	P-value
Test of endogeneity	69.5	0.000	9.357	0.009	48.21	0.000	210.921	0.000
Underidentification test (Kleibergen-Paap rk LM statistic)	19.801	0.000	7.039	0.030	7.112	0.068	45.263	0.000
Hansen J Overidentifying restrictions	33.738	0.000	0.009	0.925	36.185	0.000	1147.72	0.000

Note: OLS regression with robust standard errors and clusters (DUID)

Uninsured status (*UNINSURED*), a critical variable, has insignificant effects on both drug utilization (*rxq*) and expenditures (*rxs*) for the total period of 2007-2016. However, when checking the separate data periods, *UNINSURED* has significant effects on drug spending (*rxs*) with values of -0.705, -1.07, -0.877, and -1.037 2007-08, 2009-10, 2010-11, and 2011-12, respectively. The result shows that there are apparent differences in drug spending between the uninsured and insured during the launching of the ACA period comparing with those from the usual period. This difference might be the evidence of how the aiming (affordability of health insurance, lowering the uninsured rate) of the Affordable Care Act works in the sense of adverse selection problem. The significantly negative effect on the higher coefficient value of UNINSURED on both drug utilization and spending for 2010-2011 created a significant gap between uninsured and insured individuals, which is a sign of the ACA insurance benefit.

Female (*FEMALE*) has a positive effect on both drug utilization (significant) and spending (insignificant), statistically significant for four periods most of the time for the separate datasets, suggesting that women tend to use more drugs while may not spend more money. Among the race variables, *hisp* (Hispanic) always has significantly negative effects on drug utilization and spending, while white has significantly positive effects on drug spending.

Along with the 2SLS approach, we performed the excluded instruments test, endogeneity test, under-identification and overidentifying test, and Hausman test. Those tests suggest good and reasonable estimations for drug spending (rxs) and quantity (rxq) models. Tables 7&8 show the test results from the total data, 2007-2016, while Tables 9&10 are the test results from the separate datasets for four two-year periods. Test results indicate the validity of the three instrument variables for the endogenous variable, the gaining of employment and health status (*eg* and *hg*). Endogeneity tests' results reject the exogenous null hypotheses of *eg* and *hg*, while Kleibergen-Paap rk LM statistics indicate no under-identification at a 10% level. And the Hansen J statistics reject the presence of overidentification of all instruments (3 IV: *lw, erg*, and *le*).

As discussed theoretically in this research, *age* and *wage* have direct and indirect effects on drug utilization; however, 2SLS estimations involve the duplicates problem if we regress the *age* and *wage* as both instrument variables to *hg* and an explanatory variable for drug utilization as the same time. Thus, we need the 3SLS estimation to get more accurate and valid empirical results.

3SLS Results

To handle the duplicates problem in 2SLS, we apply the Three-Stage Least Squares (3SLS) approach with equations (7, 8, 9, and 10) to estimate the structural coefficients on direct and indirect (employment and health) effects on the prescription drug utilization. Specifying a structural model for each endogenous repressor, the 3SLS estimator uses the cross-correlation of errors to produce a more precise and efficient estimation than 2SLS.

Table 11 presents the results of 3SLS estimations for the structural prescription drug investment equation (1) and (2), and health and employment production function equation (3) and (4) for the total data 2007-2016. The coefficients of the health changing status variable (*hg*) in both the structural prescription drug utilization (*rxq*) and spending (*rxs*) equations are positive and statistically significant, 2.811 and 2.759, respectively. The change of employment status has positive effects on both prescription drug utilization (significant) and spending as well, while an insignificant on spending equation. Thus, results from 3SLS suggest that the gaining of employment status plays an essential role in increasing drug utilization. People who used more

time to gain employment tend to use more drugs while they may not spend more, which is a sign of delayed health services because of losing jobs.

Table 12 presents 3SLS estimations for the prescription drug with the separate datasets, 2007-08, 2009-10, 2010-11, and 2011-12. The effects of both health changing status variable (*hg*) and the changes in employment status (*eg*) on drug utilization and spending are quite different from those for the total period estimation. The coefficients of the health changing status variable (*hg*) in the structural prescription drug utilization (*rxq*) equation are positive but not significant, while negative, most of the time on spending but insignificant, neither. The insignificant effects on drug utilization, along with the insignificantly negative effects on spending suggest, the longer the recovery time of the health status, individuals may tend to use less expensive medicines (generic version) and reduce the drug spending. In contrast, the count of the prescription drug does not change. The employment status changes have statistically significant negative effects on prescription drug utilization and positive effects but insignificant on spending equation for three estimations, 2007-08, 2010-11, and 2011-12. However, during 2009-10, on the contrary, the gaining of employment, *eg*, has significant positive effects on drug spending. These results suggest that during the great recession and recovery period, people spent more time gaining employment while they might not use more prescription drugs or spend more on it. As the launch time of the Affordable Care Act, individuals behaved differently; the longer is gaining an employment status, individuals tend to spend more on prescription drugs.

For the total data 2007-2016 (See Table 11), the uninsured effects on both drug utilization (-1.401) and spending (-1.077) are negative and significant as expected. For the separate datasets (See Table 12), the uninsured effects on drug spending (-0.455, -0.855, -0.659, and -0.833) are also negative and significant as expected (insignificant) on the drug utilization. The evidence of change about insurance effects associated with the Affordable Care Act may influence the prescription drug spending somehow but no apparent effects on the count of the drugs individuals purchased (adverse selection). Under the immediate implementation of ACA, the gap of drug spending and quantity between the insured individuals and uninsured became smaller than those from the total period, 2007-2016. The healthy individuals may still choose to be uninsured under the ACA because the ACA placed no penalty on acquiring insurance until 2014, even though the uninsured status would discount the impact of the individual mandate tax penalty that would compel individuals to purchase care. Some individuals did enjoy the health benefit under the ACA policy as the launch period with significant and more considerable effects for 2010-2011 on both drug utilization (Coefficient: -4.089, t= -4.98) and spending. However, the effects will decay on the value of the coefficient afterward, and the significance of the ACA effects is not that strong (2011-12 for drug spending, insignificant for utilization).

In consistence with previous findings, we also find that age and female consume more prescription drugs, the effects of these two variables on both utilization and spending. female with significant positive effects on utilization while age with significantly positive effects on spending, indicating female individuals tend to consume more drugs with not considerably higher expenditure. In contrast, aged individuals tend to spend more on prescription medicines.

Overall system heteroscedasticity tests for 3SLS with Breusch-Pagan LM, Likelihood Ratio LR, and Wald statistics, suggest no overall system heteroscedasticity in all estimations. Hansen-Sargan overidentification statistics reject the overidentification problem of all instruments for all estimations. The Hausman specification test indicates that the coefficients of the OLS and 3SLS models are not equal statistically.

Comparing with the results form 2SLS estimation, the estimated effects for hg and eg are more consistent in the 3SLS estimation than those in 2SLS. The comparisons for the uninsured effects for 2SLS and 3SLS on the prescription drug spending estimations also give out very close results except for 2007-08. These similar estimates of direct effects are indications of the robustness of these two alternative methods of estimation. What we expect from 3SLS are more precise estimates of the parameters given the validity of our specification and the use of the covariance among the disturbances.

Overall, the OLS biased estimates of the parameters due to the endogeneity of hg and eg, are inconsistent in the violation of OLS assumptions. Using 2SLS, the estimation of the parameters becomes consistent. Simultaneously, it still needs to be improved since age and wage (Duplicate problem in 2SLS) have both direct and indirect effects on drug utilizations. Finally, with 3SLS, estimations are both consistent and efficient than those obtained by OLS and 2SLS. The 3SLS approach can correct the endogenous problem (in OLS) by hg and eg and duplicates issue (in 2SLS) by age and wage.

Table 11: Structural Prescription Drug Utilization equation and health production function estimation results (t-statistics in parentheses)

Three-stage least-squares regression		
	2007-2016	
	Coef.	p-value
rxq		
rxs	0.881	0.000
hg	2.811	0.008
eg	1.785	0.006
age	3.348	0.000
female	0.103	0.011
uninsured	-1.401	0.000
lw	-0.014	0.866
white	0.116	0.043
asian	-0.503	0.000
hisp	-0.714	0.000
_cons	-6.761	0.001
chi 2 (P-value)	168.050	0.000
rxs		
hg	2.759	0.000
eg	1.169	0.127
age	2.087	0.000
female	0.042	0.449
uninsured	-1.077	0.000
lw	0.038	0.769
white	0.097	0.163
asian	-0.239	0.038
hisp	-0.556	0.000

_cons	-3.879	0.111
chi 2 (P-value)	486.020	0.000
Heteroscedasticity Tests	Chi2	P-value
Breusch-Pagan LM Test	8356	0.000
LR Test	16500	0.000
Wald Test	7600	0.000
Hansen-Sargan overidentification statistic	0.797	0.372
Hausman test	88.11	0.000

Table 12: Structural Prescription Drug Utilization equation and health production function estimation results (t-statistics in parentheses)

Three-stage least-squares regression								
	2007-08		2009-10		2010-11		2011-12	
	Coef.	Z	Coef.	Z	Coef.	Z	Coef.	Z
rxq								
rxs	0.343	[0.27]	1.673	[2.49]	-5.628	[-6.85]	4.882	[2.38]
hg	0.677	[1.04]	0.398	[0.56]	-0.745	[-0.27]	-19.691	[-1.02]
eg	0.387	[0.38]	-2.225	[-1.58]	-6.34	[-2.09]	-0.52	[-0.04]
age	0.813	[0.34]	-1.60	[-1.32]	11.843	[6.69]	-8.23	[-1.56]
female	0.089	[1.03]	-0.026	[-0.28]	0.463	[1.52]	-1.227	[-1.18]
uninsured	-0.157	[-0.27]	1.161	[1.89]	-4.089	[-4.98]	3.481	[1.39]
lw	-0.062	[-0.34]	-0.246	[-1.82]	0.086	[0.17]	0.217	[0.10]
white	-0.083	[-0.26]	-0.174	[-1.63]	2.089	[4.65]	-1.527	[-1.65]
asian	-0.275	[-2.12]	0.208	[0.77]	-1.15	[-1.86]	-0.78	[-0.51]
hisp	0.011	[0.02]	0.354	[1.41]	-3.356	[-5.51]	3.13	[1.27]
_cons	-2.712	[-2.21]	1.149	[0.46]	-12.437	[-1.28]	14.484	[0.48]
chi 2 (P-value)	525.3	(0.000)	190.62	(0.000)	59.23	(0.000)	11.67	(0.307)
rxs								
hg	-0.442	[-0.68]	0.325	[0.33]	-0.17	[-0.19]	3.93	[0.55]
eg	0.685	[0.69]	1.831	[1.85]	1	[1.06]	0.414	[0.08]
age	1.936	[9.29]	1.793	[8.21]	1.832	[6.06]	2.044	[1.57]

female	-0.055	[-0.57]	0.101	[1.09]	0.05	[0.52]	0.265	[0.74]
uninsured	-0.455	[-2.91]	-0.885	[-4.16]	-0.659	[-3.31]	-0.833	[-1.11]
lw	-0.135	[-0.97]	0.144	[1.07]	0.024	[0.15]	-0.021	[-0.02]
white	0.251	[2.28]	0.095	[0.77]	0.346	[3.08]	0.334	[1.32]
asian	-0.023	[-0.10]	-0.331	[-1.52]	-0.161	[-0.83]	0.099	[0.16]
hisp	-0.461	[-3.49]	-0.336	[-2.16]	-0.549	[-4.14]	-0.634	[-0.75]
_cons	0.092	[0.04]	-2.88	[-1.30]	-1.579	[-0.51]	-4.159	[-0.35]
chi 2 (P-value)	278.82	(0.000)	149.87	(0.000)	195.63	(0.000)	72.25	(0.000)
Heteroscedasticity Tests	Chi2(1)	P-value	Chi2(1)	P-value	Chi2(1)	P-value	Chi2(1)	P-value
Breusch-Pagan LM Test	62.08	0.000	1581.323	0.000	1831.748	0.000	2223.409	0.000
LR Test	63	0.000	2610.41	0.000	7615.65	0.000	7877.02	0.000
Wald Test	1411	0.000	1642.465	0.000	1813.42	0.000	2117.23	0.000
Hansen-Sargan overidentification statistic	0.177	0.674	0.363	0.547	0.239	0.625	0.047	0.829

DISCUSSION AND CONCLUSION

This paper investigates empirically the effects of gaining employment and health status on prescription drug utilization in the United States using a nationally representative dataset, the Longitudinal MEPS Data, for 2007-2016. The findings suggest that a change of status from unemployment to employment strongly affect individual prescription drug utilization with no noticeable effect on drug spending. The longer time on gaining employment is associated with more prescription drug utilization, which is the sign of delaying health services behavior related to employment-based health insurance. However, our finding contradicts those of Kozman et al. (2012). Why? By individually check for 2009-2010 and 2010-2011, we find the negative relationship between gaining employment and drug utilization; the longer it takes the individual to find a job, the lower the drug utilization, which suggests a change in individuals' preferences for drug utilization patterns during the great recession because of the extreme budget concerning (Fodman and Book 2010). Despite this, in general, there is a positive relationship between the gaining employment process and prescription drug utilization; hence, a good economy and shorter time for individuals' getting employment will lower the drug utilization in the sense that timely treatment could reduce the severity of illness.

We also find significant positive effects of gaining healthy status on both prescription drug

utilization and spending during this period, consistent with the original suggestion of the Grossman model. Results from the simultaneous equation system demonstrate the pathways through which the gaining of employment and health factors influence prescription drug utilization and suggest an essential role for individual employment and health status and their determinants.

Besides, age has both a direct and indirect effect on prescription drug utilization and spending; we find that age had a positive relationship with both drug utilization and expenditure. Education has an indirect impact on drug utilization by affecting the individual's health status, finding suggests that the more the education years, the less likely, the faster the gaining of health status. Wages only has indirect effects on drug utilization by affecting both the changes of health status and employment status, no direct effects on drug utilization and spending. In our study, results suggest that the regional employment-population ratio indirectly affects drug utilization and spending by changing the individual's gaining of the employment process.

There are a few limitations in this research and potential improvement in future research. One limit is the MEPS data, which only includes the number of prescriptions the respondents filled, not the number of drugs the doctor written. However, as researchers acknowledged a complicated situation in the pharmaceutical area, the physicians are the chief players. The latter specifies the prescriptions used by individual patients (Alowi and Kani, 2019).

Another limitation of this analysis is the UNINSURED, which might be an arguable variable here in this research since it only captures the uninsured individuals. This variable provides no information about the copay, deductible, and out of pocket, the most effective insurance factors on prescription drug utilization. Moreover, the insurance types also affect drug utilization; for example, Medicaid and Medicare recipients might utilize drugs differently than individuals that are privately insured or employment-based insurance recipients. However, the uninsured status can exactly give evidence of how the aiming (affordability of health insurance, lowering the uninsured rate) of the Affordable Care Act works in the sense of adverse selection problem. Checking the uninsured effects on drug utilization, we find no significant differences before and after 2009-2010.

Meanwhile, there was a significantly negative effect on the higher coefficient value of UNINSURED on both drug utilization and spending for 2010-2011, which created a significant gap between uninsured and insured individuals. This result confirmed the ACA insurance benefit, which suggests that individuals' prescription drug utilization decision was significantly affected by the insurance status during the launch of the Affordable Care Act, while only for a limited period. In this study, we have the regional employment to population ratio, a location variable, as an instrumental variable to capture the effect of gaining employment on prescription drug utilization. While in the future study, it might be possible to capture the changes in insurance status based on the differential expansion of Medicaid if we can effectively control for location in the future study.

REFERENCES

Alowi M., Kani Y. (2019) Promotion of Prescription Drugs and Its Impact on Physician's Choice Behavior. J Pharma Care Health Sys 6: 200. doi:10.4172/2376-0419.1000200

Bass, U.F., Woodward J.A., 1978. Services research report. Skills training and employment for ex-addicts in Washington, D. C.: A report on TREAT. DHHS Publication No. (ADM): 78-694.

Berger M, Leigh JP (1989), Schooling, Self-Selection, and Health, Journal of Human Resources 24 (3):433-455.

Davis, M., Poisal, J., Chulis, G., Zarabozo, C., Cooper, B., 1999. Prescription drug coverage, utilization, and spending among Medicare beneficiaries. Health Affairs 18(1): 231-243.

Fillenbaum, G.G., Hanlon, J.T., Corder, E.H., Ziqubu-Page, T., Wall, W.E., Brock, D., 1993. Prescription and Nonprescription Drug Use among Black and White Community-Residing Elderly. American Journal of Public Health 83 (11).

Fodeman J., Book R.A. (2010) "Bending the Curve": What Really Drives Health Care Spending. Backgrouder No. 2369.

Gibson, T.B., McLaughlin, C.G., Smith, D.G., 2005. A Copayment Increase for Prescription Drugs: The Long-Term and Short-Term Effects on Use and Expenditures. Inquiry 42: 293–310.

Grossman M., 1972. On the Concept of Health Capital and the Demand for Health. The Journal of Political Economy, 80(2): 223-255.

Grossman M (1999) "The Human Capital Model of the Demand for Health," NBER Working Paper 7078.

Grossman M (2000) The human capital model. In Handbook of Health Economics, Volume 1 (Eds. A.J. Culyer and J.P. Newhouse). Elsevier Science BV.

Haislmaier E, Badger D (2018) How Obamacare Raised Premiums. Backgrouder No. 3291.

Han, M., Rizzo J. A., 2012. The Health Returns to Medical Expenditures: Does Age Matter?

Henkel D (2011) Unemployment and substance use: a review of the literature (1990-2010). Curr Drug Abuse Rev 4(1):4-27.

Holahan, J., 2011. The 2007–09 recession and health insurance coverage. Health Affair (Millwood) 30(1): 145–152.

Kozman, D., Graziul, C., Gibbons, R., Alexander, G.C., 2012. Association between unemployment rates and prescription drug utilization in the United States, 2007–2010. BMC Health Services Research 12:435.

Leibowitz, A., Manning, W.G., Newhouse, J.P., 1985. The demand for prescription drugs as a function of cost-sharing. Social Science & Medicine. 21(10): 1063–1069.

Long SH. (1994) Prescription Drugs and the Elderly: Issues and Options. Health Affairs 13:2, 157-174.

Lusardi, A., Schneider, D., Tufano, P., 2010. The economic crisis and medical care usage. Natl Bur Econ Res Working Paper Ser, 15843:1–14.

Lusardi A, Schneider DJ, Tufano P (2015) The economic crisis and medical care use: comparative evidence from five high-income countries. Social Science Quarterly 96(1). DOI: 10.1111/ssqu.12076

Okunade, A. A., You, X., Koleyni, K., 2018. Cross-country Medical Expenditure Modeling Using OECD Panel Data and ARDL Approach: Investigating GDP, Technology and Ageing Effects. Health Econometrics in Contributions to Economic Analysis, Emerald Publishing.

Roe, C.M., McNamara, A.M., Motheral, B.R., 2002. Gender- and Age-Related Prescription Drug Use Patterns. Ann Pharmacother 36(1): 30-39.

Rosen S, Taubman P (1982) Changes in Life-Cycle Earnings: What Do Social Security Data Show? Journal of Human Resources 17(3): 321-338.

Silverman K., Robles E. (1999) Employment as a drug abuse treatment intervention: A behavioral economic analysis. In: Chaloupka F.J, Bickel W.K, Grossman M, Saffer H, editors. The economic analysis of substance use and abuse: An integration of econometric and behavioral economic research. Chicago: University of Chicago Press pp. 279–299.

Simoni-Wastila, L., Ritter, G., Strickler, M.S., 2004. Gender and Other Factors Associated with the Nonmedical Use of Abusable Prescription Drugs. Substance Use & Misuse 39: 1089-1098.

Sjoqvist, F., Birkett, D., 2003. What is drug utilization research and why is it needed? WHO booklet "Introduction to Drug Utilization Research".

Skoog, J., Midlov, P., Borgquist, L., Sundquist, J., Halling, A., 2014. Can gender difference in prescription drug use be explained by gender-related morbidity?: a study on a Swedish population during 2006. BMC Public Health 329: 1471-2458.

Stronks K., van de Mheen H, van den Bos J, Mackenbach JP (1997) The interrelationship between income, health and employment status. Int J Epidemiol 26(3):592-600.

Svarstad, B.L., Cleary, P.D., Mechanic, D., Robers, P.A., 1987. Gender Differences in the Acquisition of Prescribed Drugs: An Epidemiological Study. Medical Care 25(11): 1-23.

Sznitman, S.R., 2007. Drugs and gender: A contradictory project in interviews with socially integrated men and women who use drugs. Nordic Studies on Alcohol and Drugs 24: 107-126.

Theodorou M., Kaitelidou D., Galanis P., Middleton N., Theodorou P., et al. (2011) Quality of life measurement in patients with hypertension in Cyprus. Hellenic J Cardiol 52(5):407-15.

Truffer, C.J., Keehan, S., Smith, S., Cylus, J., Sisko, A., Poisal, J.A., Lizonitz, J., Clemens, M.K., 2010. Health spending projections through 2019: the recession's impact continues. Health Affair (Millwood) 29(3): 522–529.

You, X., Okunade, A. A., 2017. Income and Technology as Drivers of Australian Healthcare Expenditures. Health Economics 26(7).

EXPLAINING CORPORATE COMPETITIVENESS VIA COGNITIVE CONFLICT AND ENVIRONMENTAL MUNIFICENCE

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ABSTRACT

Corporate competitiveness refers to the firm's ability to create and sustain competitive advantage against its industry rivals. This construct basically shows whether a firm can efficiently utilize its resources and capabilities to compete other firms effectively. It is very critical for companies to possess competitive posture so that they can survive in the long run. In this paper, we argue that top management team cognitive conflict will positively affect firm's corporate competitiveness and this relationship is positively moderated by environmental munificence. Grounded on resource dependence and upper echelons theories, this study contributes to the literature by explaining how corporations can become more competitive in the industry.

INTRODUCTION

As Ho (2005) argues, "good corporate governance assures accountability and improves performance, and is a source of competitive advantage" [13, p. 211]. Governance relates to all rights and responsibilities among internal and external stakeholders of the company [1]. Effective governance mechanisms provide the firm with "well-balanced" relationships among executives, owners, board members, and other stakeholders of the company [1]. Basically, good governance is at the heart of managing corporations successfully.

Corporate competitiveness refers to "a firm's potential and process of competitive advantage, ability to sustain performance such as market share and growth, employment and rewarding of its factors" [13, pp. 213-216]. Furthermore, competitive advantage can be defined as "present and future conditions and abilities of producing superior products and services with better prices and quality, yielding long-term and sustainable economic benefits" [13, p. 213]. Thus, we can

argue that creating and sustaining competitive advantage is at the very core of this corporate phenomenon.

Top management teams include executives who are responsible for formulating and implementing most appropriate strategies for their firms' continuing success. These executives' behavioral and cognitive characteristics are expected to be largely reflected in their strategic actions [11]. Cognitive conflict among executives can be defined as "task-oriented disagreements arising from differences in perspective" [3, p. 495] within a top management team (TMT). This sort of a conflict improves the quality of decision-making processes and help the firm gain better organizational outcomes [3]. In other words, cognitive conflict helps executive make better-quality decisions. In this paper, we argue that TMT cognitive conflict will improve corporate competitiveness of the firm and this relationship is positively moderated by environmental munificence.

What is Corporate Competitiveness?

Deavers (1997) argues that corporate competitiveness depends on how effectively firms utilize their core competencies [6]. Competitiveness, as a strategy, can be defined as "a process that leads to the emergence of a good which, in turn, gives the producing firm a sustainable advantage on the market" [12, p. 640]. In addition, according to the competitiveness literature, firms can sustain their competitive posture by constantly pursuing entrepreneurial initiatives [12]. Lee and Choi (2006) also echo this argument by stating that innovation and production of better-quality products or services will help the firm improve its competitiveness [15].

Momaya (2016) defines corporate competitiveness as "the ability of a firm to evolve leadership and strategies needed to execute relevant corporate activities effectively to grow" [17, p. 420]. Marin, Rubio, and de Maya (2012) also define competitiveness of the firm as the "ability to

produce goods and services creating value or to act against the rivalry originated in the relationship with other firms" [16, p. 366]. They argue that corporate competitiveness can be improved via the development of corporate resources and capabilities [16].

Competitiveness assumes that there is a "well-balanced" match between internal competencies of the firm and external opportunities of the environment [16]. In other words, if a firm aims to be competitive in the corporate world, it will have to successfully link its distinct competencies with industry opportunities. As a result of that, the firm can improve itself toward becoming a competitive member within a specific industry [19]. Therefore, corporate competitiveness plays a critical role in achieving positive performance outcomes along with surviving in the long run.

Cognitive Conflict and Corporate Competitiveness

Although the term "conflict" sounds quite negative at the first place, it may benefit organizations in several ways. Cognitive conflict among TMT members is expected to improve the decision quality via encouraging heterogeneous views and diverse opinions [3]. Cognitively conflicted teams tend to "discuss and debate various preferences and opinions about their tasks" [18, p. 733]. By doing so, these executives have an opportunity to exchange ideas while making well-defined and good-quality strategic decisions [18].

During their decision-making processes, top managers evaluate the context in which their firms compete against industry rivals by using their cognitive capabilities. As a result of this critical evaluation stage, it is quite normal that different individuals may express diverse perspectives and opposing preferences toward similar organizational goals [18]. Throughout their discussions, TMT members will be able to access to the knowledge and information on a broader scale [4] since they are not agreeing on everything via consensus. Thus, cognitive conflict will enable executives to enhance their creativity by supporting innovative mindsets [4].

Cognitive conflict can be defined "as the task-related divergence resulting from a comparison between one's current own mental model and perceived information" [4, p. 121]. When cognitive conflict within top teams occurs, executives may gain positive outcomes including "developing better solutions and preempting group-meeting hazards such as groupthink" [5, p. 315]. Consequently, these executives can come up with better strategies that enable their companies to compete their rivals more effectively. In other words, cognitive conflict will make these TMT members to produce competitive strategies toward a stronger organizational future.

Via cognitive conflict, TMT members can leverage their differences in ideas, judgments, and prospects to create a more productive teamwork setting [8]. Although this conflict creates disagreements among executives, the "end" result is expected to become positive due to high-level of interactions within team meetings [5]. By using different cognitive maps [2], executives can "consider a number of strategic alternatives from a variety of diverse perspectives" [7, p. 369] and better overcome difficulties under uncertain and ambiguous conditions [7]. As a consequence, their decision-making processes will become more effective, which, in turn, results in improving the competitive posture of the firm. Therefore, we argue that cognitive conflict positively affects corporate competitiveness of the firm.

Proposition 1: *TMT cognitive conflict is positively related to corporate competitiveness.*

Environmental Munificence as a Moderator

Munificence can be defined as "an environment's ability to support sustained growth" [10, p. 1006]. In munificent environments, the resource availability to the firm tends to be high, which results in creating a positive influence on organizational processes and structures [10]. In addition, munificent environments provide the firm with advantages in regard to their readiness for external threats [10].

As Wiersema and Bantel (1993) argue, non-munificent environments lead to “little or no organizational slack, conditions of scarcity, and a threat to the firm's survival” [21, p. 487]. More specifically, if an environment is not munificent, companies won’t be able to easily find opportunities for organizational growth [21]. If munificence exists, however, firms can better deal with uncertainties and hostilities that potentially affect their performance [9]. Furthermore, a munificent environment will serve as a strong “supporting tool” for organizational status of legitimacy [9]. Therefore, we argue that munificence has a positive contingency effect on the relationship between cognitive conflict and corporate competitiveness.

Proposition 2: *Environmental munificence positively moderates the relationship between TMT cognitive conflict and corporate competitiveness.*

DISCUSSION

Do TMT cognitive conflict and environmental munificence affect corporate competitiveness? This study addresses this question by exploring two critical antecedents of this phenomenon. We propose that TMT cognitive conflict positively affects corporate competitiveness, and this relationship is positively moderated by environmental munificence.

This conceptual study contributes to the corporate governance literature in a couple unique ways. First, we argue that TMT cognitive conflict is positively related to corporate competitiveness. From a general perspective, competitiveness can be defined as “the strength of an organization in comparison with its competitors” [20, p. 59]. Parallel to this definition, corporate competitiveness describes the firm’s ability and potential for creating and sustaining competitive advantage among industry rivals [13]. By using arguments in the upper echelon’s theory, we propose that differences in perspectives among TMT members along with a large amount of information exchange caused by cognitive conflict will help companies improve their

competitiveness. Second, in this context, we argue that environmental characteristics do matter as well. Munificence can be described as "an environment's ability to support sustained growth of an organization" [9, p. 45]. In our proposition, we consider this specific characteristic of an environment a contingency factor in our previously identified relationship. Thus, we offer a moderated model to explain corporate competitiveness.

Despite all these contributions, we also recognize our limitations. First, in future studies, this conceptual model should be empirically tested. Second, it may be fruitful to consider more contingency effects (e.g. country-level differences) in order to further explore corporate competitiveness. And finally, it will be interesting to see whether board members' cognitive and/ or behavioral characteristics may help to better understand this phenomenon.

CONCLUSION

In sum, this early-stage theoretical study examines two critical antecedents of corporate competitiveness, namely TMT cognitive conflict and environmental munificence. In today's global world, where competition is the "key" for continuous success, it is very important to understand how companies will stay competitive among their industry rivals. By using "well-established" arguments of upper echelons and contingency theories, we have unpacked some critical antecedents of corporate competitiveness.

REFERENCES

[1] Aguilera, R.V., Filatotchev, I., Gospel, H. & Jackson, G. (2008). An organizational approach to comparative corporate governance: Costs, contingencies, and complementarities. *Organization Science*, 19(3), 475-492.

[2] Alexander III, E.R. (1979). The reduction of cognitive conflict: Effects of various types of communication. *Journal of Conflict Resolution*, 23(1), 120-138.

[3] Amason, A.C. & Sapienza, H.J. (1997). The effects of top management team size and interaction norms on cognitive and affective conflict. *Journal of Management*, 23(4), 495-516.

[4] Badke-Schaub, P., Goldschmidt, G. & Meijer, M. (2010). How does cognitive conflict in design teams support the development of creative ideas?. *Creativity and Innovation Management*, 19(2), 119-133.

[5] Chiravuri, A., Nazareth, D. & Ramamurthy, K. (2011). Cognitive conflict and consensus generation in virtual teams during knowledge capture: Comparative effectiveness of techniques. *Journal of Management Information Systems*, 28(1), 311-350.

[6] Deavers, K.L. (1997). Outsourcing: A corporate competitiveness strategy, not a search for low wages. *Journal of Labor Research*, 18(4), 503-519.

[7] Ensley, M.D., Pearson, A.W. & Amason, A.C. (2002). Understanding the dynamics of new venture top management teams: Cohesion, conflict, and new venture performance. *Journal of Business Venturing*, 17(4), 365-386.

[8] Forbes, D.P. & Milliken, F.J. (1999). Cognition and corporate governance: Understanding boards of directors as strategic decision-making groups. *Academy of Management Review*, 24(3), 489-505.

[9] Goll, I. & Rasheed, A.A. (2004). The moderating effect of environmental munificence and dynamism on the relationship between discretionary social responsibility and firm performance. *Journal of Business Ethics*, 49(1), 41-54.

[10] Goll, I. & Rasheed, A.A. (2005). The relationships between top management demographic characteristics, rational decision making, environmental munificence, and firm performance. *Organization Studies*, 26(7), 999-1023.

[11] Hambrick, D.C. & Mason, P.A. (1984). Upper echelons: The organization as a reflection of its top managers. *Academy of Management Review*, 9(2), 193-206.

[12] Herrmann, A.M. (2008). Rethinking the link between labour market flexibility and corporate competitiveness: A critique of the institutionalist literature. *Socio-Economic Review*, 6(4), 637-669.

[13] Ho, C.K. (2005). Corporate governance and corporate competitiveness: An international analysis. *Corporate Governance: An International Review*, 13(2), 211-253.

[14] Kreutzmann, H. (2008). Dividing the World: Conflict and inequality in the context of growing global tension. *Third World Quarterly*, 29(4), 675-689.

[15] Lee, K.C. & Choi, B. (2006). Six Sigma management activities and their influence on corporate competitiveness. *Total Quality Management & Business Excellence*, 17(7), 893-911.

[16] Marín, L., Rubio, A. & de Maya, S.R. (2012). Competitiveness as a strategic outcome of corporate social responsibility. *Corporate Social Responsibility and Environmental Management*, 19(6), 364-376.

[17] Momoya, K. (2016). City clusters and break-out in corporate competitiveness: Patterns and perspectives focusing on innovation capabilities and India. *Competitiveness Review*, 26(4), 415-434.

[18] Mooney, A.C., Holahan, P.J. & Amason, A.C. (2007). Don't take it personally: Exploring cognitive conflict as a mediator of affective conflict. *Journal of Management Studies*, 44(5), 733-758.

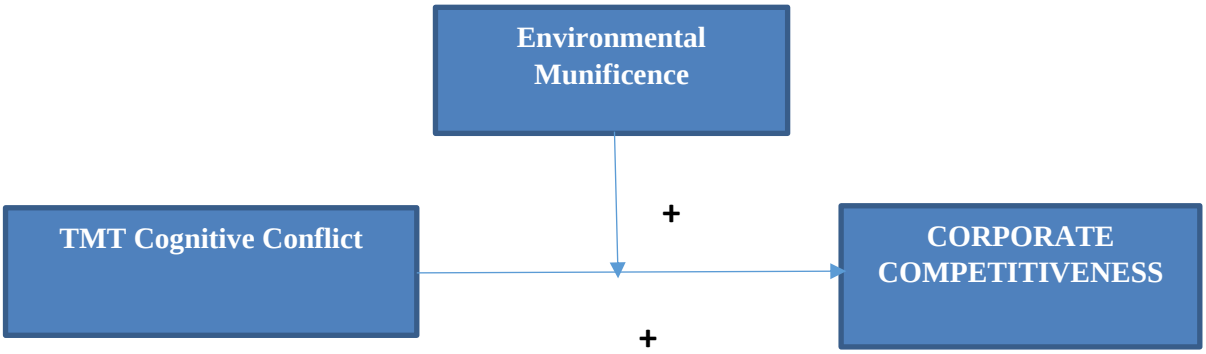
[19] Tantalo, C., Caroli, M.G. & Vanevenhoven, J. (2012). Corporate social responsibility and SME's competitiveness. *International Journal of Technology Management*, 58(1/2), 129-151.

[20] Vilanova, M., Lozano, J.M. & Arenas, D. (2008). Exploring the nature of the relationship between CSR and competitiveness. *Journal of Business Ethics*, 87(1), 57-69.

[21] Wiersema, M.F. & Bantel, K.A. (1993). Top management team turnover as an adaptation mechanism: The role of the environment. *Strategic Management Journal*, 14(7), 485-504.

APPENDICES

Figure 1 Theoretical framework



Gender Diversity and Leadership Lessons From the Biblical Era

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ABSTRACT

Gender Diversity and Leadership Lessons From the Biblical Era

This paper examines the role of gender diversity in Biblical Leadership as experienced through Miriam, one of the great prophetesses and leaders in Biblical times. Miriam was a sister of Moses and of Aaron. Much has been written about her brothers and their Leadership roles.

However, little is known about the leadership role of Miriam. While some attribute this to a lesser degree of gender diversity in the Biblical era, the thrust of our research in this paper shows how influential she really was in the sojourn of the Israelites in the desert after the Israelites left Egypt.

We aim to study some of her leadership attributes and learn lessons in Leadership that resonate as forcefully today as they did in the Biblical era.

Introduction

The United States and many other nations are facing a serious crisis of leadership (Annan, 2016; Pearse, 2018; Shahid, 2014; Veldsman, 2016; World Economic Forum, 2014). The public distrusts leaders of all kinds of institutions including business, education, religion, government, and health care. One CEO posits that "capitalism has been slowly committing suicide" by moving away from stakeholder capitalism and becoming the kind of selfish, predatory capitalism that only cares about top executives and investors (Leonhardt, 2019). Many CEOs have been more concerned about current profits than manufacturing safe, quality products which, in effect, means the long-term strength of an organization is being sacrificed for short-term goals (Friedman & Kass, 2018).

Many lessons about leadership can be derived from an examination of the Bible. The concepts of servant leadership (Greenleaf, 1991), covenantal leadership (Pava, 2003), and spiritual leadership (Fry, 2003) all have their roots in the Biblical tradition. One of the great leaders of the Bible was Moses; many scholars have examined his leadership style (Baron, 1999; Feiler, 2010; Friedman & Friedman, 2018; Grumet, 2014; Herskovitz & Klein, 1999; Morris, 2006; Wildavsky, 2005/1984).

Unfortunately, little has been written about Miriam, sister of Moses and one of the great heroines of the Bible. She is referred to as a prophetess, yet the Torah (also known as the Five Books of Moses, the Pentateuch) never mentions any of her prophecies. There are only a few stories in the Torah about her, yet the Talmud lists Moses, Aaron, and Miriam as the three noble leaders that took care of the ancient Israelites in the wilderness (Babylonian

Talmud, Taanit 9a). The prophet Micah (6:4) mentions her by name: "For I brought you up out of Egypt and redeemed you from the house of slavery; and I sent Moses, Aaron and Miriam to lead you." Clearly, Miriam was an important part of the leadership team. What exactly was her contribution as a leader?

Miriam and the Birth of Moses

The first time the sister of Moses is mentioned is after the birth of Moses. She is the sister who was standing on the riverbank watching what would happen to her three-month old brother. Miriam was the eldest of the siblings; Aaron was only three years older than Moses. Clearly, it was Miriam who played an important role in Moses' development. The Torah does not mention her by name:

> But when she could hide him no longer, she got a wicker basket for him and coated it with tar and pitch. Then she put the child in it and placed it among the reeds along the bank of the Nile. His sister stood at a distance to see what would happen to him (Exodus 2:3-4).

The Egyptians had decreed that every Hebrew son should be thrown into the Nile as a way to stem the growth of the Hebrew slaves. The parents, Jochebed and Amram, were only able to hide the infant Moses for three months. What is surprising is that it was not the father or mother who stood watch after leaving their baby in the river. It is reasonable to assume that they were afraid that the baby would be found by an Egyptian and drowned, something they could not bear to see. The Egyptians had been practicing infanticide on the Hebrew babies for several months so this would be expected of them. Miriam must have had a feeling that it would be important for her to be around. Indeed, her being there was very fortunate. When Pharaoh's daughter went to bathe by the river and found the basket, she decided to

keep the baby. She immediately knew that it was a Hebrew boy (Exodus 2: 6). Miriam brazenly appeared to Pharaoh's daughter and asked whether she should get her a wet nurse for the child from the Hebrews. She said to the Egyptian princess (Exodus 2:7): "Shall I go and summon for you a Hebrew woman to nurse the child for you?" This could have been dangerous. One assumes that it was not a common occurrence for a Hebrew girl to go to the princess of Egypt and telling her what to do and even suggest a Hebrew wet nurse. Miriam found the perfect Hebrew wet nurse for the child, Jochebed, his own mother. This worked out very well since Moses was raised in the palace and received a first-class education.

Kasher (1944, p. 73), citing numerous sources, posits that God wanted Moses to get an education. In ancient Egypt, the nobility received a first-rate education; without any doubt, slaves did not receive any education. By living in the palace as the adopted son of the Egyptian princess, Moses received a sophisticated education that would earn him the respect of the people and enable him to speak to royalty. According to Ibn Ezra, the medieval commentator, Moses would not have commanded any respect among the Hebrews had he been raised as a slave. Of course, his true mother Jochebed (and sister) was able to tell him the truth about his origins so that he would always feel close to his people. In fact, as soon as Moses grew up, he "went out to his brethren" and "saw their hard labor" (Exodus 2:11). Moses killed an Egyptian taskmaster who was viciously beating one of the Hebrew slaves (Exodus 2:11-12). Moses was not only taught by his mother and sister to love his people, but they also imbued in him a sense of justice.

The Talmud (Babylonian Talmud, Megillah 14a) states that Miriam prophesied before Moses was born. Her prophecy was that her mother, Jochebed, would give birth to the one who would save the Hebrews. According to the Talmud, this is why Miriam stood near

the child when it was in the river. She wanted to see if Moses would actually save Israel as she had prophesied. In any case, Miriam was a visionary who looked ahead who wanted to be near the infant Moses just in case she could somehow change fate. Whether she was a prophetess or not is immaterial, Miriam made a point to watch events unfold from a distance and then boldly approached Pharaoh's daughter with a suggestion that would change the destiny of the Jewish people. Had Miriam not been there, Moses might have been saved by the princess of Egypt but would not have his own mother as a wet nurse. A good leader is proactive and takes chances and does not rely on others.

According to the Talmud, Miriam played an important role in the birth of Moses. She told her father, Amram, to remarry his wife. Amram had divorced Jochebed because of Pharaoh's harsh decree:

> A Tanna taught: Amram was the greatest man of his generation; when he saw that the wicked Pharaoh had decreed 'Every son that is born ye shall cast into the river', he said: In vain do we labour. He arose and divorced his wife. All [the Israelites] thereupon arose and divorced their wives. His daughter said to him, 'Father, thy decree is more severe than Pharaoh's; because Pharaoh decreed only against the males whereas thou hast decreed against the males and females. Pharaoh only decreed concerning this world whereas thou hast decreed concerning this world and the World to Come. In the case of the wicked Pharaoh there is a doubt whether his decree will be fulfilled or not, whereas in thy case, though thou art righteous, it is certain that thy decree will be fulfilled, as it is said: Thou shalt also decree a thing, and it shall be established unto thee! He arose and took his wife back; and they all arose and took their wives back (Babylonian Talmud, Sotah12a; Soncino translation).

Miriam After the Crossing of the Sea of Reeds

We do not hear about Miriam again until after the Israelites left Egypt. It took ten

plagues but finally the Egyptians allowed the Hebrew slaves to leave. Once they left, the Egyptians had a change of heart and decided to pursue them. A miracle occurred, the sea split and the Israelites crossed over. The Egyptians followed the Israelites into the sea but the water crashed down on the Egyptians and they drowned. Moses led the Hebrews in the "Song by the Sea" (Exodus 15: 1-19). It appears that Moses led the song and the people sang responsively. As noted above, Moses was an educated man — he received a superior education living in the royal palace — and this song may have been too sophisticated for the people. The song was chanted as a prayer with Moses saying a verse and the people repeating it after him (Babylonian Talmud, Sotah 30b). It is also interesting that Moses did not include the women in the "Song by the Sea." This was probably a huge mistake on the part of Moses. He may not have realized that the women also suffered greatly in Egypt and also desperately wanted to show gratitude to God for rescuing them from slavery. Scripture states:

> And Miriam the prophetess, the sister of Aaron, took a timbrel in her hand; and all the women went out after her with timbrels and with dances. Miriam chanted to them: "Sing to the Lord, for he is highly exalted; both horse and driver he has hurled into the sea" (Exodus 15: 20-21).

Miriam did indeed recognize that there are other ways to pray to God. She took the first verse of Moses' Song by the Sea, "I shall sing to the Lord, for he is highly exalted; both horse and driver he has hurled into the sea." In Moses' version, the first verse was in the singular and each person sang "I"; Miriam's version was plural. She wanted everyone to sing together with music and dancing. This was a much more emotional way to show gratitude. Miriam's prayer was brief and is clearly a song, not a prayer. Since the song consisted of only one verse (note everyone agrees with this; some feel that the Torah only mentions the

first verse but the people actually sang the entire song), it was probably very easy for everyone to join in.

Much later in Jewish history, the Hassidic movement started by Rabbi Israel Baal Shem Tov in Eastern Europe in the beginning of the 18th century was a reaction to the Judaism that stressed scholarship and intellectualism and looked down on the common folk. Studying Torah was considered much more important to them than prayer. The Hassidic view was that everyone could find a way to serve God, not only scholars. Hassidim also prayed with joy and fervor. What Miriam did is very reminiscent of what the Hassidic movement did. Miriam understood that Judaism could not survive without appealing to everyone and that there had to be joy and fervor in prayers. Moreover, she understood the importance of including women in the rituals.

The Midrash asks where did the women get the timbrels from to sing and dance the "Song by the Sea"? The Midrash answers that the women trusted in God and had confidence that he would perform miracles for them so they brought musical instruments with them when they left Egypt (Mechilta 15:20). The women had more faith than the men. This may be hinted at in "And Miriam the prophetess, the sister of Aaron, took a timbrel in her hand…" As a prophetess, she told the women to bring along musical instruments when leaving Egypt. Presumably, the men were more concerned with taking valuables with them and would not have wasted precious space for musical instruments. The Torah makes it very clear that the Israelites left Egypt with "silver and gold articles and clothing" they took from the Egyptians when leaving Egypt and they "despoiled the Egyptians" (Exodus 12: 35-36). The men were looking for valuables and the women were seeking timbrels.

Miriam and Aaron Complain About the Cushite Wife

Scripture relates the story about Miriam and Aaron criticizing Moses for taking a Cushite wife.

> Miriam and Aaron began to talk against Moses regarding the Cushite woman he had married, for he had married a Cushite. And they said, "Has the Lord indeed spoken only to Moses? Has he not spoken to us also?" And the Lord heard it. Now the man Moses was a very humble man, more humble than anyone else on the face of the earth (Numbers 12: 1-2).

Since Moses was so humble, God interceded on his behalf and Miriam became afflicted with a deadly disease, *tzaraas* (a skin disease often mistranslated as leprosy). Moses prayed for her and God decided that she was to remain quarantined for seven days outside the camp. The verse states (Numbers 12:15): "the people did not journey until Miriam was brought back in [home]." The people showed a great deal of respect for Miriam and did not want to break camp and move on until Miriam was healed. Clearly, the people loved Miriam. The Talmud (Babylonian Talmud, Sotah 9b) sees this as "measure for measure." Miriam waited to see what would happen to baby Moses when he was placed in the river, the people showed respect for Miriam by waiting seven days for her.

It is not clear who the "Cushite" women was. We know that Moses had one wife, Zipporah, but she was a Midianite. The Midianites were not Cushites; they were descendants of Abraham. The Midrash (Sifri, Numbers 12:1; Yalkut Shimoni Numbers 12:1) and most of the commentaries believe that Miriam found out that the Moses had separated from his wife. According to one Midrash, Miriam noticed that Zipporah was not adorning herself with the ornaments that women typically wear. Miram asked her the reason for this and Zipporah told her that her brother no longer had interest in her (Sifri, Numbers 12:1). Apparently, Moses

felt that since God communicated with him directly at any time of the day, it would be wrong for him to have sexual relations with her.

When Miriam found out about Moses' celibacy, she was upset that Moses was acting, in a way that she thought was inappropriate (and insensitive to Zipporah), so she went to Aaron to rebuke their brother. Miriam made the point that both Aaron and she communicated with God yet did not become celibate. [What Miriam did not realize was that Moses had a more personal and direct relationship with God than did the other prophets such as Aaron and herself (see Numbers 12:8).] It seems that Miriam's mistake was in not talking directly to Moses and asking him for the reason he became celibate. In any case, the Midrash makes it clear that Miriam had good intentions and was trying to stand up for Zipporah. Her intent was not to castigate her brother.

The fact that Moses separated from Zipporah may be hinted at in the text. The story in the Bible that precedes the story of Miriam deals with the complaints of the rabble who strongly desired meat. These ingrates remembered the "free fish" they had to eat in Egypt and complained about the manna that came down from heaven (Numbers 11:4-5). God sent them quail to eat but punished them with death. The place they died was called *Kivrat Hata'vah* (graves of lust). The people who were buried there had lusted after meat. The connection with Miriam's story may have to do with the fact that Moses suppressed his desire for his wife, Zipporah, because he wanted to be ritually pure when speaking to God. Moses acted the opposite of the rabble who had no self-control; they had plenty to eat but lusted after foods not available in the wilderness, i.e., fish. The Torah uses this literary device – a contrast effect – to show how different people react to similar situations (see Ibn Ezra on

Genesis 38:1 where he uses this explanation to explain why the story of Judah and Tamar follows the sale of Joseph).

Alter (2004:741) provides an alternative explanation for this story. He notes that it is not clear whether or not Cush can be located in Midian. He cites the view of Baruch Levine that Miriam was concerned with "the fact that Moses had compromised Zipporah's privileged status by this second marriage." Miriam and Aaron felt that this kind of behavior was "unworthy of a prophetic leader." There are a number of commentators that assert that Moses did take a second wife (e.g., Joseph Ibn Kaspi). Liebowitz (1982: 131-132), quoting Kaspi rejects the explanation that Moses had become celibate. He maintains, that on the contrary, "his natural vitality and activities had not become weakened at eighty and even a hundred. Abraham who was inferior to him begat a son at a hundred." Kaspi posits that Miriam was ignorant of Moses' motives for taking a second wife because she did not have his prophetic gifts. As God himself confirmed, Miriam and Aaron's level of prophecy was inferior to that of Moses who spoke "mouth to mouth" with Him (Numbers 12: 6-8). In any case, Miriam seems to have been unhappy with the way Moses was treating Zipporah by taking a second wife. Moreover, she may have felt that even if Moses felt the need for a second wife, why not marry a woman from the children of Israel?

Ironically, years later, after Miriam's death, when the Israelites were about to enter the Promised Land, the people began to sin with Moabite and Midianite women (Numbers 25). Moabite and Midianite women committed sexual immorality with the Israelite men and enticed them into worshipping the idol, Baal-Peor. Zimri, from the tribe of Shimon, openly took Cozbi, a Midianite woman, "in the sight of Moses" to openly have an affair with her. This depravity resulted in a plague – a divine punishment—that killed 24,000 Hebrews

(Numbers 25). The Talmud (Babylonian Talmud, Sanhedrin 82a) says that Zimri brought Cozbi to Moses and audaciously asked: "Son of Amram [Moses' father was Amram], is she forbidden or permitted to me? And if you declare that she is forbidden to me, who permitted the daughter of Jethro [Zipporah] to you." Of course, there was a big difference between the two circumstances. Moses married Zipporah before the Torah was given. After the Torah was given, idolatrous women were forbidden to the Hebrews (Rashi).

Death of Miriam

Miriam's death in the Wilderness of Zin in the first month is mentioned in the Torah (Numbers 20:1). This was actually the first significant event that occurred during the last year of wandering in the wilderness. The Israelites wandered the wilderness for 40 years as a punishment for doubting God and believing the report of the spies (Numbers 13). The first thing that happened after she died was that the people complained to Moses and Aaron about the lack of water. The sages assert that the lack of water was the direct result of her death since it was in her merit that the Israelites had water in the wilderness; Miriam's well followed them miraculously throughout the 40 years of wandering in the wilderness (Babylonian Talmud, Taanit 9a). Hattin (n.d.) sees the connection between the well and the death of Miriam as a metaphor:

> Some of this may be unduly speculative, for the Torah does not explicitly indicate that Israel was provided with a continuous well of water by the merit of Miriam. In all probability the Rabbinic linkage is an attempt to convey something more profound than simply narrative detail. In effect, by ascribing the well to Miriam's merit, the Sages are emphasizing the impact that her guidance had on the people of Israel. The life-giving waters that refreshed them

> during the entire course of their wilderness wanderings were understood by the Sages as metaphors for her inspiring words and deeds, for even as the Torah tells us relatively little about her lengthy career, she is present at the critical and tense moments when the fate of the people hangs in the balance. It is Miriam who preserves her brother who will become the future liberator and it is she who rouses Israel to song even as they reel from the staggering events at the Sea of Reeds. Like cool waters that refresh the weary and anxious traveler as he cautiously makes his way through the uncertain wilderness, Miriam buoys the people of Israel and raises their faltering spirits (Hattin, n.d., para. 18).

The Torah does not mention whether or not Miriam had a spouse or children**.** The Talmud and Midrash fill in the missing details. Miriam was married to Caleb (he was one of the 12 spies and he did not rebel against God). King David was one of her descendants (Babylonian Talmud, Sotah 11b-12a).

Conclusion

The Israelite women were at a much higher spiritual level than the men. It is quite reasonable to assume that the Miriam's leadership style which was more down to earth than Moses's style contributed to this. The way she took charge of the women at the "Song by the Sea" is the way for a leader to act. She did not allow Moses to ignore the women and made them part of the festivities. Moreover, she turned the song into an inspired dance. The same song sung as a prayer by Moses and the men was transformed and elevated into a spiritual epic poem that would inspire the people. The women in the wilderness would always be superior to the men thanks to Miriam. It is not surprising that the men died in the wilderness and the women entered the Promised Land. Indeed, the Bible states that only two men over

the age of 20 at the time of the incident spies made into the Promised Land, Caleb and Joshua (Numbers 26:65). Caleb was Miriam's husband.

Kadari (2014) makes a very interesting point about the Israelite women during the 40 years of wandering in the wilderness. The men, of course, sinned numerous times. The major transgressions dealt with:

(1) Sin of the Golden Calf

Kadari (2014) states the following about this transgression:

> The narrative of the Golden Calf in Ex. 32:2 has Aaron appealing to the people: "Take off the gold rings that are on the ears of your wives." As the Rabbis tell it, the men were eager to sin and build the Calf, and therefore turned to their wives with a request for their jewelry. However, the women were unwilling to cooperate in this sinful activity and in consequence only the men contributed their jewelry. Scripture relates in the following verse: "And all the people took off the gold rings that were in their ears," but does not specify that the women offered their earrings (Kadari, 2014, para. 2).

The Midrash states unequivocally that the women refused to give their husbands their jewelry for the purposes of idolatry (Pirkei D' Rabbi Eliezer 44; Midrash Tanchuma, Pinchas 7). They had more faith than their spouses and did not sin with the Golden Calf.

The second major transgression was the sin of the spies.

(2) Sin of the Spies

> In the sin of the spies the men slandered the Land, as is portrayed in Numbers 14:36: "those who came back and caused the whole community to mutter against him." The women, however, had no hand in this, and accordingly the punishment that all that generation would die in the wilderness was imposed only on the males. Numbers 26:65 says: "They shall die in the wilderness" Not one of them [*ish*] survived." From a close reading of the verse, that specifies "*ish*" (man), and not *ish ve-ishah* (man and woman), the Rabbis conclude that the women did not die, because they did not

> participate in this sin (Kadari, 2014; Midrash Tanchuma, Pinchas 7).

It was because of the sin of the spies that the Israelites were punished with 40 years of wandering in the wilderness until they all died out. Only their children would enter the Promised Land. The Israelite men were cowards; the women were not.

Leaders that want to be successful have to be close to the people. Moses was closer to God than the people. He was not aware when the people needed water. Miriam was the visionary who not only waited by the river to see what would happen to the infant Moses, she brazenly told the princess of Egypt what to do. Even her punishment came about because she felt the pain of Zipporah whose husband no longer lived with her. A leader has to be proactive and know when his/her followers are lacking something as basic as water. Miriam sang and danced with the women; Moses led them in prayer. The name Miriam means bitter. She was born at an extremely bitter time in Jewish history. The Egyptians were drowning Jewish babies in the river. She helped change the course of history. Weisberg (2014) posits:

> One group of slaves, however, did not succumb, and carried in their hearts an inextinguishable spark of optimism. They retained their human dignity; they continued to believe in a better life. Encouraging their families daily with superhuman strength, they remained confident that their prayers would be answered.
> This group of slaves was the Jewish women. "In the merit of the righteous women of that generation, our forefathers were redeemed from Egypt" (Babylonian Talmud, Sotah 11b).

Miriam's name has two meanings: bitter (from the Hebrew root *mar*) and rebellion (from the Hebrew root *meri*) (Weisberg, 2014). The Midrash claims that the reason she got the name which means bitterness was because the Egyptians started to embitter the lives of the Hebrew when she was born (Yalkut Shimoni, Exodus 165). Weisberg (2014) suggests

that both traits were what made her great. She felt the bitterness of the servitude and the pain of the people. She also was not afraid to rebel against the slave mentality that overwhelmed the Israelites. This is the mark of a great leader: one who feels the pain of his/her people and is willing to fight for them.

References

Alter, R. (2004). *The five books of Moses.* New York: W. W. Norton & Company.

Annan, K. (2016, February 3). The world has a leadership crisis, not a knowledge crisis. Retrieved from https://www.linkedin.com/pulse/world-has-leadership-crisis-knowledge-kofi-annan

Baron, D. (1999). *Moses on management*. New York: Pocket Books.

Feiler, B. (2010, March 29). Moses is America's prophet. *CNN.com*. Retrieved from http://www.cnn.com/

Friedman, H. H. & Friedman, L. W. (2018). Even Great Leaders Make Mistakes: Learning Leadership from Moses. *Journal of Leadership and Management*, Retrieved from http://leadership.net.pl/index.php/JLM/article/view/135

Friedman, H. H. & Kass, F. (2018, February 22). 'Substance over form': Meaningful ways to measure organizational performance. Available at SSRN: https://ssrn.com/abstract=3128595 or http://dx.doi.org/10.2139/ssrn.3128595

Fry, L. W. (2003). Toward a theory of spiritual leadership. *Leadership Quarterly, 14*, 693-727.

Greenleaf, R. K. (1991). *The servant as leader*. Indianapolis, Ind.: Robert K. Greenleaf Center.

Grumet, Z. (2014). *Moses and the path to leadership*. Jerusalem: Urim Publications.

Hattin, M. (n.d.). Miriam's well. *Virtual Beit Midrash*. Retrieved from https://www.etzion.org.il/en/miriams-well

Herskovitz, P. J. and Klein, E. E. (1999). The biblical story of Moses: Lessons in leadership for business. *The Journal of Leadership Studies*, Vol. 6, No. 3-4, 84-95.

Kadari, T. (2014). Hebrew women in the wilderness: Midrash and Aggadah. *Jewish Women's Archive*. Retrieved from http://jwa.org/encyclopedia/article/hebrew-women-in-wilderness-midrash-and-aggadah

Kasher, M. M. (1944). *Torah Shelemah: Exodus*. New York: American Biblical Encyclopedia Society, Inc.

Liebowitz, N. (1982). *Studies in Bamidbar (Numbers).* Jerusalem: World Zionist Organization.

Morris, G. K. (2006). *In pursuit of leadership: Principles and practices from the life of Moses.* Maitland, FL: Xulon Press.

Pava, M. L. (2003). *Leading with meaning: Using covenantal leadership to build a better organization*. New York: Palgrave Macmillan

Pearse, C. (2018, November 7). 5 reasons why leadership is in crisis. *Forbes*. Retrieved from https://www.forbes.com/sites/chrispearse/2018/11/07/5-reasons-why-leadership-is-in-crisis/#701fdafb3aca

Shahid, S. (2014, November 7). Why the world in 2015 faces a leadership crisis. *World Economic Forum*. Retrieved from https://www.weforum.org/agenda/2014/11/world-2015-faces-leadership-crisis/

Veldsman, T. (2016, August 29). Global leadership is in crisis – it's time to stop the rot. *The Conversation*. Retrieved from https://theconversation.com/global-leadership-is-in-crisis-its-time-to-stop-the-rot-64495

Weisberg, C. (2014). Miriam: Tambourines of rebellion. *Chabad.Org*. retrieved from

http://www.chabad.org/parshah/article_cdo/aid/248870/jewish/Miriam-Tambourines-of-Rebellion.htm

Wildavsky, A. (2005/1984). *Moses as political leader*. New York: Shalem Press.

World Economic Forum (2014). Top 10 trends of 2014: A lack of values in leadership. *WEForum.org*. Retrieved from http://reports.weforum.org/outlook-14/top-ten-trends-category-page/7-a-lack-of-values-in-leadership/

IMO 2020: The assessment of investment decisions and financial risks

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Maritime Finance:
Financial Strategies and Risk Hedging of IMO 2020

Extended Abstract

In 2016, the International Maritime Organization (IMO) limited the sulphur allowed in fuel used on board ships from 3.5% to 0.5% mass-by-mass, starting on January 1st, 2020. This regulation necessitates either a considerable capital investment (e.g., scrubber) or a substantial increase in operational cost in the maritime business. Most importantly, each strategy is associated with financial risk of future uncertainty. However, the financial implications of these two strategies, risk and its hedging tools have received limited attention in the extant literature. Thus, this research aims to (1) outline and investigate the financial strategies for these two IMO 2020 decisions; (2) identify the potential risk associate with each decision; and (3) propose financial hedging products to control the future uncertainty. This research utilizes General Equilibrium Theory to quantitatively demonstrate the management of these risks through financial hedging derivatives. This research contributes by filling a gap in the academic literature and industry practices. It can guide industry practitioners to precisely assess these financial strategies and realize its hedging tools. Academically, this paper initiates a much-needed step for scholars to introduce financial applications and tools to the domain of maritime business.

Objective

The objectives of this research paper are as follows:

I. Outline and investigate the financial strategies of the IMO 2020. Specifically, decision-makers are currently facing two main options to comply with the IMO 2020. These two

options are either installing stack gas scrubbing system (open/closed-loop) or using Very-Low Sulphur Fuel Oil (VLSFO).

II. Identify the potential risks associated with each decision. Specifically, using open-loop scrubbers has a regulatory uncertainty as many countries (e.g., Malaysia, Pakistan, the Suez Canal, Panama Canal, etc.) are banning open-loop scrubbers. On the other hand, the use of VLSFO brings about risks to stakeholders regarding compatibility and price volatility. The ship-owner and operator must obtain compatible fuel and undergo fuel testing to ensure the fuels compliance. Most importantly, the recent data shows that the price of VLSFO has a significant level of volatility. For instance, the price of VLSFO at Rotterdam Bunker was traded at $600 per metric tonne (mt) on January 06, 2020 and then went down to $214/mt on April 15, 2020. Such a price change creates a substantial financial risk of future uncertainty, resulting in an increase in operational costs and cash flow stability, which is the key metric of business stock price.

III. Propose financial hedging products to control the future uncertainty. Specifically, this research paper focuses on introducing hedging tools of the price volatility of VLSFO.

Data/Methodology

This research paper uses an illustrative example to demonstrate the financial impacts of each decision. First, the paper presents the expected capital expenditure of installing scrubber and the expected increase in operational cost by using VLSFO. Second, the paper preforms a financial analysis of each option. Third, the paper identifies the financial risks associate with these two options. Fourth, the paper presents a financial derivative of VLSFO introduces by

Foreign Exchange Company (CME), the world's largest financial derivatives exchange, to precisely hedge the future uncertainty of VLSFO price.

Results/Findings

Open-loop scrubbers use seawater directly from the ocean, utilize it, and then discharge it back into the ocean. The open-loop scrubbers do not work as effectively in fresh water. One risk with open-loop scrubbers is the regulatory uncertainty. With many countries banning open-loop scrubbers, closed-loop can be used in fresh water and are not restricted by regulations. Closed-loop scrubbers create wastewater, which must be discharged in port creating other issues. Hybrid scrubbers allow flexibility between open and closed loop systems. These are the least common versions of scrubbers. For a VLCC, scrubbers represent a $4,000/day in the time charter market; this shows the difference between utilization of scrubbers and VLSFO. For a Panama vessel, there is an estimated $3,000/day difference between vessels with scrubbers and vessels using VLSFO. The price gap between vessels using HSFO/scrubbers and VLSFO is volatile with regional differences. Scrubbers increase the power consumption of the main engine by 1-2%. The cost of fitting an open-loop scrubber in a new build VLCC is around $2.5-3.0 million. The cost of retrofitting a scrubber on an existing VLCC is $4-$4.5 million. The installation of a scrubber takes between 20 and 30 days. During this time, the vessel is not earning revenue and thus must be included as the opportunity cost. The average 2015 VLCC earnings per day is about $62,100, giving a cost of $1,242,000-$1,863,000. The total cost including capital and opportunity cost is $5,242,000-$6,363,000. Thus, assuming a 10-years life at fixed-rate depreciation with zero worth of salvage at $6 million total cost, the daily cost of scrubber is about $1,600.

The price differences between VLSFO and HSFO has recently decreased from about $300 in early January, 2020 to just $34 in mid-April 2020. Considering the closing price on April 15, 2020, the price of VLSFO is $214/mt (daily rage $205-$230) and the price of HSFO is $180/mt (daily rage $155-$220) at Rotterdam Bunker. This difference can result in $2,100 more in operational cost by using VLSFO for a 10-year-old Capesize iron ore carrier that consumes about 62 tons daily.

Additionally, CME group has introduced serval financial derivatives that are publicly traded for cash-settlement as tools to hedge future price uncertainty with global offering covers three major bunkers: Houston, Rotterdam, and Singapore. This means that any business can lock the VLSFO April, 15 price of $214/mt with just $10 cost (exchange fees $7/$9 and cash settlement fees of $1). This provides a complete hedge of future price volatility.

Implications for Research/Policy

The results of this research can contribute a unique value to both industry and academia. Industry practitioners can use the findings of this paper as a guide to analyze the financial impacts of the two main options to comply with IMO 2020. Specifically, decision-makers can use the findings of this paper to precisely compare the expected capital expenditure of installing scrubber and the expected increase in operational cost by using VLSFO. Additionally, industry practitioners can employ the paper findings to comprehensively understand the risks associated with each decision and precisely hedge the price volatility of VLSFO. Academically, this paper initiates a much-needed step for scholars to introduce financial applications and tools to the domain of maritime business.

Keywords: *Maritime Finance, IMO 2020, Future Uncertainty, Financial Strategy, Spot Market, Price Hedging.*

Month of the Year Anomalies in US Equity Market Return

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ABSTRACT

Numerous studies have been performed to investigate month of the year anomalies in the equity markets all around the world. Many of these studies have utilized arithmetic means to compute average daily returns. Additionally, they don't reflect the contemporary patterns that exist in modern equity markets structure. This study aims to portray differences in US equity market monthly returns during 2001-2020, based on both arithmetic and geometric means. The study further computes seasonal indexes for the twelve different months during the period of study. The results of this research mainly reveal that Septembers are least pleasing to the general equity investors, as the average monthly return on stocks as represented by S&P 500 was actually negative. Additionally, the standard deviation of daily returns was the highest in September. Aprils, on the other hands, were the most favorable month of the year on the grounds of the highest monthly return.

Key Words: Market Returns, Geometric Mean, Month of The Year, Ratio to Moving Average, Seasonal Indexes.

JEL: G11, G12, G17

INTRODUCTION

There have been enough changes in the equity market arena in the past 20 years that would necessitate contemporary studies for the monthly effect phenomenon in the equity market. Average Daily Trading Volume (ADTV) of stocks comprising S&P 500 has gone up from 1.23 billion shares in 2001 to 4.92 billion shares in 2020. There are many factors that have caused this more than four-fold increase in trading activity. Proliferation of computerized trading, rapid growth of exchange traded funds (ETF's), introduction of leveraged ETF's, higher percent of younger individuals and even teenagers investing in equity markets, have all played a significant role in elevation in trading activity. These factors might have very well changed the monthly trading pattern. In addition, in efficient markets, one would expect that once an exploitable pattern, such as a monthly return anomaly is known, investors would alter their trading patterns to exploit the anomaly, and therefore such anomalies should not persist over long periods of time. It is the intention of this study to update the information on the month of the year effect in view of changes in trading pattern and compute monthly indexes using ratio-to-moving-averages method, to explore the persistence of this anomaly over decades.

REVIEW OF LITERATURE

In an attempt to devise loftier investment strategies, equity market research analysts have always tried to detect patterns in the stock market performance. Research on possible months of the year variations in S&P 500 stocks dates back to 1950's. Most research shows the presence of January effect in US equity market, Al-Saad and Moosa (2005). Bob Pisani of

CNBC (September 2021) noted that "Since 1945, September has been the worst month, on average, for the S&P 500". Anthony Gu (2003) found that the so-called January effect is showing a noticeable decline in both large and small firm stock indices since 1988 and the January effect is practically disappearing for the Russell indices. Parikh (2009) found that the Stock market shows a higher degree of volatility in returns in December as compared with the other moths of the year. Mouselli, et al. (2016) noted that "the existence of May effect may be considered as a contradiction to the efficient markets hypothesis".

DATA AND METHODOLOGY

In this study, we used monthly values of S&P 500 total return from Yahoo Finance website (http://www.finance.yahoo.com) from January 1, 2001 to December 31, 2020. We conducted various statistical and financial analyses to compute average monthly return for January, though December.

Ratio-to-Moving-Average method was used to detect month variations. Since each year consists of twelve trading months, twelve period moving averages were used to compute monthly indexes for average monthly return in SP500TR.

Additionally, Ordinary Least Squares method (OLS) utilizing 12 dummy variables was employed to predict the monthly returns as well as to test for significant difference among average monthly returns for different months of the year.

ANALYSIS OF RESULTS

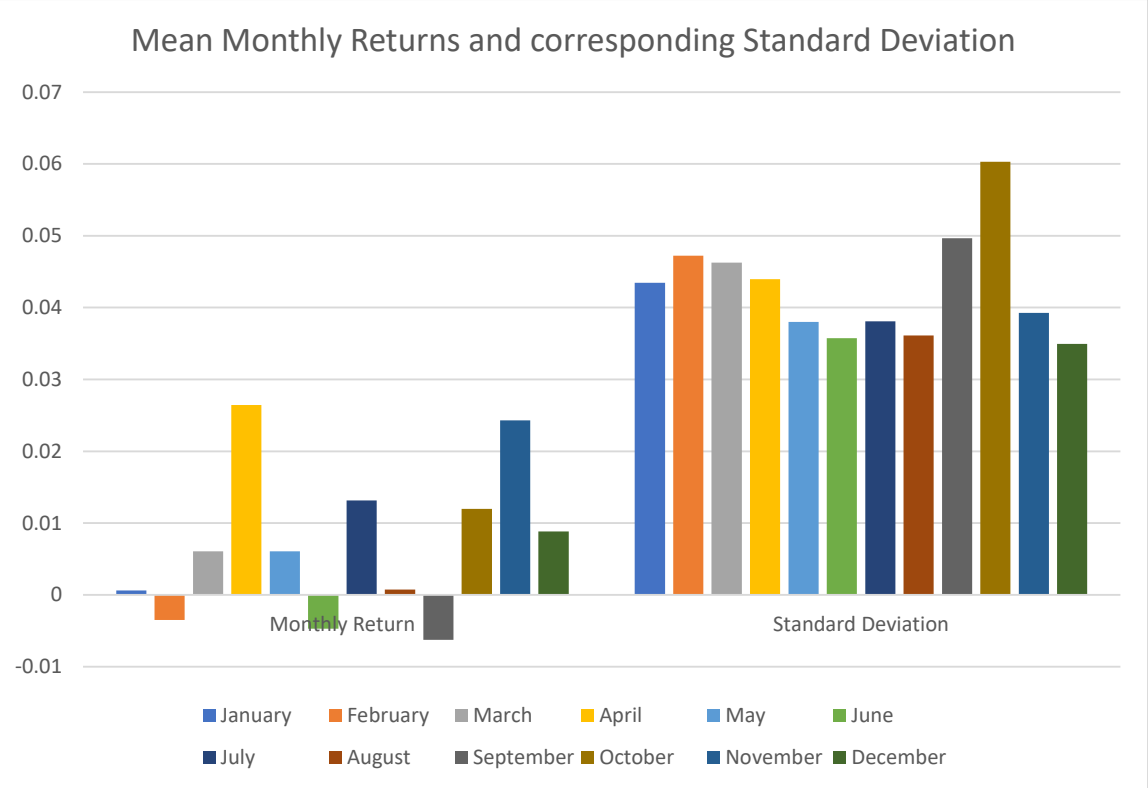
During the period of study, there were 20 full years and included 240 months. Exhibit 1 provides the descriptive statistics for the period of the study. It shows that the average monthly return for September (-0.00626 or -0.626%) is lowest and for April (0.026448 or 2.6448%) is the highest. Interestingly, October have the highest level of volatility, as measured by standard deviation (0.0603) and Decembers have the lowest degree of volatility (0.0349). The highest one-month return over the study period also took place in April (12.82%) and lowest one-month return over the study period also took place in October (-16.795%).

Exhibit 1: Descriptive Statistics for S&P 500 TR monthly returns (January 2001-December 2000)

Months	Mean	Standard Deviation	Range	Minimum	Maximum
January	0.000604	0.043455596	0.1644237	-0.08429	0.080134906
February	-0.00349	0.047246943	0.1639517	-0.10648	0.057473716
March	0.006067	0.046245094	0.2111115	-0.12351	0.087597995
April	0.026448	0.043938867	0.1888249	-0.06063	0.128194033
May	0.00606	0.038023514	0.1357822	-0.07985	0.055931617
June	-0.00471	0.035762106	0.1547814	-0.0843	0.070476712
July	0.013169	0.038093824	0.1535884	-0.07795	0.075633448
August	0.00073	0.03612943	0.1344855	-0.06261	0.07187983
September	-0.00626	0.049661229	0.1979274	-0.10869	0.089241391
October	0.011983	0.060307237	0.2772427	-0.16795	0.109292051
November	0.0243	0.039247308	0.1812155	-0.07175	0.109463625
December	0.008816	0.034957762	0.1571217	-0.09029	0.066831833

Exhibit 2 portrays monthly returns and corresponding standard deviations. As we will demonstrate, there were no significant differences among the average monthly returns.

Exhibit 2: Average Monthly Returns and corresponding Standard deviations for the Twelve Months of The Year



A single factor Analysis of Variance was conducted to determine if there are significant differences among average monthly returns. Exhibit 3 is a portion of the output for ANOVA depicting no significant differences among daily returns (p-value = 0.282061).

Exhibit 3: Single factor ANOVA testing for significant differences among average monthly returns

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.024969	11	0.00227	1.208659	0.282061	1.830818
Within Groups	0.428197	228	0.001878			
Total	0.453166	239				

Exhibit 4 shows the output of an Ordinary Least Squares (OLS) regression utilizing twelve dummy variables to capture month of the year effect. We ran the regression forcing the constant term to zero to predict average monthly returns. The results indicate no overall significant difference among the average monthly returns (Significance F = 0.0854).

Exhibit 4: Regression output for predicting monthly returns using twelve dummy variables

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	12	0.036652	0.003054	1.62634573	0.085442
Residual	228	0.428197	0.001878		
Total	240	0.464849			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
January	0.000603527	0.00969	0.062281	0.95039341	-0.01849	0.019698
February	-0.00348824	0.00969	-0.35997	0.71920253	-0.02258	0.015606
March	0.006067	0.00969	0.626087	0.53188419	-0.01303	0.025161
April	0.026447983	0.00969	2.729312	0.00684184	0.007354	0.045542
May	0.00606039	0.00969	0.625405	0.53233088	-0.01303	0.025154
June	-0.00470576	0.00969	-0.48561	0.62770752	-0.0238	0.014388
July	0.013169115	0.00969	1.358993	0.17549159	-0.00592	0.032263
August	0.000729944	0.00969	0.075327	0.94002064	-0.01836	0.019824
September	-0.00625751	0.00969	-0.64575	0.51909294	-0.02535	0.012837
October	0.011983427	0.00969	1.236635	0.21749479	-0.00711	0.031078
November	0.024299823	0.00969	2.507632	0.012851	0.005206	0.043394
December	0.00881557	0.00969	0.909727	0.36392724	-0.01028	0.02791

We also used ratio-to-moving-averages method and computed monthly indexes for the twelve months. It is worthy of note that the sum of these twelve indexes should be exactly twelve. Months with computed indexes below or above 100, would signify below or above average monthly returns respectively and indexes being exactly 100 would signify at the average monthly return.

Exhibit 5 shows daily returns for January, February, March, May, June, August, September are below average, and rest of the months enjoy an above average monthly return.

Exhibit 5: Seasonal Indexes for Monthly Stock Returns

Month of The Year	January	February	March	April	May	June
Monthly Indexes	99.36%	98.96%	99.91%	101.93%	99.90%	98.84%
Month of The Year	July	August	September	October	November	December
Seasonal Indexes	100.61%	99.38%	98.68%	100.49%	101.72%	100.18%

It is interesting to note that February and April correlation coefficient has the most negative magnitude, indicating that monthly returns for these two months tend to be the opposite of each other. Additionally, July and September monthly returns tend to move in the same direction. Exhibit 6 displays correlation coefficients matrix between the average monthly returns of the twelve months of the year.

Exhibit 6: Correlation Coefficients Matrix between the average monthly returns of the 12 months of the year.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	1											
Feb	0.21	1										
Mar	-0.29	0.24	1									
Apr	-0.13	-0.63	-0.35	1								
May	-0.37	-0.49	-0.27	0.37	1							
Jun	0.45	0.19	-0.10	0.15	-0.04	1						
Jul	-0.17	-0.15	0.10	0.42	0.07	0.25	1					
Aug	-0.15	-0.34	-0.11	0.22	0.37	0.29	0.08	1				
Sep	0.09	0.26	0.42	-0.01	-0.22	0.42	0.59	0.08	1			
Oct	0.19	0.38	0.14	-0.21	-0.17	0.08	-0.24	-0.47	0.02	1		
Nov	0.11	-0.39	-0.31	0.19	0.18	0.35	0.20	0.16	-0.08	0.23	1	
Dec	-0.17	0.06	0.09	0.45	-0.16	0.18	0.37	-0.11	0.36	0.08	0.03	1

CONCLUSION

- Average monthly equity market return during the period of January 2001 to December 2020 was lowest for Septembers and highest for Aprils, although the differences are not statistically significant.
- Monthly indexes for Aprils and Julys, Octobers, Novembers and Decembers are above 100 percent, and conversely, for rest of the months are below 100 percent.
- In light of the fact that some studies in the past have shown a significant difference among monthly returns, it appears that we are witnessing a diminishing month of the year anomaly.
- Average monthly volatility of the equity market as measured by standard deviation during the period of January 2001 to December 2020 has been the lowest in Decembers and highest in Octobers.

REFERENCES

Al-Saad, K., Moosa, I.A. (2005), Seasonality in stock returns Evidence from an emerging market. *Applied Financial Economics*, 15, 63-71.

Bahadur K., Fatta, C. & Joshi, N. K. (2005). The Nepalese stock market: efficiency and calendar anomalies. *Economic Review*, 17, 443-56.

Gu, Anthony. (2003), The Diminishing January Effect: Experience of Five G7 Countries, *International Journal of Finance*, 15(1), 2465-2475.

Keim, D.B. (1983), Size-related anomalies and stock return seasonality. *Journal of Financial Economics*, 12(1), 13-32.

Mouselli, S., Al-Samman, H. (2013), An Examination of the Month-of-the-year Effect at Damascus Securities Exchange. *International Journal of Economics and Financial Issues*, 6(2), 571-577.

Pisani, Bob, (2021), September is the toughest month for stocks, but this time could be different, https://www.cnbc.com/2021/09/01/september-is-the-toughest-month-for-stocks-but-this-time-could-be-different.html

Wachtel, S.B. (1942), Certain observations on seasonal movements in stock prices. *The Journal of Business of the University of Chicago*, 15(2), 184-193.

NEW PRODUCT DEVELOPMENT CREATIVITY, A DATA ENVELOPMENT ANALYSIS APPROACH

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ABSTRACT

Innovation is critical for firm competitiveness and survival. A key part of innovation is team brainstorming and idea generation. Using a sample of one hundred and twenty-eight new product development managers in the United States, we examine factors that support the highest levels of efficiency for generating novel, useful, and manufacturable ideas during the initiation stage of the new product development process. The efficiency of new product development managers in achieving desirable creativity levels when considering various factors is assessed with Data Envelopment Analysis. We provide practical recommendations to enhance team creative output.

Track: Management, Marketing, Accounting, Economics and Finance, Strategy, Organizational Behavior Organizational Theory, Human Resource Management, Consumer Behavior, International Business

INTRODUCTION

Team creativity and innovation is critical for firm competitiveness and survival. Given the role that organizational creativity plays in firm profitability [1] and high failure rates of innovation efforts [8], companies look for ways to enhance and optimize their new product development efforts. Relevant aspects of team creativity include the safety of a team's communication environment [4], the amount internal and external team communication [5], and the richness of the most utilized communication channels [6].

While the new product development literature supports the relationship between higher levels of communication safety [4], adequate channel richness [6], and frequency of communication [5], firms with resource constraints need to find strategies to optimize the use of resources supporting creative efforts. In certain circumstances it may be time-consuming or expensive to create safer communication environments or to communicate with richer channels, such as face-to-face

meetings or videoconferences. In addition, there may be circumstances in which new product development teams can produce the same quality and number of outputs with less resources, which in resource-constrained settings can be leveraged for other ventures.

This study exemplifies the use of Data Envelopment Analysis to identify new product development teams that use inputs most efficiently to generate creative outputs, as well as a set of recommendations that lacking teams can implement to become more efficient.

DATA ENVELOPMENT ANALYSIS

Data Envelopment Analysis (DEA) is a method developed originally by Charnes et al. in their 1978 paper [3], where they applied linear programming to estimate production frontiers. It is a non-parametric method that incorporates available data to compare feasible inputs and outputs of existing operations - generally manufacturing or service operations. Since its publication, the method has been extensively used in a range of industries to determine the most efficiently operating units (generally referred to as Decision Making Units (DMUs)) and create pathways for less efficiently operating units to improve the levels of their efficiency to that of their best performing peers. The name of the method comes from the phenomenon that the virtual "frontier" created by the most efficient units` "envelope" all non-efficient units.

DEA is a relatively easy to understand, interpret and act upon, and as a result is a very popular method in practical economics and operations research. If one can identify a set of Decision Making Units with common inputs and outputs (without an upper limit on the number of inputs and outputs used), the method will be able to generate (among other things) the following: a.) Identify which DMUs are the most efficient and which need improvement, b.) Identify a set of benchmark DMUs for all units, c.) Determine target values for the level of inputs or outputs each DMU needs to achieve the best efficiency among all DMUs.

The are several versions and variations of the basic methodology, the most important of which from the standpoint of this publication are discussed shortly:

1. Scaling assumptions
   There are two basic scaling assumptions one has to decide on when employing the method: Constant versus Variable returns to scale (CRS vs. VRS). CRS assumes that at any given DMU the outputs change *in constant proportion* with the changes in input, whilst VRS works with the assumption that the change in output is not linear, but either increasing or decreasing with the size of the input.
2. Input our Output orientation
   Input orientation focuses on how to change the inputs of DMUs in order to achieve the desired efficiency, while Output orientation focuses on the opposite, namely: What output should be reached with given inputs to achieve top efficiency.

EMPIRICAL ILLUSTRATION

The Data Envelopment Analysis approach was used to examine the efficiency of new product development teams in the United States. Creativity and manufacturability of ideas were

considered *outputs*, and several dimensions of team communication were considered *inputs*. These included the extent of each team's psychologically safe communication climate, communication channel richness, amount of internal communication, as well the amount of external communication outside the project group but within the business unit, outside the business unit but within the company, and outside the company. Please find the summary of inputs and outputs in Table A.

	Name	Code
Input 1	Communication channel richness	ChanRich
Input 2	Amount of internal communication	Int Com
Input 3	Amount of external communication (outside the project group, within the business unit)	ExtCom1
Input 4	Amount of external communication (outside the project group and business unit, within the company)	ExtCom2
Input 5	Amount of external communication (outside the company)	ExtCom3
Input 6	Psychologically safe communication climate	ComSafe
Output 1	Level of creativity	Creativity
Output 2	Level of manufacturability	Manufacturable

TABLE A: SUMMARY OF INPUTS AND OUTPUTS USED FOR THE MODEL

To ensure meaningful efficiency values are obtained, the sample size of inputs and output performance measures must be large enough. A popular rule of thumb suggests considering $3*(s+m)$ [2,7], where s is the number of outputs, m the number of inputs. The size dataset for this study is more than adequate based on these standards, as it considers 128 teams versus the suggested 24. The data was gathered via a Qualtrics survey panel of new product development managers. Table B shows a subsection of the full range of data used for analysis:

DMUs	Inputs						Outputs	
	ChanRich	Int Com	ExtCom1	ExtCom2	ExtCom3	ComSafe	Creativity	Manufacturable
C3	186	7	7	7	6	7.0	6.0	5
C4	105	6	5	5	3	6.3	5.8	6
C6	165	7	7	7	7	7.0	7.0	7
C7	109	6	6	6	4	6.0	6.0	6
C10	160	6	6	3	5	4.7	4.0	6
C11	119	6	5	4	4	6.3	5.8	6
C12	149	6	6	3	6	6.0	6.4	7
...	...	...	...	...	...	...	...	...
C246	142	4	5	5	5	4.3	5.0	4
C248	126	7	5	5	1	5.3	5.2	7
C249	116	7	6	6	5	6.7	5.4	7

TABLE B: DATA USED FOR ANALYSIS

The nature of the operations means that the inputs do not yield constant returns to scale (since doubling the amount of communications would not necessarily double the outputs), and thus VRS is used. Since the managers of the DMUs mostly have control over the inputs, the input oriented approach was used, and thus the results will give suggestions on how to adjust the input values to reach peak efficiency.

RESULTS

The DEA model was run and the following results - shown in Tables C through E - were obtained. First, the relatively most efficient DMUs were identified. 47 of the 128 decision making units were identified to have the highest efficiency of 1.0. The lowest efficiency score was 0.6164.

DMU	Efficiency
C3	0.6991
C4	0.8570
C6	0.8776
C7	0.8393
C10	0.9087
...	...
C245	1.0000
C246	1.0000
C248	1.0000
C249	0.8140

TABLE C: LIST OF EFFICIENCIES

For each DMU which does not have the desired efficiency of 1, a set of reference DMUs (called peers) have been identified from the set of DMUs with the efficiency of 1. These are the closest firms that are on the efficiency frontier, and act as a "role models" for the non-efficient DMU. Table D shows the list of peers for 6 selected non-efficient DMUs, and their relative importance, denoted by Lambda values.

DMU	Peer	Lambda	DMU	Peer	Lambda
C3	C27	0.1626	C7	C146	0.0624
	C120	0.0378		C65	0.0226
	C110	0.4059		C210	0.2581
	C174	0.2061		C174	0.4555
	C210	0.1876		C34	0.2013
C4	C146	0.4361	C10	C27	0.1032
	C65	0.1856		C90	0.6548
	C174	0.1348		C24	0.2421
	C34	0.2295			
	C24	0.0140			
			C249	C146	0.1262
C6	C166	0.7143		C90	0.0048
	C138	0.1429		C152	0.1510
	C120	0.1429		C174	0.7179

TABLE D: LIST OF PEERS AND THEIR IMPORTANCE

The non-efficient DMUs will have a target value for each of their inputs. Reaching those target values will enable them to be as efficient as their peers. Table E shows each of the targets.

DMU	Category	Original	Target	DMU	Category	Original	Target
C3	ComSafe	7.00	4.89	C7	ComSafe	6.00	5.04
Efficiency:	ChanRich	186.00	128.67	Efficiency:	ChanRich	109.00	91.49
0.6991	Int Com	7.00	4.89	0.8393	Int Com	6.00	5.04
	ExtCom2	7.00	4.40		ExtCom2	6.00	4.37
	ExtCom3	6.00	4.19		ExtCom3	4.00	3.36
	ExtCom1	7.00	4.57		ExtCom1	6.00	4.06
C4	ComSafe	6.33	5.43	C10	ComSafe	4.67	4.24
Efficiency:	ChanRich	105.00	89.98	Efficiency:	ChanRich	160.00	129.67
0.8570	Int Com	6.00	5.14	0.9087	Int Com	6.00	5.31
	ExtCom2	5.00	3.53		ExtCom2	3.00	2.73
	ExtCom3	3.00	2.57		ExtCom3	5.00	3.14
	ExtCom1	5.00	3.88		ExtCom1	6.00	5.10
C6	ComSafe	7.00	6.14	C249	ComSafe	6.67	5.43
Efficiency:	ChanRich	165.00	134.29	Efficiency:	ChanRich	116.00	94.42
0.8776	Int Com	7.00	6.14	0.8140	Int Com	7.00	5.70
	ExtCom2	7.00	6.14		ExtCom2	6.00	4.88
	ExtCom3	7.00	5.29		ExtCom3	5.00	3.20
	ExtCom1	7.00	5.29		ExtCom1	6.00	3.59

TABLE E: TARGET VALUES FOR EACH INPUT FOR NON-EFFICIENT DMUS

As an example, an examination of Table E shows that the decision-making unit C3 needs to change their level of inputs to the following values: They do not need Communication Safety (ComSafe) to be at such as high level (7.00) and should decrease the amount of resources allocated towards it to a lower level (4.89). Channel Richness (ChanRich) is also an input that should be reduced, i.e.: less resources should be allocated towards it (decrease from 186 to 128.67), etc... Note that due to the relative subjectivity of some of these categories, it would be difficult to attain the exact amount, but it does provide organizations with a good idea on what and how should be changed in their operations to attain the efficiency level showed by their most efficient peers.

Ultimately the applied DEA method gives the following broad suggestions for new product development teams already generating the required creative outputs: it can help managers identify communication areas where they may not need to invest so many resources to continue to produce their current levels of creativity

The preceding example shows how the DEA approach can be employed to identify a company's most efficient new product development teams. This example shows how DEA can be useful is

assessing not only the *causes* responsible for the new product development teams' inefficiencies, but also the *set of changes* that each team needs to make to reach the highest possible efficiency.

MANAGERIAL IMPLICATIONS AND CONCLUSIONS

An optimal team environment for organizational creativity usually requires high amounts of communication safety, internal and external communication, and channel richness. However, there may be situations in which companies have to work with limited resources and cannot invest the time, effort, or money to create safer communication environments, use richer communication channels, or promote higher levels of internal and external communication.

In environments with restricted resources, organizations managing teams involved in new product development creativity can leverage the DEA approach to identify the most efficient teams and related pathways for lacking teams to become efficient, optimizing their use of recourses.

In addition, for new product development teams already generating the required creative outputs, the DEA approach can help managers identify communication areas where they may not need to invest so many resources to continue to produce their current levels of creativity.

REFERENCES

[1] R. Adams, S. Jeanrenaud, J. Bessant, D. Denyer, P. Overy, Sustainability-oriented Innovation: A Systematic Review, *International Journal of Management Reviews*. 18 (2016) 180–205.

[2] R.D. Banker, A. Charnes, W.W. Cooper, Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*. 30 (1984) 1078–1092.

[3] A. Charnes, W.W. Cooper, E. Rhodes, Measuring the efficiency of decision-making units, *European Journal of Operational Research*. 2 (1978) 429–444.

[4] C.B. Gibson, J.L. Gibbs, Unpacking the Concept of Virtuality: The Effects of Geographic Dispersion, Electronic Dependence, Dynamic Structure, and National Diversity on Team Innovation., *Administrative Science Quarterly*. 51 (2006) 451–495.

[5] R.T. Keller, Cross-Functional Project Groups in Research and New Product Development: Diversity, Communications, Job Stress, and Outcomes., *Academy of Management Journal*. 44 (2001) 547–555.

[6] A. Oke, M. Idiagbon-Oke, Communication channels, innovation tasks and NPD project outcomes in innovation-driven horizontal networks, *Journal of Operations Management*. 28 (2010) 442–453.

[7] S.C. for the R. of C.S. Provision, *Data Envelopment Analysis: A technique for measuring the efficiency of government service delivery,* AGPS, Canberra, 1997.

[8] G.A. Stevens, J. Burley, Piloting the rocket of radical innovation, *IEEE Engineering Management Review*. 32 (2004) 111–122.

Symposium Proposal

THE FORMATION AND CONSEQUENCES OF FIRM AND BRAND IDENTITIES: NOVEL RESEARCH PERSPECTIVES FROM MULTIPLE BUSINESS DISCIPLINES

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ABSTRACT

The goal of this Symposium is to offer novel perspectives on the broad theme of 'formation and consequences of firm and brand identities' through three different, yet related lenses across business disciplines. The Symposium aims to facilitate a broad cross-disciplinary discussion of the formation and consequences of firm and brand identities as key research constructs among various business fields. The three presenters hail from the disciplines of marketing, finance, and management information systems and bring their respective unique expertise to bear as they triangulate the theme of the session.

SUMMARY

The goal of this Symposium is to offer novel perspectives on the broad theme of 'formation and consequences of firm and brand identities' through three different, yet related lenses across business disciplines. The three presenters hail from the disciplines of marketing, finance, and management information systems and bring their respective unique expertise to bear as they triangulate the theme of the Symposium.

Specifically, as our society becomes increasingly digitalized and as people spend more time online, individuals' online experience and user-generated content such as electronic word-of-mouth (eWOM) are critical for firms considering their influences on, for example, purchasing decision and satisfaction. The first presentation of this Symposium is titled "**Virtual Brand Communities and Electronic Word-of-Mouth: The Impact on Community Identification.**" From the perspective of management information systems and looking at both brand identification (i.e., identification with the brand) and community identification (i.e., identification with online community that may not be managed by the brand), the session's first presentation focuses on the mediating role of identification between individuals' online experience and different types pf eWOM behaviors (e.g., opinion giving, opinion passing and opinion seeking). This study concludes that online experiences affect the formations of brand and community identification differently, and that brand identification and community identification have different impacts on the three types of eWOM behaviors.

The marketing presentation in this Symposium is titled "**Franchisors and Franchisees: Ambiguous Identities and Their Repercussions.**" It highlights the ambiguity related to the identity of franchisors vs. franchisees, taking into account the legal precautions franchisors employ to limit their own liability vis-à-vis malfeasance that may occur on the premises of their franchisees. While franchisors attempt to draw strict legal lines vis-a-vis franchisees as legally independent firms, a franchise system's identity in the public eye rests on the joint and inseparable identification of franchisees' outlets with the system's brand and operating standards. This presentation contrasts the ambiguity of identities within franchise systems and the repercussions related to vicarious liability and corporate social responsibility.

Finally, from the perspective of finance, firm identity has been frequently linked to the personality and visibility of companies' prominent executives, often also referred to the 'C-Suite'. The last presentation in this Symposium is titled "**Gender in the C-Suite: Its Effect on Corporate Financial Policies and Performance**." This presentation highlights the very timely role of gender, and specifically of females, among members of the C-Suite. It focuses on gender differences in terms of financial decision making and explains how certain types of firms could benefit more from female executives. The presentation offers a discussion of gender's critical role as a part of firms' financial management in the future.

Ultimately, the Symposium aims to facilitate a broad cross-disciplinary discussion of the formation and consequences of firm and brand identities as key research constructs among various business fields. For attendees of SEDSI, this Symposium breaks the mold of discipline-specific sets of presentations and offers a venue at which a topic of interest may be discussed by interested attendees across discipline boundaries.

The Application of the Kelly Criterion to Personal Financial Statements and Investments

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ABSTRACT

A number of studies and popular attention have been devoted to the idea of the "disappearing" middle class. In this study, we use a Kelly Criterion to examine how the allocation of investible funds between the stock market and "riskless" investments explains some of these effects. In our application of this model, we use data published by the Federal Reserve and US Census Bureau to create four different representative personal financial statements. These groups are based on household income reflecting the national average, bottom 20%, middle 70%, and top 10% of American households. We find that based on the median financial statements for these groups, the recommended allocation to risky assets for groups other than the top 10% of households is minimal.

INTRODUCTION

America's middle class faces a variety of problems in today's changing economy. Our focus in this paper is on the allocation of risk by different economic classes between relatively riskless investments (like paying off debt and accounts secured by FDIC insurance) and a risky investment proxied by equities. We posit that this risk allocation may have some explanatory power for many are witnessing about the middle class. There are many headwinds for the middle class in the US. One problem, perhaps bigger than any other, is the fact that the middle class itself is shrinking. According to the Organisation for Economic Co-operation and Development (OECD) [23], there has been very little growth of the middle class over the last three decades. This has led to an overall decrease in what has historically been called "blue collar" workers. In fact, stagflation, which occurs when there is an increase in prices along with an increase in unemployment, combined with certain socio-economic circumstances have caused what some would term "unfair" situations. Additionally, there is a widening wealth gap between upper-class and middle-income households. This leads to added income inequality, and eventually results in the middle-class left behind during times of economic growth. While there are many forces driving these changes, we believe that exposure to economic catastrophe is one of them.

There are many tools designed to mitigate economic catastrophe in the US (the legal institution of bankruptcy, the social safety net, etc.). We focus on asset allocation in terms of risky versus riskless investments. To aid in this endeavor we apply a mathematical idealized risk allocation model in the form of Kelly Criteria. These are a class of mathematical models in continuous time and continuous state-space that identify the maximum level of risk one can take in order to have a long-term, zero probability of ruin or bankruptcy. By definition, applying a Kelly Criteria to personal financial statements would result in more optimal risk

management. Additionally, these findings can be generalized easily to those in the middle class. Many of these ideas are already commonly used by professional wealth advisors; however, this idea is notably absent from personal financial literature (in a literature survey covering more than 100 academic papers, literature reviews, and meta-analyses on personal financial literacy, we found no mention of the Kelly Criteria). Our hope is that connecting the risk allocation decisions of debt and investments will lead to a more mathematically grounded personal finance instruction and possible a robust middle class that is well equipped for the volatility of capitalistic markets. At the very least, the application of this idea helps combat one source of the current middle class attrition.

The remainder of this article is as follows: We, first, briefly survey of the key literature related to our study. The second section covers our methodology both for the specific Kelly Criterion applied in this paper and our construction of three representative personal financial statements. Third, we outline our findings under various methodologies, and finally, we conclude with both a summary of our findings, an outline of our study's limitations, and avenues for future research.

LITERATURE REVIEW

There are many forces driving changing the middle class that are beyond the structure of personal financial statements. Some economists believe the middle class is not growing in proportion to how much it contributes to the economy. Specifically, increased costs of living and automation of labor have arguably caused a lack of social mobility within the middle class [16]. Many of these inequalities are, also, reflected in personal finances.

A decrease in economic growth and social mobility has arguably led to materially different management of monetary resources. Huston explains that more than 65% of the middle class has made lousy financial management mistakes that have cost them up to $23,000. This has led to a 28% decline in the wealth of middle-class households. Part of the reason for this could be the fact that middle class households rarely seek financial advice. Out of the 108 million middle class families in the US, only 2% were found to actively pursue financial advice. On the other hand, 60% of affluent households had some sort of financial advisor or followed a financial plan, which amounted to them being more than twice as prepared for retirement and emergencies [16]. Aside from negative implications regarding future personal finance, the middle class was also found to make worse decisions regarding employee benefits and other forms of compensation [9]. There is a clear distinction between the effects of using financial strategies versus not pursuing any management advice. Additionally, the decreased economic opportunities for the middle class does not play a role in their ability to seek financial advice, since the term "financial advice" does not necessarily entail employing a financial advisor. Instead, it refers to the incorporation of any financial plan or management strategy, and there are many cost-free methods of this including online tools, local financial-service programs, and reputable public access sources.

The current negligence of economic advice among the middle class could be the root of some problems this group currently faces. Another aspect of this situation could be the lack of diversity among financial management strategies. To combat this, one esoteric risk

management technique combines the use of gambling models to help make financial decisions. Specifically, relatively a number of studies use a Kelly Criteria, a betting formula, to help make investments in stock markets. One of the pioneers in this field is Edward O. Thorp, the inventor of card counting and arguably the best applied statistician of his generation. In Thorp's original thesis regarding investments, he explains how he first applied the Kelly Criterion, also known as the Kelly formula or Kelly Capital Growth formula, to blackjack. Then, he transitioned to what he called "the biggest game of all," the stock market. Thorp found that the formula worked especially well for long-term investments [21, p. 3]. In another study, MacLean and Thorp both explain the effects of this formula using the "Growth-Optimum Model." The underlying finding was that most investors acquired bigger financial gains when they opted to invest for longer time periods [12, p. 427]. The Kelly Criterion is also closely associated with portfolio management. One term that is commonly used when mentioning the Kelly Criterion is the mean-variance theory, which is an analysis method that weighs the risk of an investment against its possible return. Similar to the Kelly Criterion, this method provides a management technique that can help investors seek maximum asset allocation [12, p. 302] [22]. The big difference between these techniques, and possibly why the Kelly Criterion has drawn so much attention recently, is because of the relative ease of using it to make investments and manage assets versus other techniques. It is also worth noting that the application of this approach to portfolio management has led to Edward Thorp's net worth of ~$800 million according to various online sources.

Although there have been recent studies showcasing the use of the Kelly Criterion to aid investment decisions, there has been very little research done in other fields of personal finances. In fact, Thorp's research on stock market investments was one of the only studies to even apply this formula beyond betting games. While maximizing stock investment returns (i.e. minimizing catastrophic losses caused by individual decision-making) could help the struggling middle class, it does not provide an all-inclusive impact because not all middle-class citizens hold stocks or participate in financial markets. In fact, similar to many measures of economic resources, the top 20% of citizens account for more than 93% of all stock ownership in America [10]. Furthermore, 84% of these stocks are held by the top 10% [10]. While equities are an important component of anyone's finances, they are only a single component of someone's financial situation.

We define personal financial statement, as a the summary of an individual's objectively measurable, current financial situation. For corporations these are typically separated into an income statement that covers all the income and expenses for a given period of time and a balance sheet which includes the instantaneous levels of the firm's assets and liabilities. As our focus is on the individual's allocations between risky investments and safe investments we limit ourselves to a focus on the balance sheet. Even in the context of developing a personal financial statement, many individuals make categorical errors when thinking about what would be part of their personal balance sheet (See [18] discussion on assets versus liabilities). Robert Kiyoski (net worth ~$100 million), author of *Rich Dad Poor Dad*, explains that the key to financial success lies within understanding and correctly managing personal financial statements. The most important factor these statements help identify is a given individual's cash flow. Properly reading and managing these statements leads to financial literacy, which in turn creates what Kiyosaki calls higher "financial IQ" [18]. In other words,

knowing how to manage personal financial statements almost guarantees better financial decisions.

METHODOLOGY

Kelly Criteria

There are a wide variety of Kelly Criteria which can be easily adapted to all different types of discrete and continuous-time models. Notably, applications of the Kelly Criteria to the world of investments run into two limitations of the idealized Kelly Criteria. First, market reallocations are not costless and cannot be made in continuous time (for excellent historical examples see "self-financing dynamic replication" in reference to options strategies). Second, with small amounts granularity becomes an issue because the state-space of financial investments is not continuous. With these limitations in mind, we use a specific Kelly Criterion to calculate recommended allocations toward risky investments [22]. The formula is as follows:

$$f = \frac{(R - r)}{\sigma^2} \quad (1)$$

In this case, *f* stands for the proportion invested in the risky asset or the recommended amount to invest out of a given investor's financial net worth, which is calculated using the personal financial statement. This can also be referred to as "recommended allocation". *R* is the rate of return on the risky asset. On the other hand, *r* represents the rate of return on the safe or "riskless" asset. σ^2 refers to the variance of return on the risky asset. The main purpose of this formula is to calculate how much money a given investor should put towards both risky and riskless investments, relative to the individual's total financial resources. Once we solve for *f*, it can be subtracted from one, giving the remaining proportion that should be invested in riskless investments or saved [5]. This study makes no distinction between investing money into riskless investments versus solely saving. Thus, we ignore the motivation for precautionary savings which while important must be notably absent given savings rates for the majority of the US population. In other words, for the sake of our model, saving money is identical to investing in riskless investments.

We pull from current risky and "riskless" investment rates to match our model's recommendations to real-world investments available to almost everyone in the US. Through national statistics, we calculate items in six key categories on a personal financial statement. For robustness, median national statistics are used to exclude well known skew effects present in the underlying data. Riskless investments represent depositing money into a given financial institution and receiving a return on that deposit, which is very different from investing money into risky investments such as bonds [18]. On the other hand, this study classifies risky investments through variations of stocks and mutual funds shares. National statistics on how much money is allocated towards these two groups of investments provides a broad baseline which the recommended allocation amounts, derived from the modified Kelly Criterion, can be compared against. The difference between the recommended

allocation amount and actual amount invested shows how much Americans' investments differ from the Kelly Criterion's recommendation.

To apply the Kelly Criterion to these statements, *f* or the recommended allocation amount is needed based on the risky and riskless investments. This study approaches solving for f through two different methods. In the first method, the rate of return on the risky investment and the variance rate remains the same while different rates of return on the riskless investment are used. The different riskless investments represent the most common ways Americans can save their money. In this study, the four different riskless investments used are basic savings accounts, online banking, money market accounts, and 1-year certificates of deposits or CDs. The second method keeps rates of return on the risky and riskless investments constant, but uses different variance rates. For the sake of clarity, this study uses variance rates from two different stock market indexes (SP500 and DOW) and three different stocks (Apple, Microsoft, and SK Innovations). These two methods result in different *f* values, allowing for comparison between two applications of the Kelly Criterion. To account for variations in starting financial net worth and represent a myriad of financial decisions, the amount of assets owned and liabilities owed are separated into three general groups: small, medium, and large. These groups are referred to as 1, 2, and 3 respectively. By doing this, the difference in the recommended allocation amount can be traced back to how much money or assets a given investor started with. This design allows for basic reasons as to how the allocation amount varies among different personal financial statements. Groups 1, 2, and 3 have different starting points which helps track differences based on each investor's actual financial net worth. Although *f* remains the same for each group, the actual amount allocated based on a given investor's financial net worth varies among each group. Since f represents the proportion of money that should be invested, it can be multiplied with each group's personal financial statement. A negative *f* indicates that an investor should not only restrict future risky investments, but actually curtail current risky investments as well. An *f* between 0 and 1 represents the percentage of an individual's net worth that should be invested in risky investments. When *f* is greater than 1, this means that an individual should over-invest in the risky investment in discussion. In other words, the formula is suggesting that the given investor should put more money towards the risky investment than he or she currently has, either through a second loan or by trading on margin.

Representative Balance Sheets

This study uses national averages published by the Federal Reserve and US Census Bureau to construct a "typical" middle class personal financial statement. The basic personal financial statement includes a balance sheet with two main sides: assets and liabilities. On the assets side, the three main subsets that are used in this study include retirement accounts, real estate equity, and stocks. For the liabilities side, mortgages, student loans, and cash credit are used. The rationale behind these six specific subsets involves constructing a balance sheet that can be applicable to the majority of Americans. In 2018, home mortgages accounted for 68% of the composition of household liabilities. Consumer credit and student loans were the next two largest areas, making up 16% and 10% of liabilities respectively [19]. Likewise, retirement accounts constituted for roughly half of the median value of assets for households in 2016 [24]. Real estate and equities were second and third in terms of household assets. In

fact, all other assets accounted for only 5% or less of the total median value of assets in households [24]. Because the initial personal financial statement is made up of national statistics, the findings of this study is designed to be generalized to the majority of the American population.

There are four different personal financial statements used in this study. The first statement consists of national statistics that includes the entire American population. The three following groups are divided by income. Group 1 includes the bottom 20% of Americans, Group 2 covers the middle 20%-90%, and Group 3 consists of the top 10% or the highest earning households. The six key items for each personal financial statement are displayed for all groups in Figures 1-4.

Figure 1: National Average. This table shows key household balance sheet items for the national average.

Assets	Liabilities
Retirement Accounts- $60,000	Home Mortgages- $202,284
Real Estate Equity- $185,000	Student Loans- $31,172
Stocks and Mutual Funds Shares- $25,000	Cash Credit Owed- $5,673

Figure 2: Group 1 (Bottom 20%). This table shows key household balance sheet items for the bottom 20% of incomes.

Assets	Liabilities
Retirement Accounts- $30,000	Home Mortgages- $134,757
Real Estate Equity- $37,048.8	Student Loans- $26,000
Stocks and Mutual Funds Shares- $2,363	Cash Credit Owed- $3,000

Figure 3: Group 2 (20%-90%). This table shows key household balance sheet items for incomes between the 20th and 90th percentiles.

Assets	Liabilities
Retirement Accounts- $75,000	Home Mortgages- $164,189
Real Estate Equity- $153,900	Student Loans- $36,700
Stocks and Mutual Funds Shares- $19,877	Cash Credit Owed- $5,725

Figure 4: Group 3 (Top 10%). This table shows key household balance sheet items for the top 10% of incomes.

Assets	Liabilities
Retirement Accounts- $180,000	Home Mortgages- $295,455
Real Estate Equity- $576,400	Student Loans- $46,700
Stocks and Mutual Funds Shares- $116,760	Cash Credit Owed- $11,200

Since retirement savings greatly vary by age, a baseline age of 40 years old was used for all statements. The national median for retirement accounts hovered around $60,000. The conditional mean was a little more than this, totaling close to $63,000 [3]. When income level was taken into account, Group 1 averaged $30,000 in retirement savings while the

average for the top ten percent reached $180,000 [15]. The second item on the assets side was real estate equity, which reflects an individual's primary residence, excluding additional real estate properties owned. The national median for this was $185,000. Fluctuating from $37,048 to $576,400, this subset's range of $539,352 was the largest of any one asset [7]. One reason for this variation could be explained by a higher number of renters in lower income levels. Out of the 47 million households who rent their homes, approximately 65.6% belong to the bottom twenty percent [4]. Stocks and mutual funds shares had the second highest variation, amounting to a staggering $114,397 difference between Groups 1 and 3. Again, the contrast in ownership rates among income groups played a huge role. For example, only 1.7% of Group 1 owned any stocks or mutual funds. Conversely, Group 3 had an 84% ownership rate [25].

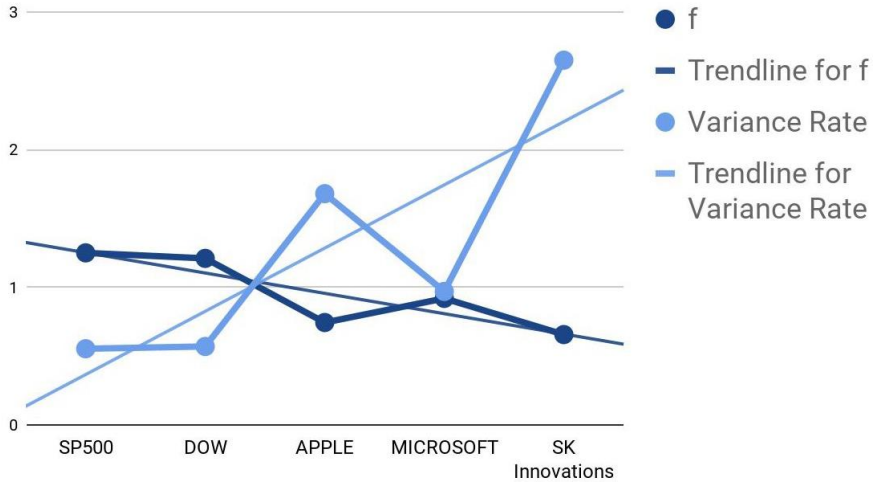
For the liabilities side, home mortgages and income level typically had a direct relationship, with mortgages tending to rise with an increase in income level. Since real estate equity grew with income level, home mortgages could also be expected to rise. Interestingly, student loans also had a direct relationship with income level. Households in Group 3 had an average student loan of $46,700, which was upwards of $20,000 more compared to Group 1 [1]. Cash credit owed refers to the amount of credit debt an individual carries with his or her bank account, typically referring to the debt owed on a credit card. Cash credit owed also increased with the rise in income level, signifying that debt typically rises with more household income [17].

The first method mentioned in the previous section constrains the rate of return on the risky investment and the variance rate to remain constant. The typical rate of return in the stock market is 7.96% [13]. For the sake of this study, the S&P 500 variance rate of 0.5336 (from January 2020) is used as the constant in method one [20]. The first riskless investment used was a basic savings account, with an interest rate or rate of return around 0.05% [14]. Vio Bank's online banking account is the second riskless investment, averaging an interest rate of 1.95% [8]. BMO Harris Bank's interest rate of 1.95% is used for the money market account [6]. For the last riskless investment, a one-year certificate of deposit from Marcus by Goldman Sachs is used, which offered a 2.15% interest rate [2]. For each riskless investment, the best possible interest rate offered by any company during January 2020 was used. Note that the recommended allocation some of the risk-free investments highlights a boundary condition in our selected Kelly Criterion (0% volatility for a given investment horizon).

The second method presented in the previous section, the risky and riskless investment rate of returns remain constant while the variance rate changes based on several selected risky investments. A priori, real-world investments do not have a known long-term average return and standard deviation. In an effort to only have one dependent variable, this study uses the same rate of return on the risky investment for all scenarios. The S&P 500 and DOW's variance rates of 0.5336 and 0.57 caused recommended allocation amounts of 1.25 and 1.21, respectively. Microsoft's variance rate of 0.97 led to a f being 0.9192. Apple had a variance rate of 1.68, while SK Innovations topped out with a variance rate of 2.65. These companies had recommended allocation amounts of 0.744 and 0.6565, respectively. The

five different risky investments' recommended allocation amount along with their variation rates are displayed in Figure 5.

Figure 5. Recommended Allocation Based on Variance Rate. This table shows the comparative recommended allocations based on rates of return and variance for the S&P 500, Dow Jones Industrial Index, Apple, Microsoft, and SK equities.



There is a notable inverse relationship between variance rates and recommended allocation amounts. Naturally, when there is greater variation between investments there is moreinherited risk. This leads to a lower recommendation allocation towards the risky investment. Contrarily, changes in the rate of return on the riskless investment did not have the effect as changes in variance rates. The recommended allocation amount was more resistant towards riskless investment rates, hovering around 1.2 for all four rates of return. Changes in variance rates caused *f* to vary between 0.65 to 1.25. These variations highlight the need for dramatically different investment/debt payoff strategies based on the volatility of the risky asset in question.

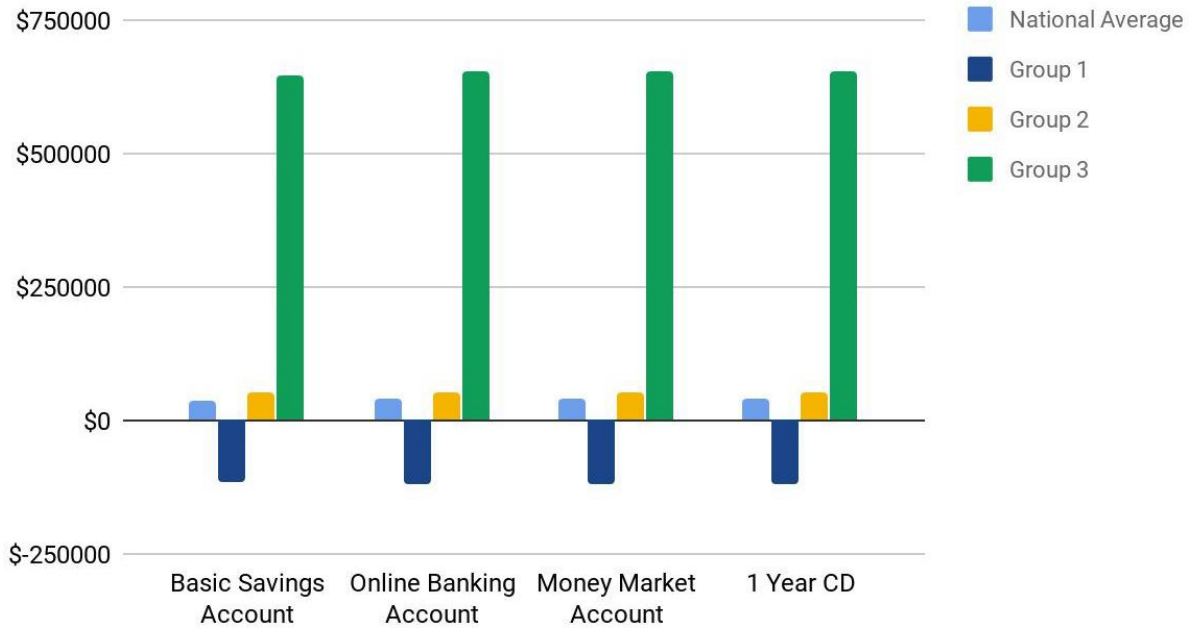
RESULTS

Our results indicate a number of different recommendations that are dependent on household wealth. The recommended allocation amounts found using method one consistently hovered around 1.25. To contextualize, this means that the Kelly Criterion recommends that a given investor should allocate all of his or her money plus 25% more towards the risky investment (through leverage or margin). Interestingly, a change in interest rates or the rate of return on riskless investments had very little effect on the recommended allocation amounts. Higher interest rates tend to encourage riskless investments, since the investor can expect a larger rate of return for saving his or her money. Conversely, lower interest rates cause higher recommended allocation amounts to the risky investment. The highest recommend allocation amount 1.2594 was derived using the basic savings account as the riskless investment, which had the lowest interest rate of all investments at 0.05%. Alternatively, the one-year CD had the highest interest rate (2.15%) and resulted in the highest recommended allocation amount of 1.2461. Higher risk-free rates caused lower recommended allocation amounts towards the risky investment, which is contrary to most other types of financial advice.

Method two illustrates the effect of changes in variance rate. The recommended allocation amount was varied much more with a change in variance. The S&P 500'svariance rate of 0.5336 resulted in *f* being 1.25. On the other hand, SK Innovation's relatively large variance rate of 2.65 caused *f* to drop down to 0.6565. For comparison, this range of 0.5935 in the recommended allocation amount was roughly 45 times larger than the range in *f* for the first method, which was only 0.0133. Consistent with what would typically be expected from the risk-reward tradeoff in investments, each subsequent increase in the variance rate clearly resulted in a lower recommended allocation amount. This shows that the Kelly Criterion encourages larger investments to be made towards risky investments that have significantly lower variance rates. As the trendlines show in Figure 5, there is a proportional decrease in the recommended allocation amount for each increase in the variance rate. Comparing the two methods also shows that the Kelly Criterion accounts for variation more than it does for the riskless rate of return.

The recommended allocation amounts are applied to each personal financial statement group through multiplying *f* with the total financial net worth of a given group. This net worth is found by totaling all assets and liabilities. The average national personal financial net worth was $30,871. Group 1 had a net worth of -$94,073, meaning individuals in this income group owed approximately $94,000 more than they had. Groups 2 and 3 had a net worth of $42,163 and $519,805, respectively. The figure below applies each recommended allocation from method one to all four financial net worth measures.

Figure 6. Recommended Allocation Amount in Dollars. This table shows the comparative recommended allocations based on rates of return and variance for the S&P 500, Dow Jones Industrial Index, Apple, Microsoft, and SK equities.

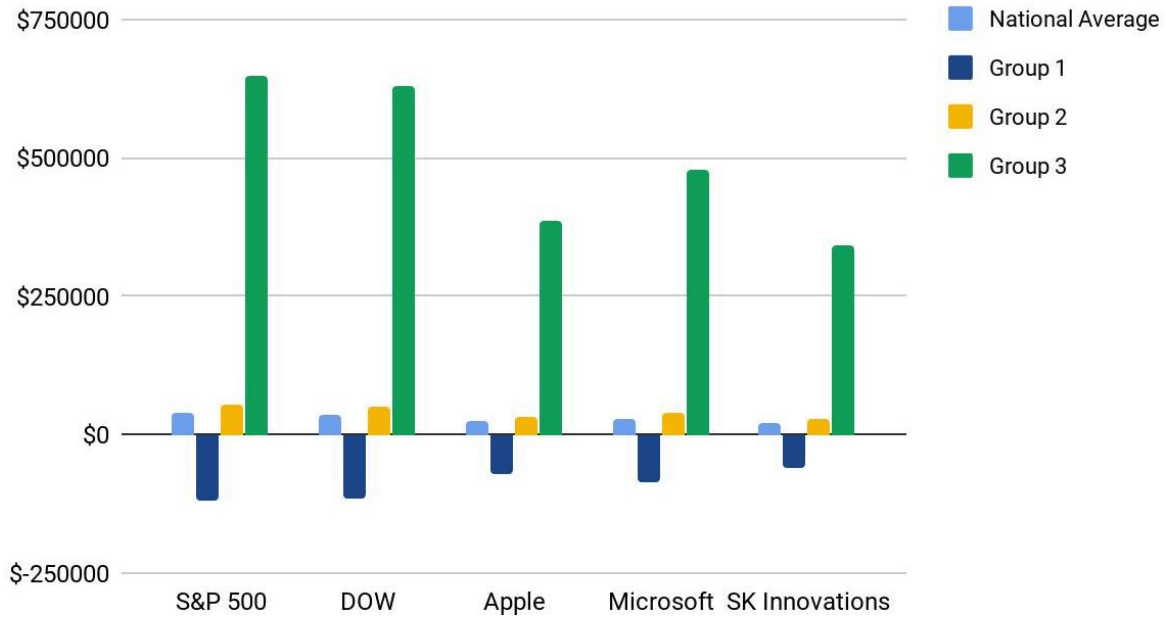


As expected, each group had an allocation amount proportional to their starting financial net worth. The negative allocation amounts for Group 1 indicate that the Kelly Criterion recommends individuals in this income group to exempt all risky investments and invest

additional money towards the riskless investment. For example, using the basic savings account,the Kelly formula suggests that Group 1 should allocate -$117,244 towards the risky investment.This means that $117,244 should be put towards the riskless investment, and no risky investments should be made. Group 1's average allocation amount hovered around -$118,000. For Group 2, this number was closer to $53,000. In Group 3's case, the Kelly Criterion recommended allocation amount was around $650,000. The national average was near $38,500. These allocations are shown in Figure 6.

In method two, the allocation amounts followed the same basic trend as *f*, having more variation than method one. For Group 1, the average allocation amount was approximately -$89,600. Groups 2 and 3 had average amounts of $40,304 and $496,901, respectively. The national average was a little less than Group 2's allocation amount, averaging around $29,500. The greater variation among *f* in method two caused the average recommended allocation amounts tobe lower than method one's allocation amounts. Group 3 had the greatest difference, averaging approximately $153,000 more in method one. These allocations are shown in Figure 7.

Figure 7. Recommended Allocation Amount in Dollars. This table shows the comparative recommended allocations based on rates of return and variance for the S&P 500, Dow Jones Industrial Index, Apple, Microsoft, and SK equities.



CONCLUSION

This study uses national statistics to compile the financial net worth for three different income groups as well as the national average. Two different methods were used to compare the recommended allocation, derived using the Kelly Criterion. In the first method, the risky investment rate of return and the variance rate were kept constant, while four types of riskless investment rate of returns are used: basic savings account, online banking account, money market account, and a one year certificate of deposit. These riskless investments were chosen

based on popularity among investors. An unanticipated inverse relationship was found between the rate of return on the riskless asset and the recommended allocation amount. In the second method, the risky and riskless rate of return were kept constant, while five different variance rates for the risky investment were used. There was a clear inverse relationship between the recommended allocation amount and the variance rate.

All recommended allocation amounts, with both methods, seemed to overvalue the true *f* that each income group usually invests into the risky investment. In method one, the recommended allocation amount ranged from 124.61% to 125.94% of a given investor's financial net worth. For the average American, this would translate to approximately a $38,500 risky investment. Using method two, the allocation amount recommended between 65% to 125% of an individual's net worth to be invested into risky investments. Although this method did have a more conservative approach, it still recommended more than half of an individual's net worth to be invested into risky investments at all times. This translated to the average person investing about $29,500 towards the risky investment. This amount is significantly lower than what the typical individual should be saving for retirement and interestingly, remarkably close to what we typically observe in retirement preparations. These differences and the limitations listed earlier are perhaps why some bettors tend to deviate from the use of the Kelly formula and favor more complex betting strategies that recommend lower allocation amounts (some of which are referred to as Fractional Kelly Criteria). These issues are limiting for our conclusions.

For the sake of this study, several assumptions were made regarding each group's personal financial net worth. To begin with, this study assumes that all individuals are willing to invest their entire net worth between risky or riskless investments. In reality, some investors tend to save their money without the use of financial institutions and diversify their investment portfolios through different types of investments. Although this study does not account for these investment behaviors, it still provides a basic analysis on how the Kelly Criterion recommends individuals to invest based on their personal financial statement. One common theme among all groups is that the Kelly formula tends to over-recommend. In other words, the recommended allocation amount towards the risky investment tends to be larger than what is actually invested or able to be invested in reality.

There are some other limitations of this study that future research could address, leading to better applications of statistical models to financial management strategies. First off, each income group's personal financial statement is mainly based on averages. Some exceptions to this include the retirement accounts and real estate equity subsets, which include medians. Outside of these, the statistics for other items are likely skewed high by outliers. Additionally, some investors in each income group tend to deviate from the anticipated financial behavior portrayed by each personal financial statement. This could mean that their true financial net worth is different from the one provided by this study. While this would negate the specific recommended allocation, it does not negate the usefulness of the formula.

Furthermore, this study compares two stock market indexes with three individual stocks. In reality, there would be separate methods for investing in index funds and stocks. Additionally, the rate of return on the risky asset would differ depending upon which variance rate was used. However, in an attempt to eliminate confounding variables, this study uses the same rate of

return on the risky investment with different variance rates. This could have led to substantial deviation from the true recommended allocation amount based on the rate of return on the risky investment that corresponds to each variance rate. Ideally, a third method that measures changes in the rate of return on the risky asset would provide more data for a better statistical analysis.

Unironically, the Kelly Criterion betting formula recommended investors to allocate more than 100% of their financial net worth towards the risky investment in all but three cases. Considering the long-term return rate of 7.96% for the stock market, this over-allocation could actually be beneficial to investors looking to make long-term investments. As Edward O. Thorp mentioned in his original thesis regarding the use of the Kelly Criterion to make investments, "the Kelly strategy will tend, in the long run, to an infinitely large multiple of wealth" [21, p. 3]. In this light, the large and somewhat un-proportional allocation amounts could actually be a better alternative to smaller risky investments when considering long-term returns. Thorp did not specify what exactly constitutes a long-term investment, but provided a basic exponential relationship between time and returns using the Kelly Criterion. Many of the assumptions of this paper also assume that the US will continue to have functioning capital markets—an assumption that was made in many other countries that today no longer have these markets. The most valuable aspect of this study and the modified Kelly Criterion is helping decide between one risky and riskless investment. Given these assumptions, investors can use these findings and the formula to help decide how much of their money they want to invest amid two investments. Applying this approach to personal financial management opens many fruitful areas for further research.

Risk allocation has many applications beyond savings in risk-free and risky investments. The decisions related to high or low volatility earnings in career path or short-term versus long-term employment are good examples of where Kelly Criteria could be adapted. An intertemporal Kelly Criteria could be used to determine proper asset allocation for retirement or to manage longevity risk. These are only a few areas where research in this area could be expanded, and we are hopeful that these ideas can lead to a more prosperous and volatility-robust middle class.

REFERENCES

[1] Baum, Sandy, Victoria Lee, and Alexandra Tilsley. “Which Households Hold the Most Student Debt?” Urban Institute, May 20, 2019. https://www.urban.org/urban-wire/which-households-hold-most-student-debt.
[2] “Best CD Rates for February 2020.” Bankrate, February 6, 2020. https://www.bankrate.com/banking/cds/cd-rates/.
[3] Bricker, Jesse, Lisa J. Dettling , and Alice Henriques. “Federal Reserve Bulletin.” FederalReserve. FED Board of Governors, September 2017. https://www.federalreserve.gov/publications/files/scf17.pdf.
[4] Bustamante, Jaleesa. “Homeowners vs Renters Statistics & Demographics by State [2020].”iPropertyManagement, December 18, 2019. https://ipropertymanagement.com/research/renters-vs-homeowners-statistics.
[5] Chu, Dani, Yifan Wu, and Tim B. Swartz. “Modified Kelly Criteria.” Journal of QuantitativeAnalysis in Sports 14, no. 1 (2018): 1–11.
[6] Dixon, Amanda. “7 Best Money Market Account Rates for February 2020.” Bankrate, February 9, 2020. https://www.bankrate.com/banking/money-market/rates/.
[7] FRED. “Households; Owners' Equity in Real Estate, Level.” Federal Reserve Bank of St. Louis,December 12, 2019. https://fred.stlouisfed.org/series/OEHRENWBSHNO.
[8] Goldberg, Matthew. “Best Online Savings Accounts of February 2020.” Bankrate, February 9,2020. https://www.bankrate.com/banking/savings/rates/.
[9] Huston, Sandra and Danielle Winchester, “All Financial Advice for the Middle Class is NotEqual”, (Journal of Consumer Policy, 2015), 248.
[10] Jacobson, Louis, “What percentage of Americans own stocks?”, *Politifact*, last modified September 18, 2018, https://www.politifact.com/california/statements/2018/sep/18/ro-khanna/what-percentage-americans-own-stocks/
[11] Kiyosaki, Robert, “The Personal Financial Statement: Your Foundation for Being Rich”, *RichDad*, last modified December 12, 2017, https://www.richdad.com/personal-financial-statement-example
[12] Maclean, Leonard, Edward 0 Thorp, and Wilham T Ziemba, “Kelly Capital Growth InvestmentCriterion, The: Theory and Practice”, (World Scientific Handbook in Financial Economic Series, 2011), 427.
[13] Maverick, J.B. “What Is the Average Annual Return for the S&P 500?” Investopedia, January29, 2020. https://www.investopedia.com/ask/answers/042415/what-average-annual-return-sp-500.asp
[14] Moon, Chris. “Average Savings Account Interest Rates for 2019: Compared Across Banks.”ValuePenguin, May 21, 2019. https://www.valuepenguin.com/banking/average-savings-account-interest-rates.
[15] Parker, Tim. “What's the Average 401(k) Balance by Age?” 401 (k) Retirement Savings. Investopedia, January 18, 2020. https://www.investopedia.com/articles/personal-finance/010616/whats-average-401k-balance-age.asp.
[16] Rakesh Kochar, “Pew Research Center”, *PWC*, last modified September 6, 2018, https://www.pewresearch.org/fact-tank/2018/09/06/the-american-middle-class-is-stable-in-size-but-losing-ground-financially-to-upper-income-families/.

[17] Resendiz, Joe. “Average Credit Card Debt in America: February 2020.” ValuePenguin, July 15,2019. https://www.valuepenguin.com/average-credit-card-debt#income.
[18] “Riskless Investment.” The Free Dictionary. Farlex, 2012. https://financial-dictionary.thefreedictionary.com/riskless investment.
[19] Sawhill, Isabel V., and Christopher Pulliam. “Six Facts about Wealth in the United States.”Brookings. Brookings Institute, June 28, 2019. https://www.brookings.edu/blog/up-front/2019/06/25/six-facts-about-wealth-in-the-united-states/
[20] “SP 500 Variance: ^GSPC BATS.” SP500 Rates. Macroaxis, January 20, 2020. https://www.macroaxis.com/invest/technicalIndicator/^GSPC--Variance.
[21] Thorp, Edward O., “The Kelly Criterion for Blackjack Sports Betting, and the Stock Market”,(Handbook of Asset Liability and Management, 2006), 3.
[22] Thorp, Edward O. "The Kelly criterion in blackjack sports betting, and the stock market." The Kelly capital growth investment criterion: theory and practice. 2011. 789-832.
[23] *Under Pressure: The Squeezed Middle Class* (OECD, 2019), 30.
[24] US Census Bureau. “Wealth, Asset Ownership, & Debt of Households Detailed Tables: 2016.”The United States Census Bureau. USCB, September 19, 2019. https://www.census.gov/data/tables/2016/demo/wealth/wealth-asset-ownership.html.
[25] Wolff, Edward N. “Household Wealth Trends in the United States, 1962 to 2016: Has Middle Class Wealth Recovered?” NBER. National Bureau of Economic Research, November30, 2017. https://www.nber.org/papers/w24085.

THE INFLUENCE OF CEO ORIGIN ON THE MARKET VALUATION OF SPUN-OFF SUBSIDIARIES: THE MODERATING EFFECT OF FIRM CAPITAL INTENSITY

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ABSTRACT

Corporate spin-offs aim to maximize the shareholder value of both the divesting firm (parent firm) and its spun-off subsidiary (child firm). We argue that appointing a CEO who has previously worked in the parent firm ("insider") will negatively influence the market valuation of spun-off subsidiary. After looking at the first two-year market valuation of 128 completed U.S. spin-offs for a 14-year time span, we found that having an "insider" CEO in the child firm is negatively and significantly related to the firm's market valuation. In addition, we have examined the contingency effect of firm capital intensity on this relationship and found a significant positive effect. Thus, our findings reveal that both CEO origin and capital intensity significantly influence spun-off subsidiaries' market value after becoming independent entities.

INTRODUCTION

Corporate spin-offs are a unique form of corporate strategy [10]. This strategy refers to the separation of an "unwanted" subsidiary/ division (a.k.a. child firm) from its corporate parent. As a result of this transaction, which does not generate cash, the child firm becomes an independent, publicly traded entity. The ultimate goal in undertaking a spin-off event is to maximize value for the shareholders of parent and child firms. Previous literature has examined this corporate restructuring technique from many different perspectives including factors that affect the parent firm's and child firm's performance following the spin-off event [1] [4] [7] [10] [11] [19] [27] [53] [54] [55] [59] [60] [62] [69]. In our knowledge, there has been no studies examining the importance of CEO origin in the context of market valuation of spun-off subsidiaries. In this study, we will examine whether CEO origin makes a significant difference in the change in market valuation of the child firm. We will also look at the moderating effect of capital intensity as an important measure of the firm's asset parsimony [13] on this main relationship.

Existing spin-off literature has examined this corporate transition from the perspectives of parent and child firms. For instance, from the child firm's perspective, Ozbek (2021) has looked at the effects of board independence and directors' industry experience on the market performance of spun-off subsidiaries and found positive, significant relationships [53]. Ozbek (2020) has concluded that while CEO's external directorships are positively and significantly related to the post-spin-off change in market performance of the child firm, CEO age is negatively and significantly related to this change [54]. Ozbek and Boyd (2020) have examined the effects of board size and CEO duality on the market valuation of corporate spin-offs and found positive, significant relationships [55]. From the parent firm's perspective, Abarbanell et al. (2003) have found that the parent firm will "experience abnormal trading volume on the effective date of the spin-off" [1, p. 252] and consequently become more profitable in the first year following the spin-off event. Ahn and Walker (2007) have suggested that the board heterogeneity of parent firm is positively related to the choice of spin-off and if the outside board members' ownership increases, this will also strengthen the possibility of parent firm engaging in a spin-off event [4]. Chemmanur et al. (2014) have argued that a spin-off event will positively influence the total factor productivity of plants belonging to the parent firm (and that of its child) [19]. Despite all these previous findings, there is still an important need for examining how the role of CEO origin plays out in the context of child firm's market valuation and whether firm capital intensity can further influence this relationship.

CEO origin is considered "a key contextual factor" [43, p. 20] in the upper echelons since it gives critical cues on how well a CEO is "connected" to the firm's internal and external environment. As Zhang and Rajagopalan (2003) argue, if a firm needs a CEO with new knowledge, skills set, and perspectives due to his/ her prior external managerial appointments, it

will prefer to appoint an "outsider" CEO [70]. On the other side, if a firm needs a CEO who has an extensive internal (firm-specific) knowledge and can "ensure continuity" [43, p. 27] in their current operations, it will choose to appoint an "insider" CEO. Since spun-off subsidiaries form "brand new" top management teams following the corporate separation, it is very important to understand whether an "insider" or "outsider" CEO will benefit these recently independent companies better.

As resource dependence theorists argue, "a firm's survival is contingent on its ability to gain control over environmental resources" [15, p. 420]. This can be achieved via the establishment and strengthening of "linkages to the external environment" [15, p. 420] of the firm. According to Bode, Wagner, Petersen, and Ellram (2011), if firms want to reduce the negative effect of environmental uncertainly on their operations, they will need to have access to external resources critical to their performance [14]. Pfeffer and Salancik (1978) have stated that as long as companies have appropriate governance structures that enable them to access critical resources from the external environment, they can also complete their legitimacy process within the industry more efficiently [57]. Ultimately, having access to external resources enables the firm to both reduce transaction cost and survive in the long run [35]. All these findings clearly show how important external resources are to the firm performance and survival. As explained earlier, CEO origin is an important proxy to understand whether either having access to external resources or being committed to existing practices is more important to the firm performance. In the context of spun-off subsidiaries, it is indeed very important to examine whether having an "insider" or "outsider" CEO will lead to better performance outcomes after starting to compete as stand-alone entities in the market.

In this study, our first research question examines whether CEO origin has a significant impact on the change in market valuation of spun-off subsidiaries. Our second research question looks at the moderating effect of firm capital intensity on this relationship. Previous research has shown that CEO origin is considered a "double-edged sword" regarding its influence on the firm performance and "expected to influence the firm's future strategic direction" [66, p. 743]. As Zhang and Rajagopalan argue (2010), CEO origin has an important role on how these "top" decision makers can formulate and implement changes in their organizations [72]. Outside CEOs are expected to "amplify either the adaptive or disruptive effect of strategic change" [72, p. 337]. They can be either adaptive since they bring in "brand new" knowledge and resources to be utilized in the firm without being committed to the status quo or disruptive since they have less familiarity with firm's resources and capabilities resulting in a high possibility of taking many risky actions and failure [72]. Thus, it is very critical to investigate whether spun-off subsidiaries will benefit from CEOs who either have previously worked at the parent company ("insider") or come from the industry ("outsider"). By examining the effect of CEO origin on the change in market valuation of spun-off subsidiaries, we aim to fill an important gap in the governance literature. In other words, our research will help to understand whether an "insider" or "outsider" CEO can more successfully contribute to the value creation process in corporate spin-offs.

Elmasr (2007) define capital intensity as "the amount of plant, property, equipment, inventory and other tangible or physical assets required to generate a unit of sales revenue" [25, p. 61]. As some scholars argue, capital intensity refers to the firm's operating leverage and may increase the overall business risk [17] [63]. After being separated from their corporate parents, these child firms will run their business operations independently and how much risk they should (and can) take will need to be determined by the CEO. To answer this question, we assess the interaction

effect of firm capital intensity on our previous identified relationship as well. By doing so, we will further contribute to the literature via testing whether this firm-level construct can serve as a significant moderator on the market valuation of spun-off subsidiaries.

Our empirical results show that having an "insider" CEO is negatively related to the market valuation of the child firm. We also find that capital intensity makes a positive and significant moderating effect on this relationship. This research contributes to the literature in some unique ways. First and foremost, our findings reveal that CEO origin does matter in the context of child firm's market valuation. In particular, appointing an "insider" CEO will create a negative effect on its market valuation. Second, our interaction effect shows that for high capital-intensive firms, appointing an "insider" CEO will result in a better (more positive) effect on their market valuation. Third, our study offers further validity of the resource dependence theory in the context of corporate spin-offs. Overall, we show the impacts of both CEO origin and firm capital intensity on the change in market valuation of spun-off subsidiaries by using a sample of 128 completed U.S. spin-offs between 2000 and 2014.

Our paper is organized as follows. First, we define corporate spin-offs. Second, we present both hypotheses and support our arguments by utilizing findings of previous research. Then, we explain our methodology and offer our results. And finally, we discuss our results and state our concluding thoughts.

DEFINING CORPORATE SPIN-OFFS

Spin-offs, in general, are defined as "value-increasing events" [4, p. 76]. As Bergh et al. (2008) explain, "a spin-off occurs when a firm distributes on a pro rata basis all the shares it owns in a subsidiary to its own shareholders" [11, p. 133]. As a result of this corporate transaction, the spun-off subsidiary becomes an independent, publicly traded entity [32]. An important difference

in this transaction compared to other corporate restructuring techniques is that it is tax-free and does not involve any cash [32]. Due to all these characteristics, spin-offs offer a fruitful empirical context [26] to examine how value is created following the corporate separation.

According to Internal Revenue Service (IRS) Code Section 355, these corporate transactions need to meet five criteria to be considered a spin-off event [32, p. 2481]: "(1) The parent must possess control (>80 percent ownership of common stock voting power and >80 percent ownership of each class of nonvoting shares) of the subsidiary prior to the spin-off; (2) after the spin-off occurs, both the parent and the subsidiary must still be engaged in lines of business in which each has been active for at least five years; (3) the transaction must not be used as a means of avoiding dividend taxation; (4) shareholders of the parent must maintain a significant ownership interest in both the parent and the spin-off; and (5) the spin-off must have a substantial business purpose, separate from simply saving on income taxes." If these conditions are met, a corporate parent will be "eligible" to spin off a division (or subsidiary) as a tax-free transaction.

Because of the spin-off event, both the divesting company and its spun-off subsidiary aim for some important benefits. First, spin-off events focus on increasing the overall shareholder wealth via establishing more effective internal control mechanisms [62] and creating positive abnormal returns [68]. Second, these events are expected to reduce the level of information asymmetry [42] and ambiguities [12] between managers and owners of the company (a.k.a. principal-agent relationship). Third, spin-offs enable the management team to better lead the company towards corporate goals [34] via creating more clarity and transparency in the organizational structure and processes [11]. Fourth, they help to reduce overdiversification via getting rid of unrelated (or unwanted) businesses [10]. Fifth, corporate parents may want to "reduce their complexity in the

capital markets" [10, p. 101] so that they can provide their both current and potential investors with a clearer corporate picture. By accomplishing all these goals, a spin-off event aim to benefit to the corporate parent, its spun-off subsidiary, and their shareholders.

HYPOTHESIS DEVELOPMENT

As Aguilera, Filatotchev, Gospel, and Jackson (2008) define, corporate governance refers to "the structure of rights and responsibilities among the parties with a stake in the firm" [3, p. 475]. One of these important parties are top management teams led by the CEO. There have been many studies explaining the impact of CEO characteristics on firm performance [8] [9] [18] [33] [40] [51] [64]. In their upper echelon's perspective, Hambrick and Mason (1984) have argued that "organizational outcomes - both strategies and effectiveness - are viewed as reflections of the values and cognitive bases of powerful actors in the organization" [33, p. 193]. The CEO represents the head of those "powerful actors" and thus, their strategic decisions make some significant impacts on achieving corporate goals. Therefore, their characteristics including CEO origin, background, experience, cognition, etc. will serve as critical proxies while examining firm performance in different contexts.

The Effect of CEO Origin

CEO origin is a "double-edged sword" in the strategy literature since there have been various arguments for whether appointing a new CEO from either within or outside the firm will result in better performance outcomes [39]. If a CEO is hired from outside the firm, it is called an "outsider"; and if a CEO is promoted from inside the firm, it is called an "insider" [72]. Previous research has shown that CEO origin is an important governance element while explaining the relationship between strategic change and firm performance [72] since CEOs are the head of executive leadership team in organizations. It is particularly important to recognize that,

especially in “brand new” companies such as spun-off subsidiaries, a new CEO is expected to bring “fresh knowledge, skills, and perspective” [39, p. 682] gained from previous industry experiences. Thus, he or she can formulate and implement strategies more effectively toward a better firm future.

Outsider CEOs are known as those “top” executives who “have typically high motivation to initiate strategic change” [40, p. 1286]. When a board of directors needs a new CEO who can effectively respond the demands of the external environment via utilizing his/her industry experiences and knowledge, they will look for an “outsider” CEO. These CEOs can offer unique solutions to those organizational needs via bringing their “new perspectives, skills, or knowledge” [43, p. 27]. From the perspective of the organizational adaptation view, “outsider” CEOs also are “better equipped to expand the resource base of the firm and promote innovation, learning, and high performance” [31, p. 59] due to their knowledge and expertise on the external market. These “brand new” managerial approaches led by an “outsider” CEO will enable both the top management team to “enhance information processing” and the firm to “enhance its adaptive capacity and realize positive financial outcomes” [31, p. 61].

On the other side, “insider” CEOs possess more firm-specific information compared to “outsider” CEOs and tend to refrain from implementing strategic changes due to their status quo-based orientation [71]. Although they have an already-established social network and/or coalitions within the executive team and board of directors [64], these “insiders” can be strongly challenged by the external environment. Since they tend to have “emotional commitments to or vested interests in the firm’s status quo” [72, p. 337], “insider” CEOs may face serious decline in the organizational performance. Although they are familiar with the company culture and

operational procedures, “insider” CEOs possess a high risk of failure due to their lack of interest/ desire (or abundance of fear) in making strategic changes in their organizations.

According to arguments of resource dependence theory, corporations are defined as “an open system, dependent on contingencies in the external environment” [36, p. 1404]. As resource dependence theorists argue, firm’s poor performance may result from “a misalignment of organizational behavior with the environment” [36, p. 1413]. Especially, when uncertainties and ambiguities increase in the external settings, the firm may experience performance decline more harshly. A newly appointed “outsider” CEO will have access to critical external resources (both tangible and intangible) to the firm, which enables him or her to better cope with the pressure caused by the external environment [36]. While an “insider” CEO may be quite suffering to handle those pressures, an “outsider” CEO’s external knowledge and/or connections can serve as a big “asset” for the firm.

In the context of spun-off subsidiaries, it is extremely critical for the child firm to establish its organizational identity (and thereafter, legitimacy) among its industry competitors [22] so that it can long survive. After becoming independent, these firms will be in a strong need of an executive leadership that can deal with their “identity ambiguity” [22, p. 178]. In addition, these “brand new” firms will need executives who can make external resources available to them [23] so that they can better cope with uncertainties and ambiguities. An “insider” CEO may face several struggles to meet all these external environment-based needs (or demands). Thus, we argue that appointing an “insider” CEO is negatively related to the market valuation of the child firm.

Hypothesis 1: *There is a negative association between appointing an “insider” CEO and the change in market valuation of spun-off subsidiaries.*

The Moderating Effect of Capital Intensity

Capital intensity reflects "capital assets that are expensive relative to the annual output values of the firm" [48, p. 1651]. These assets are critical to the firm performance in the sense that they create value (e.g. return on investment) if they are used for a long period of time and consistently [48]. While company executives are making their strategic plans about how to utilize these assets efficiently, they will have to also consider "long-term adaptive thinking" [48, p. 1651]. Because these firms "invest heavily in technology, facilities, and equipment" [56, p. 717], any mistakes related to the strategic planning process can lead to very costly outcomes [48] [56].

Capital intensity is an important driver of the firm value [49]. Capital-intensive firms "require steady, surprise-free, and coordinated operations" [48, p. 1651] to stay competitive among their industry rivals. From the perspective of strategy formulation and implementation, capital intensity makes "it difficult for firms to accommodate changes in strategy" [29, p. 184]. From the perspective of decision-making, capital intensity limits CEO's discretion, which may lead to both lack of strategic options and possession of less opportunities while dealing with uncertainty [29].

In the context of corporate spin-offs, capital intensity can play a significant contingency role on the child firm's market valuation. If a spun-off subsidiary is capital-intensive, its "top" decision-maker (the CEO) will have to particularly possess an excellent understanding of firm's pre-spin-off operations including an efficient utilization of plants, property, and equipment. Moreover, because of creating a "brand new" management team in the post-spin-off era, the CEO's knowledge in these internal matters will better assist the child firm with its adaptation process to independency while also competing its industry rivals. Thus, we argue that capital intensity strengthens the relationship between the CEO origin (appointing an "insider" CEO) and the market valuation of the child firm.

Hypothesis 2: *Firm capital intensity positively moderates the relationship between appointing an "insider" CEO and the change in market valuation of spun-off subsidiaries.*

METHODOLOGY

Sample

The sample of companies analyzed in this study includes completed U.S.-based spin-offs between 2000 and 2014. For all these spun-off subsidiaries, 100% of their outstanding shares were distributed to the shareholders to the parent company's shareholders. We used *SDC Platinum* database to identify all these spin-off events, which later were double confirmed by using some other online resources including *Lexis/Nexis* and *WSJ*.

At the beginning, we had a sample size of 205 spin-off events; however, within the two years following the corporate separation, some of these subsidiaries lost their independency due to being acquired by (or merged into) other companies or filing bankruptcy [28]. Thus, our final sample became 128 due to these corporate issues in addition to the missing data.

The data for spun-off subsidiaries related to their governance characteristics were gathered from the proxy statements (DEF 14-A) on the *Securities and Exchange Commission* (SEC) website. This data was hand-collected. In addition, the industry- and firm-level data related to their financials were directly extracted from the *Compustat* database.

Analysis

We used CEO origin as our independent variable and firm capital intensity as our moderator in this study. We also controlled for many other variables that could potentially affect the results of this study. We tested the change in market valuation of spun-off subsidiaries within two years

after the corporate separation. Our conceptual framework including the summary of our empirical testing is provided in Figure 1.

We used OLS (ordinary least squared) regression with standard errors to test our models. According to Kao, Van Roy, and Yan (2009), OLS regression is "a conventional approach to computing regression coefficients" [38, p. 891]. The advantages of this estimation method include the following: "it is better understood and easier to implement; and it is more straightforward for researchers while addressing econometric issues and making comparisons across studies" [41, p. 1085]. Following Aiken and West (1991), our full and contingency models are shown below [5]:

The change in market valuation of spun-off subsidiaries (full model) $= \beta_0 + \beta_1$ *CEO origin* $+ \epsilon_1$

The change in market valuation of spun-off subsidiaries (contingency model) $= \beta'_0 + \beta'_1$ *CEO origin* $+ \beta'_2$ *CEO origin x Capital intensity* $+ \epsilon'_1$

Measurement

Dependent variable

Consistent with both our theoretical arguments and empirical investigation of this study, the dependent variable measured the change in market valuation of spun-off subsidiaries two years after their separation from their corporate parents. Following Nelson, Moffitt, and Affleck-Graves (2005), we measured our dependent variable as the change in market value of equity (MVE), which was calculated by the number of common shares outstanding times the closing annual share price [52]. As Sunaryo and Saripujiana (2018) argue, MVE is a critical "measuring tool that can calculate the present value of all future cash flows to be obtained by shareholders to describe the size of a company" [65, p. 81]. They also state that if the value of MVE is large for

companies, this will be considered a critical sign for their "ability to generate greater profits due to the breadth of opportunities to obtain funds from internal and external parties" [65, p. 82]. In our study, this dependent variable served as an important indicator of these subsidiaries' survivability as recently independent entities. Besides, we decided to adjust this variable prior to taking its log so that cases with negative values would not be omitted.

Independent variable

CEO origin is the sole independent variable in this study. Following Tian et al. (2011), this variable took the value of 1 if the child firm's CEO had worked at the parent company prior to the separation of both companies, and 0 if he or she had been hired from outside the company [66]. In other words, we coded CEO origin 1 for "insider" CEOs and 0 for "outsider" CEOs.

Control variables

Several controls variables were included in our empirical testing. Firm leverage was measured by the ratio of total debt to total assets [16]. Firm size (ln) was measured by logarithm of firm's total assets [37]. Firm sales growth (ln) was measured by logarithm of change in sales in two years following the spin-off event [21]. Firm capital intensity (also the moderator) was measured by the ratio of capital expenses to total sales [50]. Industry dummy was coded 1 for firms in the manufacturing industry and 0 for those in the service industry. Year dummy was coded 1 for those spin-offs that occurred during a financial crisis such as 2001-02 and 2008-09 and 0 for the rest. Industry dynamism was measured by the ratio of the standard error of the regression slope coefficient to the mean sales value for five years before the spin-off event [46]. Industry munificence was measured by the ratio of regression slope coefficient to the mean sales value for five years before the spin-off event [46]. Industry complexity, which reflected "the degree of market concentration in each industry" [46, p. 691], was measured via following Boyd (1990)

[15]. CEO duality was coded 1 if the CEO and Chairperson were the same person and 0 if they were not. CEO compensation mix was measured by the ratio of long-term compensation to total compensation [24].

RESULTS

Table 1 reports the descriptive statistics of all variables in this study. According to this table, the mean for CEO origin is 0.809, which means that almost 81% of CEOs in the child firm are "insiders." Table 2 reports the OLS regression results testing Hypotheses 1 and 2. In this table, Model 1 only includes control variables; Model 2 adds the independent variable (CEO origin); and Model 3 adds the interaction variable (firm capital intensity). Besides, according to the results for the variance inflation factor (VIF) test, the mean VIF is 1.21 and all VIF values for each variable (the highest being 1.37) is less than 2.50. This proves that multicollinearity is not an issue in this study [2] [61].

VARIABLES	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Change in MV (ln)	0.135	0.954	1.000												
2. Firm leverage	0.259	0.252	0.034	1.000											
3. Firm size (ln)	6.898	1.877	-0.149***	0.378***	1.000										
4. Firm sales growth (ln)	9.390	0.073	0.230***	0.003	-0.064	1.000									
5. Firm capital intensity	0.855	5.014	-0.055	-0.081	-0.080	-0.003	1.000								
6. Industry dummy	0.473	0.500	-0.003	-0.214**	-0.100**	-0.066	0.094	1.000							
7. Year dummy	0.092	0.290	-0.197*	0.135***	0.265***	0.119	-0.037	-0.181	1.000						
8. Industry munificence	0.076	0.097	-0.376***	0.092	0.228***	-0.155**	-0.040	-0.264***	0.148**	1.000					
9. Industry dynamism	0.031	0.032	-0.042	-0.019	0.181	0.037	-0.008	-0.037	0.114**	0.351***	1.000				
10. Industry complexity	0.161	0.155	0.010	0.001	0.062	-0.100	-0.062	-0.114	0.204***	0.160	0.360***	1.000			
11. CEO duality	0.390	0.488	0.062	0.066	0.082	0.141	-0.081	-0.016	0.001	-0.059	0.045	-0.080	1.000		
12. CEO compensation mix	0.566	0.314	0.029	0.181**	0.227***	-0.181**	0.006	0.019	-0.017	0.050	-0.029	-0.028	0.073	1.000	
13. CEO origin	0.809	.393	-0.162	0.045	0.119**	0.065	0.026	0.000	0.095	0.041	0.077	0.082	0.048	-0.008	1.000

*****p < 0.01; **p < 0.05; *p < 0.1**

Table 1 Means, standard deviations, and intercorrelations among study's variables

DV: Change in market valuation (ln)	MODEL 1 (controls)	MODEL 2 (full)	MODEL 3 (moderation)
Control variables			
Firm leverage	0.369 (0.353)	0.376 (0.350)	0.361 (0.353)
Firm size (ln)	-0.041 (0.040)	-0.033 (0.040)	-0.028 (0.041)
Firm sales growth (ln)	2.302* (1.187)	2.419** (1.083)	2.401** (1.076)
Firm capital intensity	-0.009* (0.004)	-0.008 (0.005)	-0.083** (0.039)
Industry dummy	-0.175 (0.155)	-0.165 (0.155)	-0.178 (0.157)
Year dummy	-0.589** (0.238)	-0.569** (0.228)	-0.579** (0.228)
Industry munificence	-3.204*** (0.858)	-3.183*** (0.857)	-3.308*** (0.880)
Industry dynamism	3.047 (2.913)	3.136 (2.849)	3.327 (2.863)
Industry complexity	0.620 (0.639)	0.695 (0.604)	0.718 (0.607)
CEO duality	0.003 (0.140)	0.015 (0.139)	0.009 (0.140)
CEO compensation mix	0.271 (0.232)	0.260 (0.227)	0.233 (0.231)
Explanatory variables			
CEO origin	---	**-0.341*** **(0.174)**	-0.395** (0.188)
Interaction variable			
CEO origin X Capital intensity	---	---	**0.076*** **(0.040)**
Sample size	128	128	128
R-squared	0.251	0.273	0.278

*****p < 0.01; **p < 0.05; *p < 0.1**

Table 2 Independent and contingency models of CEO origin and capital intensity (Robust standard errors in parentheses)

According to Model 2, CEO origin is significantly and negatively ($b = -0.341; p < 0.1$) related to the change in market valuation of the child firm. This result provides support to Hypothesis 1, which predicts a negative relationship between appointing an "insider" CEO and the dependent variable. This significant result indicates that an "insider" CEO will negatively influence the change in market valuation of the child firm. According to Model 3, the interaction of CEO origin and firm capital intensity is significantly and positively ($b = 0.076; p < 0.1$) related to the change in market valuation of the child firm. This result also provides support to Hypothesis 2, which predicts a strengthening interaction effect. This significant result indicates that for highly capital-intensive spun-off subsidiaries, the effect of appointing an "insider" CEO on the change in market valuation of this child firm will become more positive. Figure 2 provides the two-way plot for this interaction effect as well. Thus, we have found statistically significant results for both hypotheses.

DISCUSSION

This study has investigated how CEO origin and firm capital intensity affect the change in market valuation of spun-off subsidiaries following the separation from their corporate parents. Since the spin-off context is unique in the sense that it results in a subsidiary/ division becoming independent and having no longer parental support, it is critical to understand how CEO origin will affect the child firm's market success based on well-established arguments of the resource dependence theory.

CEO origin has been seen as "a key adaptation mechanism in response to shifting environmental demands" [39, p. 688] in the governance literature. More specifically, while an "outsider" CEO brings "fresh knowledge, skills, and perspectives" [39, p. 682] in his or her new organization, an "insider" CEO tends to possess "narrow perspectives and psychological commitment to the

status quo" [39, p. 682] despite their "in-depth" knowledge about the firm culture and operational procedures. For instance, Tushman and Rosenkopf (1996) have suggested that "outsider" CEOs will bring unique competencies to the top management team and helps to increase its "functional heterogeneity" [67, p. 940]. Menon and Pfeffer (2003) have found that external knowledge that "outsider" CEOs bring will help to become "more varied and less tied to the path-dependent experience" [47, p. 509] of their firms. From the viewpoint of "insider" CEOs, although they are very familiar with their organizations' capabilities, resources, and problems, they tend to stick to the old practices [58]. These CEOs "tend to be hired when performance is healthy, the ongoing strategy appears viable, and the board seeks continuity" [58, p. 1455]. In other words, unless a firm is going through some significant changes in its business operations, choosing an "insider" CEO may be more likely. On the opposite side, a study by Tian et al. (2011) has revealed a negative relationship between a newly appointed "insider" CEO and abnormal stock return of the firm [66]. Since spun-off subsidiaries are considered "brand new" companies that require an "immediate adaptation" to the external environment including openness to change and "easy" access to outside resources, the appointment of an "insider" CEO will negatively affect the change in their market valuation. Thus, our findings are parallel with the literature that appointing an "outsider" CEO in these firms may work much better after being separated from their corporate parents.

Capital intensity is considered an important indicator of the firm's ability to make changes in the production capacity and offerings in addition to its flexibility in making distinct options available to the CEO [30]. Capital-intensive firms are those that require "a large amount of financing to produce products or services" [44, p. 161]. High capital intensity refers to a firm-level condition that "investing in assets often replaces the use of labor" [44, p. 163]. Although high capital

intensity increases the business risk factor, it can also help them improve their productivity as long as the plant, property, and equipment are used efficiently [20]. For example, in the literature, Finkelstein and Boyd (1998) have found that capital intensity is negatively related to the managerial discretion [29]. Lee, Koh, and Kang (2011) have suggested that the moderating effect of capital intensity on the relationship between leverage and financial distress is positive [45]. Park (2012) has examined whether capital intensity moderates the relationship between self-managing teams and organizational commitment and found a strengthening effect [56]. These previous findings are parallel with our results in the sense that for highly capital-intensive spun-off subsidiaries, the relationship between appointing an "insider" CEO and change in market valuation of the child firm will be strengthened (more positive). Thus, capital intensity is indeed an important moderator in the context of child firm's market valuation.

From the perspective of theoretical contributions, this paper has shown the importance and applicability of the resource dependence theory in the context of corporate spin-offs. More specifically, we have concluded that appointing an "insider" CEO who has less knowledge (and linkages) about (to) the external environment of the child firm will result in a decline in the market valuation following the spin-off event. Additionally, we have found that firm capital intensity will have a significant strengthening contingency effect. More specifically, for highly capital-intensive child firms, appointing an "insider" CEO will make a more positive impact on their market valuation. From the perspective of managerial implications, this study reveals that appointing an "insider" CEO following the spin-off event will not help with regard to the child firm's market valuation; however, it this firm is highly capital-intensive, this will lead to a more positive effect.

Despite all these previously explained contributions, we recognize our limitations in this study. First, our study looks at a 14-year long time span and it can be expanded in the future. Second, future studies can explore whether our findings will be compatible in some other corporate restructuring techniques such as equity carve-outs and split-offs. Third, governance researchers can look at effects of some other executive-level variables and further explore possible interactions among them. Fourth, it may be beneficial to investigate how these findings may (or not) change in the long term (e.g. five years or more) following the spin-off.

CONCLUSION

We have studied how CEO origin, moderated by firm capital intensity, will influence the market valuation of corporate spin-offs. Our findings clearly show that both variables indeed matter for the child firm's market valuation. Appointing an "insider" CEO will make a negative impact on this market performance and firm capital intensity will make this relationship more positive. We truly hope that this empirical study will further intrigue the governance research in the context of corporate spin-offs among scholars.

REFERENCES

[1] Abarbanell, J.S., Bushee, B.J. & Raedy, J.S. (2003). Institutional investor preferences and price pressure: The case of corporate spin-offs. *The Journal of Business*, 76(2), 233-261.

[2] Adeboye, N.O., Fagoyinbo, I.S. & Olatayo, T. O. (2014). Estimation of the effect of multicollinearity on the standard error for regression coefficients. *Journal of Mathematics*, 10(4), 16-20.

[3] Aguilera, R.V., Filatotchev, I., Gospel, H. & Jackson, G. (2008). An organizational approach to comparative corporate governance: Costs, contingencies, and complementarities. *Organization Science*, 19(3), 475-492.

[4] Ahn, S. & Walker, M.D. (2007). Corporate governance and the spinoff decision. *Journal of Corporate Finance*, 13(1), 76-93.

[5] Aiken, L.S. & West, S.G. (1991). *Multiple regression: Testing and interpreting interactions*. Sage Publications, Inc., Newbury Park, CA.

[6] Aldrich, H.E. (1979) *Organizations and Environments*. Prentice-Hall, Englewood Cliffs, NJ.

[7] Allen, J.W. (2001). Private information and spin-off performance. *The Journal of Business*, 74(2), 281-306.

[8] Barker, V.L. & Mueller, G.C. (2002). CEO characteristics and firm R&D spending. *Management Science*, 48(6), 782-801.

[9] Beber, A. & Fabbri, D. (2012). Who times the foreign exchange market? Corporate speculation and CEO characteristics. *Journal of Corporate Finance*, 18(5), 1065-1087.

[10] Bennett, V.M. & Feldman, E.R. (2017). Make room! Make room! A note on sequential spinoffs and acquisitions. *Strategy Science*, 2(2), 100-110.

[11] Bergh, D.D., Johnson, R.A. & Dewitt, R.L. (2008). Restructuring through spin-off or sell-off: transforming information asymmetries into financial gain. *Strategic Management Journal*, 29(2), 133-148.

[12] Bergh, D.D. & Sharp, B.M. (2015). How far do owners reach into the divestiture process? Blockholders and the choice between spin-off and sell-off. *Journal of Management*, 41(5), 1155-1183.

[13] Berman, S.L., Wicks, A.C., Kotha, S. & Jones, T.M. (1999). Does stakeholder orientation matter? The relationship between stakeholder management models and firm financial performance. *Academy of Management Journal*, 42(5), 488-506.

[14] Bode, C., Wagner, S.M., Petersen, K.J. & Ellram, L.M. (2011). Understanding responses to supply chain disruptions: Insights from information processing and resource dependence perspectives. *Academy of Management Journal*, 54(4), 833-856.

[15] Boyd, B. (1990). Corporate linkages and organizational environment: A test of the resource dependence model. *Strategic Management Journal*, 11(6), 419-430.

[16] Brammer, S. & Millington, A. (2004). The development of corporate charitable contributions in the UK: A stakeholder analysis. *Journal of Management Studies*, 41(8), 1411-1434.

[17] Brealey, R. & Myers, S. (1984). *Principles of Corporate Finance*, 2nd edition. McGraw Hill, Hightstown, NJ.

[18] Buyl, T., Boone, C., Hendriks, W. & Matthyssens, P. (2011). Top management team functional diversity and firm performance: The moderating role of CEO characteristics. *Journal of Management Studies*, 48(1), 151-177.

[19] Chemmanur, T.J., Krishnan, K. & Nandy, D.K. (2014). The effects of corporate spin-offs on productivity. *Journal of Corporate Finance*, 27, 72-98.

[20] Chowdhury, S.D. & Geringer, J.M. (2001). Institutional ownership, strategic choices and corporate efficiency: Evidence from Japan. *Journal of Management Studies*, 38(2), 271-291.

[21] Collins, C.J. & Smith, K.G. (2006). Knowledge exchange and combination: The role of human resource practices in the performance of high-technology firms. *Academy of Management Journal*, 49(3), 544-560.

[22] Corley, K.G. & Gioia, D.A. (2004). Identity ambiguity and change in the wake of a corporate spin-off. *Administrative Science Quarterly*, 49(2), 173-208.

[23] Dalziel, T., Gentry, R.J. & Bowerman, M. (2011). An integrated agency–resource dependence view of the influence of directors' human and relational capital on firms' R&D spending. *Journal of Management Studies,* 48(6), 1217-1242.

[24] David, P., Kochhar, R. & Levitas, E. (1998). The effect of institutional investors on the level and mix of CEO compensation. *Academy of Management Journal*, 41(2), 200-208.

[25] Elmasr, H. (2007). Capital intensity and stock returns. *Journal of Investment Strategy*, 2(1): 61-65.

[26] Feldman, E.R., Gilson, S.C. & Villalonga, B. (2014). Do analysts add value when they most can? Evidence from corporate spin-offs. *Strategic Management Journal*, 35(10), 1446-1463.

[27] Feldman, E.R. (2016a). Dual directors and the governance of corporate spinoffs. *Academy of Management Journal*, 59(5), 1754-1776.

[28] Feldman, E.R. (2016b). Managerial compensation and corporate spinoffs. *Strategic Management Journal*, 37(10), 2011-2030.

[29] Finkelstein, S. & Boyd, B.K. (1988). How much does the CEO matter? The role of managerial discretion in the setting of CEO compensation. *Academy of Management Journal*, 41(2), 179-199.

[30] Fritz, D.A. (2009). The impact of capital intensity and demand instability on strategy selection in tradition bound organizations. *Proceedings of the Academy of Strategic Management*, 8(1), 19-24.

[31] Georgakakis, D. & Ruigrok, W. (2017). CEO succession origin and firm performance: A multilevel study. *Journal of Management Studies*, 54(1), 58-87.

[32] Gertner, R., Powers, E. & Scharfstein, D. (2002). Learning about internal capital markets from corporate spin-offs. *The Journal of Finance*, 57(6), 2479-2506.

[33] Hambrick, D.C. & Mason, P.A. (1984). Upper echelons: The organization as a reflection of its top managers. *Academy of Management Review*, 9(2), 193-206.

[34] Hambrick D.C. & Stucker K. 1999. *Breaking away: executive leadership of corporate spinoffs*. In The Leader's Change Handbook: An Essential Guide to Setting Direction and Taking Action, Jossey Bass Business and Management Series, San Francisco, CA.

[35] Hillman, A.J. & Dalziel, T. (2003). Boards of directors and firm performance: Integrating agency and resource dependence perspectives. *Academy of Management Review*, 28(3), 383-396.

[36] Hillman, A.J. & Withers, M.C., and Collins, B.J. (2009). Resource dependence theory: A review. *Journal of Management*, 35(6), 1404-1427.

[37] Kane, G.D. & Velury, U. (2004). The role of institutional ownership in the market for auditing services: An empirical investigation. *Journal of Business Research*, 57(9), 976-983.

[38] Kao, Y.H., Roy, B. & Yan, X. (2009). Directed regression. *Advances in Neural Information Processing Systems*, 22, 889-897.

[39] Karaevli, A. (2007). Performance consequences of new CEO 'Outsiderness': Moderating effects of pre-and post-succession contexts. *Strategic Management Journal*, 28(7), 681-706.

[40] Karaevli, A. & Zajac, E.J. (2013). When do outsider CEOs generate strategic change? The enabling role of corporate stability. *Journal of Management Studies*, 50(7), 1267-1294.

[41] Kraft, A., Leone, A.J. & Wasley, C.E. (2007). Regression-based tests of the market pricing of accounting numbers: The Mishkin test and ordinary least squares. *Journal of Accounting Research*, 45(5), 1081-1114.

[42] Krishnaswami, S. & Subramaniam, V. (1999). Information asymmetry, valuation, and the corporate spin-off decision. *Journal of Financial Economics*, 53(1), 73-112.

[43] Kunisch, S., Menz, M. & Cannella, A.A. (2019). The CEO as a key microfoundation of global strategy: Task demands, CEO origin, and the CEO's international background. *Global Strategy Journal*, 9(1), 19-41.

[44] Lannelongue, G., Gonzalez-Benito, J. & Quiroz, I. (2017). Environmental management and labour productivity: The moderating role of capital intensity. *Journal of Environmental Management*, 190, 158-169.

[45] Lee, S., Koh, Y. & Kang, K.H. (2011). Moderating effect of capital intensity on the relationship between leverage and financial distress in the U.S. restaurant industry. *International Journal of Hospitality Management*, 30, 429-438.

[46] Lepak, D.P., Takeuchi, R. & Snell, S.A. (2003). Employment flexibility and firm performance: Examining the interaction effects of employment mode, environmental dynamism, and technological intensity. *Journal of Management*, 29(5), 681-703.

[47] Menon, T. & Pfeffer, J. (2003). Valuing internal vs. external knowledge: Explaining the preference for outsiders. *Management Science*, 49(4), 497-513.

[48] Miller, C.C. & Cardinal, L.B. (1994). Strategic planning and firm performance: A synthesis of more than two decades of research. *Academy of Management Journal*, 37(6), 1649-1665.

[49] Miller, T.W. & Mathisen, R.E. (2004). Drivers of the value of the firm: Profitability, growth, and capital intensity. *Journal of Accounting & Finance Research*, 12(6), 70-79.

[50] Nadkarni, S. & Herrmann, P.O.L. (2010). CEO personality, strategic flexibility, and firm performance: the case of the Indian business process outsourcing industry. *Academy of Management Journal*, 53(5), 1050-1073.

[51] Nelson, J. (2005). Corporate governance practices, CEO characteristics and firm performance. *Journal of Corporate Finance*, 11(1-2), 197-228.

[52] Nelson, J.M., Moffitt, J.S. & Affleck-Graves, J. (2005). The impact of hedging on the market value of equity. *Journal of Corporate Finance*, 11(5), 851-881.

[53] Ozbek, O.V. (2021). Market Performance of Spun-Off Subsidiaries: Effects of Board Independence and Directors' Industry Experience. *American Business Review*, 24(1), 249-267.

[54] Ozbek, O.V. (2020). The market success of corporate spin-offs: Do CEO external directorships, age, and their interactions matter? *American Business Review*, 23(2), 235-252.

[55] Ozbek, O.V. & Boyd, B. (2020). The influence of CEO duality and board size on the market value of spun-off subsidiaries. *Journal of Strategy and Management*, 13(3), 333-350.

[56] Park, R. (2012). Self-managing teams and employee attitudes: The moderating role of capital intensity. *International Journal of Human Resource Management*, 23(4), 714-730.

[57] Pfeffer, J. & Salancik, G.R. (1978). *The external control of organizations: A resource dependence perspective.* Harper & Row, New York, NY.

[58] Quigley, T.J., Hambrick, D.C., Misangyi, V.F., and Rizzi, G.A. (2019). CEO selection as risk-taking: A new vantage on the debate about the consequences of insiders versus outsiders. *Strategic Management Journal*, 40(9), 1453-1470.

[59] Sapienza, H.J., Parhankangas, A. & Autio, E. (2004). Knowledge relatedness and post-spin-off growth. *Journal of Business Venturing*, 19(6), 809-829.

[60] Semadeni, M. & Cannella Jr, A.A. (2011). Examining the performance effects of post spin-off links to parent firms: Should the apron strings be cut?. *Strategic Management Journal*, 32(10), 1083-1098.

[61] Senaviratna, N.A. & Cooray, T.M. (2019). Diagnosing multicollinearity of logistic regression model. *Asian Journal of Probability and Statistics*, 1-9.

[62] Seward, J.K. & Walsh, J.P. (1996). The governance and control of voluntary corporate spin-offs. *Strategic Management Journal*, 17(1), 25-39.

[63] Shapiro, A.C. & Titman, S. (1986). An integrated approach to corporate risk management. *The Revolution in Corporate Finance*, 3, 251-265.

[64] Shen, W. & Cannella, A.A. (2002). Revisiting the performance consequences of CEO succession: The impacts of successor type, postsuccession senior executive turnover, and departing CEO tenure. *Academy of Management Journal*, 45(4), 717-733.

[65] Sunaryo, R.I. & Saripujiana, D. (2018). The effects of information asymmetry, earning management, voluntary disclosure and market value of equity on cost of equity capital. *Journal of Economics, Business, and Accountancy Ventura*, 21(1), 79-88.

[66] Tian, J., Haleblian, J. & Rajagopalan, N. (2011). The effects of board human and social capital on investor reactions to new CEO selection. *Strategic Management Journal*, 32(7), 731-747.

[67] Tushman, M.L. & Rosenkopf, L. (1996). Executive succession, strategic reorientation and performance growth: A longitudinal study in the US cement industry. *Management Science*, 42(7), 939-953.

[68] Veld, C. & Veld-Merkoulova, Y.V. (2008). An empirical analysis of the stockholder-bondholder conflict in corporate spin-offs. *Financial Management*, 37(1), 103-124.

[69] Wruck, E.G. & Wruck, K.H. (2002). Restructuring top management: Evidence from corporate spinoffs. *Journal of Labor Economics*, 20(S2), S176-S218.

[70] Zhang, Y. & Rajagopalan, N. (2003). Explaining new CEO origin: Firm versus industry antecedents. *Academy of Management Journal*, 46(3), 327-338.

[71] Zhang, Y. & Rajagopalan, N. (2004). When the known devil is better than an unknown god: An empirical study of the antecedents and consequences of relay CEO successions. *Academy of Management Journal*, 47(4), 483-500.

[72] Zhang, Y. & Rajagopalan, N. (2010). Once an outsider, always an outsider? CEO origin, strategic change, and firm performance. *Strategic Management Journal*, 31(3), 334-346.

APPENDICES

Figure 1 Theoretical model including the level of significance of results
(**S**: significant; **NS**: non-significant)

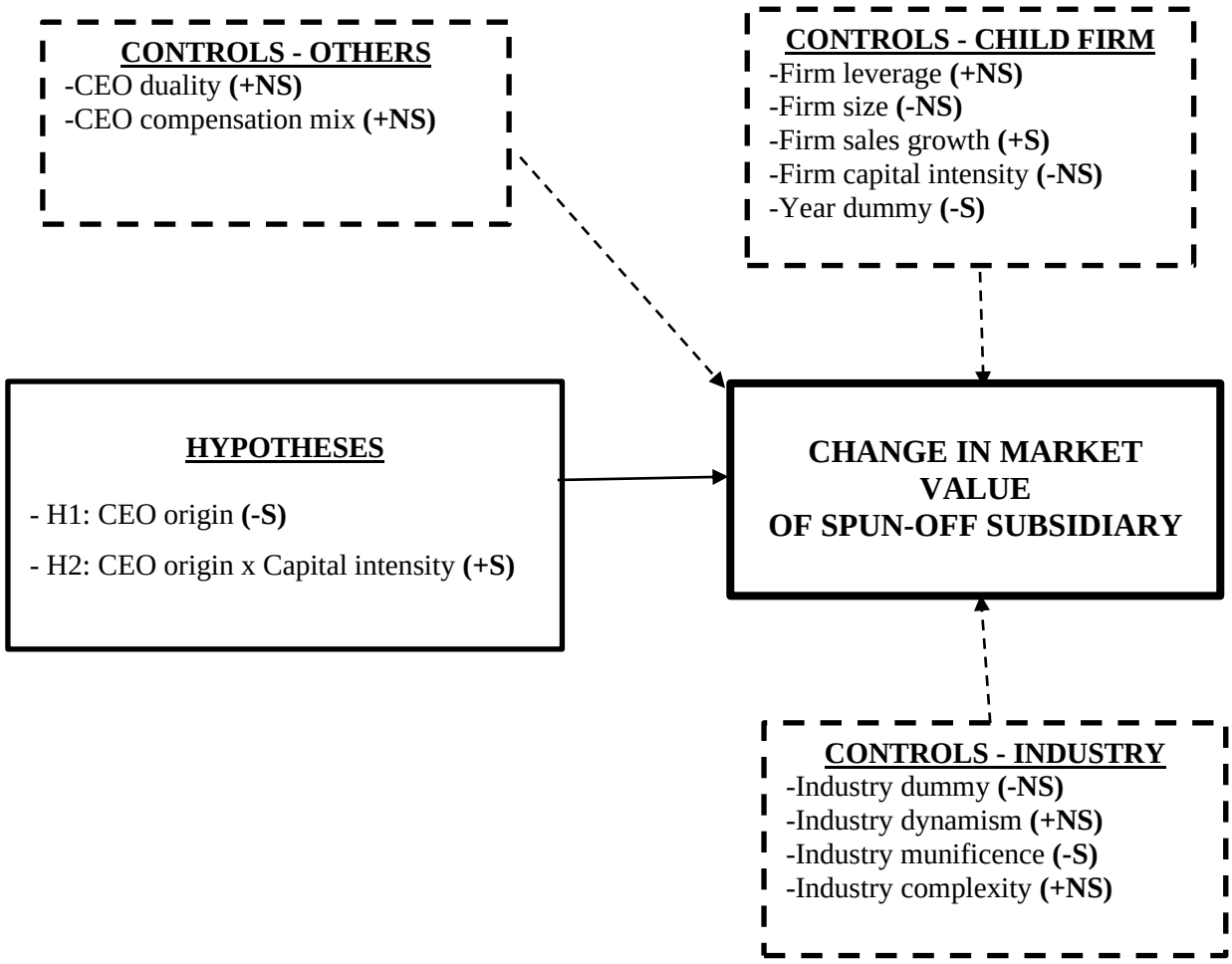
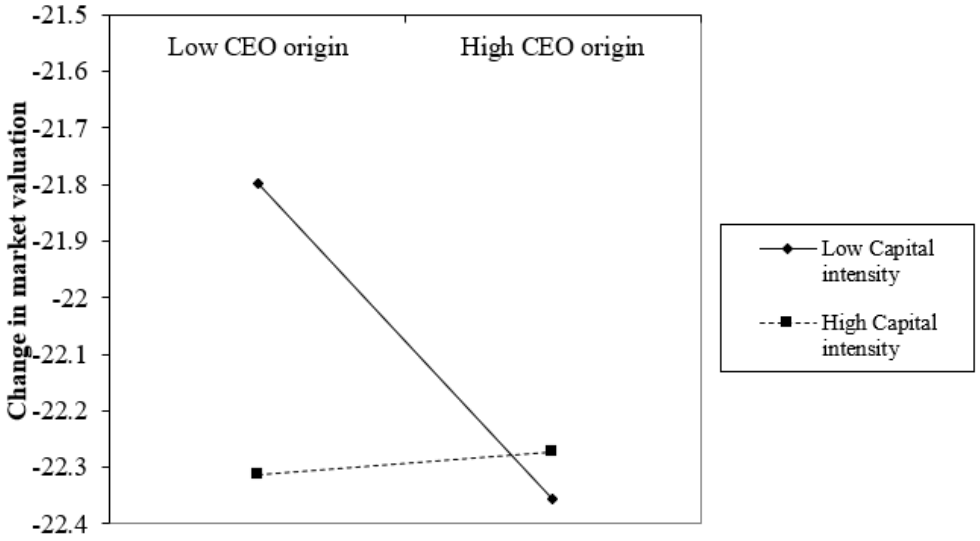


Figure 2 Two-way interaction effect of CEO origin and firm capital intensity
(High CEO origin refers to having an "insider" CEO whereas low CEO origin refers to having an "outsider" CEO)



Online Education, Online Teaching and Online Assessment - Abstracts

Effective Delivery and Assessment of Online Laboratory Classes in Engineering Technology Education

Oral Presentation

Dr. Md Shahriar Hossain [1], ***Dr. Rafiqul Islam*** [1]

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Several courses offered in the engineering and technology education require lab-based hands-on activities for strengthening theoretical knowledge. However, the face-to-face meeting with the students in those courses have been restricted due to the pandemic since March 2020. Due to the health risk and CDC guidelines, several universities all over the United States switched to online instructions, mostly relying on virtual lecture delivery tools and simulation software which substituted some lab-based activities. This research is aimed to evaluate the effectiveness of some new methods for lab-based course instruction and assessment. In this situation, we offered several innovative hands-on learning methods and assessment tools customizing respective course requirements. These methods include, giving small individual project, distributing equipment to the student allowing work at home, using simulation software, and providing video instruction for the hands-on activity. The performance of the students is assessed by oral presentation and oral examination, random quiz from large question bank, structured report writing, personalized lab test by random experimental setup, and video/picture/product submission from the completed hands-on activity. The effectiveness of these methods and tools is evaluated by a structured survey among the respective students, on a five-point Likert scale.

TELEPRESENCE AND SOCIAL PRESENCE IN ONLINE LEARNING

Oral Presentation

Dr. ChongWoo Park [1], ***Dr. Dong-gook Kim*** [2]

1. *Augusta University,* ***2.*** *Dalton State College*

According to the constructivism, individuals construct their own knowledge by interacting with the world. The importance of interactions in learning has been discussed in the instructional design literature. In online learning, students and instructors interact with each other through computer-mediated communication. As a means of interactions between students and instructors in online learning, communication technologies play a critical role in student learning experiences. Presence is broadly defined presence as the perceptual illusion of non-mediation during a technologically mediated experience and consists of two interrelated phenomena—telepresence and social presence.

In this study, drawing upon the literature including the constructivist's point of view in online learning and the concept of presence in the computer-mediated communication, we attempt to understand how the use of interactive communication technology is associated with the concept of telepresence and social presence in the online learning environment and how such presences influence the online learning experience.

To test the research model, we are collecting survey data from undergraduate students who have been taking online business courses where an interactive communication tool was required to use for class communication and collaboration. Preliminary data analysis shows that telepresence and social presence driven by tool interactivity has a positive impact on student satisfaction in online learning. Educators may be able to take advantage of this finding by employing a tool or an activity to help students build higher telepresence and social presence in online learning, which ultimately would lead to a better learning experience.

The Impact of Individual Capability of Time Management on Online Courses learning Performance

Oral Presentation

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E-learning or virtual learning has become the essential element of most educational institutions in and around the world due to the pandemic crisis of COVID-19. E-learning is a rapidly growing development in higher education. Nowadays, one out of three students takes at least one online course during his or her college career. E-learning is regarded as convenient and student-oriented, but the practice runs at a cost. Since E-learning requires a great level of student proactive involvement, students are in need to have great self-management skills to obtain a good learning outcome. Otherwise, a worse performance is highly likely to happen. Prior studies randomly assign students to an online or in-person section of one course, find negative effects on online student test scores, and claimed that one potential explanation is: students taking online courses require more time management capabilities from the students in a face-to-face class to be a success. As a result, this consideration raises the current research project to study how time management skills and capabilities a student has to influence his or her learning performance when this student takes an online course. Survey data is collected from online students. SEM is used to verify how system design, short-term and long-term time management skills influence student performance, usage intention, and usefulness.

Production and Service Operations Management - Abstracts

A Cross-Trained Workforce Task Assignment and Tour Scheduling Problem in a Children's Gymnastics Facility.

Oral Presentation

Dr. Megan Wydick Martin [1], ***Dr. Cliff Ragsdale*** [2]

1. *Meredith College,* ***2.*** *Vi*

With the excitement of the 2021 Olympics, the popularity of the ancient Greek sport, gymnastics, is on the rise. Gymnastics has become one of the leading summer Olympic sports to watch and children around the world are getting involved. As a result, gymnastics facilities must identify a weekly personnel schedule that seeks the most cost-effective set of coach-to-program assignments using a cross-trained workforce with varying availability. Typically, gymnastic facility business owners require 24+ hours to complete the formulation of an 8-week personnel schedule, which is not easily adjusted due to the complexity of hard copy calculations, employee job qualifications and established coach-to-gymnast relationships. We first identify the optimal (utopian) assignment plan using an integer linear programming problem. The optimal coach-to-program assignment can differ considerably from the status quo, requiring multiple reassignments from the current state to reach optimality. Making these adjustments with minimal coach reassignment maintains a level of comfort and familiarity with the children and sustains a level of staffing cost which is ideal for the business operations. We utilize the multiple objective optimization technique to identify the *n* best coach-to-program reassignments from the current state that provide the greatest progress toward the utopian staffing cost solution. This provides the decision maker with a summary of the trade-off between the number of program reassignments and the resulting progress achieved toward the optimal staffing cost. The decision maker can then make an informed decision about the best number of program reassignments (*n*) to choose based on the staffing cost objective; in other words, identifying the desired level of disruption (or reassignment) and the impact on staffing cost.

A Process Mapping Framework

Oral Presentation

Prof. Dag Naslund [1], ***Dr. Rahul Kale*** [1]

1. *UNF*

The importance of process management has long been advocated in the logistics and supply chain management literature, and in management literature in general. There are several articles in the logistics and supply chain management literature that refer to process mapping for various reasons. Simplified, successful process management requires that key cross-functional are defined and mapped. Further, many different process mapping methods and tools may be found in the literature. However, to the best of our knowledge, there is a lack of comprehensive, rigorous frameworks to guide process mapping efforts. Similarly, guidance is lacking on process mapping method selection. Perhaps, as a result, there are many instances in existing literature that identify problems with process mapping. We address this lack of frameworks in the literature by first identifying various problems and issues with existing process mapping efforts through a systematic literature review. Second, we propose a comprehensive, rigorous, well-grounded process mapping framework including guidance on process mapping method selection. We believe that this framework will serve as a useful guide for future mapping efforts for both researchers as well as practitioners in logistics and supply chain management, as well as in management in general.

A SIMPLE ALGEBRAIC METHOD FOR THE ECONOMIC ORDER QUANTITY MODEL WITH PLANNED BACKORDERS

Oral Presentation

Dr. Cenk Caliskan [1]

1. *Utah Valley University*

The Economic Order Quantity (EOQ) model is the cornerstone of inventory management and all business students study it. It is often a challenge to teach the model because some students are not mathematically well-prepared. The model is optimized using differential calculus, and not all business students easily understand the derivation. When a second decision variable is added to the model, which happens with the planned backorders model, the challenge becomes even bigger. We present a simple method to teach the EOQ model with planned backorders to undergraduate business students or practitioners who are not well-versed in differential calculus. Our approach uses only algebra and it is very short, succinct and intuitive.

An Investigation of Neighborhood Searches for the Flow Shop Early/Tardy Problem With Unforced Idle Time Allowed

Oral Presentation

Dr. Jeffrey Schaller [1]***, Dr. Jorge M.S. Valente*** [2]

1. *Eastern Connecticut State University,* ***2.*** *University of Porto*

This paper addresses the problem of flow shop scheduling when the objective is to minimize total earliness and tardiness when adding additional idle time is allowed in order to reduce the earliness of some jobs. Specifically, the use of neighborhood searches to improve solutions generated by constructive heuristics for the problem is investigated. Different neighborhood searches are tested, and the results are compared in terms of the objective values obtained and the time taken by the search. How the searches perform with different methods for generating initial solutions is also tested. The extent of the improvement achieved, and the amount of processing time required will be presented for a variety of test problems.

Drug Price Setting and Supply Chain Management Under the Fair Accountability and Innovative Research (FAIR) Drug Pricing Act

Oral Presentation

Dr. Chuanhui "Charles" Xiong [1]

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The pharmaceutical industry is one of the most profitable businesses in the United States. Branded drug prices continue to increase each year, not only attracting a lot of attention (from the public, the media, and the government) but also having a significant impact on the business practices of the industry. Nevertheless, there is no legal obligation for the pharmaceutical manufacturer to justify or explain the massive increase in drug prices. In 2016, legislation in California and Nevada began to develop state-level bills to increase drug price transparency and identify outlier drug price spikes. For the federal level, in 2017 the Fair Accountability and Innovative Research Drug Pricing Act (FAIR) was proposed with bipartisan cooperation. In March 2021, 4 senators reintroduced the Fair Accountability and Innovative Research (FAIR) Drug Pricing Act. FAIR requires drug companies to provide notice and justification for price increases. But there are many unanswered questions with the development stage of the FAIR which can significantly affect all players in the pharmaceutical industry supply chain. The purpose of this research is to (1) characterize the optimal threshold of the price increase to require drug companies to provide notice and justification; (2) analyze the strategy for supply chain players to release the price increasing information; and, (3) provide guidance for different players in the pharmaceutical supply chain to react once Fair Accountability and Innovative Research Drug Pricing Act passes.

Inventory management subject to lead-time variability and supply uncertainty

Oral Presentation

Dr. Esmail Mohebbi [1]

1. *University of West Florida*

Supply uncertainty is commonly regarded as a disturbing risk factor when managing a supply chain. In particular, organizations might face the challenge of having to devise policies that could mitigate the negative impacts of potential interruptions in their supply processes due to the suppliers' unavailability. The significance of this challenge has been accentuated by the worldwide COVID-19 pandemic and its ensuing impacts on global supply chains. We consider the inventory replenishment decision in the face of intermittent interruptions in the supply process. Accounting for the replenishment lead time, we tackle the issue of uncertainty in the supplier's availability through a stochastic inventory control model and share some numerical results.

Optimal Coal Mine Allocation and Subsequent Delivery Schedule for a Power Company

Oral Presentation

Dr. nasreddine saadouli [1]

1. *Gulf*

A Power company uses high moisture and ash with low calorific content coal. The company needs to improve upon the present grade of coal being used through a network of coal suppliers from all over the world within budget, time and cost constraints. A linear programming formulation is used to determine the optimal supply of coal from different mines in various countries depending on a number of technical and chemical specifications of the coal. Consequently, and to co-ordinate all activities, a delivery schedule is developed and monitored using the critical path method. A case study of a real company is studied and the results are analyzed and discussed.

Optimum Production Rate and Number of Shipments Under Random Machine Breakdown

Oral Presentation

Dr. Md Shahriar Hossain [1]

1. *Northwestern State University*

This paper presents a production house inventory model for a timber manufacturing industry. Random machine breakdown is a common scenario in the production floor. For avoiding sudden machine breakdown, the production house routinely conducts preventive maintenance. A certain amount of inventory is intentionally built up at the production house before a scheduled preventive maintenance is started every after a certain period depending on the number of shipments. Delayed maintenance schedule reduces total maintenance cost but increases machine breakdown probability as well as unplanned downtime, resulting production delay. On the other hand, frequent maintenance reduces machine breakdown probability but increases total maintenance cost. A controlled production rate serves as a significant parameter for optimally trading-off between maintenance frequency and machine breakdown. Considering all the above-mentioned conflicting scenarios regarding random machine breakdown, stock-out and uncertain demand rate, this paper derives a mathematical model for minimizing the total cost by combining the production, inventory, and maintenance costs, when optimizing production rate and number of shipments. The model becomes a nonlinear constrained optimization problem with two discrete variables. An iterative search algorithm is used to obtain the sub-optimal solution. The model is illustrated with a numerical example.

SOLVING THE TEAM ORIENTEERING PROBLEM WITH TIME WINDOWS AND MANDATORY VISITS USING A CONSTRAINT PROGRAMMING APPROACH

Oral Presentation

Dr. Ridvan Gedik [1], ***Dr. Emre Kirac*** [2], ***Dr. Furkan Oztanriseven*** [3]

1. *Florida Southern College,* ***2.*** *Christopher Newport University,* ***3.*** *Le Moyne College*

This study investigates the use of a constraint programming (CP) modeling approach in solving a well-known variant of the selective vehicle routing problem with global constraints and interval decision variables. The team orienteering problem with time windows and mandatory visits (TOPTW-MV) can be seen in many real-world applications such as tourist tour planning, routing healthcare personnel and trucks, disaster relief planning and execution. In this problem, a list of locations is given where a subset of these locations must be visited exactly once with a fleet of homogeneous vehicles and others are optional. If a location is visited, a profit is collected. The profit, service time and visit time window (within when a service may start and end) for each location is known and deterministic. The objective is then creating a set of vehicle routes that start and end at a depot, visiting all mandatory locations exactly once and optional locations at most once in such a way that total profit is maximized subject to several other operational side constraints (tour preservation, sequence dependent travel times and limited resources, etc.). The proposed CP-based approach obtains 99 of the best-known solutions and explores 64 new best-known solutions for the benchmark instances.

The impact of risk management maturity on robustness in the upstream and downstream supply chains: A preliminary empirical study

Oral Presentation

Dr. Mauro Falasca [1], ***Dr. Scott Dellana*** [1], ***Dr. Ying Liao*** [1], ***Dr. William Rowe*** [1]

1. *East Carolina University*

This research explores the relationships among different dimensions of supply chain risk management maturity (SCRMM) and supply chain robustness in both upstream and downstream supply chain (SC) organizations. SCRMM is characterized by factors of SC risk management orientation, improvement of risk management processes, internal risk management processes, external risk management processes and SC risk mitigation. A structural equation model is proposed and tested based on the participation of over 100 SC managers spanning multiple industry sectors. Two research groups (upstream and downstream SC organizations) are analyzed to determine whether the relationships among the constructs differ by position in the SC. The preliminary empirical findings indicate that the model constructs help predict robustness throughout the SC, suggesting that companies can benefit from a culture of continuous improvement regardless of their position in the SC.

This research explores the relationships among different dimensions of supply chain risk management maturity (SCRMM) and supply chain robustness (ROB) in both upstream and downstream supply chain (SC) organizations. In this study, SCRMM is characterized by factors of SC risk management orientation (RMO), improvement of risk management processes (IMP), internal risk management processes (IRM), external risk management processes (ERM) and SC risk mitigation (MIT). A structural equation model is proposed and tested based on the participation of 117 SC managers spanning multiple industry sectors. The theoretical model positively relates RMO to IRM, ERM and IMP. IMP is included in the model as a mediator between RMO and IRM, as well as between RMO and ERM. The impact of IRM and ERM on MIT is also explored, while MIT is positively related to ROB. Finally, organization size is included in the study as a control variable. Two subsamples (a group of 44 upstream SC firms and a group of 73 downstream SC firms) are used to evaluate the model and determine whether the relationships among the constructs differ by position in the SC. Preliminary results indicate that, for upstream SC organizations, the relationship between RMO and both IRM and ERM is fully mediated by IMP. Moreover, both IRM and ERM have a significant direct positive effect on MIT and, ultimately, on ROB. In the case of downstream SC organizations, while IMP fully mediates the relationship between orientation and internal risk management processes, a partial mediation effect is found in the link between RMO and external risk management processes. The preliminary study findings indicate that the model constructs help predict robustness throughout the SC, suggesting that companies can benefit from a culture of continuous improvement regardless of their position in the SC. However, a culture of continuous improvement helps better explain the model relationships in the upstream SC rather than the downstream SC. In the end, managers can feel confident that the different dimensions of SCRMM contribute to SC robustness, and that a culture of continuous improvement represents a catalyst between a firm's orientation towards risk management and both internal and external risk management processes. Overall, this research study advances knowledge of how firms address the challenging issue of risk management in the supply chain, while the preliminary empirical results offer a firm-level SC risk management framework for managerial decision-making. Keywords: supply chain management, supply chain risk, supply chain risk management maturity, supply chain robustness

Production and Service Operations Management - Papers

A SIMPLE ALGEBRAIC METHOD FOR THE ECONOMIC ORDER QUANTITY MODEL WITH PLANNED BACKORDERS

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ABSTRACT

The Economic Order Quantity (EOQ) model is the cornerstone of inventory management and all business students study it. It is often a challenge to teach the model because some students are not mathematically well-prepared. The model is optimized using differential calculus, and not all business students easily understand the derivation. When a second decision variable is added to the model, which happens with the planned backorders model, the challenge becomes even bigger. We present a simple method to teach the EOQ model with planned backorders to undergraduate business students or practitioners who are not well-versed in differential calculus. Our approach uses only algebra and it is very short, succinct and intuitive.

Keywords: inventory, EOQ, economic order quantity, algebraic methods, teaching, pedagogy.

INTRODUCTION

The basic Economic Order Quantity (EOQ) model is the cornerstone of inventory management. It has been developed by Harris [12], who says that "the solution of this problem requires higher mathematics." Many undergraduate business students have difficulty in understanding the derivation of the optimal solution because it uses differential calculus. When there are multiple decision variables, such as that happens with the planned backorders extension of the EOQ problem, this difficulty is even more pronounced. A number of algebraic approaches have been proposed in the literature to derive the optimal solution for the EOQ problem and its extensions. The biggest problem with these approaches is that they are even more complicated than the standard differential calculus based approach, therefore they defeat the purpose of simplifying the analysis. Another problem is that they are all problem specific, and rely on some characteristics of the total cost function, thus they cannot be applied to other problems. Some algebraic methods are even more problematic, requiring certain assumptions based on the characteristics of the optimal solution.

In this paper, we present a simple algebraic derivation approach that can be used to teach the EOQ problem with planned backorders. Anecdotal experience shows that the approach

is well-liked by the students who are not well-prepared in calculus and that they learn better and retain the information longer.

LITERATURE REVIEW

Grubbström and Erdem [11] derive the optimal solution to the EOQ problem with backorders without using calculus. However, their approach is based on the a priori knowledge of a characteristic of the optimal solution. Therefore, it is a verification of the optimal solution, rather than a derivation. This approach is adapted to the Economic Production Quantity (EPQ) problem by Cárdenas-Barrón [1], and Wee et al. [20] extend it to the case where there is a temporary price change. Huang [13] extends it to the EOQ and EPQ problems where some of the items are defective. The approach has been criticized by Ronald et al. [16] for its use of the a priori knowledge about the optimal solution characteristics, but they also use another a priori information about the optimal solution, therefore theirs is not a real derivation, either.

When the total cost function is the square of a linear expression, it is very easy to determine the optimal solution because the minimum of a squared expression occurs at zero. Sphicas [17] exploits this fact and develops an algebraic method that transforms the total cost function to this form and calls it "complete the perfect square" method. This approach has been adapted to various extensions of the EPQ problem by Cárdenas-Barrón [2] and Huang et al. [14]. The biggest problem with this approach is that it is too complicated, requires some obscure terms to be added to the total cost function "to complete the square," and it is not possible to apply it to other optimization problems in inventory management or other areas of operations management.

There are two well-known inequalities involving real numbers, called "the arithmetic mean-geometric mean inequality" and "Cauchy-Bunyakovsky–Schwarz inequality." Teng [18] use the former to derive the optimal solutions for the EOQ and EPQ problems with backordering. Cárdenas-Barrón et al. [4] also uses the former to derive the optimal solution for a two-echelon system which he calls "a vendor-buyer system," effectively extending the approach of Teng [18]; and Cárdenas-Barrón [3] uses both inequalities to derive the optimal solution for both the EOQ and EPQ problems with backordering.Teng et al. [19] develops a hybrid method that combines the complete the perfect square and the arithmetic mean-geometric mean inequality based approaches.

Finally, yet another algebraic approach to solve the EOQ and EPQ problems with backordering is developed by Minner [15], which he calls "the cost comparisons" method. It is a simple marginal analysis based approach that first approximates the total cost function by assuming a fixed planning horizon, and then by taking limits, extends the planning horizon to infinity and finds the optimal solution. It is a rather long and complicated approach, and it fails to check the uniqueness of the optimal solution. The approach proposed by Minner [15] is based on optimizing the order interval, and Wee et al. [21] modifies the same approach to optimize the order quantity instead. Widyadana et al. [22] adapt the cost comparisons approach to an approximate deteriorating items model they propose. Çalışkan [9] improves this model and shows discrepancies in its numerical results and Çalışkan [5] proposes a more accurate approximation model than the one in Widyadana et al. [22]. Chung [10] adapt

the cost comparisons approach to a two-echelon vendor-buyer problem. Çalışkan [7] and Çalışkan [8] shows that the cost comparisons method is equivalent to the differential calculus approach while being quite a bit longer and more complicated, and it doesn't check for the uniqueness of the optimal solution.

We present in this paper a very simple, short and intuitive approach to derive the optimal solution for the EOQ problem with backorders. All of the aforementioned methods are much longer, more complicated, and less intuitive compared to our proposed method. Furthermore, they are not generalizable and they make some a priori assumptions about the optimal solution. Our approach can be generalized to optimizing any differentiable total cost function, and we don't make any a priori assumptions about the characteristics of the optimal solution. Our approach is accessible to anyone who lacks a solid background in differential calculus but can understand algebraic manipulations. We believe it is a great pedagogical tool to teach inventory management to undergraduate business students who sometimes lack the necessary mathematical background. Some anecdotal evidence from the classroom indicates that the students enjoy learning the material taught by this method, learn the material better and retain the information longer. The method that we present in this paper is a simplified adaptation of the approach for the EOQ problem with backorders, that is applied to the deteriorating items inventory models in Çalışkan [5], Çalışkan [6] and Çalışkan [9].

THE EOQ MODEL WITH PLANNED BACKORDERS

The demand per unit of time is assumed to be constant and deterministic and it occurs uniformly over time. There is an inventory holding cost per unit per unit of time that is incurred for each item in the inventory. Every time an order is placed, an ordering cost is incurred per order. Any unsatisfied item in an inventory ordering cycle is immediately satisfied from the received order at the beginning of the next cycle. There is a cost for keeping an item on backorder per unit per unit of time. When an order is received, it is received all at once. The objective is to determine the order and backorder quantities that minimize the sum of the per unit time costs of ordering, inventory holding and backordering. The following are the variables and the parameters of the model:

D = the demand per unit time
S = the cost of ordering per order
h = the cost of inventory holding per unit per unit time
b = the cost of backordering per unit per unit time
Q = the number of units to order in each ordering cycle
B = the number of units to backorder in each ordering cycle
T = the time between orders (order interval)
T_I = positive inventory time in each cycle (inventory interval)
T_B = zero inventory time in each cycle (backorder interval)

The maximum inventory level in an inventory cycle is $Q - B$ because the accumulated backorders in the previous cycle has to be satisfied first, as soon as an order is received.

Therefore, the average inventory level per cycle and the average backorder level per cycle can be calculated as follows:

$$\bar{I} = \frac{Q-B}{2}\left(\frac{T-T_B}{T}\right) = \frac{Q-B}{2}\left(\frac{\frac{Q-B}{D}}{\frac{Q}{D}}\right) = \frac{(Q-B)^2}{2Q} \tag{1}$$

$$\bar{B} = \frac{B}{2}\left(\frac{T_B}{T}\right) = \frac{B}{2}\left(\frac{\frac{B}{D}}{\frac{Q}{D}}\right) = \frac{B^2}{2Q} \tag{2}$$

Order (Q) and Backorder (B) Quantities as the Decision Variables

The average per unit time total cost for the planned backorders model could be expressed in terms of Q and B as follows:

$$TC(Q,B) = \frac{SD}{Q} + \frac{h(Q-B)^2}{2Q} + \frac{bB^2}{2Q} \tag{3}$$

Assume that Q is fixed for now. Let B^* be the optimal backorder quantity for the fixed value of Q and let:

$$B_u = B^* + \Delta B \tag{4}$$

$$B_l = B^* - \Delta B \tag{5}$$

for some $\Delta B > 0$. Then, due to the optimality of B^*, the following two inequalities will hold:

$$TC(Q,B_u) - TC(Q,B^*) \geq 0 \tag{6}$$

$$TC(Q,B_l) - TC(Q,B^*) \geq 0 \tag{7}$$

Eq. 6 can be further simplified as follows:

$$\begin{aligned}
&\frac{SD}{Q} + \frac{h(Q-B_u)^2}{2Q} + \frac{bB_u^2}{2Q} - \frac{SD}{Q} - \frac{h(Q-B^*)^2}{2Q} - \frac{b(B^*)^2}{2Q} \geq 0 \\
&\frac{SD}{Q} + \frac{h(Q-B_u)^2}{2Q} + \frac{bB_u^2}{2Q} - \frac{SD}{Q} - \frac{h(Q-B^*)^2}{2Q} - \frac{b(B^*)^2}{2Q} \geq 0 \\
&\frac{h}{2Q}\left[(Q-B_u)^2 - (Q-B^*)^2\right] + \frac{b}{2Q}(B_u+B^*)(B_u-B^*) \geq 0 \\
&h(2Q-B_u-B^*)(B^*-B_u) + b(B_u+B^*)(B_u-B^*) \geq 0 \\
&-h(2Q-B_u-B^*) + b(B_u+B^*) \geq 0
\end{aligned} \tag{8}$$

Eq. 7 can also be similarly simplified as follows:

$$\frac{SD}{Q} + \frac{h(Q-B_l)^2}{2Q} + \frac{bB_l^2}{2Q} - \frac{SD}{Q} - \frac{h(Q-B^*)^2}{2Q} - \frac{b(B^*)^2}{2Q} \geq 0$$

$$\frac{SD}{Q} + \frac{h(Q-B_l)^2}{2Q} + \frac{bB_l^2}{2Q} - \frac{SD}{Q} - \frac{h(Q-B^*)^2}{2Q} - \frac{b(B^*)^2}{2Q} \geq 0$$
$$\frac{h}{2Q}\left[(Q-B_l)^2 - (Q-B^*)^2\right] + \frac{b}{2Q}(B_l+B^*)(B_l-B^*) \geq 0$$
$$h(2Q-B_l-B^*)(B^*-B_l) + b(B_l+B^*)(B_l-B^*) \leq 0$$
$$-h(2Q-B_l-B^*) + b(B_l+B^*) \leq 0 \tag{9}$$

Eqs. 8 and 9 will therefore result in the following:

$$-h(2Q-B_u-B^*) + b(B_u+B^*) \geq 0 \geq -h(2Q-B_l-B^*) + b(B_l+B^*) \tag{10}$$

If we decrease ΔB, approaching zero, both B_l and B_u will approach B^*. Furthermore, both sides of Eq. 10 will approach one another. Therefore, we obtain the following:

$$-h(2Q-2B^*) + 2bB^* = 0$$
$$B^* = Q\left(\frac{h}{b+h}\right) \tag{11}$$

We can eliminate the backordering variable B from Eq. 3 by substituting Eq. 11 in Eq. 3:

$$TC(Q) = \frac{SD}{Q} + \frac{h\left(Q - \frac{h}{b+h}Q\right)^2}{2Q} + \frac{bQ^2\frac{h^2}{(b+h)^2}}{2Q} = \frac{SD}{Q} + \frac{hb^2Q + bh^2Q}{2(b+h)^2}$$
$$TC(Q) = \frac{SD}{Q} + \frac{hb(b+h)Q}{2(b+h)^2} = \frac{SD}{Q} + \frac{hbQ}{2(b+h)} \tag{12}$$

Let $h' = h\frac{b}{b+h}$. We can then see that Eq. 12 is actually in the same form as the total cost function of the basic EOQ model:

$$TC(Q) = \frac{SD}{Q} + \frac{h'Q}{2} \tag{13}$$

Let Q^* be the optimal order quantity that minimizes Eq. 13 and let

$$Q_u = Q^* + \Delta Q \tag{14}$$
$$Q_l = Q^* - \Delta Q \tag{15}$$

for some $\Delta Q > 0$. Then, based on the optimality of Q^*, the following two inequalities will hold:

$$TC(Q_u) - TC(Q^*) \geq 0 \tag{16}$$
$$TC(Q_l) - TC(Q^*) \geq 0 \tag{17}$$

We can simply Eq. 16 as follows:

$$\left[\frac{SD}{Q_u} + \frac{h'Q_u}{2} - \frac{SD}{Q^*} - \frac{h'Q^*}{2}\right] \geq 0$$

$$SD\frac{(Q^* - Q_u)}{Q_u Q^*} + \frac{h'}{2}(Q_u - Q^*) \geq 0$$
$$-\frac{SD}{Q_u Q^*} + \frac{h'}{2} \geq 0 \tag{18}$$

Similarly, we can simplify Eq. 17 as follows:

$$\left[\frac{SD}{Q_l} + \frac{h'Q_l}{2} - \frac{SD}{Q^*} - \frac{h'Q^*}{2}\right] \geq 0$$
$$SD\frac{(Q^* - Q_l)}{Q_u Q^*} + \frac{h'}{2}(Q_l - Q^*) \geq 0$$
$$-\frac{SD}{Q_l Q^*} + \frac{h'}{2} \leq 0 \tag{19}$$

Eqs. 18 and 19 result in the following:

$$-\frac{SD}{Q_u Q^*} + \frac{h'}{2} \geq 0 \geq -\frac{SD}{Q_l Q^*} + \frac{h'}{2} \tag{20}$$

If we make ΔQ smaller, approaching zero, both Q_l and Q_u will approach Q^* and both sides of Eq. 20 will approach one another. Therefore, we obtain the following:

$$-\frac{SD}{(Q^*)^2} + \frac{h'}{2} = 0$$
$$Q^* = \sqrt{\frac{2DS}{h'}} = \sqrt{\frac{2DS}{h}}\sqrt{\frac{b+h}{b}} \tag{21}$$

Proving the Uniqueness of the Optimal Solution

In order to prove that (Q^*, B^*) is the unique minimum, we need to show that the following equation holds for $Q_1, Q_2 \geq 0$, $Q_1 \neq Q_2$; $B_1, B_2 \geq 0$, $B_1 \neq B_2$; and $0 < \lambda < 1$:

$$\lambda TC(Q_1, B_1) + (1-\lambda)TC(Q_2, B_2) >$$
$$TC(\lambda Q_1 + (1-\lambda)Q_2, \lambda B_1 + (1-\lambda)B_2) \tag{22}$$

First, we will transform Eq. 3 into the following equivalent form:

$$TC(Q, B) = \frac{SD}{Q} + \frac{h(Q-2B)}{2} + \frac{(h+b)B^2}{2Q} \tag{23}$$

We will prove the convexity of the three terms in Eq. 23 separately. For the first term, the following inequality needs to hold:

$$\frac{\lambda SD}{Q_1} + \frac{(1-\lambda)SD}{Q_2} > \frac{SD}{\lambda Q_1 + (1-\lambda)Q_2} \tag{24}$$

This can be simplified as follows:

$$\frac{\lambda Q_2 + (1-\lambda)Q_1}{Q_1 Q_2} > \frac{1}{\lambda Q_1 + (1-\lambda)Q_2}$$
$$\lambda^2 Q_1 Q_2 + \lambda(1-\lambda)Q_2^2 + \lambda(1-\lambda)Q_1^2 + (1-\lambda)^2 Q_1 Q_1 > Q_1 Q_2$$
$$\lambda(1-\lambda)Q_1^2 + \lambda(1-\lambda)Q_2^2 - 2\lambda(1-\lambda)Q_1 Q_2 > 0 \Rightarrow (Q_1 - Q_2)^2 > 0$$

Thus, the first term is strictly convex. The second term satisfies the following equality:

$$\frac{\lambda h(Q_1 - 2B_1)}{2} + \frac{(1-\lambda)h(Q_2 - 2B_2)}{2} = \frac{h(\lambda Q_1 + (1-\lambda)Q_2 - 2(\lambda B_1 + (1-\lambda)B_2))}{2} \tag{25}$$

Thus, the second term is both convex and concave. The third term should satisfy the following:

$$\frac{\lambda(h+b)B_1^2}{2Q_1} + \frac{(1-\lambda)(h+b)B_2^2}{2Q_2} > \frac{(h+b)(\lambda B_1 + (1-\lambda)B_2)^2}{2(\lambda Q_1 + (1-\lambda)Q_2)} \tag{26}$$

This can be simplified as follows:

$$\frac{\lambda Q_2 B_1^2 + (1-\lambda)Q_1 B_2^2}{Q_1 Q_2} > \frac{\lambda^2 B_1^2 + 2\lambda(1-\lambda)B_1 B_2 + (1-\lambda)^2 B_2^2}{\lambda Q_1 + (1-\lambda)Q_2}$$
$$\lambda^2 Q_1 Q_2 B_1^2 + \lambda(1-\lambda)Q_2^2 B_1^2 + \lambda(1-\lambda)Q_1^2 B_2^2 + (1-\lambda)^2 Q_1 Q_2 B_2^2 >$$
$$\lambda^2 Q_1 Q_2 B_1^2 + 2\lambda(1-\lambda)Q_1 Q_2 B_1 B_2 + (1-\lambda)^2 Q_1 Q_2 B_2^2$$
$$Q_2^2 B_1^2 + Q_1^2 B_2^2 - 2Q_1 Q_2 B_1 B_2 > 0 \Rightarrow (Q_2 B_1 - Q_1 B_2)^2 > 0$$

Thus, the third term is also strictly convex. Therefore, $TC(Q, B)$ is strictly convex and (Q^*, B^*) is the unique optimum solution to the EOQ problem with backordering.

Order (T) and Backorder (T_B) Intervals as the Decision Variables

We can express the average per unit time total cost in terms of T and T_B as follows:

$$TC(T, T_B) = \frac{S}{T} + \frac{hD(T - T_B)^2}{2T} + \frac{bDT_B^2}{2T} \tag{27}$$

A close inspection of Eq. 27 reveals that it has the same form as Eq. 3. Q and B in Eq. 3 are replaced by T and T_B, SD is replaced by S, and h and b are replaced by hD and bD. Therefore, the optimal order and backorder intervals will be as follows:

$$T_B^* = T^* \left(\frac{h}{b+h}\right) \tag{28}$$

$$T^* = \sqrt{\frac{2S}{hD}}\sqrt{\frac{b+h}{b}} \tag{29}$$

(T^*, T_B^*) is the unique optimum solution because Eq. 27 can be proven to be convex the same way as Eq. 3.

CONCLUSIONS

In this research, we develop a very short, succinct, simple and intuitive approach to derive the optimal solution for a two-variable problem encountered in inventory management: the Economic Order Quantity problem with planned backorders. The approach is based entirely on algebra, and does not require the knowledge of differential calculus. In addition, we also show without using calculus that the optimal solution is unique. Therefore, it is a great pedagogical tool to teach the EOQ model to undergraduate business students who may not have sufficient preparation in calculus, or practitioners who are similarly not very well-versed in calculus.

References

[1] L. E. Cárdenas-Barrón. The economic production quantity (EPQ) with shortage derived algebraically. *International Journal of Production Economics*, 70(3):289 – 292, 2001.

[2] L. E. Cárdenas-Barrón. Optimal manufacturing batch size with rework in a single-stage production system — a simple derivation. *Computers & Industrial Engineering*, 55(4): 758 – 765, 2008.

[3] L. E. Cárdenas-Barrón. An easy method to derive EOQ and EPQ inventory models with backorders. *Computers & Mathematics with Applications*, 59(2):948 – 952, 2010.

[4] L. E. Cárdenas-Barrón, H.-M. Wee, and M. F. Blos. Solving the vendor—buyer integrated inventory system with arithmetic—geometric inequality. *Mathematical and Computer Modelling*, 53(5):991 – 997, 2011.

[5] C. Çalışkan. A derivation of the optimal solution for exponentially deteriorating items without derivatives. *Computers & Industrial Engineering*, 148:106675, 2020. URL https://doi.org/10.1016/j.cie.2020.106675.

[6] C. Çalışkan. EOQ model for exponentially deteriorating items with planned backorders without differential calculus. *American Journal of Mathematical and Management Sciences*, 0(0):1–21, 2021. URL https://doi.org/10.1080/01966324.2021.1957729.

[7] C. Çalışkan. A note on "A modified method to compute economic order quantities without derivatives by cost-difference comparisons". *Journal of Statistics and Management Systems*, 24(5):1059–1075, 2021. URL https://doi.org/10.1080/09720510.2020.1859809.

[8] C. Çalışkan. A note on cost comparisons method for the EOQ and EPQ problems. *Journal of Statistics and Management Systems*, 24(5):1101–1112, 2021. URL https://doi.org/10.1080/09720510.2021.1923924.

[9] C. Çalışkan. A simple derivation of the optimal solution for the EOQ model for deteriorating items with planned backorders. *Applied Mathematical Modelling*, 89:1373 – 1381, 2021. URL https://doi.org/10.1016/j.apm.2020.08.037.

[10] C.-J. Chung. An easy method to derive the integrated vendor-–buyer production-–inventory model with backordering using cost–difference rate comparison approach. *Mathematical and Computer Modelling*, 57(3):632 – 640, 2013.

[11] R. W. Grubbström and A. Erdem. The EOQ with backlogging derived without derivatives. *International Journal of Production Economics*, 59(1):529 – 530, 1999.

[12] F. Harris. How many parts to make at once. *Factory, The Magazine of Management*, 10(2):135–136, 152, February 1913.

[13] Y.-F. Huang. The deterministic inventory models with shortage and defective items derived without derivatives. *Journal of Statistics and Management Systems*, 6(2):171–180, 2003.

[14] Y.-F. Huang, C.-L. Chou, and J.-J. Liao. An EPQ model under cash discount and permissible delay in payments derived without derivatives. *Yugoslav Journal of Operations Research*, 17(2):177 – 193, 2007.

[15] S. Minner. A note on how to compute economic order quantities without derivatives by cost comparisons. *International Journal of Production Economics*, 105(1):293 – 296, 2007.

[16] R. Ronald, G. K. Yang, and P. Chu. Technical note: The EOQ and EPQ models with shortages derived without derivatives. *International Journal of Production Economics*, 92(2):197 – 200, 2004.

[17] G. P. Sphicas. EOQ and EPQ with linear and fixed backorder costs: Two cases identified and models analyzed without calculus. *International Journal of Production Economics*, 100(1):59 – 64, 2006.

[18] J.-T. Teng. A simple method to compute economic order quantities. *European Journal of Operational Research*, 198(1):351 – 353, 2009.

[19] J.-T. Teng, L. E. Cárdenas-Barrón, and K.-R. Lou. The economic lot size of the integrated vendor—buyer inventory system derived without derivatives: A simple derivation. *Applied Mathematics and Computation*, 217(12):5972 – 5977, 2011.

[20] H. Wee, S. Chung, and P. Yang. Technical note a modified EOQ model with temporary sale price derived without derivatives. *The Engineering Economist*, 48(2):190–195, 2003.

[21] H.-M. Wee, W.-T. Wang, and C.-J. Chung. A modified method to compute economic order quantities without derivatives by cost-difference comparisons. *European Journal of Operational Research*, 194(1):336 – 338, 2009.

[22] G. A. Widyadana, L. E. Cárdenas-Barrón, and H. M. Wee. Economic order quantity model for deteriorating items with planned backorder level. *Mathematical and Computer Modelling*, 54(5):1569 – 1575, 2011.

OPTIMUM PRODUCTION RATE AND NUMBER OF SHIPMENTS UNDER RANDOM MACHINE BREAKDOWN

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ABSTRACT

This paper presents a production house inventory model for a timber manufacturing industry. Random machine breakdown is a common scenario in the production floor. For avoiding sudden machine breakdown, the production house routinely conducts preventive maintenance. A certain amount of inventory is intentionally built up at the production house before a scheduled preventive maintenance is started every after a certain period depending on the number of shipments. Delayed maintenance schedule reduces total maintenance cost but increases machine breakdown probability as well as unplanned downtime, resulting production delay. On the other hand, frequent maintenance reduces machine breakdown probability but increases total maintenance cost. A controlled production rate serves as a significant parameter for optimally trading-off between maintenance frequency and machine breakdown. Considering all the above-mentioned conflicting scenarios regarding random machine breakdown, stock-out and uncertain demand rate, this paper derives a mathematical model for minimizing the total cost by combining the production, inventory, and maintenance costs, when optimizing production rate and number of shipments. The model becomes a nonlinear constrained optimization problem with two discrete variables. An iterative search algorithm is used to obtain the sub-optimal solution. The model is illustrated with a numerical example.

INTRODUCTION

This research is ensued from some local timber industries who wants to know the optimum production rate and maintenance schedules to minimize their total cost of production. Similar problems were addressed by Vijayanathan *et al.* in 2019 [1], where the authors optimized the production overtime period and backorder quantity for a joint production and maintenance scheduling. On the other hand, Dhouib *et al.* in 2012 [2] presented a joint optimal production control/preventive maintenance policy for imperfect process manufacturing cell. Recently in 2019, Lai *et al.* [3] discussed about the optimal decision of an economic production quantity model for imperfect manufacturing under hybrid maintenance policy. However, the availability of an optimization model for production rate and number of shipments with a random machine breakdown in a timber industry, is very limited. Hence, this research is conducted to address a specific practical scenario presented in this paper.

The production house in the timber industries can vary the rate of production (P) up to their maximum capacity. Random machine breakdown is a common scenario in the production floor. Production rate P acts as a parameter for the machine breakdown probability. For avoiding sudden machine breakdown, the production house routinely conducts preventive maintenance. A certain amount of inventory (Q) is built up at the production house when a scheduled preventive maintenance starts every after a certain period, T_c. See Figure 1]. Delayed maintenance schedule reduces total maintenance cost but increases machine breakdown probability as well as unplanned downtime, resulting production delay. On the other hand, frequent maintenance reduces machine breakdown probability but increases total maintenance cost. Here, production rate (P) controls the inventory level of the production house.

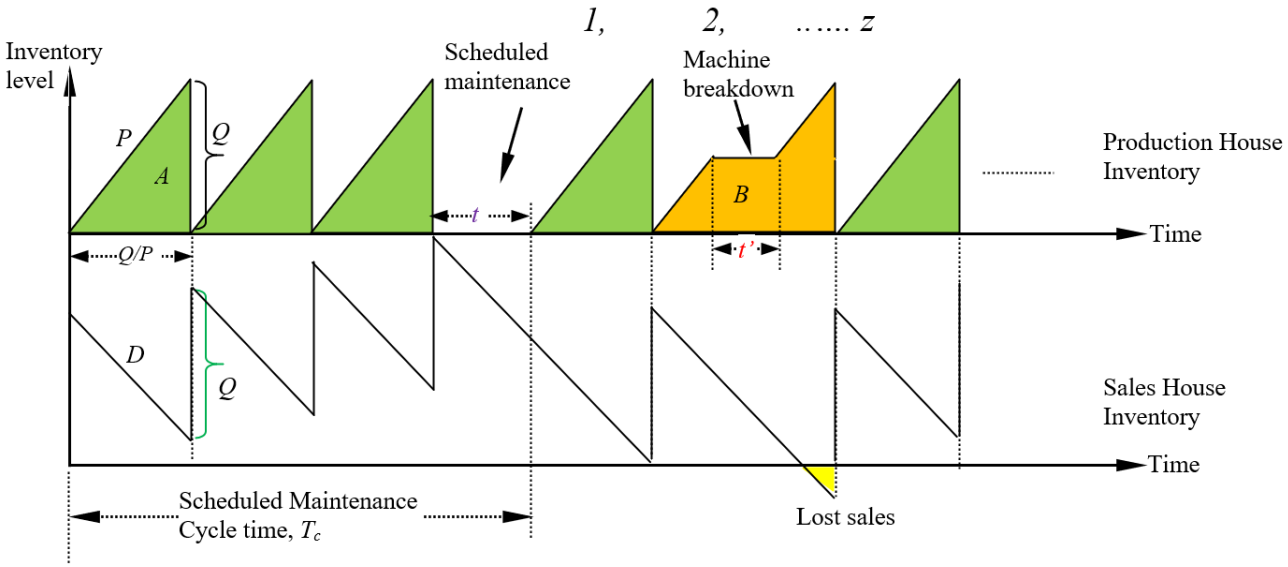

Figure 1: Production House and Sales House inventory levels showing early maintenace and backordering situations.

For trading-off between maintenance frequency and machine breakdown, a controlled production rate acts as a significant parameter. The delayed production due to unplanned machine breakdown, and probabilistic demand rate (D) creates uncertainty in the inventory level at the sales house, as well. It is observed that the maintenance schedule (T_c) directly depends on the shipment size (z). Hence, an optimum production rate (P^*) and shipment size (z^*) need to be determined, which can minimize the total cost for the production house.

METHODOLOGY

Considering all the above-mentioned conflicting scenarios regarding random machine breakdown, stockout and uncertain demand rate, this paper derives a mathematical model for minimizing the total cost (TC) by combining the production, inventory, and maintenance costs, when optimizing P and z. While developing the model, it is also assumed that,

- Scheduled maintenance cost (C_m) is a polynomial function of maintenance time, t such that, $C_m = c_3(t + t^{-1/2})$
- Unit production cost (C_p) is a polynomial function of production rate such that $C_P = c_1 P^{-2} + c_2$
- Production rate (P) can be varied up to their maximum capacity
- Production rate is greater than demand rate
- Time to next machine breakdown follows exponential distribution

Parameters

Q = Shipment size (units)

t' = Unscheduled maintenance time due to machine breakdown (hours)

W = Total working hour in a year (hours)

λ = Average number of failures per hour

H = Inventory holding cost ($/unit/year)

C_m' = Unscheduled maintenance cost, ($/maintenance)

D = Demand rate (unit/year)
s = Shipment cost ($/shipment)
c_1, c_2 = Parameters for calculating production cost
c_3 = Parameter for calculating scheduled maintenance cost

Intermediate variables

$\bar{T}_f$ = Mean time to failure before scheduled maintenance
$\bar{I}$ = Average inventory level (units)
N = Total number of scheduled maintenance cycles (per year)
n = Expected number of machine breakdown (per year)
$C_P(P)$ = Production cost ($/unit)
$C_m(t)$ = Scheduled maintenance cost, ($/maintenance)
C_I = Expected Inventory Holding Cost ($/year)
t = Scheduled maintenance time (hours)

Objective Variables

z = Number of shipments in a cycle
P = Production rate (units/hour)

MATHEMATICAL FORMULATION

From Figure 1, the maintenance Cycle Time, T_c can be defined as, $T_c = \frac{zQ}{P} + t$. On the other hand, the total working hour in a year, W can be represented as, $W = T_c N + nt' = \left(\frac{zQ}{P} + t\right) N + nt'$. Thus, the total number of scheduled maintenance cycles in a year, $N = \frac{(W - nt')P}{zQ + Pt}$.

Now, the expected number of machine breakdown in a year, n can be expressed as, $n = N.\Pr\left(failure\ time < \frac{zQ}{P}\right) = \left[\frac{(W - nt')P}{zQ + Pt}\right]\left(1 - e^{-\lambda zQ/P}\right)$, Which yields,

$$n = \frac{W\left(\frac{P}{zQ + Pt}\right)\left(1 - e^{-\lambda zQ/P}\right)}{1 + t'\left(\frac{P}{zQ + Pt}\right)\left(1 - e^{-\lambda zQ/P}\right)} \quad (1)$$

Again, the mean time to failure before scheduled maintenance, $\bar{T}_f = \int_0^{zQ/P} x\lambda e^{-\lambda x} dx = \left[-e^{-\lambda x}\left(x + \frac{1}{\lambda}\right)\right]_0^{zQ/P}$, which yields

$$\bar{T}_f = \frac{1}{\lambda} - \left(\frac{zQ}{P} + \frac{1}{\lambda}\right)e^{-\lambda zQ/P} \quad (2)$$

According to the assumptions (based on the given information from the industry), the production cost, C_P ($/unit) is a function of P, such that

$$C_P = c_1 P^{-2} + c_2 \tag{3}$$

Again, scheduled maintenance cost, C_m ($/maintenance) is a function of maintenance time t, such that

$$C_m = c_3 (t + t^{-1/2}) \tag{4}$$

From Figure (1), the area A = $\frac{Q^2}{2P}$, and area B = $\left(\bar{T}_f - \left\lfloor \frac{\bar{T}_f}{Q/P} \right\rfloor \frac{Q}{P} \right) Pt'$. Thus, average inventory level, $\bar{I}$ can be defined as $\bar{I} = \frac{(Area\ B)n + (Area\ A)zN}{W}$, which becomes

$$\bar{I} = \frac{Pnt' \left(\bar{T}_f - \left\lfloor \frac{\bar{T}_f}{Q/P} \right\rfloor \frac{Q}{P} \right) + \frac{z(W - nt')P}{zQ + Pt} \left(\frac{Q^2}{2P} \right)}{W} \tag{5}$$

So, the expected inventory holding cost, C_I becomes

$$C_I = \frac{H}{W} \left[Pnt' \left(\bar{T}_f - \left\lfloor \frac{\bar{T}_f}{Q/P} \right\rfloor \frac{Q}{P} \right) + \frac{zQ^2 (W - nt')}{2(zQ + Pt)} \right] \tag{6}$$

Now, the Expected Total Cost, TC can be defined as $TC = H\ \bar{I} + C_P D + C_m N + C_m' n + zNs$, where the total shipment cost is zNs. Hence the problem can be formulated as,

Minimize,

$$TC(P,t,z) = \frac{H}{W} \left[Pnt' \left(\bar{T}_f - \left\lfloor \frac{\bar{T}_f}{Q/P} \right\rfloor \frac{Q}{P} \right) + \frac{zQ^2}{2P} N \right] + D\left(c_1 P^{-2} + c_2 \right) + c_3 (t + t^{-1/2}) N + C_m{}' n + zNs$$

Subject to,

$$\bar{T}_f = \frac{1}{\lambda} - \left(\frac{zQ}{P} + \frac{1}{\lambda} \right) e^{-\lambda zQ/P} \tag{7a}$$

$$\frac{zQP(W - nt')}{zQ + Pt} = D \tag{7b}$$

$$n = \frac{W \left(\frac{P}{zQ + Pt} \right) \left(1 - e^{-\lambda zQ/P} \right)}{1 + t' \left(\frac{P}{zQ + Pt} \right) \left(1 - e^{-\lambda zQ/P} \right)} \tag{7c}$$

$$N = \frac{(W - nt')P}{zQ + Pt} \tag{7d}$$

$(D/W) < P \le P_\infty, 0 < t, 0 < z$ and integer. (7e)

Eq. (7b) and (7c) can be combined as $zQP\left\{W-\frac{W\left(\frac{P}{zQ+Pt}\right)\left(1-e^{-\lambda zQ/P}\right)}{1+t'\left(\frac{P}{zQ+Pt}\right)\left(1-e^{-\lambda zQ/P}\right)}t'\right\}=D\left(zQ+Pt\right)$, which can be further reduced to $zQY\left(W-\frac{WYFt'}{1+t'YF}\right)=D$, where $\left(\frac{P}{zQ+Pt}\right)=Y$, and $\left(1-e^{-\lambda zQ/P}\right)$. This yields, $Y=\frac{D}{WzQ-t'FD}$, or $t=\frac{\left(WzQ-t'DF\right)}{D}-\frac{zQ}{P}$, finally expressed as $t=\frac{1}{D}\left[WzQ-t'D\left(1-e^{-\lambda zQ/P}\right)\right]-\frac{zQ}{P}$. Thus, the final formulation of the problem becomes,

Minimize,

$$TC(P,z)=\frac{H}{W}\left[Pnt'\left(\bar{T}_f-\left\lfloor\frac{\bar{T}_f}{Q/P}\right\rfloor\frac{Q}{P}\right)+\frac{zQ^2}{2P}N\right]+D\left(c_1P^{-2}+c_2\right)+c_3(t+t^{-1/2})N+C_m{}'n+zNs$$

Subject to,

$$\bar{T}_f=\frac{1}{\lambda}-\left(\frac{zQ}{P}+\frac{1}{\lambda}\right)e^{-\lambda zQ/P} \tag{8a}$$

$$t=\frac{1}{D}\left[WzQ-t'D\left(1-e^{-\lambda zQ/P}\right)\right]-\frac{zQ}{P} \tag{8b}$$

$$n=\frac{W\left(\frac{P}{zQ+Pt}\right)\left(1-e^{-\lambda zQ/P}\right)}{1+t'\left(\frac{P}{zQ+Pt}\right)\left(1-e^{-\lambda zQ/P}\right)} \tag{8c}$$

$$N=\frac{\left(W-nt'\right)P}{zQ+Pt} \tag{8d}$$

$(D/W)<P\le P_\infty, 0<z$ and integers. (8e)

RESULTS AND DISCUSSION:

The model becomes a nonlinear constrained optimization problem with two discrete objective variables. An iterative search algorithm is used to obtain the near optimum solution for production rate (*P*) and the number of shipments (*z*). The model is validated with illustrating a numerical example,

Numerical example:

The example presented here is representative of a practical scenario. The data is provided as follows,

- Shipment size — Q = 200 units/shipment
- Unscheduled maintenance time due to machine breakdown — t' = 6 hours
- Total working hour in a year, — W = 2000 hours
- Average number of failures per hour — λ = 0.01
- Inventory holding cost — H = \$10 /unit/year
- Unscheduled maintenance cost — C_m' = \$100 /maintenance
- Demand — D = 50000 units/year
- Parameters for calculating unit production and maintenance costs — c_1 = 2000, c_2 = 5, c_3 = 100
- Shipment cost — s = \$100/shipment

Using the above information, an iterative search algorithm is used to obtain the near optimum solutions, z^* = 8, P^* = 39, for a minimum expected total cost, TC = \$408,623/year. The optimum solution also yields, the maintenance cycle time, $T_c = \frac{zQ}{P} + t = \frac{1}{D}\left[WzQ - t'D\left(1 - e^{-\lambda zQ/P}\right)\right] = 61.98$ hours

Figure 2 and Figure 3 illustrate the solution space on a surface plot and on a contour plot, respectively.

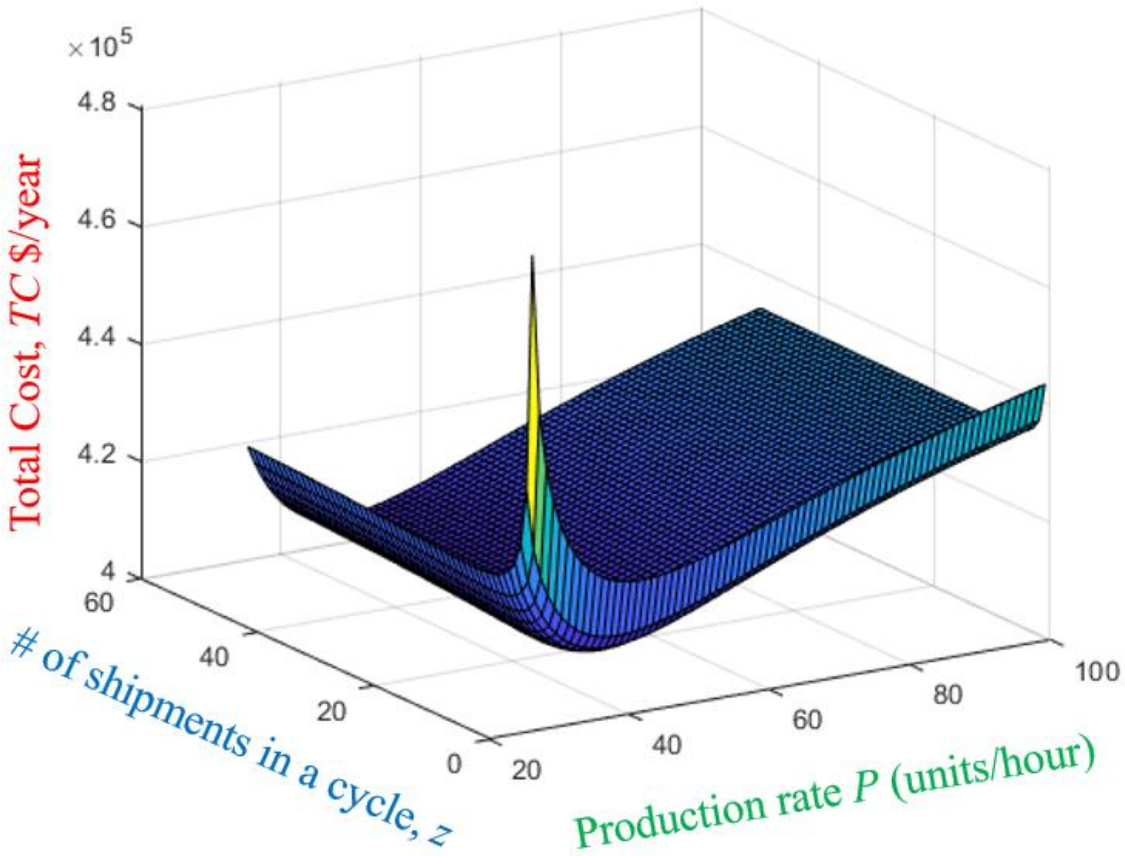

Figure 2: Solution space on a surface plot

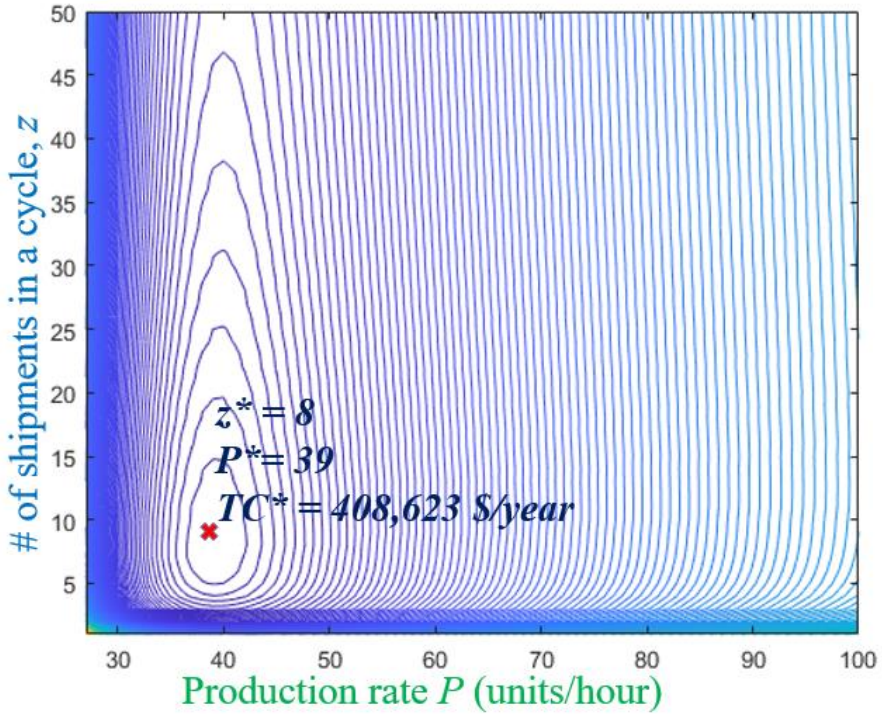

Figure 3: Optimum solution is presented on a contour plot

CONCLUSION

The model becomes a nonlinear constrained optimization problem with two integer variables. The uncertainty of machine breakdown, and discrete objective function, lead to a complex structure of the problem which could not be solved with MATLAB optimization Toolbox. The model presented in this paper considers the production house inventory only which will be extended for a joint inventory model, by including sales house inventory cost and shipping quantity as a variable. An efficient heuristic need to be developed to find the global solution from a large solution space. In a more practical situation, the joint expected total cost model needs to be developed considering uncertainties in the machine breakdown rate as well as in the market demand, which will lead to a complex structure of the problem including the join probability distribution. At the same time the discrete variables will make the problem non-convex and computationally prohibitive. Hence, a simulation model of the concerned supply chain system and corresponding numerical analysis is planned to be done as a future extension of this research.

REFERENCES

[1] Vijayanathan, C.A., Hossain, M.S.J. and Sarker, B.R. (2019) "Optimizing production overtime period and backorder quantity in joint production and maintenance scheduling," *Proceedings of the International Conference on Industrial Engineering and Operations Management*, Pilsen, Czech Republic, July 23-26, pp. 1136 – 1147.

[2] Dhouib, K., Gharbi, A., and Aziza, M. B., (2012) "Joint optimal production control/preventive maintenance policy for imperfect process manufacturing cell," *International Journal of Production Economics*, Vol. 137, No. 1, pp. 126-136.

[3] Lai, X., Chen, Z. and Bidanda, B. (2019) "Optimal decision of an economic production quantity model for imperfect manufacturing under hybrid maintenance policy with shortages and partial backlogging," *International Journal of Production Research*, Vol. 57, No. 19, pp. 6061 – 6085.

Special Topic on Research and Teaching related to COVID-19 - Abstract

Does COVID Affect Students Differently? A Cross-Gender and Cross-STEM Course Investigation of Learning Performance

Oral Presentation

Dr. John C. Guo [1], ***Mr. Shawn Lough*** [1], ***Dr. Leigh Mutchler*** [1], ***Dr. Ping Wang*** [1]

1. *James Madison University*

This study aims to shed light on individual-level psychological mechanisms that exert impacts on pertaining learning behaviors and associated learning performance in a cross-gender, cross-subject research design. Specifically, we leverage anchor theories of behavior prediction to elucidate the roles of subjective norms, learning behavior control, behavioral intention, and their nomological connections tied to the actual learning performance construct. Furthermore, we adopt a cross-gender and cross-subject design because, although women have made great strides in college degree completion, numerous studies indicate that women continue to struggle in the Science, Technology, Engineering, and Mathematics (STEM) courses, causing a performance gap between the two genders. Moreover, the pandemic has significantly changed how students learn; therefore, this study assesses and reveals students' attitudinal capacities relating to post COVID era experiences that may exhibit distinct effects due to gender and STEM course differences.

Our research method consists of two stages. In stage one, we assign students to four groups based on the attributes of gender and course. We selected a freshman STEM course in Computer Information Systems (CIS) and a freshman STEM course in Business Analytics (BSAN), thus creating four groups: female in CIS, male in CIS, female in BSAN, and male in BSAN. As course instructors, we can observe and elicit students' attitudinal, emotional, and behavioral responses via anecdotal conversations, semi-structured interviews, and focus group discussions in each stratum. Our main focus is to capture individual-level psychological manifestations of key constructs (e.g., subjective norm) derived from prior theoretical development as well as indigenous or new factors that are not present in extant literature. The treatments afforded by this 2X2 full factorial design allow us to gather data that may expose hidden insights, thereby adding hypotheses to be tested in stage two, which collects and analyzes survey data through a validated instrument using actual learning performance as the endogenous variable. Currently, we have collected over 300 responses from the two courses in 2021 spring. Some of these sample responses are used in a pre-study to test the overall fit of our research model.

The current pedagogy landscape is facing mounting challenges stemming from political and public healthcare arenas. Much has been lost, and much has been gained. It is thus critical to adapt for the long-term changes by embedding resilience, inclusion, and engagement in the classroom. Against this backdrop, our study offers insights to enrich the growing scholarship of assessing and understanding students' psychological capacities based on granular attributes that provide more in-depth viewpoints than non-discriminant research designs.

KEYWORDS: Gender effect, STEM Courses, Theory of Planned Behavior, triangulation in research.

Does Firms' Commitment to Ethics Influence Their Decisions in Responding to the COVID-19 Pandemic?

Oral Presentation

Dr. Kevin Pan [1], ***Dr. Alan Blankley*** [1], ***Dr. David Hurtt*** [2], ***Dr. Reginald Harris*** [1]

1. *Samford University,* ***2.*** *Baylor University*

In this study, we examine whether voluntary mentioning of ethics-related terms in firms' 2019 10-K reports predicts firms' voluntary 8-K financial disclosures in the first quarter of 2020, i.e., the onset of the COVID-19 pandemic. Interestingly, we found that voluntary mentioning of ethics-related terms in the 2019 10-Ks is a statistically significant predictor of firms' voluntary 8-K disclosures in first quarter of 2020 mentioning well-being, health, and safety. This predictor is independent of industry, firm's size, litigation risk, or loss in earnings. The results suggest that firms' reference to ethics in their 10-K disclosures may be positively predictive of future ethical decision making.

FACT REPO : A MACHINE LEARNING RESOURCE FOR IDENTIFYING AND ANALYZING MISINFORMATION DURING THE COVID-19 PANDEMIC

Oral Presentation

Dr. Nathan Green [1], ***Mrs. Septina Larasati*** [2], ***Mr. Daniel Duro*** [1], ***Dr. Diane Murphy*** [1], ***Dr. Kathryn Laskey*** [3]

1. *Marymount University,* ***2.*** *Language Kits,* ***3.*** *George Mason University*

Identification of misinformation is a growing issue for online platforms and for the Social Media community as a whole. While current systems often rely on the larger community reporting misinformation manually, the automatic detection, flagging or removal from search engines and social media would streamline efforts to mitigate this ever-growing problem. We have created a manually annotated corpus of misinformation, opinion, and facts around online information campaigns, COVID-19. The corpus is freely available and uses a novel annotation and delivery system to make it easier for researchers in nontechnical fields to contribute and consume the data and annotations into their systems.

Increased Importance of Global Virtual Teams Following the COVID-19 Pandemic

Oral Presentation

Dr. O. Volkan Ozbek [1]

1. *Trinity University*

The coronavirus has ever changed the world. As many believes, nothing is going to be the same after this pandemic. People interactions, business relationships, healthcare, transportation, and tourism are some of the most important facets in our daily lives that are mandated to change due to this “unexpected” health crises. In this paper, we argue that the importance of global virtual teams (GVTs) will be much bigger following the pandemic. More specifically, due to several new restrictions among/ for individuals, businesses will have to solely rely on GVTs much more than previously to further protect people’s health while running their global operations without further interruption.

What type of tweets are shared during Covid-19? Sentiment Analysis approach

Oral Presentation

Dr. Maryam Mahdikhani [1]

1. *College of Charleston*

The study is motivated by the tweets related to Covid-19 with wrong or fake information from beginning of the pandemic to development of vaccines. We analyze almost 2 million tweets on Covid-19 that are written in English to evaluate each tweet's content and to identify if they are having fake information or not. We then extract the features and analyzed in each phase of Covid-19 pandemic what were the content of popular tweets with the wrong information. We further applied the advanced machine learning algorithm to detect the fake information and fake news on the posted tweets.

Whose Job Is It? The Burden of Emotional Labor In Higher Education on Women of Color

Oral Presentation

Dr. Phylicia Taylor [1], ***Dr. Deedgra Williams*** [2]

1. *Florida A&M University,* ***2.*** *Florida A & M University*

The COVID-19 global pandemic has impacted countries, individuals, and organizations. The pandemic effects have predominately been felt from a healthcare standpoint. However, they have also been felt within industries and sectors like education, hospitality, tourism, philanthropy, and corporate America. As research continues to uncover how COVID-19 will impact society medically, researchers are also striving to reveal how the pandemic will affect people economically, psychologically, professionally, spiritually, and emotionally. These shared experiences and the ramifications of the pandemic have had different effects on people based on gender, age, ethnicity, religion, etc. Understanding the intersectionality of women is important to explaining how the pandemic has affected this group, specifically women of color. Women all wear several hats ranging from parent, bread-winner, leader, spouse, employee, caretaker, etc. All these roles, coupled with the pandemic, have undoubtedly affected how women navigate day-to-day life. This research aims to investigate the effects of the COVID-19 pandemic on women of color in higher education (students, faculty, and staff) by examining the dynamics between emotional labor, burnout, and unconventional work arrangements and environments. This research examines the interplay from an economic, psychological, organizational, and individual lens to understand women's evolving workforce experiences. Ultimately, researchers, practitioners, and administrators will use this research to develop and implement policies and practices that support women in higher education at HBCUs and minority-serving institutions. Doing so will prompt universities to make institutionally researched-backed changes that impact national and global stages regarding women workforce experiences as we continue to navigate a global pandemic. Ultimately, this research will allow institutions of higher learning to serve as models for how other impacted industries and sectors should support women through researched-backed policies and practices that are transformative and mutually beneficial.
This work is funded by FAMU ADVANCE (NSF Award HRD-184267).

Special Topic on Research and Teaching related to COVID-19 - Papers

DOES FIRMS' COMMITMENT TO ETHICS INFLUENCE THEIR DECISIONS IN RESPONDING TO THE COVID-19 PANDEMIC?

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ABSTRACT

In this study, we examine whether voluntary mentioning of ethics-related terms in firms' 2019 10-K reports predicts firms' voluntary 8-K financial disclosures in the first quarter of 2020, i.e., the onset of the COVID-19 pandemic. Interestingly, we found that voluntary mentioning of ethics-related terms in the 2019 10-Ks is a statistically significant predictor of firms' voluntary 8-K disclosures in first quarter of 2020 mentioning well-being, health, and safety. This predictor is independent of industry, firm's size, litigation risk, or loss in earnings. The results suggest that firms' reference to ethics in their 10-K disclosures may be positively predictive of future ethical decision making.

INTRODUCTION

A firm's commitment to ethical decision making is not easy to quantify. This is partly true because a commitment to act ethically is a commitment to moral principles, which does not easily lend itself to quantification, and further, the vast majority of data collected by companies is related to "transactions" which are routinely captured in companies' systems and can be recorded easily in database systems as structured data. Outside of unusual circumstances, these data tend to lack an ethical component.

The use of data analytics techniques, such as text analytics, however, can help quantify a firm's commitment to ethics. Because a commitment to ethical principles can be articulated and disclosed, advances in textual analysis techniques can help quantify certain aspects of the articulated commitment and use this data to draw inferences about a firms' ethical commitment. For example, Loughran et al. [6] developed a computer program to identify ethics-related terms such as "ethics" and "corporate responsibility" in the 10-K annual reports. They primarily focused on a data sample prior to the Sarbanes-Oxley Act. They also filtered out "Code of Ethics"-related terms because firms are required by the Sarbanes-Oxley Act to disclose their implementation of a code of ethics. In other words, the authors identified firms' voluntary use of ethics-related

terms. They found that firms using ethics-related terms are more likely to be the object of class action lawsuits and, additionally, tended to have poor corporate governance. Loughran et al. concluded that firms' use of ethics-related terms is more likely to hide misconduct, and such firms may, in fact, be less ethical in their actions (2009) than other firms.

It would be interesting to study whether firms that mention ethics in 10-K reports continue to mislead the public. Specifically, the rise of the COVID-19 pandemic provides a natural experiment to review firms' responses to the pandemic in an ethical manner by prioritizing employees' and customers' well-being, health, and safety. While all public companies are required to file with the SEC and are required to make certain mandatory filings, like the annual 10-K and quarterly 10-Q reports, the SEC encourages firms to use form 8-K to file voluntary information when the need arises.

Since material events that affect a company's financial standing can happen more often than every quarter, the SEC also requires companies to file 8-Ks to report these events. The SEC has a list of events for which a company must file an 8-K disclosure [11]. For example, item 1.01 is Entry into a Material Definitive Agreement. Item 2.01 is Completion of Acquisition or Disposition of Assets. An 8-K can contain more than one item. For example, many 8-K's contain item 9.01, Financial Statements and Exhibits in addition to its primary item, e.g., item 1.01. A company has 4 days to file an 8-K.

Meanwhile, there are also events that a company can choose to voluntarily disclose before the quarterly reports that are not required by the SEC. Specifically, for an unprecedented event such as the COVID-19 pandemic, a company may choose to disclose measures being implemented to protect the safety, health, and well-being of its stakeholders including its employees and customers. In such a filing, a company may discuss how it prioritizes the safety and health of its employees during this time. Such a disclosure is not mandated by the SEC as it is not one of the required items. [11]

In this study, we examine whether voluntary mentioning ethics-related terms in the 2019 annual 10-K report such as "corporate responsibility," predicts firms' voluntary 8-K financial disclosures in the first quarter of year 2020, i.e., the onset of the COVID-19 pandemic. By "voluntary mentioning ethics-related terms," we mean that we exclude ethics-related terms that are part of the firms' mandatory disclosures related to its Code of Ethics in the 10-K [6].

We chose this time period because firms had a choice whether, and how, to inform shareholders and the public about their responses regarding the COVID-19 pandemic. The COVID-19 pandemic was declared a national emergency in the United States on January 31, 2021 [2]. We assume that firms filing voluntarily during the first quarter of 2020, when the uncertainty surrounding the pandemic was greatest and the financial effect on the business was more difficult to predict than in subsequent quarters, created an incentive not to disclose. For firms that chose to mention in their voluntary 8-K disclosures their concern over the welfare of employees, customers, and other stakeholders to the firm, we take as at least some evidence of a commitment to ethical behavior since the disclosure was voluntary and the outcome to the firm highly uncertain.

The rest of the paper is organized as follows: Literature Review and Hypothesis, Sample and Methods, Analysis Results, and Discussion.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

8-K filings

Previous studies have examined factors that predict firms' filing of voluntary 8-Ks. He and Plumee [5] divided 8-Ks into mandatory and voluntary: voluntary 8-Ks are 2.02 (Results of Operations and Financial Condition), 7.01 (Regulation FD Disclosure), and 8.01 (Other Events. The registrant can use this Item to report events that are not specifically called for by Form 8-K, that the registrant considers to be of importance to security holders); all the other items are considered mandatory. They found number of analysts following to be a negative predictor of number of 8-Ks. Interestingly, Zhao [12] showed that more frequent 8-K filings are followed by lower future returns and lower future volatilities.

Industry

To help analyze companies, different classification systems have been developed. In this study, we used the 17-industry portfolio developed by French [4]. Even though COVID-19 pandemic affects all industries to some extent, some industries are affected more than the others. We aim to use a parsimonious set of industry categories. Therefore, while French provided a variety of industry groupings, e.g., 5-industry, 10-industry, 12-industry, 17-industry, and so on, we want to use the smallest number of groupings where transportation is its own industry, since transportation is especially afflicted by COVID-19. Therefore, we use 17-industry groupings to control for industry as a factor for filing 8-Ks, because it the smallest where transportation is its own industry group.

Text Analysis

Loughran and McDonald developed a dictionary based on financial disclosures, and the dictionary represent sentiments such as positive, negative, uncertain, litigious sentiments [7]. Detailed review of text analysis is beyond the scope of this manuscript. For a detailed review of text analysis for finance and accounting, see Loughran and McDonald [8].

Hypothesis Development

Loughran et al. [6] studied the use of ethics-related terms in 10-Ks and found that firms' behaviors often contradict their use of ethics-related terms. In line with this notion, we hypothesize the following:

A firm's use of ethics-related terms in year 2019 10-Ks is a negative predictor of a firm's voluntary disclosure in first quarter of year 2020 regarding health, safety, and well-being.

Number of voluntary COVID-19 8-Ks mentioning well-being related terms

$$= \beta_0 + \beta_1 \textbf{ Mention of Ethics in year 2019 10-K} + \beta_2 \text{lnMarketCap} + \beta_3 \text{Loss} + \beta_4 \text{M\&A}$$

$$+ \beta_5 \text{Restructuring} + \beta_6 \text{Big4} + \beta_7 \text{Historical tendency} + \beta_8 \text{Inevitable Disclosure Doctrine}$$

$$+ \beta_9 \text{ High Litigation Risk} + \beta_{10} \text{ Earnings} + \text{Industry Fixed Effects} + \varepsilon \quad (1)$$

where Mention of Ethics is an indicator variable set equal to 1 if a firm's 2019 10-K report uses an ethics-related term other than code of ethics-related terms. This is the main variable of interest in our study.

The other variables in the regression equation variable serve as control variables, as they are firm characteristics that may affect a firm's decision to file voluntary 8-Ks:

MarketCap is market capitalization, which represents firm size: larger firms are more likely to file voluntary 8-Ks since they have more resources [5].

Loss: firms with loss in any of the four quarters in the previous year are more likely to file voluntary 8-Ks [5]

Auditor: firms with Big-4 auditors may be more likely to file voluntary 8-Ks since they have more resources.

Number of analysts following: firms with more analysts following are more likely to file voluntary 8-Ks

Historical tendency to file 8-Ks: firms that filed more 8-Ks in 2019 Q1 are more likely to file voluntary 8-Ks concerning COVID in 2020 Q1.

Inevitable disclosure doctrine: managers' outside employment opportunities can affect their decisions to disclose information [1]

High litigation: Following the literature of using high technology industry as a proxy variable for high litigation risk, we define HITECH as a binary indicator variable that is set equal to 1 if the firm belongs to the following four-digit SIC industry codes, signifying technology-intensive industries: 2833–2836 (drugs and pharmaceuticals), 3570–3577 (computer and office equipment), 3600–3674 (electrical equipment and electronics), 7371–7379 (software services) or 8731–8734 (R&D services). [3][10]

Earnings: an indicator variable that is positive if earnings decreased in the second quarter of 2020 compared to the second quarter of 2019. This represents what the managers sees on the horizon.

Industry Fixed Effects control for effects of industry.

SAMPLE AND METHODS

Sample Selection

As COVID-19 started to affect businesses in the United States in January 2020, and the stock market bottomed at the end of March 2020, we used publicly available data on the SEC EDGAR Website for the month of January, February, and March of 2020. As the pandemic progresses, it would become less a voluntary choice for a firm to disclose information about COVID-19 since the public and shareholders would likely inquire about COVID-19's impact on a company in its quarterly reports and earnings call conference, making it less a voluntary choice for managers to disclose. Therefore, we focus our study on the early stage of COVID-19 where there was much uncertainty and companies made voluntary decisions to file 8-Ks to discuss about COVID-19.

Since our aim is to study motivations for the firms to file voluntary 8-Ks, we first define the number of firms to study. In this period, there were 5,839 unique firms that filed a 10-K or 10-Q. After merging data with CompuStat and excluding companies that do not match CompuStat data during this period, there are 3,530 unique firms (See Table 1, Panel A).

In the same period of January through March of 2020, there are 17,631 total 8-Ks filed by all companies (See Table 1, Panel B). Among these 17,631 8-Ks, 2,481 are press releases of quarterly or annual earnings reports, i.e., 10-Q or 10-K. As the purpose of this study is to examine voluntary 8-K in response to an event, these 2,481 were excluded from further analysis; we use the remaining 15,150 non-earning 8-Ks for further analysis. Of the remaining 15,150 non-earning 8-Ks, 9,798 are from firms with matching CompuStat data. Of these 9,798 8-Ks, 6,717 are voluntary 8-Ks, i.e., items 2.02, 7.01, and 8.01 (the same definition of voluntary as He and Plumlee, 2019). Among these 6,717 non-earning voluntary 8-Ks, there are 1,373 non-earning voluntary COVID-19-mentioning 8-Ks filed by 1,049 companies. Of these 1,373 voluntary 8-Ks mentioning COVID-19, 938 mention "well-being", "safety", or "health" (Table 1, Panel B).

Table 1 Sample Selection

Panel A. Number of Unique Firms

During 2020 Q1 (January through March)	Number of observations
Unique firms that filed a 10-K or 10-Q	5,839
Unique firms that filed a 10-K or 10-Q and have complete CompuStat data available	3,691
Unique firms that filed a 10-K or 10-Q and have complete CompuStat data available and have 2019 Q1 earnings to compare 2020 Q1 earnings	3,530

Table 1 Sample Selection

Panel B. Number of 8-Ks

During 2020 Q1 (January through March)	Number of observations
Total 8-Ks	17,631
8-Ks that are not quarterly earnings press release	15,150
Non-earning 8-Ks that have matching CompuStat data and 2019 Q1 data	9,798
Non-earning voluntary 8-Ks that have matching CompusStat data and 2019 Q1 data (Items 2.02, 7.01, 8.01)	6,717
Non-earning voluntary 8-Ks that have matching CompusStat data and 2019 Q1 data and mention COVID-19 or coronavirus	1,373
Non-earning voluntary 8-Ks that have matching CompusStat data and 2019 Q1 data and mention COVID-19 and well-being	938

Methods for Ethics-related Terms in 10-Ks

We follow the same procedure as Loughran et al. [6] to identify 10-Ks having ethics-related terms, excluding the use of Code of Ethics-related terms. First, we applied the same procedures to clean financial disclosures established by McDonald [9], including removing XML tags, special characters, and tables. Please see McDonald [9] for a detailed description of the data parsing and cleaning procedure. Then, we developed a Python program to identify all the ethics-related terms, using the same list of terms defined by Loughran et al. [6]. We also used a Python program to identify all the Code of Ethics-related terms, using the same list of terms defined by Loughran et al. [6].

For each 10-K document,

Number of Ethics-related terms excluding Code of Ethics = Number of Ethics-related terms – Number of Code of Ethics-related Terms (2)

The indicator variable 10-K Ethics is defined as

10-K Ethics = 1 if Number of Ethics-related terms excluding Code of Ethics > 0

10-K Ethics = 0 if Number of Ethics-related terms excluding Code of Ethics = 0

Descriptive Statistics

For the dependent variables, Table 2 Panel A provides a summary of statistics. Since there are 9,798 non-earning 8-Ks coming from 3,530 firms, the average number of non-earning 8-Ks per firm is 2.78. There are 6,717 voluntary non-earning 8-Ks and the average number per firm is 1.90. For voluntary non-earning 8-Ks that mention COVID-19, the average is 0.39 8-Ks per firm. For voluntary non-earning 8-Ks that mention COVID-19 and well-being related terms, the average is 0.27 8-Ks per firm.

Table 2 Panel B provides a frequency table of the number of firms that have varying numbers of Non-Earning Voluntary 8-Ks that Mention COVID-19 and Well-Being Related Terms.

The descriptive statistics of industries are shown in Table 2, Panel C. The industries with the highest non-earning voluntary COVID-19 8-Ks are: Clothes, Retail Stores, Transportation, and Cars.

The descriptive statistics of independent variables are summarized in Table 2, Panel D. The data comes from CompuStat except 2019 Q1 (first quarter) 8-Ks, which come from the SEC.

Table 2

Descriptive Statistics

Panel A Dependent variables

8-Ks during 2020 Q1	N (Number of firms)	Mean	Median	Max	Min
Non-earning 8-Ks	3,530	2.78	2.0	55	0
Non-earning voluntary 8-Ks	3,530	1.90	2.0	13	0
Non-earning voluntary 8-Ks that mentions COVID-19	3,530	0.39	0.0	6	0
Non-earning voluntary 8-Ks that mention COVID-19 and well-being related terms	3,530	0.27	0.0	6	0

Panel B Frequency Table of Non-Earning Voluntary 8-Ks that Mention COVID-19 and Well-Being Related Terms

Number of non-earning voluntary 8-Ks during 2020 Q1 that mention COVID and well-being related terms	N (Number of firms)
0	269
1	592
2	113
3	21
4	9
5	3
6	1

Panel C Industry

Industry	Number of observations (N)	Non-Earning 8-Ks per firm	Non Earning Voluntary 8-Ks per firm	Non Earning Voluntary COVID 8-Ks per firm
1 Food	80	2.65	1.63	0.33
2 Mines	65	2.23	1.65	0.35
3 Oil	163	3.02	2.12	0.28
4 Clths	31	2.61	1.97	1.23
5 Consumer Durables	54	2.67	1.67	0.44
6 Chemicals	81	2.48	1.40	0.37
7 Cnsum Drugs	376	2.88	1.96	0.26
8 Construction	109	2.19	1.44	0.26
9 Steel	33	2.79	1.79	0.39
10 Fabricated Products	22	2.45	1.50	0.27
11 Machinery	336	2.33	1.49	0.46
12 Cars	56	2.98	1.89	0.71
13 Transportation	112	3.38	2.41	0.76
14 Utilities	89	3.33	2.17	0.33

15 Retail Stores	137	2.93	2.07	0.88
16 Finance Banks	760	2.94	2.23	0.29
17 Other	983	2.57	1.69	0.40

Panel D Descriptive Statistics for other independent variables

Independent variable	All firms N	All firms Mean	Firms that filed non-earning voluntary COVID-19 8-Ks N	Firms that filed non-earning voluntary COVID-19 8-Ks Mean	Firms that did not file non-earning voluntary COVID-19 8-Ks N	Firms that did not file non-earning voluntary COVID-19 8-Ks Mean	T-statistic (p-value)
Decreased Earning	3,530	0.36	1016	0.33	2514	0.38	2.91 (<0.01)
Big Bath	3,530	0.27	1016	0.35	2514	0.24	6.3 (<0.001)
LnMarketCap	3,530	6.62	1016	7.21	2514	6.38	10.37 (<0.001)
Loss	3,530	0.48	1016	0.44	2514	0.50	-3.04 (<0.01)
M&A	3,530	0.28	1016	0.33	2514	0.27	3.65 (0.001)
Restructuring	3,530	0.26	1016	0.34	2514	0.23	6.64 (<0.001)
Big 4 Auditor	3,530	0.43	1016	0.50	2514	0.40	5.34 (<0.001)
2019 Q1 8-Ks	3,530	2.92	1016	3.23	2514	2.80	7.37 (<0.001)

ANALYSIS RESULTS

To test our hypothesis, we conduct a regression analysis. To validate our regression analysis, we calculate the VIFs (Variance Inflation Factors), shown in Table 3A. All the VIFs are less than 5, suggesting that the regression analysis is appropriate.

Table 3B shows the results of the OLS regression analysis with dependent variable as the number of all voluntary 8-Ks mentioning COVID-19 or coronavirus and well-being, safety, or health. Interestingly, the result coefficient is statistically significant (two tail p-value <0.05), and yet the sign is the opposite of what we expected in our hypothesis. In our hypothesis, we expected that the mentioning of ethics in 2019 10-K is a negative predictor of the 2020 quarter one responses highlighting safety, health, and well-being. The result showed that opposite: mentioning of ethics in 2019 10-K is a positive predictor of 20201 quarter one responses highlighting safety, health, and well-being.

For the control variables, the results also show that firm size (measured by Log of market Cap) and historical trend of 8-Ks are significant factors of filing non-earning 8-Ks. Decreased earnings is also a factor from these control variables. The inclusion of these controls show that a firm's use of ethics-related terms is an independent factor from these other factors.

Table 3 Regression Results

A. VIF (Variance Inflation Factor):

Variable	VIF
Decreased EPS	1.43
Big Bath	1.50
LnMarketCap	1.62
2019 Qtr Loss	1.52
MandA	1.27
Restructuring	1.31
Big 4	1.22
2019 Q1 8-Ks	1.07
IDD	1.05
High Litigation	3.46
High Litigation * Decreased earning	2.26
High Litigation * Big Bath	1.73
10-K Ethics	1.06

B. Regression results (n = 3,530)
Dependent variable: non-earning voluntary 8-Ks that mention COVID and well-being per company during first three months of 2020

	Coefficient	p-value
Intersect	0.5046	<0.001***
10-K Ethics	**0.1231**	**0.015****
Decreased earnings in 2020 Q1 (vs 2019 Q1)	-0.0024	0.968
Big Bath	0.11	0.064*
LnMarketCap	0.0341	0.017**
Loss: net income < 0 in any of the 4 quarters in 2019	0.0814	0.17
M & A	0.0508	0.382
Restructuring	-0.0421	0.47
Big 4	0.0668	0.196
2019 Q1 8-Ks	0.0179	0.128
IDD	-0.0221	0.657
High Litigation	-0.0367	0.752
High Litigation * Decreased EPS	-0.0548	0.67
High Litigation * Big Bath	-0.1107	0.416
Industry fixed effects	Included	

Decreased earnings: 1 if EPSPX reported between April and June of 2020 (which correspond to quarter ending March through May) < EPSPX reported between April and June of 2019, 0 otherwise.
EPSPX -- Earnings Per Share (Basic) Excluding Extraordinary Items

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively.

DISCUSSION

While previous literature might have suggested firms' decisions are contractor to their previous declaration [6], our study shows that firms' decisions facing a new crisis are consistent with their previous declarations. Our study thus contributes to the field by making a relevant discovery in a novel dataset.

Meanwhile, our study uses data exclusively from the COVID-19 pandemic. Therefore, the scope of our study is most appropriate for examining firms' decisions in a crisis situation such as a pandemic. It may not be applicable to firms' decisions in less turbulent times. Further, our dependent variable of firms' responses is also defined by firms' own subjective disclosures. It could be that firms make disclosures that paint a more ethical picture than their actual actions. Future studies should examine firms' actions in more objective terms other than what is disclosed by the firms themselves.

APPENDIX
Variable definitions

Variable	Description
LnMarketCap	=Natural log of market cap (MkValt) (CompuStat)
Loss	= an indicator variable set equal to 1 if any quarter in 2019 reports a negative net income. (CompuStat)
M&A	= an indicator variable set equal to 1 for non-zero acquisitions or mergers as reported on a pre-tax basis (AQP) in year t-1, and 0 otherwise. (CompuStat)
Restructuring	= an indicator variable set equal to 1 for non-zero restructuring costs as reported on a pre-tax basis (RCP) in year t-1, and 0 otherwise. (CompuStat)
Decreased earnings	= an indicator variable set equal to 1 for EPSPX reported between April and June of 2020 (which correspond to quarter ending March through May) greater than EPSPX reported between April and June of 2019. (CompuStat)
Big Bath	=an indicator variable set equal to 1 as fiscal year-end observation in CompuStat for which Special Items (SPI) is negative and exceeds one percent of total assets (AT). (CompuStat)
IDD	= an indicator variable set equal to 1 for a firm headquartered in a state where the inevitable disclosure doctrine is adopted
High litigation (HITECH)	= binary indicator variable that is set equal to 1 if the firm belongs to any of the following four-digit SIC industry codes: 2833–2836, 3570–3577, 3600–3674, 7371–7379, or 8731–8734;
10-K Ethics	= binary indicator variable that is set equal to 1 if the firm's 2019 10-K contains any ethical terms, excluding "code of ethics" terms

REFERENCES

[1] Ali, A., Li, N., & Zhang, W. (2019). Restrictions on managers' outside employment opportunities and asymmetric disclosure of bad versus good news. *The Accounting Review*, 94(5), 1-25.

[2] Azar, A. M. Determination that a Public Health Emergency Exists. U.S. Department of Health and Human Services. January 31, 2020. Retrieved from https://www.phe.gov/emergency/news/healthactions/phe/Pages/2019-nCoV.aspx

[3] Field, L., Lowry, M., & Shu, S. (2005). Does disclosure deter or trigger litigation?. *Journal of Accounting and Economics*, 39(3), 487-507.

[4] French, K. R. (2022) Detail for 17 Industry Portfolios, accessed January 1, 2022, available at https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/det_17_ind_port.html

[5] He, J., & Plumlee, M. A. (2020). Measuring disclosure using 8-K filings. *Review of Accounting Studies*, 25(3), 903-962.

[6] Loughran, T., McDonald, B., & Yun, H. (2009). A wolf in sheep's clothing: The use of ethics-related terms in 10-K reports. *Journal of Business Ethics*, 89(1), 39-49.

[7] Loughran, T., & McDonald, B. (2011). When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks. *The Journal of Finance*, 66(1), 35-65.

[8] Loughran, T., & McDonald, B. (2016). Textual analysis in accounting and finance: A survey. *Journal of Accounting Research*, 54(4), 1187-1230.

[9] McDonald, B. (2019, January). *Stage One 10-X Parse Data.* University of Notre Dame Software Repository for Accounting and Finance. Available at https://sraf.nd.edu/data/stage-one-10-x-parse-data/

[10] Roychowdhury, S., & Sletten, E. (2012). Voluntary disclosure incentives and earnings informativeness. *The Accounting Review*, 87(5), 1679-1708.

[11] Securities and Exchange Commission (SEC) (2012). Investor Bulletin: How to Read an 8-K. Accessed December 31, 2021. Available at https://www.sec.gov/investor/pubs/readan8k.pdf

[12] Zhao, X. (2017). Does information intensity matter for stock returns? Evidence from Form 8-K filings. *Management Science*, *63*(5), 1382-1404.

FACT REPO : A MACHINE LEARNING RESOURCE FOR IDENTIFYING AND ANALYZING MISINFORMATION DURING THE COVID-19 PANDEMIC

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ABSTRACT

Identification of misinformation is a growing issue for online platforms and for the Social Media community as a whole. While current systems often rely on the larger community reporting misinformation manually, the automatic detection, flagging or removal from search engines and social media would streamline efforts to mitigate this ever-growing problem. We have created a manually annotated corpus of misinformation, opinion, and facts around online information campaigns, COVID-19. The corpus is freely available and uses a novel annotation and delivery system to make it easier for researchers in nontechnical fields to contribute and consume the data and annotations into their systems.

Introduction

Identification of misinformation has received attention in the past year due to several crises such as COVID-19, the 2020 election, and Russian interference in the 2016 election [2]. Despite the recent uptick in public awareness, misinformation has been a problem for a long time. Current techniques for misinformation mainly consist of platform moderation using communities to report possible violations. Automatic means that have been tried, usually revolve around surface word forms that target a particular problem or through social graph analysis. Data for these analyses are typically hard to come by and are typically not annotated in detail. At best a social media account or website is identified as a perpetrator of misinformation without much discussion on how that information is portrayed.

Our goal was to release an annotated corpus of both fact and misinformation around multiple topics. The corpus contains the context surrounding each statement as well as expert annotation. The corpus is presented in an easily consumable format with examples, making it easy for new researchers to participate in related research. The corpus is publicly hosted on github.com and is packaged along with an easy-to-use annotation system that directly stores annotation results to github.com. To the best of our knowledge, this is the first such system to use this type of annotation backend. Using github.com allows researchers to focus on their research and not on setting up their own repository and annotation servers locally.

Natural Language Processing (NLP) has been successful in tackling many subjects from language usage, modeling, grammar checking to translation. While not perfect, NLP has been critical to many of the new tools in Data Science and Machine Learning. Analysis of text is known to be a difficult challenge as compared to more numerical and categorical datasets used in other modeling fields. For this reason, many researchers have successfully vectorized and converted language data into more "friendly" forms. This has led to many advancements in individual toolsets for solving specific problems in open language. These approaches have been less successful when trying to analyze higher level meaning, pragmatics, and intent of textual data. To do so in the current scientific context would require large, annotated datasets that in most cases would require manual annotation. This time-consuming process has been a roadblock to research into different areas of textual data. In this paper, we will be addressing one of these issues, fact representation and misinformation.

Disinformation is the common term used in the media for sites, people, or organizations that are deliberately putting out incorrect information. In Fact Repo, we make a distinction between disinformation and misinformation. We define misinformation as the counter or opposite to a fact, i.e., something that is verifiably false. Disinformation on the other hand, we define as misinformation with intent. We believe, without knowing the writer or speaker, the accuracy of detecting this phenomenon will be inconsistent. Detection of misinformation is a much more straightforward task. In the future, the use of misinformation and social network analysis may lead to stronger disinformation models.

In order to create proper misinformation and fact detection models, proper annotated resources are needed. In this paper, we go over the process used in Fact Repo from annotation guidelines, annotation tools, data scraping, formatting, and storage. It is our goal, given the transparency and open-source friendly code, tools, and data, that the larger community will be able to use and extend this project for their research into knowledge graphs, misinformation detection, disinformation detection, and new unforeseen areas

RELATED WORK

Knowledge graphs and repositories have been around for some time [8][15][6]. These are used for a variety of purposes, such as information extraction, auto complete, and logic systems. They tend to be a mix of automatically extracted facts along with some hand curated examples. This has worked well for historic, scientific, and laws of nature type facts that are unlikely to change and unlikely to be debatable. It has become a difficult problem to rely on such structures for fast-changing disinformation campaigns on social media as well as typical conspiracy theory sites covering topics such as net-neutrality, scientific misunderstandings, or incorrect information on vaccines. In a world of social media and individually run blogs, it is a hard task for a small group of people to keep track of every new study, blog, or tweet that comes on a subject.

To handle these problems, there has been a growing amount of research on the evaluation of trusted information [11][17]. Approaches have included a combination of social network analysis and linguistic features combined with modern machine learning approaches. Much

of the work in this area has dealt less with determining whether information is factual than with determining whether the source of information is questionable.

Knowledge databases of facts and tools for fact extraction can be an important task for summarization [4][5][9], language modeling [13], and other high level NLP tasks. While most will come from common knowledge repositories, as we get into a world of disinformation, these knowledge repositories may not be able to keep up with new disinformation campaigns.

Large data projects such as Gigaword [14] and much earlier the WSJ Corpus [7] are common tools for training. As new massive projects come about most are auto-annotated for low level linguistics such as part-of-speech, named entity, and in some cases dependency structures.

Fake News and misinformation corpora have existed for some time [12][16]. These have primarily been collections of documents labeled as entirely misinformation or entirely true. The corpora have led to advancements in document classification of misinformation, primarily through n-gram approaches [3][10]. Some data sets have worked on the statement level and have been larger in scale such as [18] but due to sampling have not had the full context of the statement annotated.

METHODOLOGY

To create a complete and open corpus, we provided basic data scrapers, data format rules, and an annotation tool with guidelines. Each one of those is detailed below. The process for creating the annotate corpus can be seen in Figure 1

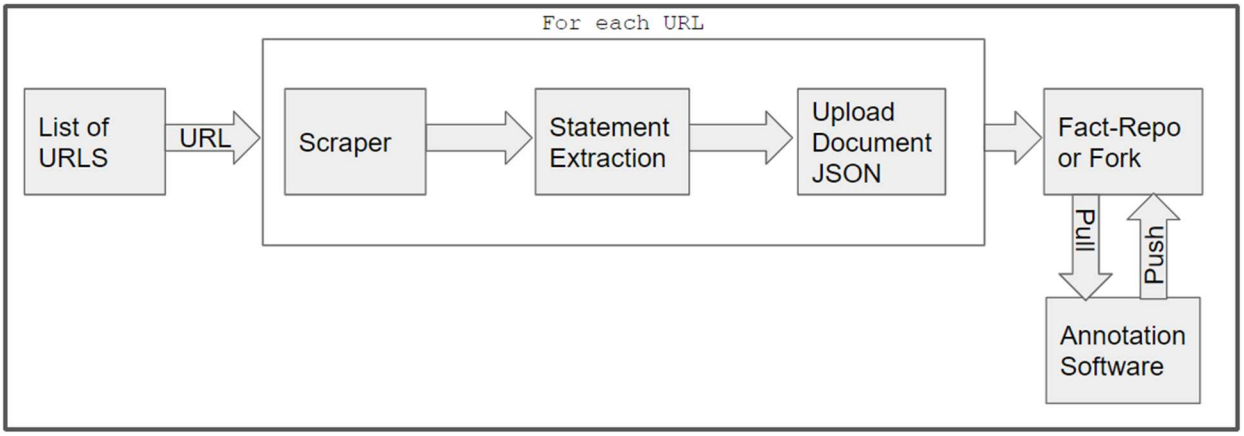

Figure 1: Full Process Flow from Data Source to Annotation

Annotation System

Annotation of data is a laborious process and there is currently no standard software with which to do it. Research teams use different processes and often create their own internal software for the task. Since disinformation is likely to be a continuing problem in society, we decided to make an open-source annotation front-end that would use a free and accessible back-end. This means other researchers can use our software to contribute to this misinformation project or they can use the software for their own separate machine learning projects. The architecture behind this software is novel in its creation as it does not use a live server but instead GitHub data files [1]. Thus, it is free of cost and does not require additional hardware.

While JSON is human readable in comparison to database back-ends, it would be tiresome to annotate directly into these files and would be inherently error prone. We created a simple annotation front-end that loads a JSON file and presents the user with possible annotation options. Each sentence is presented to the annotator and their selection is highlighted in green. The front-end is feature-agnostic, so it will present any option that exists in the JSON file. This will allow future researchers to customize the annotator to their needs without additional coding.

The annotations tool used for this is a sentence level annotator that we developed to handle web content. The annotation software is open-source and annotates directly via GitHub repositories. Our data scrapers are parametrized to handle different GitHub repositories. As statements are scraped, they are uploaded to the corresponding GitHub repository to a "pending annotation" directory. The annotation software for this project will pull from the corresponding GitHub into a web interface for sentence level annotation.

While this tool is a general-purpose annotator, it has been customized to be included in this open-source project to annotate the above JSON format on a per statement level. Since this is an open-source driven repository, the tool can be used by anyone who has been given push permissions to the repository. If someone without push permissions to the repository would like to contribute, they will have to fork the repository and issue a pull request when they have completed their annotation. While this process is a change for some in the NLP annotation community, it is a standard workflow for open-source communities.

When scraping the web, "junk" is often observed. This junk may be poorly scraped data, random encoding, or missed programming code such as JavaScript. Our system removes as many of these as we can predict, but some will still slide by. Our annotation system allows the user to annotate the original sentence in the user interface to remove stray characters. Most often this is just from miscellaneous formatting characters on a website.

Source Selection

Initially at the start of the resource creation process, we decided to go for a naturalistic approach to data collection. This meant we would gather the resources as they arrived in hopes of getting a real-life distribution of facts and misinformation. Graduate students were given the task to gather as many URLs as they could on the subject.

For the second set of data, we focused more heavily on getting examples of misinformation. Many of our sites in this resource came from other websites who had previous identified a website as misinformation. These sites did not annotate the individual statements but instead a particular article. This assisted us in getting a more heavily weighted data resource for misinformation.

The source URLs are provided in the repository for future extraction and examination if needed

Preprocessing

Data scraping can be a tedious task and full of potentially unwanted code and tags. To assist anyone extending the corpora we included 3 scrapers.

1. The first basic scraper covers any general HTML website and extracts any visible text on the site. This eliminates text that is in tags that do not display to screen such as 'style', 'script', 'head', 'meta', etc. The basic scraper has some additional features that allow it to improve over time.
2. Since the corpora is intended to be heavy in factual information, we include a basic scraper for Wikipedia as well.
3. The third scraper is to help users branch into social media by using existing wrappers for scraping twitter. The latter two are generally clean text since they both a run through APIs.

While a stopword list is common practice in most NLP pipelines, we needed a boilerplate phrase list to eliminate text on websites that is not helpful. For instance, most websites contain visible text such as copyrights, legal information, and tag lines. None of these are likely to contain factual information or misinformation. As the corpus can focus heavily on certain sites such as news organizations, these phrases come up on every page. To handle this, we allow the annotators to add common phrases, for which we do not have a use, to a stop-phrase list so that they will not be harvested in the future. This stop-phrase list is available in the repository to assist future research.

For this corpus, we are not interested in harvesting and indexing all text, just facts and misinformation statements. To eliminate extraneous sentences, we filter all harvested text down into declarative and exclamatory statements. For making interesting knowledge graphs, we also put a minimum threshold of 5 words per statement.

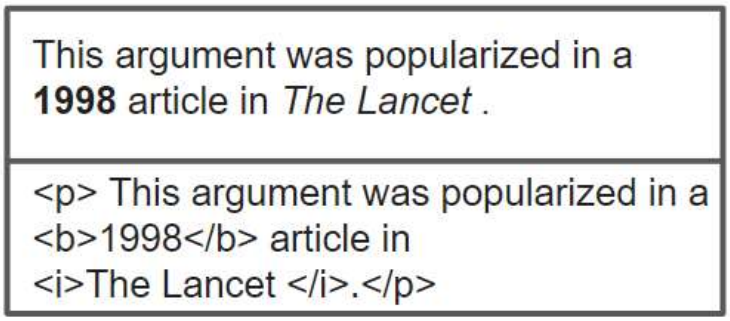

Figure 2: Example of how a simple sentence is built on a hierarchical tag system

Unfortunately, most websites are not simple for extraction of full sentences. HTML content is full of styling tags. This often leads to text extraction that creates fragmented statements. To handle this, we reconstruct sentences together automatically for various commands such as style as seen in Figure 2. This reconstruction does rely on proper punctuation at the end of sentences via period or exclamation mark. We do not consider this a serious limitation since we are looking for full statements, although this would need to be adjusted for different social media posts in the future. This reconstruction involves iteratively looking for contiguous lines missing punctuation and merging them together. For Example, in Figure 2, we would get four statements.

1. The argument was popularized in a
2. 1998
3. article in
4. The Lancelot.

Once tags are removed these 4 strings remain. Only the first one matches our heuristic of at least 5 words. Since even #1 does not contain punctuation, they are iteratively combined until the full sentence remains. In a very informal blog post, the situation can occur where we get multiple statements without punctuation. The annotation software has mechanisms to allow the annotator to split these in the rare cases it happens.

Data Format

The back end is made up of JSON files which are human readable. We chose JSON so researchers without a technology background could participate in this research, even without a database or server background. JSON was also chosen for its ability to add additional features to documents without creating the sparsity seen in many relational databases [3]. This is important since not all webpages, demonstrate every feature a researcher may want to capture.

To make the data conversion and usability top importance to the system, everything is saved and annotated in standard JSON format. Each webpage contains meta data about the site including a document id, URL, category, language, timestamp of scrape, author of document, and any annotators who have touched the page. Each document contains a

sentences attribute which is a list of statements scraped from the site or document. Each of these sentences contains the core of our annotation.

Each sentence gets a unique id as well as its raw text, and a sentence category. Categories are meant for later analysis on how facts are presented across different domains and topics. Such as how is misinformation presented in news versus how it is presented in entertainment. Each sentence then has four Boolean flags that the annotator can set

1. fact: True if the statement is a known fact. False if the statement is not a fact. This does not mean it is misinformation, just that it is not a known fact. This may take the form of opinion, misinformation, or a statement that is unverifiable. For example, not all vaccines are given as shots. Some vaccines are given orally is a factual statement that can be shown. The opposite All vaccines are given as shots can be shown to not be universally true.
2. misinformation: True if the statement can be proven to be incorrect information. False if we cannot verify the accuracy of the statement. For example, The MMR vaccine causes autism has been shown to be false in numerous studies. As will all fact checking procedures, there are always exception articles. As a general rule, we look for an overwhelming consensus on a fact or misinformation by experts in a field. For expertise some distinction needs to be made, so we favor academic research over knowledge obtained through other sources
3. opinion: True if the statement can be thought as of true to the speaker or author of the statement. For instance, Vaccines are the best thing to happen to medicine. This statement may be true to the author, but it is not a universal verifiable fact. This flag is false in the cases where the statement cannot be seen as an opinion. There is a slim line between opinion and misinformation, so annotators must look at the context and the level of authority the author is presenting on the subject and what qualifiers the statement is using.
4. temporal: True if the fact is only true for the current time period of the data scrape. For example, 17.2% of unvaccinated children were uninsured. This is true for a particular year but as this is a permanent repository, knowledge systems will need to know this fact may have changed. If the value is set to False, then the statements veracity has nothing to do with the time in which it is read.

Annotation Procedure

While the framework behind this data resource allows for new researchers to contribute, we have paid four dedicated annotators to work on the project. Four total annotators participated in this study. Due to the extensive knowledge and nuance required to annotate the data resource, each annotator was given time to become an expert in the domain. Problem annotations were handled through training and weekly discussions with researchers to discuss the proper annotations so standards remained consistent.

Annotating facts and misinformation is very tricky and requires some domain knowledge. For certain topics such as geography, accepted historical facts, scientific laws, and biographic data,

the annotation process is more straightforward. When we look at hotly debated issues such as politics, the annotator's own personal bias can cloud some judgments. We ask that each annotator verify the statements presented. When a statement has sources on both sides, we weigh in the favor of the majority of academically or scientifically backed research. We are fully aware that research in these areas can change over time. Therefore, we only undertook this endeavor with the idea of the repository being open-source and publicly visible. As the underlying research in an area changes, we hope the community at large will fix the troublesome annotations. This is largely how the Wikipedia type models work as well. To get too bogged down in the details about the possibility of change, would be to not construct the corpus at all. For that reason, we favor the research consensus at the time, with the caveat that the annotations may change in the future. Statements that were factual at the time and later changed have the option of the temporal tag to study how the language was used at that particular time.

In order to track these decisions, a wiki document is kept alongside the project with troublesome cases and the decision made going forward for each. One such instance would be quotes. If an author factually quotes a speaker who stated misinformation, we had to decide how that is annotated. An example of a quote breakdown can be seen in Figure 3.

The concerned mother stated "Vaccines have been proven to cause autism"	Original statement
The concerned mother stated "Vaccines have been proven to cause autism"	Fact
Vaccines have been proven to cause autism	Misinformation

Figure 3: Example of how to break down a quote of misinformation

RESULTS AND DISCUSSION

This data resource annotation was performed by four graduate students. The annotations work was split up initially to increase coverage but due to this we do not have multiple annotators on the same document so we will not run any Kappa scores for this first iteration of the project. A subset of documents will be used to run Cohen's Kappa in the next iteration.

In total 500+ documents were collected for annotation. At the time of writing, over all documents, we have hand annotated 11,214 statements. Being an open system with multiple annotators this number is only increasing. Initial results show that overall more facts and opinions exist, even in documents flagged as misinformation. This shows a tricky narrative structure where much of a page may be fact or opinion and misinformation statements are slide in. This makes identification by the average reader particularly tricky and unlikely to be detected.

The majority of the work so far has been in tool creation, data wrangling, and annotation. To show applicability to machine learning we have run basic tf-idf text classifiers across the 4 categories, Fact, Misinformation, Opinion, and None. Overall, we get F-measures of around 74% without any feature engineering or parameter optimization. Machine Learning will be the focus of future iterations. An initial script to run this classifier is in the repository to get researchers started. The current corpus, annotator, tools, and analysis scripts can be found at https://github.com/LanguageKits/fact-repo .

NEXT STEPS

Upon this initial public release, we would like to expand the corpus to new areas. While the current corpus deals primarily with COVID-19, we will be adding new domains from entertainment, wiki articles, and politics. We would like this to serve as an open call for any researchers who would like to contribute or consume this data.

Additional annotation can be added to the JSON files for basic NLP tasks such as part-of-speech, named entity, and noun phrase chunking. Given the open format, we hope this will serve as a new treebank for future research and extension. With additional linguistic annotation and some social context, we will examine whether misinformation annotations can be used to show purposeful disinformation campaign

CONCLUSION

Fact Repo is an open-source fact and misinformation repository for use in NLP and knowledge graphs. Using open-source tools, the corpus is open to the community for consumption and collaboration. While initial documents were in two main areas, the corpus will expand into new areas. The corpus contains a variety of styles of content from scientific, to news, to informally written blogs. This leads to possible research on how facts and misinformation are presented to the public across different authors and styles. Fact Repo includes the tools needed to scrape, extract statements, save to a GitHub repository, and annotate that data. While we hope Fact Repo is extended, end users can certainly use these tools to create their own corpus repository by forking the current repository and changing the annotation schema.

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REFERENCES

[1] GitHub. https://github.com/.

[2] 2019. Report of the Select Committee on Intelligence, United States Senate, on Russian Active Measures, Campaigns and Interference in the 2016 U.S. Election.
[3] Hadeer Ahmed, Issa Traore, and Sherif Saad. 2017. Detection of Online Fake News Using N-Gram Analysis and Machine Learning Techniques. 127–138. https://doi.org/10.1007/978-3-319-69155-8_9
[4] Mehdi Allahyari, Seyedamin Pouriyeh, Mehdi Assefi, Saeid Safaei, Elizabeth D. Trippe, Juan B. Gutierrez, and Krys Kochut. 2017. Text Summarization Techniques: A Brief Survey. arXiv:1707.02268 [cs.CL]
[5] Elena Baralis, Luca Cagliero, Saima Jabeen, Alessandro Fiori, and Sajid Shah. 2013. Multi-document Summarization Based on the Yago Ontology. Expert Syst. Appl. 40, 17 (Dec. 2013), 6976–6984. https://doi.org/10.1016/j.eswa.2013.06.047
[6] Kurt D. Bollacker, Colin Evans, Praveen Paritosh, Tim Sturge, and Jamie Taylor. 2008. Freebase: a collaboratively created graph database for structuring human knowledge.. In SIGMOD Conference, Jason Tsong-Li Wang (Ed.). ACM, 1247–1250. http://dblp.uni-trier.de/db/conf/sigmod/ sigmod2008.html#BollackerEPST08
[7] Eugene Charniak, Don Blaheta, Niyu Ge, Keith B. Hall, John Hale, and Mark L. Johnson. 1999. BLLIP 1987-89 WSJ Corpus Release 1.
[8] Xin Luna Dong, Evgeniy Gabrilovich, Geremy Heitz, Wilko Horn, Ni Lao, Kevin Murphy, Thomas Strohmann, Shaohua Sun, and Wei Zhang. 2014. Knowledge Vault: A Web-Scale Approach to Probabilistic Knowledge Fusion. In The 20th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, KDD '14, New York, NY, USA - August 24 - 27, 2014. 601–610. http://www.cs.cmu.edu/~nlao/publication/2014.kdd.pdf Evgeniy Gabrilovich Wilko Horn Ni Lao Kevin Murphy Thomas Strohmann Shaohua Sun Wei Zhang Geremy Heitz.
[9] Günes Erkan and Dragomir R. Radev. 2004. LexRank: Graph-based Lexical Centrality As Salience in Text Summarization. J. Artif. Int. Res. 22, 1 (Dec. 2004), 457–479. http://dl.acm.org/citation.cfm?id=1622487.1622501
[10] Benjamin Horne, William Dron, Sara Khedr, and Sibel Adali. 2018. Sampling the News Producers: A Large News and Feature Data Set for the Study of the Complex Media Landscape. (03 2018).
[11] Mihalis Kritikos and European Parliament. 2019. Regulating disinformation with artificial intelligence. Brussels. http://www.europarl.europa.eu/ RegData/etudes/STUD/2019/624279/EPRS_STU(2019)624279_EN.pdf
[12] Yichuan Li, Bohan Jiang, Kai Shu, and Huan Liu. 2020. MM-COVID: A Multilingual and Multimodal Data Repository for Combating COVID-19 Disinformation. CoRR abs/2011.04088 (2020). arXiv:2011.04088 https://arxiv.org/abs/2011.04088
[13] Robert Logan, Nelson F. Liu, Matthew E. Peters, Matt Gardner, and Sameer Singh. 2019. Barack's Wife Hillary: Using Knowledge Graphs for FactAware Language Modeling. In Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics. Association for Computational Linguistics, Florence, Italy, 5962–5971. https://doi.org/10.18653/v1/P19-1598
[14] Courtney Napoles, Matthew Gormley, and Benjamin Van Durme. 2012. Annotated Gigaword. In Proceedings of the Joint Workshop on Automatic Knowledge Base Construction and Web-scale Knowledge Extraction (Montreal, Canada) (AKBC-WEKEX '12). Association for Computational Linguistics, Stroudsburg, PA, USA, 95–100. http://dl.acm.org/citation.cfm?id=2391200.2391218

[15] Fabian M. Suchanek, Gjergji Kasneci, and Gerhard Weikum. 2007. Yago: A Core of Semantic Knowledge. In Proceedings of the 16th International Conference on World Wide Web (Banff, Alberta, Canada) (WWW '07). ACM, New York, NY, USA, 697–706. https://doi.org/10.1145/1242572.1242667
[16] Jillian Tompkins. 2019. Disinformation Detection: A review of linguistic feature selection and classification models in news veracity assessments. arXiv:1910.12073 [cs.CL]
[17] Svitlana Volkova, Kyle Shaffer, Jin Yea Jang, and Nathan Hodas. 2017. Separating Facts from Fiction: Linguistic Models to Classify Suspicious and Trusted News Posts on Twitter. In Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers). Association for Computational Linguistics, Vancouver, Canada, 647–653. https://doi.org/10.18653/v1/P17-2102
[18] William Yang Wang. 2017. "Liar, Liar Pants on Fire": A New Benchmark Dataset for Fake News Detection. In Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers). Association for Computational Linguistics, Vancouver, Canada, 422–426. https://doi.org/10.18653/v1/P17-2067

INCREASED IMPORTANCE OF GLOBAL VIRTUAL TEAMS FOLLOWING THE COVID-19 PANDEMIC

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ABSTRACT

The coronavirus has ever changed the world. As many believes, nothing is going to be the same after this pandemic. People interactions, business relationships, healthcare, transportation, and tourism are some of the most important facets in our daily lives that are mandated to change due to this "unexpected" health crises. In this paper, we argue that the importance of global virtual teams (GVTs) will be much bigger following the pandemic. More specifically, due to several new restrictions among/ for individuals, businesses will have to solely rely on GVTs much more than previously to further protect people's health while running their global operations without further interruption.

The Coronavirus and Changing World

The coronavirus changed the lives of many all around the globe. According to the "continuously updated" COVID-19 Strategic Preparedness and Response Plan published by the *World Health Organization* (WHO) on May 21, 2020 [11], many countries including developed economies have faced this deadly challenge. Although countries try to do their best to fight this virus, many lives have still been lost. As listed on the WHO website, as of May 26th, 349,095 people have died around the globe along with almost 5,5 million confirmed cases [10].

According to the WHO, strategic objectives to win this global "battle" are identified as follows [10] [11]: to limit people interactions as much as possible, identify corona-positive patients as early as possible and treat them, examine all possible medications for helping people get healed, and provide communities with prompt and clear information. Although these steps may help to reduce the effect of this virus in the world, it is still unclear how businesses will go back to their

previous routines. In other words, there are big ambiguities/ unknowns for when businesses will be able to ever recover fully.

In this paper, we argue that the importance of global virtual teams (GVTs) will be much bigger following the pandemic. More specifically, due to several new restrictions among/ for individuals, businesses will have to solely rely on GVTs much more than previously in order to further protect people's health while running their global operations without further interruption. Thus, GVTs have become a much more critical "key" for success in global business.

What are Global Virtual Teams?

In the literature, GVTs are defined as "a major feature of contemporary organizational life, which also must be treated as an evolving team concept" [1, p. 204]. They mainly differ from other forms of organizational teams since they are "globally dispersed and comprised of different nationalities" [1, p. 205] via using electronic channels as their primary communication tools. GVTs are also known as very dynamic mechanisms that are rapidly forming, changing, and dissolving [2] due to distinct environmental conditions.

There are many benefits that come with using GVTs. These include the following: making better choices through technology-mediated communication that also strengthens intergroup ties [3], assembling teams with a greater amount of functional expertise, enabling further productivity, lowering overall cost and utilizing resources more efficiently, and sharing knowledge and information more promptly [4]. All these positive dimensions make GVTs very attractive models in today's global world.

On the other side, GVTs may raise several questions for organizations. In general, there is no "one-size fit all-solution" [2, p. 204] while establishing strong linkages within these cross-

organizational models. Some challenges of GVTs may include the following [2]: too many meetings and too much communication to make a simple decision, repeating the same conversation without making any progress, wasting time through a huge amount of email exchanges, misunderstandings caused by multiculturalism, struggles due to time differences and technological difficulties, and absence of establishing interpersonal connections (especially, the "trust" factor) and face-to-face communication among team members. All these issues may make possible outcomes of GVTs a bit "questionable".

Why are Global Virtual Teams Going to Become More Important?

In a study by Dulebohn and Hoch (2017), they offer an I-P-O (input-process-output) model in the context of virtual teams [4]. According to this model, the "I" dimension entails organizational factors, team leadership, and team composition; the "P" dimension entails cognitive, affective, motivational, and behavioral team characteristics; and finally the "O" dimension entails team-level outcomes – performance and effectiveness – as well as individual-level outcomes – performance, effectiveness, satisfaction, and commitment. They also include some moderators such as virtuality, task interdependence, task complexity, and team content. Following this pandemic, we argue that a "brand new" moderator will need to be added in this model, which is *governmental restrictions* and *changes in individuals' health conditions* due to COVID-19.

According to another study by Harvey, Novicevic, and Garrison (2004), GVTs have become a "popular" aspect of organizational life as a result of companies being forced to "adopt a more dynamic approach to day-to-day operations to survive and compete successfully in the global virtual economy" [5, p. 275]. They argue that GVTs provide organizations with a strategic flexibility while executing their operations globally [5]. In other words, GVTs can be considered critical "*virtual performance boosters*" while organizations are trying to attain successful

outcomes [5]. Especially, following the COVID-19 pandemic, the importance of these virtual boosters is expected to increase significantly.

Jarvenpaa and Leidner (1999) define a virtual team as “an evolutionary form of a network organization enabled by advances in information and communication technology” [6, p. 791]. As argued by Jimenez et al. (2017), GVTs come with three main complexities including location, distance, and time [7]. Location-related complexities refer to GVT members’ diverse “social networks, norms and cultural values”; distance-related complexities refer to “institutional, economic, technological, educational or demographic distances”; and time-related complexities refer to those difficulties caused by synchronous (or asynchronous) manner of communication [7, p. 345]. We argue that some of these complexities may have to be disregarded by companies since GVTs are going to have to serve as their primary way to get the business done during the process of post-COVID-19 normalization.

According to Kayworth and Leidner (2000), there are four main success parameters in GVTs, which are communication, culture, technology, and leadership [8]. They explain each parameter as follows [8]: Frequent and effective communication is a primary “key” for successful GVTs; culture is critical to GVTs since it has a direct impact on how people perceive information; technology is an important factor for efficient collaboration in GVTs; and leadership helps GVT members to stay on track and be focused. Because of this pandemic, organizations will need to re-examine their pre-COVID strategies in managing all these parameters and make improvements/changes necessary so that GVTs can still lead to positive performance outcomes.

Scott and Wildman (2015) also argue that there are two primary reasons for the increased importance of GVTs prior to this pandemic [9]. First and foremost, due to complex and dynamic conditions of the business environment, there has been a higher need (and demand) for team-

based work structures instead of individual-based task assignments. Secondly, due to the interconnectedness among nations and need (and availability) for speedy communication, using virtual tools while getting the work done has become a much more “popular” technique. Thanks to both factors, organizations are now better capable of acting on strategic opportunities in a timely manner [9]. Following this pandemic, we can argue that the overall effect of COVID-19 around the globe has become a third main reason for GVTs becoming more and more important. By considering all those travel restrictions, different rules and regulations that are put in effect by many nations, unavailability of treatment and curing options, as well as social distancing protocols, it is very clear that all these changes caused by the coronavirus have created a third dimension in explaining why organizations prefer using GVTs more frequently than earlier. Therefore, we conclude that from now on, using GVTs will become a much stronger aspect of the global business world, and organizations will have to adjust their team structures by keeping this new reality in mind.

REFERENCES

[1] Cordery, J., Soo, C., Kirkman, B., Rosen, B. & Mathieu, J. (2009). Leading parallel global virtual teams: Lessons from Alcoa. *Organizational Dynamics*, 38(3), 204-216.

[2] Daim, T.U., Ha, A., Reutiman, S., Hughes, B., Pathak, U., Bynum, W. & Bhatl, A. (2017). Exploring the communication breakdown in global virtual teams. *International Journal of Project Management*, 45(1), 199-212.

[3] Dixon, N. (2017). Learning together and working apart: Routines for organizational learning in virtual teams. *The Learning Organization*, 24(3), 138-149.

[4] Dulebohn, J.H. & Hoch, J.E. (2017). Virtual teams in organizations. *Human Resource Management Review*, 27(4), 569-574.

[5] Harvey, M., Novicevic, M.M. & Garrison, G. (2004). Challenges to staffing global virtual teams. *Human Resource Management Review*, 14(3), 275–294.

[6] Jarvenpaa, S.L. & Leidner, D.E. (1999). Communication and trust in global virtual teams. *Organization Science*, 10(6), 791-815.

[7] Jimenez, A., Boehe, D.M., Taras, V. & Caprar, D.V. (2017). Working across boundaries: Current and future perspectives on global virtual teams. *Journal of International Management*, 23(4), 341-349.

[8] Kayworth, T. & Leidner, D. (2000). The global virtual manager: A prescription for success. *European Management Journal*, 18(2), 183-194.

[9] Scott, C.P.R. & Wildman, J.L. (2015). Culture, communication, and conflict: A review of the global virtual team literature. In J. L. Wildman & R. L. Griffith (Eds), *Leading Global Teams*: 13-32. New York, NY: Springer.

[10] https://www.who.int/emergencies/diseases/novel-coronavirus-2019

[11] https://www.who.int/who-documents-detail/updated-country-preparedness-and-response-status-for-covid-19-as-of-21-may-2020

Student Papers (Undergraduate, Master and Ph.D Students) - Abstracts

AN IMPROVED KTNS ALGORITHM FOR THE JOB SEQUENCING AND TOOL SWITCHING PROBLEM

Oral Presentation

Mr. Mikhail Cherniavskii [1], ***Prof. Boris Goldengorin*** [1]

1. *Moscow Institute of Physics and Technology*

We outline a new Max Pipe Construction Algorithm (MPCA) with the purpose to reduce the CPU time for the classic Keep Tool Needed Soonest (KTNS) algorithm. The KTNS algorithm is applied to compute the objective function value for the given sequence of jobs in all exact and approximating algorithms for solving the Job Sequencing and Tool Switching Problem (SSP). Our MPCA outperforms the KTNS algorithm by at least an order of magnitude in terms of CPU times. Since all exact and heuristic algorithms for solving the SSP spend most of their CPU time on applying the KTNS algorithm we show that our MPCA solves the entire SSP on average 59 times faster for benchmark instances of D compared to current state of the art heuristics.

An Integrative Framework of the Tenets of Transactive Memory Systems

Oral Presentation

Ms. Irita Mishra [1]

1. *Georgia Southern University*

Transactive Memory Systems (TMSs) are developed when two or more individuals interact and share information. They form a mutual memory system where they can store the knowledge gained from each other. This is a system of "group think" where individuals in a group learn, store, use, and coordinate knowledge to achieve goals. The current study presents research examining antecedents, consequences, and components of TMSs through a comprehensive framework. 80 of the most significant studies on TMSs between 1985 and 2021 have been explored. The extant work is combined to derive new insights, implications, and areas of future research.

Analysis of Legalized Sports Gambling in the U.S.

Oral Presentation

Mr. Ryan Hartquist [1], ***Mr. Andrew Kuchel*** [1], ***Mr. Jeffrey Bridges*** [1], ***Mr. Michael Alberts*** [1]

1. *Oklahoma State University*

In the United States, only 18 states along with the District of Columbia and Puerto Rico allow legal bets on sporting events. Six more states have pending litigation to approve sports betting in 2021. Before a supreme court ruling in 2018, the Professional and Amateur Sports Protection Act (PASPA) made most sports betting illegal. Nevada was grandfathered an exempt status and was the only state with significant legalized sports gambling until the recent ruling. Since that ruling to strike down PASPA, those states which have passed legislation to legalize sports betting have realized an additional revenue stream for their governments. The main goals of this project are: to generate a model for revenue from states that have legalized sports betting that will evaluate the most significant variables and estimate potential revenue in states that have yet to legalize sports betting. The results of the analysis will identify trends and growth in revenue from legalized sports betting states and show a pathway to maximize a substantial source of income for state governments.

IMPACT OF COVID-19 ON SUPPLY CHAIN INTERNSHIPS

Oral Presentation

Ms. Hannah Cunningham [1]

1. *Anderson University*

COVID-19 has drastically changed our working environment. Jobs have shifted to virtual environments, supply chains have been reconstructed, and companies have been forced to implement new policies and procedures. One area particularly impacted by COVID-19 is internship programs. This research paper will delve specifically into supply chain internship programs during a global pandemic. This paper addresses relevant questions such as how COVID-19 changed supply chain internships, how on-site internships during COVID-19 were implemented, the challenges of working virtually, and how the pandemic has altered the future of internship programs. This research focuses on student experiences, seeks advice from companies who have implemented successful programs, and offers guidance for future internships in a post-COVID world.

Overview of the applications of Amazon Web Services (AWS) in professional sports.

Oral Presentation

Mr. Angel Perez [1], ***Mr. Dhruv Anand*** [1], ***Mr. Harry Agis-Alvarez*** [1], ***Mr. Kramer Leitman*** [1]

1. *University of North Florida*

This paper discusses the main Amazon Web Services used in sports, analyzing the specific applications in four professional organizations (Bundesliga, F1, NFL, and PGA Tour). Most of the applications used rely on machine learning models that were developed using Amazon SageMaker. These models produce predictive and descriptive statistics that are presented to fans in real-time during sporting events, which has resulted in higher fan engagement – one of the key motivations for adopting AWS by these organizations. While using cloud computing services poses some degree of risk, the benefits of these applications suggest that the use of AWS will continue to grow in professional sports.

QUALITATIVE BENEFITS OF LANGUAGE CAPABLE INDIVIDUALS

Oral Presentation

Mr. Hunter Cushing [1]

1. *Anderson University*

In the melting pot that is the United States, communities and workplaces have naturally become more diverse, due to globalization, immigration, education opportunities, and job changes. This pattern of increased diversity has noticeably brought along larger talent pools, new perspectives, ideas, and has created new industry expectations of workplace diversity, and the desire for even more. These workplace expectations have led to the search for the highest quality and experienced individuals in areas more than their local communities. What may be considered during the search to find these diverse and culturally exposed individuals would be the recruitment language capable individuals or individuals with personal experience in the learning of a foreign language. For this research, a language capable individual is considered one that is proficient in languages other than their native tongue. Through what is the language learning process to become a language capable individual, individuals experience enough communication in all mediums, possess a reason to learn, and are typically interested in the language or culture, which may translate to many beneficial things in other areas of their lives. The desire to learn or maintain a language may be personally or organizationally incentivized through financial compensation, travel, and increased professional and social opportunities. The responses of interviews and prior research combine to acknowledge many considerations in benefits that are associated with the social, personal, and workplace aspects of language capable individuals. These individuals also agree that their professional and personal cultural experience as well as practice in learning a language may have directly provided them more opportunities, increased their quality of life, and is prevalent in their current environments.

The effect of data breaches on share prices.

Oral

Mr. Michael McGarry [1]

1. *Temple University*

Data breaches are the theft of sensitive information or the disruption of company operations through cybercriminal acts. This paper studies the impact data breaches have on investors.

The impact of a data breach on security prices is not well understood. The existing research is contradictory: Some research found that a data breach has a statistically significant, long-term, negative impact on stock price. Others found that data breaches have no impact. Another study found a negative impact but that the share price quickly recovers (Richardson et al., 2019).. This lack of clarity makes it difficult for practitioners to establish an appropriate cybersecurity investment strategy.

This paper studied the share price movement of companies who disclosed a data breach between January 2007 and September 2020. It found, through event studies and statistical tests, that data breaches have a statistically significant but small impact. These results were heavily influenced by a few extreme cases.

Interviews with research analysts and investors found that they regard data breaches as immaterial. They do not believe customers will change their behavior. They do not believe that the cost of a breach is significant to a healthy company.

The implication is that companies should be wary of over-investing in cybersecurity. Companies should be followers rather than leaders, and establish a strategy of doing no more than what is necessary for regulatory compliance and to be consistent with prevalent security practices.

Market forces will not be drive continued cybersecurity insurance improvements. Governments, regulators and the growing cybersecurity insurance industry will need to take the lead in establishing and enforcing new cybersecurity standards.

THE EFFECT OF INVENTORY LEANNESS ON FIRM FINANCIAL PERFORMANCE: A LONGITUDINAL STUDY

Oral Presentation

Ms. Lakshmi Madarasu [1]

1. *Georgia Southern University*

The relationship between inventory leanness and the financial performance of an organization has been widely explored in operations management research. Evidence from previous research in operations management demonstrate mixed results regarding the relationship between inventory leanness and financial performance. The purpose of this paper is to investigate whether a firm's financial performance declines over time as more firms implement lean within the same industry, using the theoretical lens of knowledge-based theory. The novelty of this paper is in determining the effect of various inventory leanness measures and their distinctive effects on firm financial performance. This model will be analyzed using secondary data for U.S. manufacturing firms from 1990 to 2019. The results will refine our understanding of what makes a firm's financial performance decline over time, as more organizations learn to adapt lean.

THE RELATIONSHIP BETWEEN ENVIRONMENTAL PERFORMANCE OF FIRMS AND PROFITABILITY: EXPLORING THE EFFECT OF OPERATIONAL PRODUCTIVITY

Oral Presentation

Ms. Senali Amarasuriya [1]***, Dr. Gerard Burke*** [1]

1. *Georgia Southern University*

Despite the number of extant studies done on environmental performance of organizations, the relationship between firm environmental and financial performance remains ambiguous. Given the lack of consistent results about this relationship, it has become difficult for businesses to gauge the feasibility of engaging in sustainable operations while they are being increasingly pressurized by stakeholders to be environmentally concerned. Hence the research objective of this study lies in answering the managerial question, "is it financially worthwhile to invest in improving environmental performance?". The study leverages data on 220 firm-year observations from 2015 to 2019. Data on GHG emission levels to measure environmental performance is extracted from Bloomberg and data from Compustat is used to measure financial performance operationalized through operating ROA. Analysis of the data through hierarchical regression revealed that higher GHG emission levels lead to lower profitability of the company. When exploring the moderating effect of operational productivity (OP) on the main relationship, it was found that companies controlling for GHG emissions can achieve substantial profitability only in the presence of high OP levels. Accordingly, a company should be operationally productive to achieve substantial financial benefits on profitability which are expected from controlling for GHG emissions.

Keywords: environmental performance, operational productivity, profitability

The Roles of AI-Based Technologies in Helping Mobilize the Collective Tacit Knowledge (CTK)

Oral Presentation

Mrs. Najla Almousa [1]

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Abstract

The application of artificial intelligence in all aspects of life is the current trend in the era of information and advanced technology, in which artificial intelligence provides machines with human knowledge and intelligence. Moreover, these machines have become able to learn and manage tacit knowledge, which is a type of knowledge, as tacit knowledge is complex and cannot be recorded and results from the exchange of experiences and personal experiences and is closely related to social interaction among people. The domain of knowledge can be represented by a continuum, which includes three types of tacit knowledge in addition to explicit knowledge. AI applications currently used in knowledge management only help explicit and tacit knowledge in the form of relationships and bodies. (Sanzogni et al., 2017). The problem is that there is no AI machine capable of dealing with collective tacit knowledge because it is based on experience and practice that is socially acquired and is mostly activities related to human consciousness. Hence, this study will investigate what are the mechanisms of artificial intelligence and their interaction with community-based knowledge management mechanisms that help gathering tacit collective knowledge

Student Papers (Undergraduate, Master and Ph.D Students) - Papers

AN IMPROVED KTNS ALGORITHM FOR THE JOB SEQUENCING AND TOOL SWITCHING PROBLEM

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ABSTRACT

We outline a new Max Pipe Construction Algorithm (MPCA) with the purpose to reduce the CPU time for the classic Keep Tool Needed Soonest (KTNS) algorithm. The KTNS algorithm is applied to compute the objective function value for the given sequence of jobs in all exact and approximating algorithms for solving the Job Sequencing and Tool Switching Problem (SSP). Our MPCA outperforms the KTNS algorithm by at least an order of magnitude in terms of CPU times. Since all exact and heuristic algorithms for solving the SSP spend most of their CPU time on applying the KTNS algorithm we show that our MPCA solves the entire SSP on average 59 times faster for benchmark instances of D compared to current state of the art heuristics.

INTRODUCTION

Currently as far as we are aware a globally optimal solution to the Job Sequencing and Tool Switching Problem (SSP) Tang, Denardo [10] is limited to a couple of dozen jobs with no more than 25 tools in each of them da Silva et al. [9]. This class of problems includes many optimization versions of SSP solved for a large number of small-scale orders (jobs) on conveyor lines (flexible manufacturing system - FMS). We do not consider technical and technological changes (improvements) in the equipment of the FMS in order to increase its productivity. Our goal is to increase the productivity of the conveyor line by finding an optimal sequence of loading the necessary tools, materials and other production resources (hereinafter referred to as tools) including the professional skills of employees, e.g. in order to minimize the conveyor's downtime. In other words, the methods and means of increasing the productivity of the conveyor in this article are related to an optimal sequencing of jobs each of which requires its specific collection of tools. Since a production line has a limited number of slots (magazine with a limited capacity) a tool switch is necessary to store the tools required to complete all jobs. Here by *tool switch* we understand the removal of a tool from the magazine (collection of slots) and the insertion of another tool in its place. Thus, the SSP consists in finding a sequence of jobs minimizing the total number of tool switches.
In this paper we assume that the following refined assumptions are satisfied Calmels [3], da Silva et al. [9]:

- There is a set of jobs to be processed and each job requires a fixed set of specific tools;
- The set of jobs and the subset of tools required for each job is known in advance;
- No job requires a set of tools that exceeds the capacity of the machine's magazine;
- All tools are always available at least outside the magazine;

- A single machine is available to process all jobs;
- It is an offline version of the problem;
- Once the machine has started processing a job it must be completed;
- Exactly one job can be processed at any time unit;
- The processing and completion times of a job are not dependent on the set of tools and do not impact the number of tool switching times;
- The tool sockets (slots) are identical;
- Only one tool switch is done at time;
- Each tool fits in any slot of the magazine and occupies one slot;
- The time associated with removal and insertion (switch) of a tool is independent and constant;
- No breaks, no wear and no maintenance of the tools are considered.

Here, a single machine is an abstraction. It reflects many different interpretations, e.g. huge and small companies, production and service lines, and organizations - educational, medical, governmental and private. For each of these we are able to indicate an input of jobs, their operations including available resources (tools) and an expected output of ordered (sequenced) products (jobs) to be processed Goldengorin, Romanuke [6].
In this paper we are not going to overview the state of the art for mathematical models, methods and algorithms for modeling and solving the SSP. We rather refer the interested reader to the recent literature review Calmels [3], as well as the article da Silva et al. [9]. We would like to emphasize that the SSP is one of the NP-hard problems Tang, Denardo [10]. The relevant mathematical models and solution methods for SSP should take into account that the number of tool switches for the next job depends not only on a single or pair of prior scheduled jobs but, in the worst case, on all jobs scheduled before the pending job Crama et al. [4], Ghiani et al. [5], Ahmadi et al. [1]. Most publications report globally optimal solutions to the entire SSP. However, their conclusions are questionable without any proof of how they take into account the real number of switches. For details we refer to Tables 6 and 7 in da Silva et al. [9].
The SSP can be formulated as follows. We are given the sets of jobs $J = \{1, \ldots, n\}$ and tools $T = \{1, \ldots, m\}$, a single magazine C denoting the maximum number of tools (slots) that can be placed (occupied) in the machine's magazine, $C < m$, the set of tools $T_i \subset T$, $i = 1, \ldots n$ required by job i which should be in the magazine in order to complete the job i, $|T_i| \leq C$. Thus, for the given sequence of n jobs we are going to associate n instants each of which will be presented by the set tools $M_i \subset T$ in the magazine. A feasible SSP solution is the sequence $M = \{M_i\}_{i=1}^{n}$, such that sequence of jobs $(1, 2, \ldots, n)$ can be completed. An optimal solution to the SSP is a sequence M that minimizes the total number of tool switches required to move from one job to another and complete all jobs.
As shown by Tang, Denardo [10] SSP can be decomposed into 2 following problems.

1. Tool Loading Problem(TLP) - for a given sequence of jobs, find the optimal sequence of magazine states M that minimizes the total number of tool switches.

2. Job Sequencing Problem(JeSP) – finding a sequence of jobs such that the number of tool switches is minimal after solving the TLP for this sequence.

Note that most publications devoted to solving the SSP consider heuristics based on completely different classes of metaheuristics, e.g., tabu search, iterated local search, and genetic algorithms [8]. Regardless of the designed heuristic's nature they try to replace all permutations defined on the entire set of jobs and select the best values of the SSP objective function (OF), i.e. the minimum number of tool switches. One of the first and most popular algorithms to compute the SSP OF, well known for over thirty years, is the Keep Tool Needed Soonest (KTNS) algorithm [10]. The main purpose of our paper is to improve the KTNS algorithm since the efficiency of any exact or heuristic algorithm is based on a partial enumeration of SSP feasible solutions and depends on the CPU time to compute the SSP OF value.
Our paper is organized as follows. Before describing our new Max Pipe Construction Algorithm (MPCA) we provide a small numerical example to illustrate the pitfalls of slowing down the SSP OF value computation. In the next two sections we describe the solution method and formulate statements to justify the correctness of our MPCA. We provide an example demonstrating the inner workings of MPCA and design an efficient $MPCA-bitwise$ implementation and evaluate its time complexity. The Experimental Results section includes our computational study and the final section contains a summary and future research directions.

A Numerical Example

Let's consider an example. $T_1 = \{4,5,6\}, T_2 = \{1,3,4,5\}, T_3 = \{1,2,7\}, T_4 = \{2,3,7\}, T_5 = \{4,5,7\}, T_6 = \{1,2,3,6\}$ is given sequence of jobs represented as sets of tools that they require, $C = 5$ is magazine capacity. Fig. 1 shows the optimal loading of empty slots to perform job in the order of $(1,2,3,4,5,6)$. Fig. 2 shows the optimal loading of empty slots for performing job in the order $(1,2,5,3,4,6)$. The sequence $(1,2,5,3,4,6)$ is found by exhaustive brute force search and is a solution to the problem *JeSP*. In the Fig. 1,2, red arcs represent tool switches. Thus, the smallest number of switches for the $(1,2,3,4,5,6)$ sequence is 5, and for the $(1,2,5,3,4,6)$ sequence is 3.

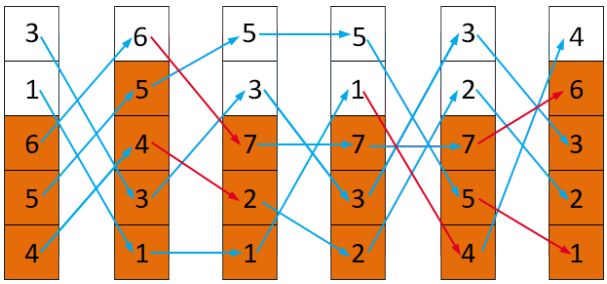


Figure 1: Solution of the *TLP* problem for the $(1,2,3,4,5,6)$ sequence.

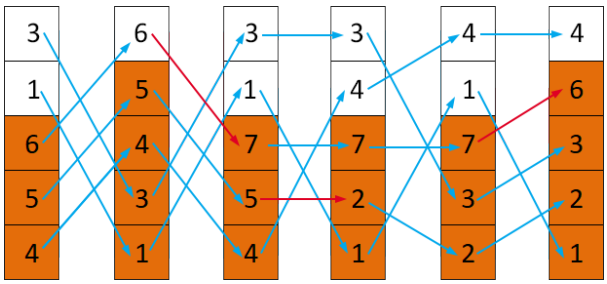


Figure 2: Solution of the *TLP* problem for the $(1,2,5,3,4,6)$ sequence.

Crama et al. [4] proved that the *JeSP* is NP-hard. Usually, TLP is solved with purpose to calculate the SSP objective function value for each job sequence in *JeSP*. To solve TLP Tang, Denardo [10] proposed the *Keep Tool Needed Soonest (KTNS)* with time complexity $O(mn)$. Ghiani et al. [5] modified *KTNS* to *Tailored KTNS* with the purpose to calculate a lower bound to the number of switches between two jobs which was used to accurately solve *JeSP*.

PROBLEM FORMULATION

Let's refresh the basic notation for *the job Sequencing and tool Switching Problem (SSP)* and further illustrate them with examples. $T = \{1, 2, \ldots, m\}$ is the set of tools, where m is the number of tools. $J = \{1, 2 \ldots n\}$ is the set of jobs, where n is the number of jobs. $T_i \subset T$ is the set of tools needed to do the job i, where $i \in J$. $C < m$ - capacity (capacity) of the magazine. $M_i \subset T$ is the state of the magazine when the job i is performed i.e. the set of tools located in the magazine at the time of the job i, where $i \in J$, $|M_i| = C$, $T_i \subseteq M_i$. $\boldsymbol{S} = \{S : S = (\sigma(1), \sigma(2), \ldots, \sigma(n))$, where σ is a permutation $\}$ is the set of all reordering of jobs. $\boldsymbol{M}(S) = \{M = (M_1, \ldots M_n) : T_i \subseteq M_i, |M_i| = C, i \in J\}$ is the set of all sequences of magazine states such that jobs can be performed in order $S \in \boldsymbol{S}$. $\boldsymbol{M} = \{M \in \boldsymbol{M}(S) : S \in \boldsymbol{S}\}$ is the set of all possible magazine states. $switches(M) = \sum_{i=1}^{n-1} C - |M_i \cap M_{i+1}|$ is the number of switches for the sequence of magazine states, where $M \in \boldsymbol{M}$. The TLP problem is formulated as finding $\underset{M \in \boldsymbol{M}(S)}{argmin}\{switches(M)\}$. The problem $JeSP$ is formulated as finding $\underset{S \in \boldsymbol{S}}{argmin}\{\underset{M \in \boldsymbol{M}(S)}{min}\{switches(M)\}\}$.

Table 1: Example of $KTNS$ processing.

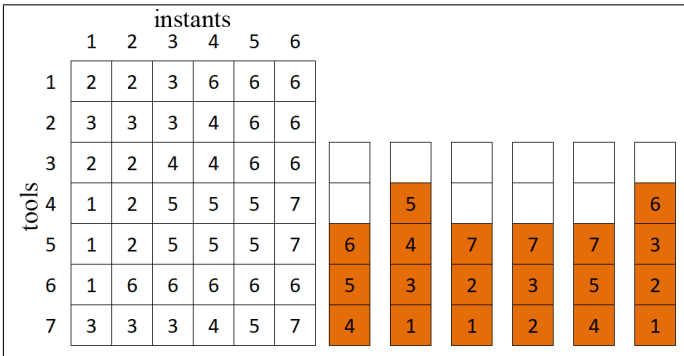
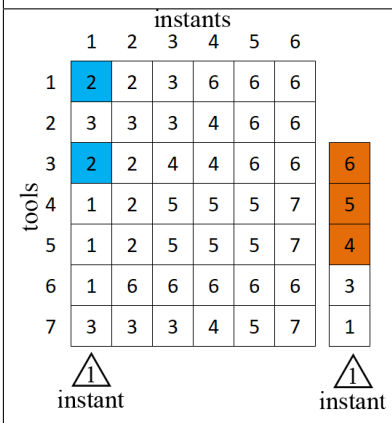
	$T_1 = \{4, 5, 6\}, T_2 = \{1, 3, 4, 5\}, T_3 = \{1, 2, 7\}, T_4 = \{2, 3, 7\}, T_5 = \{4, 5, 7\}, T_6 = \{4, 5, 7\}$ is given sequence of jobs represented as sets of tools that they require(marked in orange). At first KTNS calculates an auxiliary matrix, the element a_{ij} of which denotes the first instant starting from j at which the tool i is needed. For example starting from instant 2 the first instant at which the tool 5 is needed is instant 2 itself, the first instant in which the tool 6 is needed is 6. Starting from instant 6 the tool 4 is never needed again than $a_{4,6} = 7$
	Let's consider the first point in time. Tools required for the job scheduled at this moment $T_1 = \{4, 5, 6\}$ (marked in orange). We fill 3 slots with these tools. The remaining 2 slots are filled with the tools that are needed soonest. We see in the table (column 1) that the 1 tool will be needed at the moment 2, the 2 tool will be needed at the moment 3, the 3 tool will be needed at the moment 2, the 7 tool will be needed at the moment 3. Choose the 1 and 3 tools since they are needed soonest.

Table 2: Example of $KTNS$ processing.

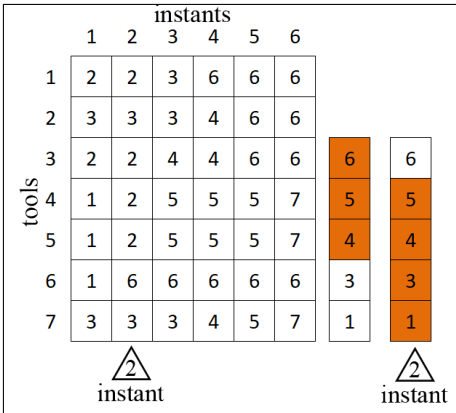
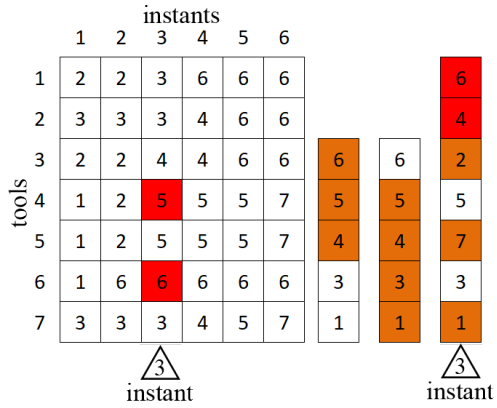
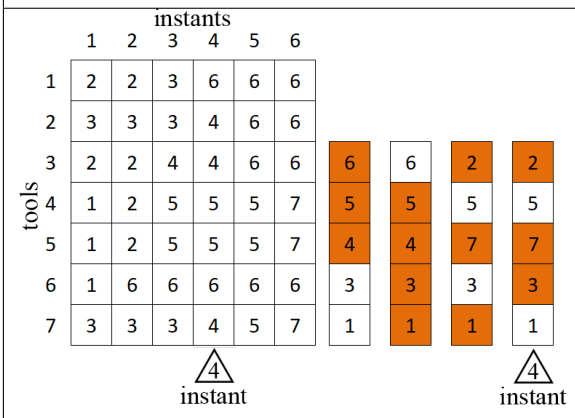
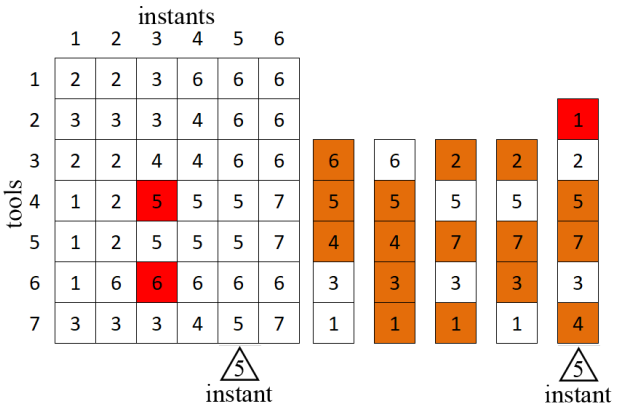
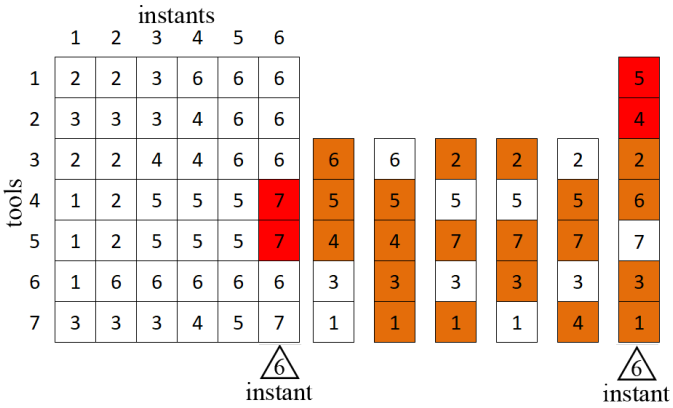
	Let's consider the instant 2. The tools necessary for the job $T_2 = \{1, 3, 4, 5\}$ scheduled at this moment (marked in orange), all these tools were already present at the previous step, so no switches are required. Let's move on to the next step.
	Let's consider the instant 3. Tools required for the job scheduled at this moment $T_3 = \{1, 2, 7\}$ (marked in orange). The 1 tool was already in the magazine in the previous step, and the 7 and 2 tools need to be charged, but the magazine is already full, so you need to remove two tools. Let's remove the tools that are needed later. We see in the table (column 3) that the 3 tool will be needed at the moment 4, the 4 tool will be needed at the moment 5, the 5 tool will be needed at the moment 5, the 6 tool will be needed at the moment 6. Let's remove the 4 and 6 tools as they will be needed later than others. Thus, there were two switches of the tool 6 for the tool 2 and the tool 4 for the tool 7.
	Let's consider the instant 4. The tools required for the job $T_4 = \{2, 3, 7\}$ scheduled at this moment (marked in orange), all these tools were already present at the previous step, so no switches are required. Let's move on to the next step.

Table 3: Example of $KTNS$ execution.

	Let's consider the instant 5. The tools required for the job scheduled at this moment $T_5 = \{4, 5, 7\}$ (marked in orange), The $5, 7$ tools were already in the magazine in the previous step, and the tool 4 needs to be charged, but the magazine is already full , so we need to delete one tool. Let's delete the tool that will be needed later than others. We see in the table (column 4) that the 1 tool will be needed at the instant 6, the 2 tool will be needed at the instant 6, the tool 3 will be needed at the moment 6. Let's remove the tool 1 as it is needed later then others. Instead of 1, it would be possible to delete 2 or 3, which would not affect the total number of switches. Thus, the 1 tool was switched with a 4 tool.
	Let's consider the instant 6. The tools needed for the job scheduled at this moment $T_6 = \{1, 2, 3, 6\}$ (marked in orange), The $2, 3$ tools were already in the magazine in the previous step, and the $1, 6$ tools need to be charged, but the magazine is already full, so two tools must be removed. Let's remove the tools that are needed later than others. We see in the table (column 6) that the 5 tool will be needed at the time 7, the 4 tool will be needed at the time 7, the 7 tool will be needed at the time 7. Let's remove the 4.5 tools as they will be needed later then others. Instead of removing $4, 5$, it would be possible to remove any pair from $4, 5, 7$ without affecting the total number of switches. Thus, there were two replacements of the tool 4 for the tool 6 and the tool 4 for the tool 1. KTNS has finished job with 5 switches.

SOLUTION METHOD

Let's define $\mathscr{T}(M) = \{\pi_{s,e}^{tool} : tool \in (T_s \cap T_e) \backslash (\bigcup_{i=s+1}^{e-1} T_i), tool \in \bigcap_{i=s+1}^{e-1} M_i\}$ as the set of all such triplets $(s, e, tool)$, that the *tool* is used for job at moments s, e, not used for job at moments $s+1, \ldots, e-1$, however, is present in the magazine at moments $s+1, \ldots, e-1$, despite the fact that at these moments the *tool* is not used for job. Let's Consider the main objects of this job - the elements of the set $\mathscr{T}(M)$, we will call them *pipes*, denote $\pi_{start,end}^{tool}$ - pipe with start at *start*, end at *end* and tool *tool*. Fig. 3 shows examples of pipes.

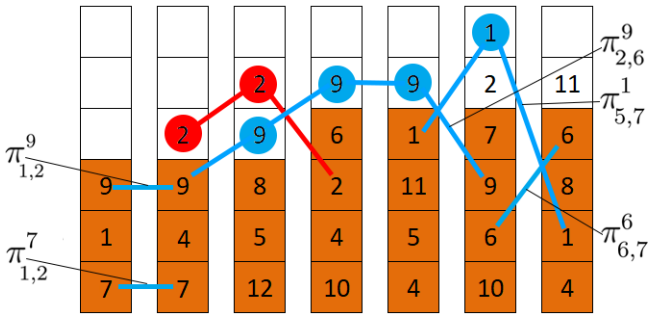


Figure 3: Examples of pipes.

Informally, the pipe is the saving of the *tool* from the moment *start*, where it was used for job (marked in orange) until the moment *end*, where it will again be used for job (marked in orange), but at intermediate points in time $start + 1, \dots end - 1$ it must not be used to job (marked in white). So for example, $\pi^{1}_{5,7}$ saves tool 1 from time 5 to time 7 even though it is not used for job at time 6. Note that $\pi^{7}_{1,2}$ is also a pipe, although there are no intermediate times between the times $1, 2$. The figure marked with a red pipe is not, since at the moment of time 1 the tool 2 is not used for job, i.e. $2 \notin T_1$. Let's call the capacity of the pipe the number of empty slots that is necessary for the existence of the pipe, which is equal to $end - start - 1$.

Algorithm 1: *MPCA*

```
pipes_count := 0
M_1 := T_1, M_2 := T_2, ..., M_n := T_n
for end = 2, ..., n do
    for start = end − 1, ..., 1 do
        candidates := {π^tool_{start,end} : tool ∈ (T_start ∩ T_end)\(⋃_{i=s+1}^{e−1} T_i)}
        empty_slots := min{C − |M_i| : i ∈ {start+, ..., end − 1}}
        if |candidates| > empty_slots then
            candidates := arbitrary elements from candidates in the amount of empty_slots.
        end
        for π^tool_{start,end} ∈ candidates do
            add tool to M_{start+1}, ..., M_{start+2}, ..., M_{end−1}
        end
        pipes_count := pipes_count + |candidates|
    end
end
return pipes_count
```

Theorem 1. Let C be the capacity of the magazine, $T_1, \dots T_n$ are the required sets of tools for jobs $1, \dots, n$, $S \in \boldsymbol{S}$ is the sequence of jobs, then

$$\min_{M \in \boldsymbol{M}(S)} \{switches(M)\} = - \max_{M \in \boldsymbol{M}(S)} \{|\mathscr{T}(M)|\} - C + \sum_{i=1}^{n} |T_i|.$$

Theorem 2. Let C be the capacity of the magazine, $T_1, \dots T_n$ are the required sets of tools for jobs $1, \dots, n$, $S \in \boldsymbol{S}$ is the sequence of jobs, $S \in \boldsymbol{S}$ - sequence of jobs, then

$$MPCA(S) = MPCA(T_1, \dots, T_n;\ C;\ S) = \max_{M \in \boldsymbol{M}(S)} \{|\mathscr{T}(M)|\}.$$

From Theorem 1, Theorem 2 it follows that the value of the objective function in the problem *JeSP* equals $\min\limits_{M \in \boldsymbol{M}(S)} \{switches(M)\} = -MPCA(S) - C + \sum_{i=1}^{n} |T_i|$.

Table 4: Example of $MPCA$ execution.

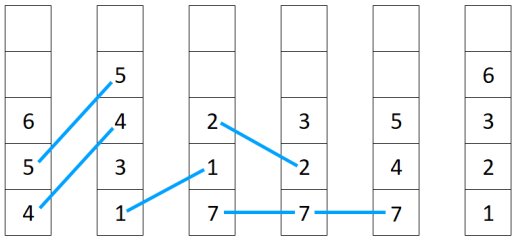
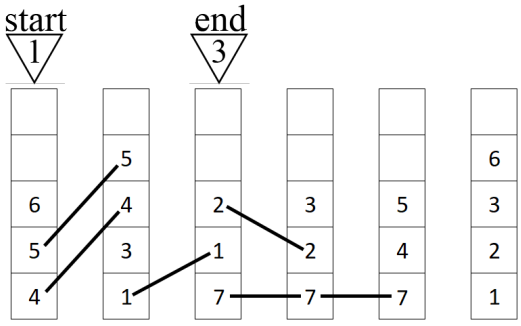
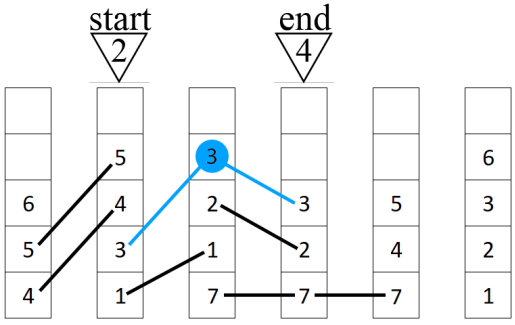
	$T_1 = \{4,5,6\}, T_2 = \{1,3,4,5\}, T_3 = \{1,2,7\}, T_4 = \{2,3,7\}, T_5 = \{4,5,7\}, T_6 = \{1,2,3,6\}$ is given sequence of jobs represented as sets of tools that they require. Let's depict all pipes of capacity 0. What is implemented in the algorithm line 1.
	Let's try to build all possible pipes with end at $end = 3$ and beginning at $start = 1$. There are no such pipes, since there are no tools that are needed both for the job scheduled at the time of 1 and for the job planned at the time of 3, while the time 2 is not needed for the interim memorial, i.e. $(T_1 \cap T_3) \backslash T_2 = \varnothing$.
	Let's try to build all possible pipes with end at $end = 4$ and beginning at $start = 2$. $(T_4 \cap T_2) \backslash T_3 = \{3\}$. At the instant 3 there are two empty slots, one of which we will occupy with the tool 3, thereby constructing a pipe $\pi^3_{2,4}$ with the beginning at the instant 2, the end at the moment 4 and tool 3. Note that pipes with an end at $end = 3$ can no longer be built, since each tool in this instant is already the end of a pipe and any expression of the form $(T_i \cap T_4) \backslash (T_3 \cup T_2 \cup \dots) = \varnothing$ since $T_4 \subseteq T_3 \cup T_2$. Then the iteration where $start = 1$ can be skipped, which is reflected in the MPCA-bitwise in line 9, where the variable $|end\_tools|$ will be equal to zero.

Table 5: Example of $MPCA$ execution.

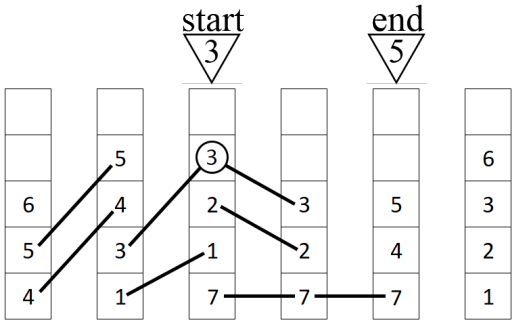
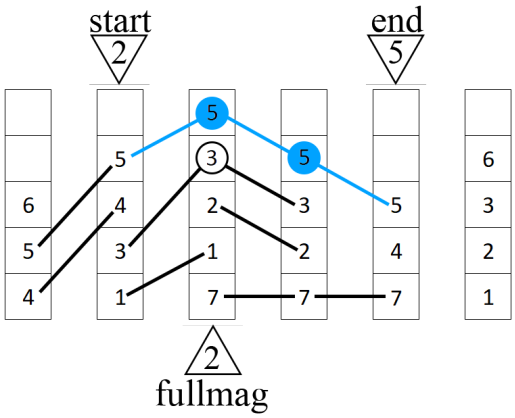
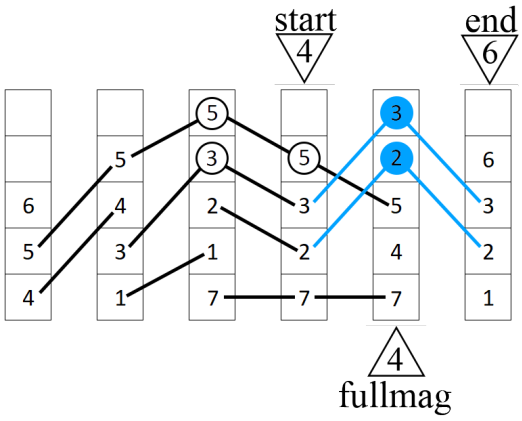
	Let's try to build all possible pipes with end at $end = 5$ and beginning at $start = 3$. There are no such pipes, since there are no tools that are needed both for the job planned at the time of 3 and for the job planned at the time of 5, while the time 4 is not needed for the intervening instant, that is, $(T_5 \cap T_3) \backslash T_4 = \varnothing$.
	Let's try to build all possible pipes with end at $end = 5$ and beginning at $start = 2$. $(T_2 \cap T_5) \backslash (T_3 \cup T_4) = \{4, 5\}$. Then the pipes $\pi^4_{2,5}$ and $\pi^5_{2,5}$ claim to be constructed. At instant 4 there are two empty slots, At instant 3 there is one empty slot, then only one pipe can be built instead of two. Let's take one empty slot at these instants 3.4, thereby constructing a pipe $\pi^5_{2,5}$ with the beginning at the instant 2, the end at the instant 5 and the tool 5. Note that at the instant 3 the magazine is completely full, so no pipes passing through the instant 2 will already be built. Then the iteration $start = 1$ can be skipped, which is MPCA-bitwise in the algorithm in line 9, when $fullmag = 2 > 1 = start$.
	Let's try to build all possible pipes with end at $end = 6$ and beginning at $start = 4$. $(T_4 \cap T_6) \backslash T_5 = \{2, 3\}$. Then the pipes $\pi^2_{4,6}$ and $\pi_{4,6,3}$ claim to be constructed. At the instant 5 there are two empty slots, we will occupy these slots with tools $2, 3$, thereby constructing two pipes $\pi_{4,6,2}$ and $\pi_{4,6,3}$. Note that at the moment of time 5 the magazine is completely full, so no pipes passing through the instant 5 can no longer be built. Then iterations $start = 3, 2, 1$ can be skipped, which is MPCA-bitwise in the algorithm in line 9. MPCA has finished job. There is 10 pipes than number of switches $= \sum_{i=1}^{n} |T_i| - C - 10 = 20 - 5 - 10 = 5$.

Table 6: Example of $MPCA$ execution.

MPCA-bitwise is an efficient implementation of $MCPA$, where the sets T_i and M_i are encoded by 64 -bit vectors, which will allow performing set operations in $\lceil \frac{m}{64} \rceil$ operations. Let's analyze the

complexity. Let's create a sparce table called *possib_tools*. Time to create it $O(nlog(n))$, time to call it $O(1)$. Let l be the maximum pipe length. The variable *end_tools* symbolizes the set of *tool* tools such that the pipe $\pi^{tool}_{start,end}$ can be built, where $start \geq fullmag$. From this variable with each new *start* all pipes $\pi^{tool}_{start,end}$ are removed, than when at the moment when $start = end - l$ variable *end_tools* will become equal to empty set and loop from string 8 will finish job because of *break* from line 10. The loop on line 3 does $n-1$ iterations, the loop on line 8 does no more than l iterations. The 11 line runs in $\lceil \frac{m}{64} \rceil$ operations. Each execution of the line 21 means loading one slot of the magazine, of which there are only Cn, thus 21 will be called at most Cn. Then the time complexity $O(l\lceil \frac{m}{64} \rceil n + nlog(n)) = O(lmn + nlog(n))$.

Algorithm 2: $MPCA - bitwise$

```
1  pipes_count := 0
2  pissib_tools[i][j] := ⋃_{k=i}^{j} T_k for all i < j
3  for end = 2, ..., n do
4      if empty[end − 1] = 0 then
5          fullmag := end − 1
6      end
7      end_tools := T_end ∩ pissib_tools[fullmag][end − 1]
8      for start = end − 1, end − 3, ..., 1 do
9          if fullmag > start or |end_tools| = 0 then
10             break
11         end
12         candidates := T_start ∩ end_tools
13         if |candidates| > 0 then
14             end_tools := end_tools\candidates
15             new_pipes_count := |candidates|
16             if new_pipes_count > 0 then
17                 for j = start + 1, start + 2, ..., end − 1 do
18                     if empty[j] ≤ new_pipes_count then
19                         new_pipes_count := empty[j]
20                         fullmag := j
21                     end
22                     empty[j] := empty[j] − new_pipes_count
23                 end
24                 pipes_count := pipes_count + new_pipes_count
25             end
26         end
27     end
28 end
29 return pipes_count
```

EXPERIMENTAL RESULTS

To compare the speed of computing the SSP objective function we present our computational study of $KTNS$, $MPCA$, $KTNS-bitwise$, $MPCA-bitwise$ algorithms as an intermediate implementations from $KTNS$ to $MPCA-bitwise$.
All computations were performed on an Intel® Core™ i5 CPU 2.60 GHz computer with 4 GB or RAM. $MPCA-bitwise$, $KTNS-bitwise$, $MPCA$ are implemented in $C++$. The implementation of $KTNS$ was taken from the repository published by Mecler et al.[8] Both MPCA and KTNS was compilated with g++ version 10.3.0 using $-O3$ flag.

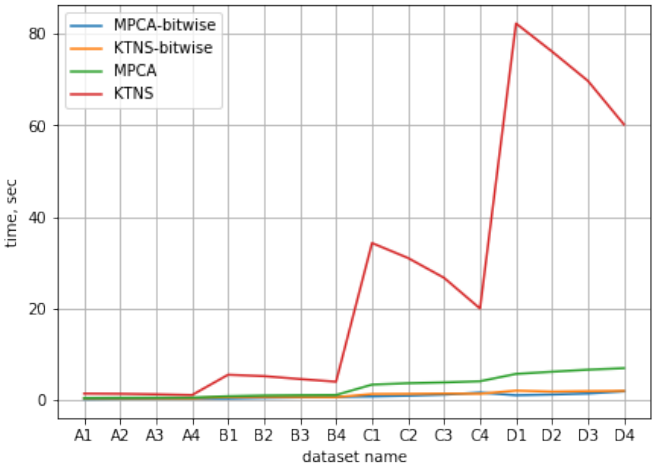


Figure 4: Comparison of KTNS[8], MPCA, KTNS-bitwise, MPCA-bitwise for Catanzaro et. al. datasets.

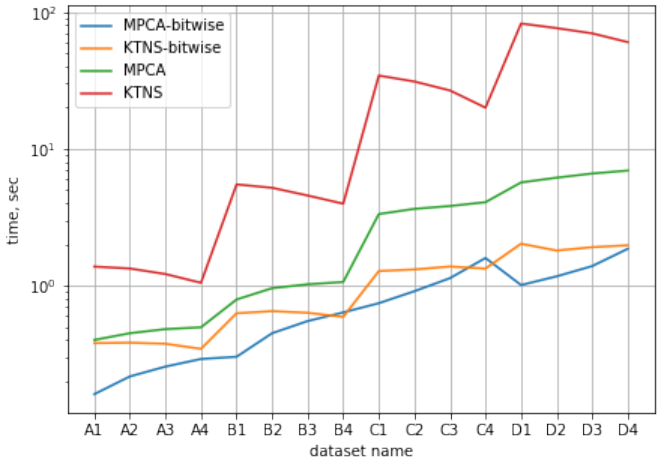


Figure 5: Comparison of KTNS[8], MPCA, KTNS-bitwise, MPCA-bitwise for Catanzaro et. al. datasets in logarithmic scale.

Table 7: Comparison of KTNS[8], MPCA, KTNS-bitwise, MPCA-bitwise, for Catanzaro et. al. datasets.

dataset	n	m	C	KTNS[8]	MPCA	KTNS-bitwise	MPCA-bitwise
A1	10	10	4	1.377	0.401	0.380	0.161
A2	10	10	5	1.334	0.449	0.383	0.217
A3	10	10	6	1.215	0.481	0.376	0.256
A4	10	10	7	1.049	0.496	0.345	0.291
B1	15	20	6	5.493	0.792	0.628	0.302
B2	15	20	8	5.187	0.958	0.651	0.449
B3	15	20	10	4.554	1.023	0.633	0.551
B4	15	20	12	3.969	1.063	0.591	0.637
C1	30	40	15	34.291	3.335	1.278	0.744
C2	30	40	17	31.021	3.640	1.313	0.910
C3	30	40	20	26.690	3.817	1.379	1.134
C4	30	40	25	19.972	4.071	1.333	1.592
D1	40	60	20	82.308	5.677	2.024	1.010
D2	40	60	22	76.167	6.149	1.805	1.169
D3	40	60	25	69.728	6.596	1.909	1.389
D4	40	60	30	60.206	6.931	1.972	1.859

10^5 random job sequences were generated for each Catanzaro et al.[2] dataset, each dataset contains 10 instances, so each row in Table 1 shows the processing time of 10^6 problems by KTNS and proposed MPCA. Results of computational experiments is given in Table 7, Figure 1,2. You can see, as mentioned in the previous section, $KTNS$ is accelerating with C growth, while $MPCA$ is decelerating, which can be seen in the graph as non-monotonicity of $KTNS$. On average, MPCA is 6 times faster than KTNS on type A datasets, 11 times on type B datasets, 28 times on type C datasets, 59 times on type D datasets.

Summary and Future Research Directions

Our $MPCA - bitwise$ algorithm speeds up 59 times on average compared to $KTNS$ for large-scale datasets type D [2]. In further research we aim to obtain a more accurate time complexity of the algorithm and test it on larger SSP benchmark instances. We also intend to measure the effect of incorporating $MPCA - bitwise$ into exact and approximate algorithms for solving SSP. Another goal is to investigate how the pipe characteristics change when increasing the capacity of the magazine C, number of jobs n, number of tools m, and how this correlates with the optimality of the sequence.

PROOF OF THEOREM 1

Let $S = (1, \dots n)$ be a sequence of jobs, $M \in \boldsymbol{M}(S)$ - sequence of magazine states, such that at instant i job i can be performed i.e. $T_i \subseteq M_i$, where $i = 1, \dots, n$.
Let $G_M = (V, A)$ denote graph where $V = \{v_i^{tool} : tool \in M_i\}$ and $A = \{(v_i^{tool}, v_{i+1}^{tool}) : v_i^{tool}, v_{i+1}^{tool} \in V\}$ i.e. arc exists iff tool is planned at instant i and at next instant $i+1$. V shows the content of each slot of the magazine at each moment of time, since $v_i^t \in V$ iff a tool t is contained in magazine at instant i. $(v_i^t, v_{i+1}^t) \in A$ iff no switch of a tool t at instant $i+1$ is needed. Therefore number of tool switches in M is equal to $C(n-1) - |A|$ e.i. the number of all possible places where switch might be needed minus number of places where switch are not needed.

Let's call a needed vertex a vertex v_i^t such that $v_i^t \in T_i$. Let's call a useless vertex a vertex v_i^t such that $v_i^t \notin T_i$.
$\mathscr{T}(M) := \{\pi_{s,e}^t = (v_s^t, \dots, v_e^t) : t \in T_s \cap T_e, t \notin \bigcup_{i=s+1}^{e-1} T_i, t \in \bigcap_{i=s+1}^{e-1} M_i\}$ - the set of all pipes in M.
Let $\mathscr{H}^*(M) := \{P$ - path in $G_M : P$ contains no common arcs with pipes $\}$
$\mathscr{H}(M) := \{P \in \mathscr{H}^*(M) : P$ - inclusion-wise maximal path $\}$
$\mathscr{H}(M) = \mathscr{H}_0(M) \sqcup \mathscr{H}_1(M) \sqcup \dots \sqcup \mathscr{H}_n(M)$, where $\mathscr{H}_r(M) := \{P \in \mathscr{H}(M) :$ there are exactly r needed vertices $\}$

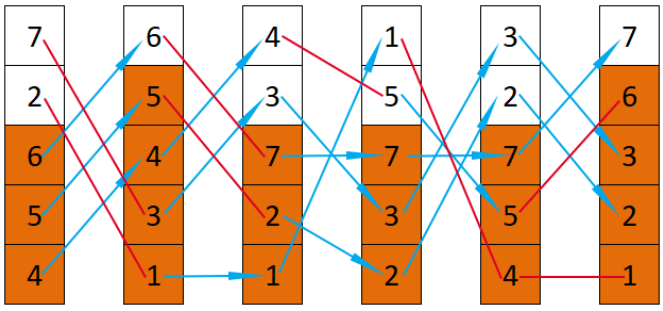


Figure 6: Example of G_M. Blue arcs are arcs of G_M, red lines symbolize switches.

Lemma 1: $\mathscr{H}(M) = \mathscr{H}_0(M) \sqcup \mathscr{H}_1(M)$
Proof:
Let $P \in \mathscr{H}_r(M)$, $r \geq 2$, $P = (v_1^t, \ldots, v_p^t)$ then let's consider two needed vertices v_i^t,v_j^t such that $v_{i+1}^t, \ldots, v_{j-1}^t$ are useless, then P is a pipe $\pi_{i,j}^t$, therefore P contains a pipe as subpath, therefore $P \notin \mathscr{H}^*(M)$, therefore $P \notin \mathscr{H}(M)$ $\square$.

Lemma 1.2. $\forall P \neq P' \in \mathscr{H}(M)\ A(P) \cap A(P') = \varnothing$
Proof: Suppose $P \neq P'$ and $\exists\ a \in A(P) \cap A(P')$, then P, P' belong to one connected subgraph of G_M. Since the arcs are only between adjacent instants and at one instant the tool cannot be present twice, then any connected subgraph of G_M is a path. P, $P' \in \mathscr{H}(M)$ then they are inclusion-wise maximal paths, then if they have a common arc a, then $P = P'$, which leads to a contradiction $\square$.

Lemma 1.3. $\forall \pi \neq \pi' \in \mathscr{T}(M)\ A(\pi) \cap A(\pi') = \varnothing$
Proof: Suppose $\pi_{s,e}^t \neq \pi_{s',e'}^{t'}$ and $\exists a \in A(\pi_{s,e}^t) \cap A(\pi_{s',e'}^{t'})$, then $\pi_{s,e}^t$, $\pi_{s',e'}^{t'}$ belong to one connected subgraph of G_M. Since $\pi_{s,e}^t$ and $\pi_{s',e'}^{t'}$ have common arc a, than $t = t'$ (Since arcs only connect vertices with the same tool). Since $\pi_{s,e}^t$ is a pipe, then $v_{s+1}^t, \ldots v_{e-1}^t$ are useless vertices, then since $v_{s'}^t$ is needed vertex then $v_{s'}^t = v_s^t$ or $v_{s'}^t = v_e^t$. Since $\pi_{s,e}^t$ and $\pi_{s',e'}^{t'}$ have common arc a, then $\pi_{s',e'}^{t'}$ starts no later than $e-1$, with implies $s = s'$. Similar reasoning leads to $e = e'$. $\pi_{s,e}^t$ and $\pi_{s',e'}^{t'}$ have the same start s, the same end e, the same tool t and they belong to one connected subgraph of G_M which is path, then $\pi_{s,e}^t = \pi_{s',e'}^{t'}$, which leads to a contradiction $\square$.

Lemma 1.4. $switches(M) = \sum_{j=1}^n |J_j| - C - |\mathscr{T}(M)| + |\mathscr{H}_0(M)|$
Proof:
According to the **Lemma 1** $A(G_M) = A(\mathscr{T}(M)) \sqcup A(\mathscr{H}(M)) = A(\mathscr{T}(M)) \sqcup A(\mathscr{H}_0(M)) \sqcup A(\mathscr{H}_1(M))$
$\lambda := C \cdot n - \sum_{i=1}^n |T_i|$ i.e. total number of useless vertices G_M.
$\lambda = \lambda_0 + \lambda_1 + \lambda_2$, where λ_0 is number of useless vertices contained in paths from $\mathscr{H}_0(M)$, λ_1 from $\mathscr{H}_1(M)$, λ_2 from $\mathscr{T}(M)$.
Let $P \in \mathscr{H}_0(M)$, then $|A(P)| = |V(P)| - 1 = \#$(useless vertices in P) + #(needed vertices in P) $- 1 = \#$(useless vertices in P) $+ 0 - 1 = \#$(useless vertices in P) $- 1$
Then according to the **Lemma 2** $|A(\mathscr{H}_0(M))| = \sum_{P \in \mathscr{H}_0(M)}(\#$(useless vertices in P) $- 1) = \lambda_0 - |\mathscr{H}_0(M)|$
Let $P \in \mathscr{H}_1(M)$, then $|A(P)| = |V(P)| - 1 = \#$(useless vertices in P) + #(needed vertices in P) $- 1 = \#$(useless vertices in P) $+ 1 - 1 = \#$(useless vertices in P)
Then according to the **Lemma 2** $|A(\mathscr{H}_1(M))| = \sum_{P \in \mathscr{H}_1(M)} \#$(useless vertices in P) $= \lambda_1$.
Let $P \in \mathscr{T}(M)$, then $|A(P)| = |V(P)| - 1 = \#$(useless vertices in P) + #(needed vertices in P) $- 1 = \#$(useless vertices in P) $+ 2 - 1 = \#$(useless vertices in P) $+ 1$
Then according to the **Lemma 3** $|A(\mathscr{T}(M))| = \sum_{\pi \in \mathscr{T}(M))}(\#$(useless vertices in P) $+ 1) = \lambda_2 + |\mathscr{T}(M)|$.
Then $|A(G_M)| = |A(\mathscr{T}(M)) \sqcup A(\mathscr{H}_0(M)) \sqcup A(\mathscr{H}_1(M))| = |A(\mathscr{H}_0(M))| + |A(\mathscr{H}_1(M))| + |A(\mathscr{T}(M))| = \lambda_0 - |\mathscr{H}_0(M)| + \lambda_1 + \lambda_2 + |\mathscr{T}(M)| = \lambda + |\mathscr{T}(M)| - |\mathscr{H}_0(M)| = C \cdot n - \sum_{j=1}^n |T_j| + |\mathscr{T}(M)| - |\mathscr{H}_0(M)|$.
Since $switches(M) = C \cdot (n-1) - |A(G_M)|$, then $switches(M) = C \cdot (n-1) - (C \cdot n - \sum_{j=1}^n |T_j| + |\mathscr{T}(M)| - |\mathscr{H}_0(M)|) = \sum_{j=1}^n |T_j| - C - |\mathscr{T}(M)| + |\mathscr{H}_0(M)|$ $\square$.

Theorem 1. $\min\limits_{M \in \boldsymbol{M}(S)} \{switches(M)\} = \sum_{i=1}^n |T_i| - C - \max\limits_{M \in \boldsymbol{M}(S)} \{|\mathscr{T}(M)|\}$.

Proof:
Since according to **Theorem 4.** $switches(M) = \sum_{j=1}^{n} |T_j| - C - |\mathscr{T}(M)| + |\mathscr{H}_0(M)|$
Let's proof that $\exists M \in \underset{M \in \boldsymbol{M}(S)}{\operatorname{argmax}}\{|\mathscr{T}(M)|\}$ such that $|\mathscr{H}_0(M)| = 0$.
Let's consider an arbitrary $M \in \underset{M \in \boldsymbol{M}(S)}{\operatorname{argmax}}\{|\mathscr{T}(M)|\}$. Let $R_i = \{t : \exists$ path $P \in \mathscr{H}_0(M)$ such that v_i^t in $P\}$.
Than let $M_1' = M_1 \backslash R_1, \ldots, M_n' = M_n \backslash R_n$ i.e. there is $\sum_{i=1}^{n} |R_i|$ empty slots in sequence of magazine states M'.
If it is proved that it is always possible to fill in an empty slot at instant i so that the added tool $t \in M_{i-1}'$ or $t \in M_{i+1}'$, then after $\sum_{i=1}^{n} |R_i|$ repetitions of such a procedure all slots will be filled and $\mathscr{H}_0(M)$ will be empty.
Suppose that there is no M_i with empty slot that $t \notin M_i$ and $t \in M_{i-1} \cup M_{i+1}$, then $M_{i-1} \cup M_{i+1} \subseteq M_i$, then M_{i+1} has empty slot too, than $M_i \cup M_{i+2} \subseteq M_{i+1}$, then $M_i = M_{i+1}$. Then $M_1 = M_2 = \cdots = M_n$ and $|M_1| < C$, than $|\bigcup_{i=1}^{n} M_i| = |M_i| < C$, but $T_i \subseteq M_i'$, $i = 1, \ldots, n$, then $\bigcup_{i=1}^{n} T_i \subseteq \bigcup_{i=1}^{n} M_i$, then $|\bigcup_{i=1}^{n} T_i| < C$, but $|\bigcup_{i=1}^{n} T_i| = m > C$, which leads to a contradiction.
Finally $\exists M^* \in \underset{M \in \boldsymbol{M}(S)}{\operatorname{argmax}}\{|\mathscr{T}(M)|\}$ such that $|\mathscr{H}_0(M^*)| = 0$, then since $\sum_{j=1}^{n} |T_j|$ and C are constants and $|\mathscr{H}_0(M)|$ can be decreased to zero, then $\min\limits_{M \in \boldsymbol{M}(S)}\{switches(M)\} = \sum_{i=1}^{n} |T_i| - C - \max\limits_{M \in \boldsymbol{M}(S)}\{|\mathscr{T}(M)|\}$ $\square$.

PROOF OF THEOREM 2

Let $\boldsymbol{L}(S) = \{L = (L_{S_1}, \ldots, L_{S_n}) : \forall i \in J\ T_i \subseteq L_i, |L_i| \geq C\}$ is a magazine state sequence in which job can be performed in the order $S \in \boldsymbol{S}$, where empty slots are allowed (which limits the conditions $|L_i| \geq C$). Note that $\boldsymbol{M}(S) \subseteq \boldsymbol{L}(S)$, since empty slots are not allowed in $\boldsymbol{M}(S)$, i.e. the magazine will pay in full at every moment of time, i.e. $\forall i \in J\ |M_i| = C$.

Let $possib\_pipes(S) = \{\pi_{s,e}^t : \exists L \in \boldsymbol{L}(S) : \pi_{s,e}^t \in \mathscr{T}(L)\} = \{\pi_{s,e}^t : |T_j| < C, j = s+1, \ldots, e-1, t \in (T_s \cap T_e) \backslash (\bigcup_{i=s+1}^{e-1} T_i)\}$ denote all possible pipes that can be constructed(not at the same time), where S is a sequence of jobs.
Let $can\_construct(L) = \{\pi_{s,e}^t \in possib\_pipes(S) : t \notin L_j, |L_j| < C, j = s+1, \ldots, e-1\}$ denote all pipes that can be constructed in L.
We denote by $\widehat{\boldsymbol{L}}(S)$ the set of all possible sequences of the state of the magazine with possible empty slots, empty slots were filled only when constructing pipes.
Lemma 2.1: Let $L \in \widehat{\boldsymbol{L}}(S)$ then $can\_construct(L) = \{\pi_{s,e}^t \in possib\_pipes(S) \backslash \mathscr{T}(L) : \forall j \in \{s+1, \ldots, e-1\}\ |L_j| < C\}$.
That is if only pipes has been constructed in L, than pipe $\pi_{s,e}^t$ can be constructed iff $\pi_{s,e}^t$ has not been constructed in L and there is enough empty slots to construct $\pi_{s,e}^t$.
Proof:
Based on the definition of $can\_construct(\cdot)$, it suffices to prove that if $L \in \widehat{\boldsymbol{L}}(S)$ and $\pi_{s,e}^t \in possib\_pipes(S) \backslash \mathscr{T}(L)$, then $\forall j \in \{s+1, \ldots, e-1\}\ t \notin L_j$. Suppose $\exists j \in \{s+1, d \ldots, n\} : t \in L_j$, since $\pi_{s,e}^t$ is a pipe, then $\forall i \in \{s+1, \ldots, e-1\}\ t \notin T_i$, , then $t \notin T_j$, which implies that vertex v_j^t is useless, then since only pipes has been constructed $\exists \pi_{s',e'}^t \in \mathscr{T}(L) : s' < j < e'$. Since $\pi_{s',e'}^t$ is a pipe, than $\forall i \in \{s'+1, \ldots, e'-1\}\ t \notin T_i$, and since $\pi_{s,e}^t$ is a pipe, than $t \in T_s$, than $s \leq s'$. Since $\pi_{s,e}^t$ is a pipe, than $\forall i \in \{s+1, \ldots, e-1\}\ t \notin T_i$, and since $\pi_{s',e'}^t$ is a pipe, than $t \in T_{s'}$ than $s' \leq s$, then $s = s'$ and similarly $e = e'$, which implies that $\pi_{s',e'}^t$ and $\pi_{s,e}^t$ are the same pipe, then

$\pi^t_{s,e} \in \mathscr{T}(L)$ and $\pi^t_{s,e} \in possib\_pipes(S)\backslash\mathscr{T}(L)$, which leads to a contradiction $\square$.
Further we always assume that $L \in \widehat{\boldsymbol{L}}(S)$, since we will only talk about constructing and removing pipes and otherwise empty slots will not be filled.
Let $\boldsymbol{L}_{opt}(S) = \{L \in \widehat{\boldsymbol{L}}(S) : |\mathscr{T}(L)| = max\{|\mathscr{T}(M)| : M \in \boldsymbol{M}(S)\}\}$, i.e. this is the set $L \in \widehat{\boldsymbol{L}}(S)$: L contains the smallest possible number of pipes.
Let $L \notin \boldsymbol{L_{opt}}(S)$, then L does not contain the maximum possible number of pipes, i.e. you can remove some (possibly all) constructed pipes, let them be r_1 pieces, and then build another set of pipes of capacity $r_2 > r_1$. $L \notin \boldsymbol{L_{opt}}(S)$ then $\exists K \subseteq possib\_pipes(S)$: if we remove K from L, then it will be possible to construct $K' \subseteq pipes(S) : |K'| > |K|$ and vice versa , if there is such a pair (K, K'), then L contains not the maximum possible number of pipes, i.e. $L \notin \boldsymbol{L_{opt}}(S)$. Let us define $\mathscr{K}(L)$ as the set of all such pairs (K, K'). And therefore $\mathscr{K}(L) = \varnothing \iff L \notin \boldsymbol{L_{opt}}(S)$.
Let $\mathscr{K}_{min}(L) := \{(K, K') \in \mathscr{K}(L) : \nexists(\widetilde{K}, \widetilde{K}') \in \mathscr{K}(L) : \widetilde{K} \subseteq K$ and $\widetilde{K}' \subseteq K'$ and ($\widetilde{K} \neq K$ or $\widetilde{K}' \neq K')\}$ i.e. there are many such pairs in which there are no deletions and constructions that could be excluded (for example, it is pointless to delete and add the same pipe).
Since $\mathscr{K}_{min}(L) = \varnothing \iff \mathscr{K}(L) = \varnothing$, then
Lemma 2.2: $L \in \boldsymbol{L_{opt}}(S) \iff \mathscr{K}_{min}(L) = \varnothing$.

Let $needed\_instants(\pi^{tool}_{start,end}) = \{start + 1, start + 2, \ldots, end - 1\}$, i.e. the set of all times in which at least one empty slot is needed to build the pipe $\pi^{tool}_{start,end}$. Let $needed\_instants(K) = \bigcup_{\pi^t_{s,e} \in K} needed\_instants(\pi^t_{s,e})$ i.e. the set of all times in which at least one empty slot is needed to construct the pipe $\pi^t_{s,e}$: $\pi^t_{s,e} \in K$.

Lemma 2.3: Let $(K, K') \in \mathscr{K}(L), \pi^t_{s,e} \in K, \tau^{t'}_{s',e'} \in K'$, then if
$needed\_instants(\pi^t_{s,e}) \cap needed\_instants(K') \subseteq needed\_instants(\tau^t_{s,e})$, then $(K, K') \notin \mathscr{K}_{min}(L)$
Proof:
Let's denote $\pi = \pi^t_{s,e}$, $\tau = \tau^{t'}_{s',e'}$. We get L^0 by removing K from L. We obtain L^τ by constructing τ in L^0. We obtain L^π by constructing π in L^0. $\widetilde{K}' := K'\backslash\{\ \pi\}$. Thus, $\widetilde{K}'$ can be constructed in L^π, let us prove that $\widetilde{K}'$ can also be constructed in L^τ. Since $needed\_instants(\pi)$ $\cap$ $needed\_instants(K') \subseteq needed\_instants(\tau)$, then $needed\_instants(\pi) \cap needed\_instants(K') \subseteq$ $needed\_instants(\tau) \cap needed\_instants(K')$. Since $\widetilde{K}' \subseteq K'$, then
$needed\_instants(\pi) \cap needed\_instants(\widetilde{K}') \subseteq needed\_instants(\tau) \cap needed\_instants(\widetilde{K}')$, which (according to **Lemma 2.1**) means that $\widetilde{K}'$ can be constructed in L^π, then $\widetilde{K}'$ can also be constructed in L^τ that is π can be excluded from the set of K being removed, and τ can be excluded from the set of K' being added. Then $\widetilde{K} := K\backslash\{\pi\}$,$\widetilde{K}' := K'\backslash\{\tau\}$,then $\exists\,(\widetilde{K}, \widetilde{K}') \in \mathscr{K}(L) : \widetilde{K} \subset K$ and $\widetilde{K}' \subseteq K'$, therefore $(K, K') \notin \mathscr{K}_{min}(L)$. $\square$

Example: $needed\_instants(\widetilde{K}') := \{2, 3, 4\}$, $needed\_instants(\pi) := \{3, 4, 5, 6, 7\}$,
$needed\_instants(\tau) := \{3, 4\}$. According to **Lemma 2.1** since pipes from $\widetilde{K}'$ will not use slots whose time points are from $\{5, 6, 7\}$, then for the possibility of constructing $\widetilde{K}'$, it does not matter whether they are filled or not, it is important only is there enough empty slots at the time instants $needed\_instants(\widetilde{K}')$, then the "threat" for $\widetilde{K}'$ from constructing π is $needed\_instants(\widetilde{K}')$ $\cap$ $needed\_instants(\pi) = \{3, 4\}$, the "threat" to $\widetilde{K}'$ from building τ is $needed\_instants(\widetilde{K}') \cap$ $needed\_instants(\tau) = \{3, 4\}$ i.e. with respect to $\widetilde{K}'$ the construction of π is no worse than the construction of τ, and if so, if π is contained in the set of K to be removed, τ is contained in the set of K' to be added, then π, τ can be simultaneously removed from these sets by obtaining the

sets $(\widetilde{K}, \widetilde{K}') \in \mathscr{K}(L)$, then by definition $\mathscr{K}_{min}(L)$ it is true that $\mathscr{K}_{min}(L)$ does not contain (K, K').

Theorem 1: $|\mathscr{T}(MPCA(S))| = max\{|\mathscr{T}(M)| : M \in \boldsymbol{M}(S)\}$

Proof:
According to **Lemma 2.2**, it will suffice to prove that $\mathscr{K}_{min}(L) = \varnothing$, where $L = MPCA(S)$
Suppose the opposite, i.e. $\exists (K, K') \in \mathscr{K}_{min}(L)$. Since the Algorithm 1 tries to build all pipes from $possib\_pipes(S)$ and builds if possible. Then it is impossible to complete one more pipe in L without deleting one before this, therefore the set of pipes to be removed is always not empty. $K \neq \varnothing$ and since by definition $|K'| > |K|$, then $K' \neq \varnothing$.
$min\_end(K) := min\{end : \pi^{tool}_{start,end} \in K\}$

Case 1: $e = min\_end(K) = min\_end(K') = e'$.
Then let $\pi^{t}_{s,e} \in K$, $\pi^{t'}_{s',e'} \in K'$. 2 cases are possible

1. $s \geq s'$. Then since $e' = e$, then $needed\_instants(\pi^{t}_{s,e}) \subseteq needed\_instants(\pi^{t'}_{s',e'})$. Therefore, according to the Lemma 2.3 $(K, K') \notin \mathscr{K}_{min}(L)$, which leads to a contradiction.

2. $s < s'$. Since $needed\_instants(\pi^{t'}_{s',e'}) \subseteq needed\_instants(\pi^{t}_{s,e})$, then after deletion $\pi^{t}_{s,e}$ it will be possible to build $\pi^{t'}_{s',e'}$ and therefore it will be possible to move on to $(\widetilde{K}, \widetilde{K}') : \widetilde{K} = K \backslash \{\pi^{t}_{s,e}\}$, $\widetilde{K}' = K' \backslash \{\pi^{t'}_{s',e'}\}$. It is impossible to endlessly get into **Case 1.2** because each time the cardinality of K and K' decreases by 1.

Case 2: $e = min\_end(K) < min\_end(K') = e'$.
Then let $\pi^{t}_{s,e} \in K$, $\pi^{t'}_{s',e'} \in K'$. 2 cases are possible:

1. $s \geq s'$. Then since $e < e'$, then $needed\_instants(\pi^{t}_{s,e}) \subseteq needed\_instants(\pi^{t'}_{s',e'})$. Therefore, according to Lemma 2.3 $(K, K') \notin \mathscr{K}_{min}(L)$, which leads to a contradiction.

2. $s < s'$. Let $s'' = min\{i : \pi^{k}_{i,j} \in K'\}$ and we will consider the pipe $\pi^{t''}_{s'',e''} \in K'$, then
since $s' \geq s''$ either we go to **Case 2.1**, or $s < s''$ and from the minimality of s'' and $e < e''$ it follows that $needed\_instants(\pi^{t}_{s,e}) \cap needed\_instants(K') \subseteq needed\_instants(\pi^{t''}_{s'',e''})$. Therefore, according to L emma 4 $(K, K') \notin \mathscr{K}_{min}(L)$, which leads to a contradiction.

Case 3: $e = min\_end(K) > min\_end(K') = e'$.
Then let $\pi^{t'}_{s',e'} \in K'$, $s = min\{i : \pi^{k}_{i,j} \in K, j = end\}$, $\pi^{t}_{s,e} \in K$.
Emptying the slots at each of the times from the set $needed\_instants(\pi^{t'}_{s',e'}) \cap needed\_instants(K)$ will allow you to build a pipe $\pi^{t'}_{s',e'}$, otherwise even after removing K it would not be possible to build the pipe $\pi^{t'}_{s',e'}$. But note that s is minimally possible and $e > e'$, which implies that $needed\_instants(\pi^{t'}_{s',e'}) \cap needed\_instants(K) \subseteq needed\_instants(\pi^{t}_{s,e})$, which means that after removing the pipe $\pi^{t}_{s,e}$ it will be possible to construct $\pi^{t'}_{s',e'}$. Consequently, the Algorithm 1 constructed the pipe $\pi^{t'}_{s',e'}$ at an iteration earlier than $\pi^{t}_{s,e}$, since $e' < e$, and the Algorithm 1 iterates over the variable *end* in ascending order. At the iteration, when the variable *end* was equal to e', the pipe $\pi^{t'}_{s',e'}$ should have been built, since at that moment the pipes $\pi^{t}_{s,e}$ didn't exist yet, which is the same as it was removed. From which it follows that $\pi^{t'}_{s',e'}$ has already been built, which contradicts the fact that it belongs to K'. Let's move on to $(\widetilde{K}, \widetilde{K}') : \widetilde{K} = K \backslash \{\pi^{t'}_{s',e'}\}$, $\widetilde{K}' = K' \backslash \{\pi^{t'}_{s',e'}\}$

and note that after removing $\widetilde{K}$ it will be possible to build $\widetilde{K}'$ i.e. $(\widetilde{K}, \widetilde{K}') \in \mathscr{K}(L)$, but $\widetilde{K} \subset K$, $\widetilde{K}' \subseteq K'$. Then, by the definition of $\mathscr{K}_{min}(L)$, $(K, K') \notin \mathscr{K}_{min}(L)$, which leads to a contradiction. **Case 1**, **Case 2**, **Case 3** led to a contradiction, hence the assumption about $\exists (K, K') \in \mathscr{K}_{min}(MPCA(S))$ is not true, then by Lemma 2.2 we have $MPCA(S) \in \boldsymbol{L_{opt}}(S)$, which means that $|\mathscr{T}(MPCA(S))| = max\{|\mathscr{T}(M)| : M \in \boldsymbol{M}(S)\}$ $\square$.

REFERENCES

[1] Ahmadi, E. & Goldengorin, B. & Süer, G.A. & Mosadegh, H. A hybrid method of 2-TSP and novel learning-based GA for job sequencing and tool switching problem. Applied Soft Computing, 65,(2018) 214-229. https://doi.org/10.1016/j.asoc.2017.12.045

[2] Catanzaro, D. & Gouveia, L. & Labbé, M. Improved integer linear programming formulations for the job Sequencing and tool Switching Problem, Eur. J. Oper. Res. 244 (2015) 766–777, http://dx.doi.org/10.1016/j.ejor.2015.02.018.

[3] Calmels, D. The job sequencing and tool switching problem: State-of-the-art literature review, classification, and trends. 2019. International Journal of Production Research 57, 5005–5025 https://doi.org/10.1080/00207543.2018.1505057

[4] Crama, Y. & Kolen, A.W.J. & Oerlemans, A.G. & Spieksma F.C.R. Minimizing the number of tool switches on a flexible machine, Int. J. Flex. Manuf. Syst. 6 (1994) 33–54, http://dx.doi.org/10.1007/BF01324874

[5] Ghiani, G. & Grieco, A. & Guerriero, E. Solving the job sequencing and tool switching problem as a nonlinear least cost hamiltonian cycle problem. 2010. Netjobs 55, 379–385. https://doi.org/10.1002/net.20341

[6] Goldengorin, B. & Romanuke, V. V. Experimental analysis of tardiness in preemptive single machine scheduling. Expert Syst. Appl., 186, (2021) 114947, https://doi.org/10.1016/j.eswa.2021.114947

[7] Johnson D. A theoretician's guide to the experimental analysis of algorithms, DIMACS Series in Discrete Mathematics and Theoretical Computer Science. 2002. V. 59 https://doi.org/10.1090/dimacs/059

[8] Mecler, J. & Subramanian, A. & Vidal T. A simple and effective hybrid genetic search for the job sequencing and tool switching problem Computers and Operations Research. 2021. 127, 105153 https://doi.org/10.1016/j.cor.2020.105153

[9] da Silva, T. T. & Chaves, A. A. & Yanasse, H. H. A new multicommodity flow model for the job sequencing and tool switching problem. International Journal of Production Research, 59, (2021) 3617–3632, https://doi.org/10.1080/00207543.2020.1748906

[10] Tang, C.S. & Denardo E.V. Models arising from a flexible manufacturing machine, part I: minimization of the number of tool switches, Oper. Res. 36, http://dx.doi.org/10.1287/opre.36.5.767.

AN INTEGRATIVE FRAMEWORK OF ANTECEDENTS AND CONSEQUENCES OF TRANSACTIVE MEMORY SYSTEMS

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ABSTRACT

When two or more individuals interact and share information, they form a mutual memory system where they can store the knowledge gained from each other. This system of "group think" where individuals in a group learn, store, use, and coordinate knowledge to achieve goals is known throughout literature as a Transactive Memory System (TMS). This study presents research examining antecedents, consequences, and components of TMSs through a comprehensive framework. 80 of the most significant studies on TMSs between 1985 and 2021 have been explored. The extant work is combined to derive new insights, implications, and areas of future research.

INTRODUCTION

Studies in psychology, information science, and management have surmised the importance of individuals in the creation and exchange of information. These studies have been inspired by the dynamic shared within sports teams, couples, armed forces, and insects such as bees. This concept has then been applied to large organizations that thrive on efficient knowledge transfer for competitive advantage. When two or more individuals interact and share information, they form a mutual memory system where they can store the knowledge gained from each other. While an individual's cache of stored knowledge, both tacit and explicit, may assist in solving problems and enhancing the performance of an organization, a mutual memory system, based on shared experiences and information from multiple sources, can help an organization in more ways than one would expect. Team cohesiveness increases and employee turnover decreases as each individual contributes significantly to the creation of such a system (Paulus *et* al., 2012). This system of "group think" where individuals in the group learn, store, use and coordinate knowledge to achieve goals (Hollingshead, 2001; Wegner, 1986; Argote and Ren, 2012) is known throughout literature as a *transactive memory system*.

The theory of the *group mind* has not been validated so far in the operations management literature. Much of the extant literature attributes group performance to certain environmental factors or characteristics of the group itself (Austin, 2003; Huang & Chen, 2018; Bacharach & Mullins, 2019). However, groups think the same way individuals think. Just as different parts of the human brain assist an individual to perform different actions, different members of a group can contribute uniquely to complete a given task. The group undergoes mental activity to guide its next action. Group behavior can be predicted when researchers understand how groups process and structure information (Wegner, 1987). This is where the role of transactive memory systems (TMSs) becomes evident.

The knowledge of teams within an organization resides inside its work processes, interactions, physical repositories and minds of its employees. The crucial knowledge lying inside the minds of individuals working in the organization can significantly impact the collective knowledge accumulated to drive individual performance and in turn, team or organizational performance (Cross & Baird, 2000). Individual memory is important for the growth of the organization, but it is concerned with only a single person's perceptions, experience and expertise regarding team or organizational matters. On the other hand, when a network of individuals, who know each other's areas of expertise, communicate with each other and create a transactive memory system (TMS), a more expansive assortment of information is created. It benefits the organization in a far greater capacity than just an individual's memory and information. When this mechanism of sharing becomes more structured and differentiated, sending and requesting information from appropriate individuals becomes easier and more efficient (Palazzolo, 2006). The basic idea is that people develop transactive memory systems through shared interactions about each other's domains of expertise (Wegner, 1987; Brandon & Hollingshead, 2004). In simple terms, these systems contain knowledge of "who knows what and is best at doing what" (Argote, 2015).

TABLE 1: TMS DEFINITIONS OVER THE YEARS

Definition	Author(s)
Collective memory systems	Liang *et* al., 1995; Wegner, 1986, 1995; Wegner, 1991; Wegner, 1985
Cognitive structures	Lewis, 2003; Peltokorpi, 2014
Shared divisions of cognitive labor	Austin, 2003; Littlepage, 2008; Zheng, 2012
Specialized divisions of labor	Kanawattanachai & Yoo, 2007; Lewis, 2004; Huang, 2013
Differentiated structures	Argote & Ingram, 2000; Walsh & Ungson, 1991
Group-level social-cognitive structures	Dai, 2016; Kanawattanachai & Yoo, 2007
Mechanisms of interpersonal knowledge transfers	Argote & Miron-Spektor, 2011

The existing literature consistently defines these transactive memory systems in different ways. While early researchers define them as collective memory systems (Liang *et* al., 1995; Wegner, 1986, 1995; Wegner, 1991; Wegner, 1985), contemporary research has

used terms such as cognitive structures, shared divisions of cognitive labor, group-level social-cognitive structures, and mechanisms of interpersonal knowledge transfers (Argote & Ingram, 2000; Lewis, 2003; Lewis, 2004; Littlepage, 2008; Argote & Miron-Spektor, 2011; Zheng, 2012; Huang, 2013; Peltokorpi, 2014).

These transactive memory systems are used to encode, store and retrieve information about each other's domains of expertise, exchanged between members of a group to enhance the performance of the group and more broadly, of the organization as a whole. Deriving from the literature, this study aims to propose a simpler definition of TMS that is more generalizable and inclusive of extant definitions, as follows:

A Transactive Memory System is a collective repository of individual memory systems and interactions between individuals in groups and organizations about the location of expertise, that helps to encode, store, retrieve and communicate relevant shared knowledge.

TMSs can be formed when members with individual expertise come together and share knowledge in order to create a directory about "who knows what". From a supply-chain context, these members can be part of consulting teams, research teams, product development teams, and other cross-functional project teams. The purpose of these teams is to capitalize on the specialized skills of the individual team members (Lewis, 2003). TMSs are increasingly being recognized as important, yet puzzling because researchers are trying to identify ways to improve their effectiveness in varying environmental conditions. Considering their nature, TMSs are expected to survive and perform effectively in complex situations.

However, a TMS can become a black box if organizations are only interested in increasing their performance through its application. How do TMSs ensure synchronicity and continuing flow of information? Does the behavior of its individual members need to be planned or trained? Are members of a TMS ready and open to learning? TMSs are dynamic by nature. When faced with an atypical situation, TMSs might need to perform in non-routine ways to give unique responses. Understanding these mechanisms behind a TMS can help organizations employ resources for its maintenance and upkeep.

Transactive memory systems may learn and develop over time but they still need to be ready to respond at any moment. Dynamic situations can reduce the control that TMSs have over the application of their solutions. Once faced with a distinct circumstance, a TMS needs to store the response in its memory in case such a situation emerges again at any point in time. Since learning is more 'operational' than 'theoretical' for TMSs, they need to constantly configure their efficiency and effectiveness for better performance. This study aims to answer some of the questions mentioned above to better understand transactive memory systems.

LITERATURE REVIEW

Sociologists like Lebon and McDougall have advocated their theory of the group mind where the individual loses his sense of responsibility and personal consciousness when he becomes part of the group. This group or crowd comes to develop its own crowd consciousness and performs non-essential and non-productive activities. On the other hand, Daniel Wegner's theory of transactive memory systems promotes interpersonal knowledge transfer and communication. The group mind is synced with the individual's mind. There is increased within-group accountability and better performance is achieved due to collective group memory (Wegner, 1987).

Even prominent theories of supply chain management such as the knowledge-based view of the firm, organization information processing theory and socio-technical theory have major differences with the theory of transactive memory systems. The knowledge-based view of the firm (Grant, 1996, 2002; Alavi & Leidner, 2001)) considers knowledge as a strategically important resource required to build competitive advantage for an organization. But it studies actions performed at the firm level rather than the individual level. TMS, on the other hand, considers the expertise of individuals within groups and is measured at the group level. The organization information processing theory (Galbraith, 1973) is concerned with the organization constantly coping with information processing needs. Structural mechanisms are required to increase information flow within the organization, so the focus is once again on the organization. However, TMS does not require any external mechanisms for information transfer. Information processing time is decreased due to the presence of the TM directory that is constantly encoded and updated. Socio-technical theory (Bostrom & Heinen, 1977; Kull *et* al., 2013) measures the interaction and interdependency between employees and technology towards better performance of the organization. Unlike the socio-technical theory, TMS is observed at the group level rather than the organizational level. Also, it looks into the interaction between individuals for better TMS and form performance.

Such differences between renowned SCM theories and TMS highlight the need for transactive memory systems to be considered as a separate, standalone theory. Transactive memory systems have been extensively studied for over three decades and much of the work regards the concept to be a theory in itself. However, the standards set for theory building (Bacharach, 1989; Whetten, 1989) call for a deeper investigation of the constructs, relationships, boundaries and functions of TMSs.

A TMS manifests itself through specialization, coordination and credibility of exchanged information. These form the underlying constructs of strong and effective transactive memory systems (Lewis, 2003; Oshri *et* al., 2008; Noroozi, 2013; Chung *et* al., 2015; Wang *et* al., 2018; Ali *et* al., 2019). Transactive memory only exists when a team member comprehends what another person knows and uses it to develop his or her own different knowledge base. Conversely, when members develop a distinct transactive memory system, it causes their information to be differentiated and specialized (Lewis, 2003). This differentiation of knowledge is where the real benefit of a TMS is enacted because, with less overlap in member's areas of expertise, distribution of labor becomes easier and the team

can become more efficient (Wegner 1987). Specialization leads to better information retrieval, preventing redundancy and supplying more access to the range of expertise within the group (Hollingshead, 1998; Noroozi, 2013).

A strong TMS is not only achieved through specialization but also through the extent to which team members believe that the knowledge they gain through exchanges is correct and accurate. If a particular member's area of expertise has been used on several occasions without any issue or threat to accuracy, other group members begin to trust the information and in turn, the member who provides it (Wegner, 1987). That aids in the development of a more credible transactive memory system (Lewis, 2003; Wang *et* al., 2018). A more efficient TMS is one where all team members implicitly coordinate with each other, acknowledge others' strengths and weaknesses, anticipate behaviors within a team, respond appropriately, and make quick adjustments in their own behaviors in return (Chung *et* al., 2015; Lewis, 2003; Ali *et* al., 2019). Groups that have developed a specialized transactive memory find it easier to coordinate and obtain credible information about a particular group member's area of expertise.

Relationships are formed within a TMS through the development of a transactive memory system involving three stages: directory updating, information allocation and retrieval coordination (Wegner, 1987, 1995). These interdependent stages are transactive, meaning that processes impacted by TMSs get constantly updated due to information exchange between members. In the directory updating (encoding) stage, team mates gather information on their counterparts' domains of knowledge and assign each knowledge domain to the specific team member through the "who knows what" information exchange (Wegner, 1987, 1995; Rulke & Rao, 2000). Through this process, team mates take the first essential step towards specialization.

Once the directory containing this information is updated (Oshri *et* al., 2008), team members are better able to store information with the individual who holds relevant knowledge and expertise related to the knowledge acquired. This process improves the learning process and reduces load on the memories of random team mates. In the retrieval stage, group members use the stored information to identify the experts in a required knowledge area. They can then turn to that member to attain the knowledge. Accuracy of this information can strengthen the linkage between members of the team. However, if the information is not accurate, the encoding stage can begin again (Wegner, 1987, 1995).

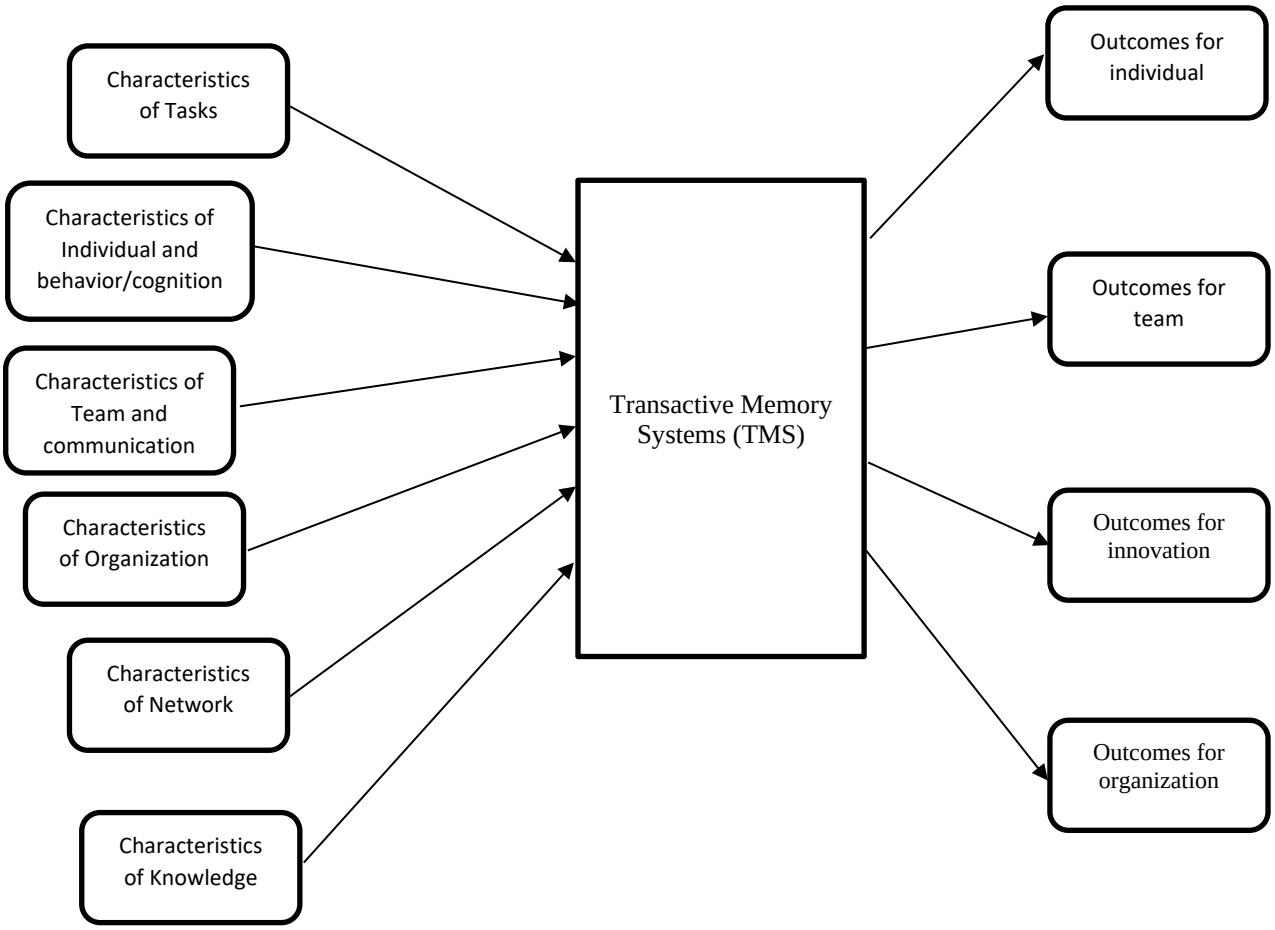
TMSs can enhance the performance of a team or group through the division of responsibility of different kinds of information on different team members by allowing each member to broaden his own knowledge in a specific area while maintaining a directory of other members' expertise. Developing TMSs can also shorten the time needed to search for appropriate knowledge. If each team member knows who to approach for the required knowledge, less time will be wasted in searching for the same. Due to the formation of transactive memory systems which mature with time, team members may be able to better predict and anticipate team behavior, leading to more cohesive and coordinated interactions as well as better performance (Lewis & Herndon, 2011).

TMSs may only be helpful for certain kinds of groups or tasks. Lewis & Herndon (2011) explored criteria for the kinds of tasks that use TMSs to improve performance. They include tasks that require diverse and specialized knowledge, tasks where it is possible to know which members possess expertise, tasks that need complete application of knowledge, tasks where efficient coordination between members is important, and tasks where credibility and accuracy of knowledge is important. The same can be said in the case when the environment for evolution and maturity of TMS turns hostile or the team members start behaving erratically. A transactive memory system only holds when the team members are willing and inclined towards better performance of the team and the organization, as a whole. If members have conflicting goals, no one benefits from the transactions.

TMS FRAMEWORK

Figure 1 summarizes the antecedents and consequences of transactive memory systems in extant research. A more detailed framework can be found in Appendix I which includes mediators and moderators as well. Eighty articles collected between 1985 and 2019 are depicted in this integrative framework. The articles are collectively presented in Appendix II at the end of the manuscript.

FIGURE 1: TMS FRAMEWORK



Classifications of all the constructs in the framework are done on the basis of characteristics of task, individual, team/group, network, organization, or environment. TMS is represented in the center, including various ways it has been operationalized and measured in the existing literature. The framework clearly divides constructs on the basis of unit of analysis to help researchers and practitioners in deciding which aspects of task, individual, team/group, network, organization, and/or environment can impact the formation of a well-structured and efficient transactive memory system. Table 2 depicts the number of articles in various types of studies conducted in the last thirty years.

TABLE 2: NUMBER OF ARTICLES IN VARIOUS STUDIES BETWEEN 1985 AND 2019

Study	Number of articles
Case study	4
Conceptual	17
Field and lab experiments	20
Literature Review	2
Secondary data	1
Survey based	36

ANTECEDENTS OF TMS

Characteristics of Knowledge

Transactions between individuals link their memory systems such that encoded information can be stored and alter retrieved for use. This encoding of information is done by categorizing the location of knowledge expertise in an individual's internal memory as well as externally in objects or other people's memories (Oshri *et* al., 2008; Yuan *et* al., 2010). For a TMS to work, this information of 'who knows what', also known as directory updating, must be developed and organized frequently. That will help in adopting the correct methodologies when faced with a difficult task and maintain the TMS as a well-oiled machine.

Representatives from different knowledge domains work together to accomplish a joint outcome by facing knowledge differentiation and integration tasks (Liao, *et* al., 2012; Oborn & Dawson, 2010). On one hand, specialization is a key characteristic of TMS whereby each expert holds differentiated knowledge about the task at hand; on the other hand, certain common knowledge is required to interpret this differentiated knowledge for better functioning of the TMS (Lewis, 2003; Lewis & Herndon, 2011; Ren & Argote, 2011). A TMS can only be successfully implemented if constituent members share common knowledge of how the group divides the tasks and coordinates differentiated knowledge (Wegner, 1995; Sharma & Yetton, 2007; Lewis & Herndon, 2011).

The existence of a knowledge boundary is determined by how individuals perceive their interactions with others. Differences across different practices, i.e., differences in sense

making cause members to attach meaning to certain phenomena and make assumptions based on their own experiences (Kotlarsky *et* al., 2015; Carlile, 2004). Creation of a shared mental model starts getting complicated if the views of all members aren't streamlined (Canon-Bowers, Salas, & Converse, 1993). Decoding knowledge across the boundaries created by these different interpretations requires individuals to understand the conditions and learn about the sources of different assumptions.

Knowledge sharing can reduce these boundaries and help members recognize each other's expertise (Ren & Argote, 2011). Apart from creating a basis for common knowledge and accurately understanding each other's expertise, sharing of knowledge can increase the team's desire to transform knowledge and coordinate collective tasks (Huang & Chen, 2018). Enhancing interpersonal connections and strengthening social ties can reinforce better knowledge sharing and contribute to the success of a TMS (Jin *et* al., 2015).

Characteristics of Tasks

Even if individuals with specialized expertise spend time together, it is not just the group membership itself that promotes the formation of TMSs. There also needs to be some form of group interdependence to stimulate the development of a TMS (Brandon & Hollingshead, 2004). This interdependence can arise out of a particular property of a task or a reward system (Hollingshead, 2001). When one member's output becomes another member's input, an appropriate task structure can facilitate a smooth transfer. Also, tasks that do not conflict with members' knowledge can motivate them to learn about others' expertise. Divisible tasks can help members allocate responsibilities among themselves and effectively manage division of labor based on skills of each member. Tasks that are not subjective but rather open to interpretation, can encourage member associations in order to find the right person to deal with the task. Engaging in the task with a high level of task orientation (Peltokorpi & Hasu, 2016) can strengthen the TMS structure and refine the transactive processes (Lewis & Herndon, 2011).

Characteristics of Individual and Individual Cognition

Cognitive interdependence is necessary to motivate and sustain transactive memory systems (Brandon & Hollingshead, 2004). This means that members must rely on each other to take responsibility of storing information (Hollingshead, 2001). A certain level of risk exists while members come together and engage in knowledge transfer within a TMS. Trust is extremely important in order to maintain a well-functioning TMS (Robertson, 2012). One can develop trust in other people's skills and abilities but in a TMS, it is equally important that individual members acknowledge others' perceptions of integrity and benevolence (Ashleigh & Prichard, 2012). Such beliefs are stimulated by expectations about others' behaviors and opinions about all matters. If team members do not trust in the integrity of others or in their benevolence towards the team, the goals that the TMS would have otherwise achieved, remain unfulfilled. At some level, team members who trust each other internalize the group's goals as their own and behave in a way that promotes group development (Liao, 2015). Prior shared experiences between the team members helps to solidify this trust (Zhang, 2012).

Researchers suggest that the personality of individuals can influence the outcomes for the team. Effective and forward communication of ideas by an assertive team member can persuade the team in a successful direction (Pearsall & Ellis, 2006). If such an assertive member takes up a leadership position within the group and gains the trust of all members, he/she can improve TMS performance and in turn, team performance. Certain other individual characteristics such as credibility, motivation, willingness to share, absorptive capacity and such others also help in enhancing the performance of a TMS (Hamid & Salim, 2011).

Characteristics of Teams

Communication between team members is extremely important for transfer of information and other resources within a TMS. The interactions that develop due to information allocation and retrieval help to update the transactive memory. Richness and strength of communication help in creating a better TMS (Adelman & Reidl, 2012; Liao, 2015). Perceived communication richness supports team members in figuring out expertise partners for given tasks by allowing communication partners to give feedback on time. Interactions aimed at encouraging knowledge dissemination through good communication quality and collaborative communication practices assists in forming a well-developed TMS (Jarvenpaa & Majchrzak, 2008). Direct communication can help mitigate errors in perception about expertise of members in a TMS (Zhang *et* al., 2010). Communication provides channels for expertise exchange and mechanisms to generate, transfer and retain knowledge (Wegner, 1987).

Team learning processes are formed from co-construction, reflection, boundary-crossing, storage and retrieval behaviors (Oertel & Antoni, 2015; Decuyper, 2010). Apart from individual learning in a TMS, the team as a whole also registers actions that need to be taken in certain situations. These actions help the TMS to perform better if a similar situation suddenly presents itself, and hence fall under team learning. Team composition is also important for the development of a TMS. A team that trains together or has undergone same experiences in the past creates a stronger TMS and definitely performs better (Kahn, 2016). Smaller teams are expected to communicate better since there are lesser number of nodes interacting with each other. On the other hand, a larger team has a greater aggregate expertise, which is a key element of a developed TMS (Lewis & Herndon, 2011).

Characteristics of Organization

Governance decisions of organizations can either harm or help TMSs. The decisions that relate to enhancing joint processes and relationship management functions can be beneficial to TMS development. An organizational climate that supports specialization, building credibility and coordination helps a team within a TMS to achieve its outcomes (Hammedi, 2012). Such organizational climate should reflect a shared perception of the behaviors that are rewarded at the individual level and that at the level of the TMS. Innovation provides the best environment for a TMS to thrive because individuals with unique expertise are banded together, and it is their job to figure out a new product or

service using their specialized skills and abilities. An organization with support for innovation becomes fertile ground for the development of a TMS (Zhang, 1991).

Characteristics of Networks

If individual members in a TMS are connected through a dense network and are able to respond and provide feedback, the TMS develops and succeeds multifold. A centralized network limits direct communication between members; all have to go through the one member who is at the center of the network. This hinders members from learning about each other's skills, and forces them to coordinate in a particular manner, irrespective of their preferences and abilities (Argote, 2018). If membership is stable, networks with high density enable members to establish a strong TMS (Lewis & Herndon, 2011; Wegner, 1987). Strong ties are formed from frequent interaction and reciprocity (Yuan, 2005; Chiu, 2006; Cabeza-Pullez, 2018). Strong ties reduce relationship conflicts and ensure better communication about 'who knows what' in a TMS (Huang, 2018).

CONSEQUENCES OF TMS

Outcomes for Individual

Members' satisfaction with the team, the feeling of psychological safety and trust, and perceptions of future work life (Lewis, 2004; Robertson *et* al., 2012) can impact individual performance. Studies indicate that the relationship between TMS and individual performance outcomes is positive when members experience efficient operations within a team. Since the members' expertise are interdependent, growth in strength of a TMS assures members of the long-term viability of the team.

Outcomes for Team

Performance outcomes for teams in TMS research include financial market share (Kanawattanachai & Yoo, 2007), return on assets, i.e., ROA (Rau, 2005; Yoo & Kanawattanachai, 2001), team evaluation (Austin, 2003), perceived team performance (Bunderson, 2003), perceived team effectiveness and efficiency (Michinov *et* al., 2008; Zhang et al., 2007) and many others. Most of the studies show a positive association between TMS and task performance.

Outcomes for Innovation

Several studies have explored the relationship between TMS and innovation-based performance or new product success (Gino *et* al., 2010; Guo *et* al., 2013). Results from some of these studies have found TMS as a mediator between task experience and team creativity (Gino *et* al., 2010) or team creativity and impact of membership change on creativity (Guo *et* al., 2013). Innovation is evaluated in terms of novelty and usefulness (Miron-Spektor & Beenen, 2015) as well as successful implementation of new ideas and creative solutions (Klein & Sorra, 1996). A transactive memory system helps in idea generation and task selection through its members' understanding of "who knows what"

(Lewis & Herndon, 2011). Recognizing the members who hold a particular expertise and are most likely to contribute then helps in achieving creative performance. Since information is frequently communicated using established routines and stored in the transactive memory of a group, it becomes easier for members to recall the required information.

Outcomes for Organization

Extending the concept of transactive memory to the organizational level helps in advancing knowledge about global strategy and the role played by TMSs in obtaining competitive advantage for firms (Argote, 2015). Not only that, TMS is known to be positively related to decision making efficiency and effectiveness of an organization (Hammedi *et* al., 2012). Improving the communication and coordination process can help a TMS in directly enhancing an organization's project performance (Hsu *et* al., 2012; Li & Huang, 2013).

DISCUSSION AND CONCLUSION

Many researchers suggest that the tasks, which require members to have the same goal, benefit the most from a transactive memory system (Zhang *et* al., 2007; Austin, 2003; Ariff *et* al., 2011; Fitzsimmons *et* al., 2015). However, it can be suggested through the results of this study that groups which engage in sharing knowledge of their expertise may be able to develop transactive memory systems faster than those merely executing ideas because there is more knowledge sharing and interaction between members in the former than the latter.

The basic assumption in TMS theory is that there exists a shared understanding of "who knows what" but many existing studies have oversimplified TMSs, or mildly examined the causes and effects of TMSs. By capturing shared knowledge only as a measurement of TMS, these studies have been unable to fully operationalize TMSs. Interpreting TMS structure as a marker of a TMS has also led to misconstrued results, thereby threatening the validity of many works.

This oversimplification of TMS fails to incorporate the assumptions, boundaries and processes of TMS which form its foundation. Differentiated knowledge, transactive encoding, storage and retrieval processes, as well as the dynamic nature of TMS due to exchanges and interactions, are what distinguish transactive memory systems from other forms of socially shared cognition. The purpose of this article to shed light on the above mentioned aspects of TMS so that researchers and managers can better incorporate them into the operationalization and measurement of TMSs.

Much research has shown that a transactive memory system is primarily developed through interactions between team members. Training for the task that a group is expected to do together can assist in better development of a transactive memory system. When group members are trained together, the team develops a stronger transactive memory system, recalls more information about the process, and makes fewer errors compared to teams where individuals had gone through the same training separately. This shared

struggle ensures that the members of the TMS are comfortable in working together. The synchronicity and continuing flow of information within a TMS is also maintained as the TMS grows stronger. This holds a lot of value for managers who invest in enhancing coordination between diverse and heterogeneous groups of individuals in an organization.

The theory of transactive memory systems has enormous potential in the fields of operations and supply chain management. Several new contexts can be explored in these domains for future research. There can exist differing effects of TMSs on tasks, relationships and processes, especially in the case of conflicts between individuals in a group. Task conflicts should improve TMS by increasing communication and expertise credibility among group members. On the other hand, relationship conflicts might disturb TMS development and functioning because of interpersonal disputes (Peltokorpi & Hood, 2018). Communications that result from process conflict can be beneficial for TMS by helping members to make new associations or rectify current dysfunctional ones (Jehn, 1997). In this way, the effects of task, process and relationship conflicts on TMSs can help researchers understand what negatively affects the formation of these systems.

Proposition 1: Relationship, process and task conflicts impact TMS development in different ways based on the level of communication between members.

In larger networks, people can have fewer chances to establish strong, long-term network ties with all members (Granovetter, 1977, 1985), which influences TMS development and functioning in terms of specialization, coordination and credibility among network members and domain experts. The number of potential links in a network grows so fast that the number of people to which each person could be linked, quickly exceeds each member's cognitive and communicative capacity. As a company starts becoming bigger, it becomes tougher to know all employees. This overwhelms single individuals who hold specialized knowledge and hampers the balance of TMSs. Exploring the effects of such overload can help researchers in understanding how to make TMSs more robust and immune to network effects.

Proposition 2: Increase in nodes within a network can decrease the strength of a TMS.

Yet another area for future research can look into the impact of opportunism in TMS development. Since transactive memory systems heavily rely on the transfer of specialized knowledge across groups, certain members can withhold information for personal gain and display of power. So far, the literature on TMS has explored the positive side of transactions which ultimately result in better firm or team performance. Opportunism differs from conflicts in the sense that the former can include the expectation of rewards for withholding information from other members of the group. It might necessarily build up to a conflict and could more likely take the form of noncompliance towards task completion. This represents the dark side of interactions, something that can bring about a surplus of ideas for future research.

Proposition 3: Members showing opportunism and withholding information about others' expertise can hamper TMS development and in turn, negatively impact firm performance.

One of the most promising topics for future research is supply chain disruptions, which are seen all around the world due to changing economic and political climate, market turbulence, internal threats, communication disruption, resource limits, disease outbreaks or environmental calamity. When an organization faces any internal or external disruption, it tends to do its best to safeguard its assets, be it resources, capital or knowledge. There may be situations where the knowledge transfer in a TMS gets "locked" such that individuals stop sharing what they know due to the strain of the disruption. However, this is exactly the kind of situation that warrants action in the form of sharing of relevant knowledge to resolve the hazardous outcomes of the disruption. Since TMSs thrive on information exchange and team member interactions, investigation of TMS lockdown will be worthwhile to investigate. Buyer-supplier relationships can be used to create an inter-firm TMS in order to resume smooth functioning of the supply chain. Understanding the causes of such an event can help in making TMSs stronger and more resilient for the future.

Proposition 4: Supply chain disruption, while negatively impacting TMS growth, can result in the formation of new TMSs to deal with the changing circumstances.

This study offers insights into the theory of transactive memory systems with antecedents influence a TMS and consequences that result from a smooth-functioning TMS. The objective of the current study was to highlight the mechanisms that drive a TMS and the need for future research in the fields of operations and supply chain management.

REFERENCES

[1] Adelman, L., & Riedel, S. L. (2012). Handbook for evaluating knowledge-based systems: Conceptual framework and compendium of methods. Springer Science & Business Media.

[2] Akgun, A. E., Byrne, J. C., Keskin, H., & Lynn, G. S. 2006. Transactive memory system in new product development teams. *IEEE Transactions on Engineering Management*, 53(1), 95–111.

[3] Alavi, M., & Leidner, D. E. (2001). Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS quarterly*, 107-136.

[4] Ali, A., Wang, H., & Khan, A. N. 2019. Mechanism to enhance team creative performance through social media: A transactive memory system approach. *Computers in Human Behavior*, 91, 115-126.

[5] Argote, L. 2013. Organizational Learning: Creating, Retaining, and Transferring Knowledge (2nd edn). Springer: New York.

[6] Argote, L., & Guo, J. M. 2016. Routines and transactive memory systems: Creating, coordinating, retaining, and transferring knowledge in organizations. *Research in Organizational Behavior*, 36, 65-84.

[7] Argote, L., & Ingram, P. 2000. Knowledge transfer: a basis for competitive advantage in firms. *Organizational Behavior and Human Decision Processes*, 82(1), 150–169.

[8] Argote, L., & Miron-Spektor, E. 2011. Organizational learning: from experience to knowledge. *Organization Science*, 22(5), 1123–1137.

[9] Argote, L., & Ren, Y. 2012. Transactive memory systems: a micro foundation of dynamic capabilities. *Journal of Management* Studies, 49(8), 1375–1382.

[10] Argote, L. 2015. An opportunity for mutual learning between organizational learning and global strategy researchers: transactive memory systems. *Global Strategy Journal*, *5*(2), 198-203.

[11] Argote, L., Aven, B. L., & Kush, J. (2018). The effects of communication networks and turnover on transactive memory and group performance. *Organization Science*, *29*(2), 191-206.

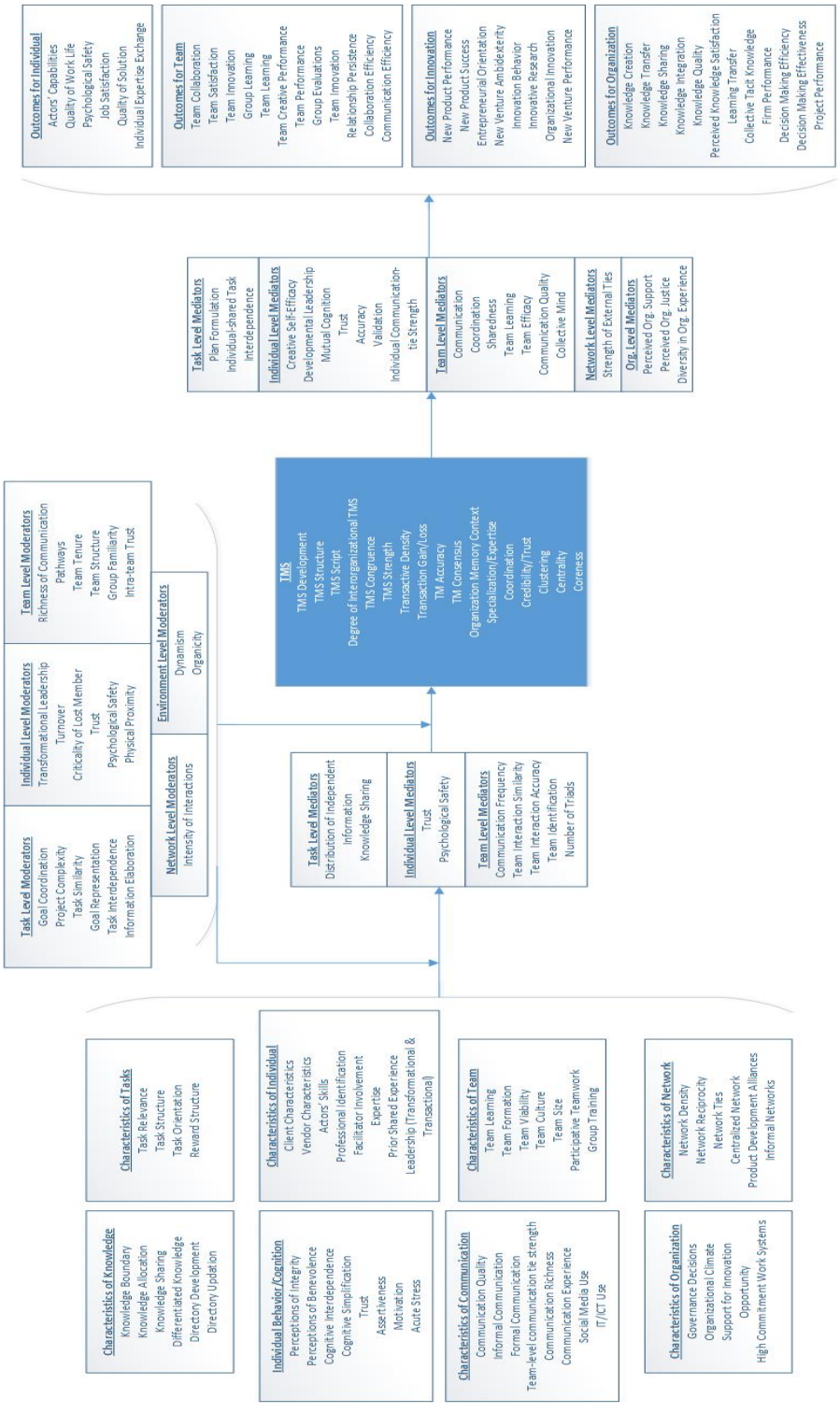
[12] Ariff, M. I., Milton, S. K., Bosua, R., & Sharma, R. 2011. Exploring the role of ICT in the formation of transactive memory systems in virtual teams.

[13] Ashleigh, M., & Prichard, J. (2012). An integrative model of the role of trust in transactive memory development. *Group & Organization Management*, *37*(1), 5-35.
[14] Austin, J. R. 2003. Transactive memory in organizational groups: the effects of content, consensus, specialization, and accuracy on group performance. *Journal of applied psychology*, 88(5), 866.
[15] Bachrach, D.G. and Mullins, R., 2019. A dual-process contingency model of leadership, transactive memory systems and team performance. *Journal of Business Research*, *96*, pp.297-308.
[16] Borgatti, S. P., & Cross, R. 2003. A relational view of information seeking and learning in social networks. *Management science*, 49(4), 432-445.
[17] Bostrom, R. P., & Heinen, J. S. (1977). MIS problems and failures: A socio-technical perspective. Part I: The causes. *MIS quarterly*, 17-32.
[18] Bunderson, J. S., & Reagans, R. E. (2011). Power, status, and learning in organizations. *Organization Science*, *22*(5), 1182-1194.
[19] Cabeza-Pullés, D., Gutierrez-Gutierrez, L. J., & Llorens-Montes, F. J. (2018). Drivers for performance in innovative research groups: The mediating role of transactive memory system. *BRQ Business Research Quarterly*, *21*(3), 180-194.
[20] Chiu, C. M., Hsu, M. H., & Wang, E. T. (2006). Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories. *Decision support systems*, *42*(3), 1872-1888.
[21] Chung, N., Lee, S., & Han, H. 2015. Understanding communication types on travel information sharing in social media: A transactive memory systems perspective. *Telematics and Informatics*, 32(4), 564-575.
[22] Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, 128-152.
[23] Dai, Y., Roundy, P. T., Chok, J. I., Ding, F., & Byun, G. 2016. 'Who Knows What?' in New Venture Teams: Transactive Memory Systems as a Micro-Foundation of Entrepreneurial Orientation. *Journal of Management Studies*, 53(8), 1320-1347.
[24] Decuyper, S., Dochy, F., & Van den Bossche, P. (2010). Grasping the dynamic complexity of team learning: An integrative model for effective team learning in organisations. *Educational Research Review*, *5*(2), 111-133.
[25] Faraj, S., & Sproull, L. 2000. Coordinating expertise in software development teams. *Management science*, 46(12), 1554-1568.
[26] Fitzsimons, G. M., Finkel, E. J., & Vandellen, M. R. 2015. Transactive goal dynamics. *Psychological Review*, 122(4), 648.
[27] Galbraith, J. R. (1973). *Designing complex organizations*. Addison-Wesley Longman Publishing Co., Inc.
[28] Gino, F., Argote, L., Miron-Spektor, E., & Todorova, G. (2010). First, get your feet wet: The effects of learning from direct and indirect experience on team creativity. *Organizational Behavior and Human Decision Processes*, *111*(2), 102-115.
[29] Granovetter, M. S. 1977. The strength of weak ties. In *Social networks*. Academic Press, 347-367.
[30] Granovetter, M. 1985. Economic action and social structure: The problem of embeddedness. *American journal of sociology*, 91(3), 481-510.
[31] Grant, R. M. 1996. Toward a knowledge-based theory of the firm. *Strategic Management* Journal, 17(10), 109–122.
[32] Grant, R. M. (2002). The knowledge-based view of the firm. The strategic management of intellectual capital and organizational knowledge, 17(2), 133-148.
[33] Guo, H., Zhao, J., & Tang, J. (2013). The role of top managers' human and social capital in business model innovation. *Chinese Management Studies*, *7*(3), 447-469.
[34] Hamid, N. A. A., & Salim, J. (2011). A conceptual framework of knowledge transfer in Malaysia e-government IT outsourcing: An integration with transactive memory system (TMS). *International Journal of Computer Science Issues (IJCSI)*, *8*(5), 51.
[35] Hammedi, W., Van Riel, A. C., & Sasovova, Z. (2013). Improving screening decision making through transactive memory systems: A field study. *Journal of Product Innovation Management*, *30*(2), 316-330.
[36] Hollingshead, A. B. 1998. Communication, learning, and retrieval in transactive memory systems. *Journal of Experimental Social* Psychology, 34(5), 423–442.
[37] Hollingshead, A. B. 2001. Cognitive interdependence and convergent expectations in transactive memory. *Journal of personality and social psychology*, 81(6), 1080.
[38] Hollingshead, A. B., & Brandon, D. P. 2003. Potential benefits of communication in transactive memory systems. *Human Communication Research*, 29(4), 607–615.

[39] Hsu, J. S. C., Shih, S. P., Chiang, J. C., & Liu, J. Y. C. (2012). The impact of transactive memory systems on IS development teams' coordination, communication, and performance. *International Journal of Project Management*, *30*(3), 329-340.
[40] Huang, C.C. and Chen, P.K., 2018. Exploring the antecedents and consequences of the transactive memory system: an empirical analysis. *Journal of Knowledge Management*.
[41] Huang, Q., Liu, H., & Zhong, X. 2013. The impact of transactive memory systems on team performance. *Information Technology & People*, 26(2), 191-212.
[42] Jarvenpaa, S. L., & Majchrzak, A. (2008). Knowledge collaboration among professionals protecting national security: Role of transactive memories in ego-centered knowledge networks. *Organization Science*, *19*(2), 260-276.
[43] Jehn, K. A. 1997. A qualitative analysis of conflict types and dimensions in organizational groups. *Administrative science quarterly*, 530-557.
[44] Kahn, S., & MacGarvie, M. (2016). Do return requirements increase international knowledge diffusion? Evidence from the Fulbright program. *Research Policy*, *45*(6), 1304-1322.
[45] Kanawattanachai, P., & Yoo, Y. 2007. The impact of knowledge coordination on virtual team performance over time. *MIS quarterly*, 31(4).
[46] Klein, K. J., & Sorra, J. S. (1996). The challenge of innovation implementation. *Academy of management review*, *21*(4), 1055-1080.
[47] Kull, T. J., Ellis, S. C., & Narasimhan, R. (2013). Reducing behavioral constraints to supplier integration: A socio-technical systems perspective. *Journal of Supply Chain Management*, *49*(1), 64-86.
[48] Lewis, K. 2003. Measuring transactive memory systems in the field: scale development and validation. *Journal of applied psychology*, 88(4), 587.
[49] Lewis, K. 2004. Knowledge and performance in knowledge-worker teams: A longitudinal study of transactive memory systems. *Management science*, 50(11), 1519-1533.
[50] Li, Y. H., & Huang, J. W. (2013). Exploitative and exploratory learning in transactive memory systems and project performance. *Information & Management*, *50*(6), 304-313.
[51] Liang, D. W., Moreland, R., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and social psychology bulletin*, 21(4), 384-393.
[52] Liao, S. H., Chang, W. J., Hu, D. C., & Yueh, Y. L. (2012). Relationships among organizational culture, knowledge acquisition, organizational learning, and organizational innovation in Taiwan's banking and insurance industries. *The International Journal of Human Resource Management*, *23*(1), 52-70.
[53] Liao, Y., & Barnes, J. (2015). Knowledge acquisition and product innovation flexibility in SMEs. *Business Process Management Journal*.
[54] Littlepage, G. E., Hollingshead, A. B., Drake, L. R., & Littlepage, A. M. 2008. Transactive memory and performance in work groups: Specificity, communication, ability differences, and work allocation. *Group Dynamics: Theory, Research, and Practice*, 12(3), 223.
[55] Michinov, N., & Michinov, E. (2008). Face-to-face contact at the midpoint of an online collaboration: Its impact on the patterns of participation, interaction, affect, and behavior over time. *Computers & Education*, *50*(4), 1540-1557.
[56] Miron-Spektor, E., & Beenen, G. (2015). Motivating creativity: The effects of sequential and simultaneous learning and performance achievement goals on product novelty and usefulness. *Organizational Behavior and Human Decision Processes*, *127*, 53-65.
[57] Nonaka, I., & von Krogh, G. 2009. Tacit knowledge and knowledge conversion: controversy and advancement in organizational knowledge creation theory. *Organization Science*, 20(3), 635–652.
[58] Noroozi, O., Weinberger, A., Biemans, H. J., Mulder, M., & Chizari, M. 2013. Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. *Computers & Education*, 61, 59-76.
[59] Oborn, E., & Dawson, S. (2010). Knowledge and practice in multidisciplinary teams: Struggle, accommodation and privilege. *Human Relations*, *63*(12), 1835-1857.
[60] Oertel, R., & Antoni, C. H. (2015). Phase-specific relationships between team learning processes and transactive memory development. *European Journal of Work and Organizational Psychology*, *24*(5), 726-741.
[61] Oshri, I., Van Fenema, P., & Kotlarsky, J. 2008. Knowledge transfer in globally distributed teams: the role of transactive memory. *Information Systems Journal*, 18(6), 593-616.
[62] Palazzolo, E. T. 2005. Organizing for information retrieval in transactive memory systems. *Communication Research*, 32(6), 726-761.

[63] Palazzolo, E. T., Serb, D. A., She, Y., Su, C., & Contractor, N. S. 2006. Coevolution of communication and knowledge networks in transactive memory systems: Using computational models for theoretical development. *Communication Theory*, 16(2), 223-250.
[64] Paulus, P. B., Dzindolet, M., & Kohn, N. W. (2012). Collaborative creativity—Group creativity and team innovation. In *Handbook of organizational creativity* (pp. 327-357). Academic Press.
[65] Pearsall, M. J., & Ellis, A. P. (2006). The effects of critical team member assertiveness on team performance and satisfaction. *Journal of Management*, *32*(4), 575-594.
[66] Peltokorpi, V. 2014. Transactive memory system coordination mechanisms in organizations: an exploratory case study. *Group & Organization Management*, 39(4), 444–471.
[67] Peltokorpi, V., & Hood, A. C. 2018. Communication in Theory and Research on Transactive Memory Systems: A Literature Review. *Topics in cognitive science*.
[68] Rau, D. (2005). The influence of relationship conflict and trust on the transactive memory—Performance relation in top management teams. *Small Group Research, 36,* 746 –771.
[69] Ren, Y., & Argote, L. 2011. Transactive memory systems 1985–2010: an integrative framework of key dimensions, antecedents, and consequences. *Academy of Management Annals*, 5(1), 189–229.
[70] Ren, Y., Carley, K. M., & Argote, L. 2006. The contingent effects of transactive memory: when is it more beneficial to know what others know? *Management Science*, 52(5), 671–682.
[71] Robertson, P. L., Casali, G. L., & Jacobson, D. (2012). Managing open incremental process innovation: absorptive capacity and distributed learning. *Research policy*, *41*(5), 822-832.
[72] Rulke, D. L., & Rau, D. 2000. Investigating the encoding process of transactive memory development in group training. *Group and Organization Management*, 25, 373-396.
[73] Walsh, J. P., & Ungson, G. R. 1991. Organizational memory. *Academy of management review*, 16(1), 57-91.
[74] Wang, Y., Huang, Q., Davison, R. M., & Yang, F. 2018. Effect of transactive memory systems on team performance mediated by knowledge transfer. *International Journal of Information Management*, 41, 65-79.
[75] Wegner, D. M., Giuliano, T., & Hertel, P. T. 1985. Cognitive interdependence in close relationships. In *Compatible and incompatible relationships*. Springer, New York, NY, 253-276.
[76] Wegner, D. M. 1987. Transactive memory: a contemporary analysis of the group mind. In *Theories of Group Behavior* (Vol. **9**), Mullen B, Goethals GR (eds). Springer-Verlag: New York; 185–208.
[77] Wegner, D. M., Erber, R., & Raymond, P. 1991. Transactive memory in close relationships. *Journal of personality and social psychology*, 61(6), 923.
[78] Wegner, D. M. 1995. A computer network model of human transactive memory. *Social cognition*, 13(3), 319-339.
[79] Whetten, D. A. 1989. What constitutes a theoretical contribution? *Academy of management review*, 14(4), 490-495.
[80] Yuan, S. T., & Sun, J. (2005). Ontology-based structured cosine similarity in document summarization: with applications to mobile audio-based knowledge management. *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)*, *35*(5), 1028-1040.
[81] Zhang, Z. X., Hempel, P. S., Han, Y. L., & Tjosvold, D. 2007. Transactive memory system links work team characteristics and performance. *Journal of Applied psychology*, 92(6), 1722.
[82] Zhang, X., Chen, Z., Vogel, D., Yuan, M., & Guo, C. (2010). Knowledge-sharing reward dynamics in knowledge management systems: Game theory–based empirical validation. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *20*(2), 103-122.
[83] Zheng, Y. 2012. Unlocking founding team prior shared experience: A transactive memory system perspective. *Journal of Business Venturing*, 27(5), 577-591.

APPENDIX I: DETAILED FRAMEWORK OF TMS



APPENDIX II: 80 STUDY TABLE

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
1	Akgun et al. (2006)	Survey based	TMS	M2: collective mind; M1: environmental turbulence	Team learning, speed-to-market, new product success	The impact of the TMS on speed-to-market is negative when market and technology turbulence associated with the environment is high and that on team learning changes quadratically with respect to the market and technology turbulence.
2	Ali et al. (2019)	Survey based	Social Media (Social, cognitive, hedonic use)	TMS (Specialization, coordination, credibility); Team creative efficacy	Team Creative Performance	The authors develop a mechanism to test the effects of the three dimensions of social media (social, cognitive, and hedonic use) on team creative performance in terms of knowledge management. The analysis reveals that the three dimensions of social media have different effects on TMS. In addition, the dimensions of TMS enhance team creative performance through team creative efficacy.
3	Argote & Guo (2016)	Conceptual	Routines, TMSs	-	Knowledge creation, coordination, retention and transfer	Overviews of research on the two knowledge repositories, routines and TMSs, with particular attention to how they form and change; compare and contrast routines and TMSs in terms of their capabilities to promote knowledge creation, coordination, retention and transfer in organizations.
4	Argote & Ren (2012)	Conceptual	-	-	-	Firms need to include TMS to attain competitive advantages and dynamic capabilities; TMS is a micro foundation of dynamic capabilities and knowledge sharing in organizations can facilitate combinative integration and renovation of an organization's knowledge assets.
5	Argote (2015)	Conceptual	-	-	-	Extending the concept of transactive memory to the organizational level and studying the concept in global firms would advance knowledge about transactive memory systems as well as increase our understanding of global strategy.
6	Argote et al. (2018)	Field experiments	Centralized network	M2: Dyadic Communication frequency, TMSs; M1:Turnover	Performance; Errors	The greater number of direct communication paths enabled fully connected groups with stable membership to develop stronger transactive memory systems (TMSs) and perform better than fully connected groups that experienced turnover.
7	Ariff et al. (2011)	Conceptual	ICT as communication medium	M2: TEP unit, TMS; M1: Task Interdependence	Team Performance	The goal of this research is to explore and describe the formation of TMS in virtual teams. The focus is on the role of ICT as a communication tool to foster TMS formation. This study hopes to provide a deeper understanding of the use of ICT as a communication tool during the formation of TMS in VTs.
8	Ashleigh & Prichard (2012)	Conceptual	Perceptions of benevolence, integrity, ability	-	Knowledge declaration, claims of expertise, congruence between expertise and role allocation, Monitoring and safeguarding behaviors, role redistribution, TMS stability	By using the TM encoding cycle, the model proposes that trust acts as an antecedent of TMSs and that wider perceptions of team members' trustworthiness (benevolence and integrity) also affect the development and maintenance of effective TMSs in teams.
9	Austin (2003)	Survey based	Group's TMS (knowledge stock, knowledge specialization, transactive memory consensus, transactive memory accuracy)	-	Group goal performance, external group evaluations, internal group evaluations	In this study, the author examined the relationship between transactive memory systems and performance in mature, continuing groups. A group's TMS, measured as a combination of knowledge stock, knowledge specialization, transactive memory consensus, and transactive memory accuracy, is positively related to group goal performance, external group evaluations, and internal group evaluations. The positive relationship with group performance was found to hold for both task and external relationship TMSs.
10	Bacharach & Mullins (2019)	Survey based	Transformational leadership, Transactional leadership	M1: Team size, team tenure, market dynamism M2: TMS	Team Performance	Transformational leadership has a stronger relationship with TMS in smaller teams and transactional leadership has a stronger relationship with TMS in less tenured teams. The strength of the relationship between TMS and team performance depends on market dynamism.

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
11	Brandon & Hollingshead (2004)	Conceptual	Task structure, reward structure, cognitive simplification	Accuracy, sharedness, validation	Construction, evaluation, validation	Task has a major influence on developmental processes; task representation and the task-expertise-person (TEP) unit are the basic constructs involved in transactive memory development, and a dynamic model of how TEP units are constructed, evaluated, and utilized is explored.
12	Brunault et al. (2014)	Survey based	TMS, participative team work	Perceived organizational support, perceived organizational justice	Quality of work life	The level of transactive memory and participative teamwork positively affects nurses' quality of work life (QWL). Participative teamwork and transactive memory were found to be positively associated with nurses' QWL. Perceived organizational support and organizational justice fully mediated the relationship between participative teamwork and QWL, but not between transactive memory and QWL.
13	Cabeza-Pulles et al. (2018)	Survey based	Trust, Collective mind, Network ties	TMS	Innovative university research	Managers of university research groups should promote the development of TMSs to stimulate innovative university research in order to make these groups more competitive.
14	Cao & Ali (2018)	Survey based	Social Media Use at Work, TMS	Absorptive Capacity, Knowledge Creation Capability	Team Creative Performance	Careful investment in social media by an organization can enhance meta-knowledge of "who knows what" within teams; exploring external knowledge alone is not enough: organizations must ensure external knowledge is utilized to create new knowledge to improve team creative performance.
15	Chen et al. (2013)	Secondary data	Knowledge differentiation, knowledge location, knowledge credibility,	Knowledge sharing, Communication quality	Technical achievement	Several TMS dimensions have positive impacts on knowledge sharing behaviors and communication quality. Moreover, communication quality positively influences technical achievement of OSS teams.
16	Chiang et al. (2014)	Survey based	High commitment work systems	TMS	NPD performance	Transactive memory system mediates the positive relationship between the high commitment work system implemented with workers in new product development teams and new product performance.
17	Choi et al. (2010)	Field Experiments	TMS, Knowledge support for KM	Knowledge sharing, knowledge application	Team Performance	IT support in organizations has a positive impact on the development of TMS in teams, and that both TMS and IT support have a positive impact on knowledge sharing and knowledge application. Knowledge sharing has a positive impact on knowledge application, which in turn has a direct impact on team performance.
18	Christian et al. (2014)	Lab experiments	TMS	M1: Lost member criticality; M2: Plan formulation	Team performance	Teams with well-developed transactive memory systems (TMS) will be better equipped to withstand the loss of a member. Those effects depend on which member is absent, such that when a more critical member is lost, the performance benefits of a TMS are reduced. This interactive effect is because of the team's ability to engage in plan formulation.
19	Chung et al. (2015)	Survey based	Formal communication, informal communication	Specialization, coordination, credibility	Travel information sharing	The users' perception of formal communication has a positive influence on the specialization, credibility, and coordination of social media. The perception of informal communication has a positive effect on the credibility and coordination of social media. Three sub-dimensions of TMS affect intentions to share travel information.
20	Comu et al. (2012)	Lab experiments	Facilitator Involvement in virtual project networks	TMS formation	Collaboration Effectiveness	In this study, the formation and maintenance of transactive memory systems (TMS) in two facilitated and two non-facilitated global virtual project networks were investigated, each executing a 2-month project. Using TMS formation and cohesive subgroup formation as a proxy for performance, quantitative evidence was found that demonstrates a negative impact on collaboration effectiveness when facilitators engage in content facilitation in virtual project networks. This paper shows that this negative impact restricts the establishment of TMSs.

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
21	Dai et al. (2016)	Field expeiments	TMS	Trust, organicity, dynamism	Entrepreneurial orientation	The transactive memory system of a new venture team enhanced their EO and that this relationship was positively influenced by intra-team trust, the structural organicity of a venture, and environmental dynamism.
22	Dai et al. (2017)	Survey based	Product development alliances, TMS of entrepreneurial teams	-	New venture ambidexterity	Product development alliances and the transactive memory systems of entrepreneurial teams contribute to new venture ambidexterity. Moreover, the authors propose that the two mechanisms reinforce one another.
23	Ellis (2006)	Lab experiments	Acute stress	Team interaction mental model similarity, team interaction mental model accuracy	Transactive memory (Through use of directory updating, information allocation, retrieval coordination)	In an effort to extend theory and research on the effects of acute stress in teams, the author examined the mediational role of mental models and transactive memory in the relationship between acute stress and team performance, using information-processing theory as an explanatory framework. Results indicated that acute stress negatively affected mental models and transactive memory, which helped to explain why teams performed more poorly under acute stress.
24	Fan et al. (2016)	Survey based	Level 1: Creative self-efficacy Level 2: TMS	-	Level 1: Innovation behavior Level 2: Team innovation	A multilevel mediation model in which creative self-efficacy partially mediates the relationship between TMSs and the individual's innovative behavior. At the team level, the TMS positively affects team innovation.
25	Fitzsimons et al. (2015)	Conceptual	Opportunity, motivation	M2: Transactive density, Transactive gain/loss, Goal recovery M1: Goal Coordination, Shared goal representation, Realtional Orientation/skills	Relationship persistence	Transactive goal dynamics (TGD) theory conceptualizes 2 or more interdependent people as 1 single self-regulating system. Six tenets describe the nature of goal interdependence, predict its emergence, predict when it will lead to positive goal outcomes during and after the relationship, and predict the consequences for the relationship. Both partners in a TGD system possess and pursue self-oriented, partner-oriented, and system-oriented goals, and all of these goals and pursuits are interdependent. TGD theory states that relationship partners' goals, pursuit, and outcomes affect each other in a dense network of goal interdependence, ultimately becoming so tightly linked that the 2 partners are most accurately conceptualized as components within a single self-regulating system.
26	Hamid & Salim (2011)	Conceptual	Client characteristics, vendor characteristics, TMS (organizational memeory context)	Prior collaboration history, team size, project complexity	Knowledge transfer in IT sourcing	The authors apply positivist approach through operationalization of identified factors that give impact towards Malaysia Public Agencies outsourcing partnership. The present paper attempts to provide an integrated conceptual framework of knowledge transfer with and integration of TMS to facilitate knowledge transfer process which further can be validated.
27	Hammedi et al. (2012)	Survey based	Transformational leadership, Organizational climate	TMS	Decision making effectiveness and efficiency	The degree to which a committee acts as a TMS is positively related to decision-making effectiveness as well as efficiency in a screening context.
28	Heavey & Simsek (2015)	Survey based	Top management team transactive memory	Strength of external ties, dynamism	Firm performance	A novel theoretical account of how the performance implications of transactive memory are shaped by the individual and conjoint influences of a top management team's external social network ties and the rate of dynamism in the firm's competitive environment. In so doing, top management team transactive memory is linked to firm performance through transformation.
29	Heavey & Simsek (2017)	Survey based	Strength of top management team TMS	Diversity in top managers' organizational experience	Firm's pursuit of ambidextrous orientation	While top management teams with well-developed transactive memory systems are able to pursue an ambidextrous orientation, the impact of transactive memory is also shaped by diverse organizational experience and functional expertise within these teams.
30	Hewitt & Roberts (2015)	Survey based	-	-	-	People in romantic relationships can develop shared memory systems by pooling their cognitive resources, allowing each person access to more information but with less cognitive effort. The TMSS-C (an existing measure of transactive memory systems for use with romantic couples), provides a valuable tool that can quickly and easily capture the underlying components of romantic couples' transactive memory systems. It has potential to help how shared memory systems might be associated with other important features of romantic relationships.

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
31	Hollingshead (2001)	Field experiments	Cognitive interdependence, specialized learning,	-	Transactive memory	Transactive memory is most differentiated when individuals have different expertise and incentives to remember the same information.
32	Hong & Zhang (2017)	Conceptual	TMS	Behavioral intention	Individual knowledge integration	Individual intention has significant and positive impact on knowledge integration directly; specificity and coordination of TMS have significant and positive effect on individual intention directly; the effect of credibility of TMS on individual intention is not significant.
33	Hood et al. (2016)	Field experiments	Positive affectivity, negative affectivity	Psychological safety	TMS	The authors develop a framework for understanding the emergence of transactive memory systems (TMS) in project-based teams characterized by different levels of group level positive affectivity (PA) and negative affectivity (NA).
34	Hsu et al. (2012)	Survey based	TMS	Communication, coordination	Project team performance	Having a mature TMS can effectively enhance performance directly, and indirectly through improving communication and coordination process.
35	Huang & Chen (2018)	Survey based	Knowledge sharing, social network ties	M1: Team psychological safety M2: TMS, knowledge integration	Team performance	Social interaction processes have a positive effect on a TMS; a TMS can foster team performance, but knowledge integration mediates the relationship between the TMS and team performance; and team psychological safety can moderate the relationship between the TMS, knowledge integration and team performance.
36	Huang et al. (2013)	Survey based	Specialization, coordination, credibility	Knowledge quality, perceived knowledge satisfaction	Team performance	TMSs have a positive impact on team performance mediated by knowledge management outcomes. The authors further found that instrumental ties could strengthen the relationship between specialization and knowledge quality, while weakening the influence of coordination on knowledge quality. In contrast, the results showed that expressive ties weaken the relationship between specialization and knowledge quality, while strengthening the influence of coordination on knowledge quality.
37	Jackson (2012)	Case study	-	-	-	Longitudinal investigation of a global engineering consulting firm which used inductive analysis of interview data to map and then develop a conceptual entity-relationship model of organizational memory.
38	Kahn & Williams (2016)	Survey based	Team formation, team size	Social presence, TMS	Outcome	TMS is highly predictive of the likelihood of a team winning a game, and that while past team member acquaintanceship predicted TMS, team size did not. Furthermore, only two dimensions of social presence, copresence and perceived comprehension, were related to TMS. These two dimensions fully mediated the relationship between past team member acquaintanceship and TMS.
39	Kotlarsky et al. (2015)	Survey based	Pragmatic knowledge boundary	Sematic knowledge boundary, syntactic knowledge boundary	TMS development	This research investigates the impact of syntactic, semantic, and pragmatic knowledge boundaries on a team's ability to develop a transactive memory system (TMS)-a collective memory system for knowledge coordination in groups. Results from the survey show that syntactic and pragmatic knowledge boundaries negatively affect TMS development.
40	Kwon & Cho (2016)	Survey based	TMS	Developmental leadership	Organizational Innovation	TMSs were found not to be significantly related to organizational innovation. Results also indicated that transactive memory systems comprise a statistically significant variable that influences developmental leadership. Subsequently, developmental leadership can be considered to be a valid construct in predicting organizational innovation; it can also be seen to fully mediate the relationship between transactive memory systems and organizational innovation.

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
41	Lazzara et al. (2015)	Survey based	Advanced Technology (telemedical robot)		TMS, Psychological safety, communication efficiency (length of communication, duration of task-based communication)	The aim of this study is to examine the impact of a telemedical robot on trauma intensive care unit (TICU) clinician teamwork (i.e., team attitudes, behaviors, and cognitions) during patient rounds. The findings suggest that there is a significant difference in communication between rounds with and without telemedicine, such that there is more task-based communication during telerounds. Telemedicine increases task-based communication and does not negatively impact team trust, psychological safety, or TMS during rounds.
42	Lee et al. (2014)	Field experiments	Closure over time	Number of transitive triads	TMS development	A negative direct effect of closure over time and a simultaneous positive indirect effect of closure over time on TMS development exists and is driven by a transitive triadic social network structure.
43	Lewis & Herndon (2011)	Conceptual	Task relevance, Task structure, Differentiated knowledge	-	TMS development	Issues concerning how researchers define and conceptualize TMSs are explored, the relationship between TMS measures and the TMS concept interpreted, and the role of task type in TMS research attended to.
44	Lewis (2003)	Field experiments	Specialization, credibility, coordination* (First-order factors)	-	Transactive memory system* (Second-order factor)	Specialized and differentiated team knowledge, members' trust and reliance on others' knowledge, and smooth, coordinated task processes indeed reflect TMSs and that these systems are related to, but distinct from, members' agreement about who knows what.
45	Lewis (2004)	Field experiments	Team members' expertise, frequency of communication, team viability, team performance	Group familiarity	TMS emergence	Teams with more established TMSs benefit from face-to-face communication which means transactive retrieval processes may have been triggered during face-to-face communication. Developing a TMS is critical to the effectiveness of knowledge-worker teams.
46	Lewis et al. (2005)	Field experiments	TMS	-	Group learning, learning transfer	Groups with a prior TMS and experience with two tasks in the same domain had better abstract understanding of the principles relevant to the task domain; the extent to which members maintained expertise across tasks influenced the degree of learning transfer.
47	Li & Huang (2013)	Survey based	TMS (Specialization, Credibility, Coordination)	Team Learning (Exploitative, Exploratory)	Project Performance (Project efficiency, effectiveness)	The findings indicate differential effects of three dimensions of a transactive memory system on exploitative and exploratory learning. Exploitative and exploratory learning are positively associated with project performance. The results also support that the interaction between exploitative and exploratory learning has a positive effect on project performance.
48	Liang et al. (1995)	Field experiments	Group training	Development of TMS	Group performance	Groups whose members get trained together recall more about the assembly procedure and produce better quality end products than groups whose members are trained alone.
49	Lin et al. (2012)	Survey based	Expertise Specialty, Expertise Credibility	Behavioral Integration (Joint decision making, collective mind, expertise integation)	Team Performance	expertise specialty, credibility and their interaction positively affect team behavioural integration. This, in turn, leads to enhanced project team performance.
50	Lio et al. (2015)	Survey based	Perceived Communication Quality, Professional Identification	M2: Team Identification	TMS (Specialization, Coordination, Credibility)	Using the Social Identity Approach, perceived communication quality predicts TMS through team identification. High levels of professional identification compensates for low levels of team identification in predicting TMS.

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
51	Liu & Zang (2010)	Field experiments	TMS	Team Efficacy	Team Performance	The results demonstrate that team efficacy fully mediates TMS and team performance.
52	Manteli et al. (2014)	Survey based	Governance decisions (business strategy, team structure and composition, task allocation)	-	TMS (Clustering, centrality, coreness)	The results of this study suggest that different governance decisions have a different impact on TMSs. Within the composition and structure of GSD teams, there are boundary spanners (formal or informal) who have a better overview of the network's activities and become central members within their network. The way tasks are allocated among distributed teams is an indicator of where expertise resides.
53	Martin & Bachrach (2018)	Conceptual	-	-	-	The authors incorporate transactive memory system theory to bridge dynamic managerial capabilities theory and networking capabilities theory. In particular, they focus on multi-level relational aspects of dynamic managerial capabilities and networking capabilities in in the context of business relationships in uncertain and changing (i.e., dynamic) network contexts.
54	Mell et al. (2014)	Lab experiments	TMS Structure	M1: Distribution of independent information; M2: Transactive Retrieval, Information Elaboration	Team Performance	The authors predict that centralized Meta knowledge can give teams a performance advantage over decentralized Meta knowledge, because centralized Meta knowledge can allow the central member to function as a catalyst for information exchange and integration. The authors propose this catalyst effect to be contingent on the extent to which the distribution of task information among members poses high coordination demands to effectively integrate members' knowledge.
55	Miller et al. (2014)	Lab experiments	Actors' skills	TMS	Actors' capabilities	The explanation in this study centers on the development of transactive memory, which forms during the initial performances of a routine, as actors search for other actors with the capabilities needed to complete a routine. Variations in the efficiency of routine formation that are inexplicable in terms of action sequences may be readily explained when actor sequences are examined. Transactive memory contributes to the theory of organizational routines by serving as a bridge between individuals' skills and collective capabilities.
56	Nevo et al. (2012)	Field Experiments	IT (technological) Support	-	TMS	This paper focuses on meta-memory, which is at the heart of TMSs. The authors examine what meta-memory is maintained by members of TMSs, whether providing this meta-memory in a technology-mediated environment can lead to transactive memory development, whether IT can realistically provide this meta-memory, and whether different requirements exist for different users and in different stages of transactive memory development.
57	Noroozi et al. (2013)	Field experiments	TMS Script	TMS: Specialization, Coordination, Credibility	Quality of joint problem solution plan, Quality of individual problem solution plan,	This study investigates how TMS script facilitates construction of a TMS, fosters learners' knowledge transfer and convergence, and improves the quality of problem solution plans. Specialization and coordination aspects of the TMS are mediators for the impacts of the script on joint but not individual problem solution plans.
58	Oertel & Antoni (2015)	Survey based	Team learning (Knowledge-based, Communication-based, Communication-based)	-	TMS	The authors analyze the relationships among different team learning behaviors and transactive memory during various phases of team development. The results show that knowledge-based processes (storage and retrieval) play a more important role during early stages of project-based teamwork, followed by a shift to a higher relevance of communication-based processes (reflection and co-construction) in later stages.
59	Oinas-Kukkonen et al. (2010)	Conceptual	-	-	-	The authors review reasons for the increased interest in network analyses in organization studies and information research. They also note the impact of new information technology capabilities for this increase in terms of improvements in analysis techniques, new ways to generate and maintain connections within and between social units, and new social connection-focused IT capabilities. They also review main streams of network-based analyses in information system research.
60	Olabisi & Lewis (2018)	Conceptual	-	-	-	The authors argue that within- and between-team coordination coordination can be facilitated—or thwarted—by boundary-spanning behaviors and patterns of knowledge exchange within and between teams. Their theorizing explains how an existing team TMS can offset the within-team coordination burdens typically associated with boundary spanning and we offer predictions about how these factors interrelate to affect TMS and coordination over time.

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
61	Oshri et al. (2008)	Case study	Directory updating, information allocation, retrieval coordination	-	TMS	The paper describes the transfer of knowledge between onsite and offshore teams through TMSs (encoding, storing and retrieving processes). The analysis suggests that in order to overcome differences derived from the local contexts of the onsite and offshore teams, some specific mechanisms supporting the development of codified and personalized 'directories' need to be introduced.
62	Pearsall & Ellis (2006)	Lab experiments	Critical team member assertiveness	TMS	Team satisfaction, team performance	In an effort to extend theory and research linking personality to team effectiveness, this study uses the workflow networks literature to investigate the effects of critical team member dispositional assertiveness on team performance and satisfaction. Results indicate that critical team member dispositional assertiveness positively affects team performance and team satisfaction. Results also indicate that both of those effects are due to improvements in the team's TMS.
63	Peltokorpi & Hasu (2016)	Survey based	Task Orientation	M2: TMS; M1: Transformational Leadership	Team Innovation	This study, by integrating team innovation and TMS research, provides a moderated mediation model with a set of hypotheses that link task orientation, TMS, and transformational leadership on innovation in research teams. Hierarchical regression and moderated mediation analyses show that TMS partially mediate the positive relation between task orientation and team innovation. Transformational leadership positively moderated the relationship between TMS and team innovation.
64	Peltokorpi & Hood (2018)	Literature Review	-	-	-	This paper reviews literature on the relationships between communication, TMS, and outcomes in dyads, groups, and teams, and proposes avenues for future research.
65	Peltokorpi (2014)	Case Study	-	-	-	The study findings show that organization design (team-based structure, small unit size), human resource management (HRM) practices (recruitment and selection, training, promotion, and reward systems and performance evaluations), and relational interactions (roles, routines) coordinate organizational TMSs. Organization design and HRM practices as more formal coordination mechanisms also support and provide continuity to relational interactions.
66	Ren & Argote (2011)	Literature review	-	-	-	Examined transactive memory systems and summarized the findings in an integrative framework to show the antecedents and consequences of TMS.
67	Reidl et al. (2012)		Communication richness, communication experience	M1: Team size, culture M2: TMS (Expertise, coordination, trust)	Team performance	In this study the authors answer the question: how communication affects the building of a knowledge management system, more specifically of a TMS as a subset of KMS, in virtual teams. The paper shows the importance of perceived richness and experience of the communication media used and how the team size of a virtual team as well as the culture of the team members influence the relationship between communication and the knowledge management.
68	Robertson et al. (2012)	Survey based	Trust in teammates, Trust in management	Transactive memory	Job satisfaction, Team Performance	The purpose of this paper is to examine, in two studies, whether trust in teammates and trust in management influenced transactive memory and how strongly transactive memory, in turn, influenced perceived team performance and job satisfaction. Findings suggest that trust in teammates predicted transactive memory and transactive memory, in turn, predicted perceived team performance and job satisfaction. Trust in management did not predict transactive memory, but it did predict job satisfaction.
69	Simeonova (2017)	Conceptual	Trust, Informal networks	TMS, Web 2.0 Technologies	Knowledge sharing	The aim of this paper is to advance understanding of interactive knowledge sharing (KS) processes through exploring the role of TMSs and Web 2.0. The use of TMS and Web 2.0 as mediating tools depends on deeper underlying structures/factors embedded within the community, namely, informal networks and trust among people. Informal networks and trust among people support the use and the positive effects of these tools.
70	Spraggon & Bodolica (2017)	Conceptual	Social Ludic Activities (SLAs)	Physical Proximity, Pyschological Safety, Intesity of Interactions, Communication Pathways' Richness	Collective Tacit Knowledge (CTK)	This paper builds upon socially distributed cognition (SDC) and transactive memory systems (TMS) to analyze SLAs' contribution to CTK creation in the workplace. SLAs may facilitate collective members' knowing and learning whereby different solutions are sought and potential tactics to cope with work issues are attuned to changing conditions by the collective members at work. Four moderating factors, namely physical proximity, psychological safety, richness of communication pathways and intensity of interactions, are identified and propositions to conceptualize their role

#	Study	Method	Independent Variable(s)	Moderation (M1) Mediation (M2)	Dependent Variable(s)	Key findings
71	Tang (2014)	Survey based	Communication quality	Benevolence trust, Competence trust; TMS	Team performance	This study empirically tests the relationships between communication quality and TMS, and the effect of TMS on team effectiveness. The results suggest that communication quality has a positive effect on TMS; the link between communication quality and TMS is mediated by benevolence- and competence-based trust; and TMS has a positive impact on team performance.
72	Tollefsen et al. (2013)	Conceptual	-	-	-	As a dynamic, multi-component system, an "alignment system" is responsive to higher-level cognitive states such as shared beliefs and intentions but can also give rise to such shared cognitive states via bottom-up processes. The authors turn to transactive memory and suggest how further research on alignment in these cases might reveal how such systems can be genuinely described as cognitive.
73	Vernham et al. (2014)	Survey based	-	-	-	This study applies the transactive memory theory to a collective inter-viewing situation and explores whether signs of truthfulness emerge through measuring joint memory recall. Couples were interviewed in their pairs about their 'real' or 'fictitious' relationships. Truth-telling pairs posed questions to one another, provided cues to one another, handed over remembering responsibility, and finished each other's sentences significantly more than lying pairs, supporting the idea that real couples have a transactive memory system, unlike pretending couples.
74	Wang et al. (2018)	Survey based	Specialization, credibility, coordination	Knowledge Transfer	Team Performance	This study investigates how TMS dimensions relate to knowledge transfer (i.e., a sub process of team learning), thereby influencing team performance in real organizations. Research findings demonstrate that the associations of specialization and credibility with knowledge transfer are more significant than that of coordination. Moreover, knowledge transfer predicts the variation in team performance and fully mediates the effect of specialization and credibility on team performance.
75	Wegner (1987)	Conceptual	-	-	-	Individual and transactive memory along with their various facets are defined and discussed.
76	Whelan & Teigland (2013)	Case based	-	-	-	In this study, the authors examine whether TMSs act as a collective filter to enable organizational groups to mitigate the potential for information overload. Findings suggest that individuals spontaneously organized without any centralized control to create a collective filter.
77	Yuan et al. (2010)	Field and lab experiments	Individual directory development; team-level directory development, team-level shared task interdependence, team-level communication tie strength	Individual shared task interdependence, individual communication tie strength	Individual expertise exchange	At the individual level, the relationship between directory development and expertise exchange is mediated by communication tie strength and moderated by shared task interdependence. Team-level variables also are significantly related to individual-level outcomes such that individual expertise exchange happens more frequently in teams with well-developed team-level expertise directories, as well as with higher team communication tie strength and shared task interdependence.
78	Zhang et al. (1991)	Survey based	task interdependence, support for innovation, cooperative goal interdependence	M1: TMS of work teams	Team performance	TMS mediates the relationship between team performance and each of the three team characteristics; team members and leaders can improve team performance by communication and task interdependence.
79	Zhang et al. (2015)	Survey based	Degree of interorganizational TMS	Mutual cognition, trust	Team collaboration	The interorganizational TMS (I-TMS) drives group members to be mutually trusting and cooperatively integrate their professional knowledge, which reflects the idea of collaboration that underlies integrated project delivery (IPD). The results in this study suggest that project parties with a low I-TMS degree should engage in frequent interaction to foster mutual cognition and trust and improve team collaboration for IPD.
80	Zheng (2012)	Survey based	Prior shared experience	M2: TMS; M1: Task similarity, Intra-team trust	New venture performance	New ventures often started by founders with prior shared experience have been shown to benefit new venture performance. The author posits that the prior shared experience effect is partially mediated by a team-level cognitive process—TMS that enables founding teams to effectively and efficiently integrate their members' expertise and skills. Two team-level factors—task similarity and intra-team trust further strengthen the effects of TMSs because they provide golden opportunities and strong motivation for team members to utilize their TMSs.

IMPACT OF COVID-19 ON SUPPLY CHAIN INTERNSHIPS

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ABSTRACT

COVID-19 has drastically changed our working environment. Jobs have shifted to virtual environments, supply chains have been reconstructed, and companies have been forced to implement new policies and procedures. One area particularly impacted by COVID-19 is internship programs. This research paper will delve specifically into supply chain internship programs during a global pandemic. This paper addresses relevant questions such as how COVID-19 changed supply chain internships, how on-site internships during COVID-19 were implemented, the challenges of working virtually, and how the pandemic has altered the future of internship programs. This research focuses on student experiences, seeks advice from companies who have implemented successful programs, and offers guidance for future internships in a post-COVID world.

INTRODUCTION

In March of 2020, our global economy began to shut down. The Coronavirus pandemic was quickly creeping into every aspect of our lives. There's little debate that the supply chain industry, in particular, took a grueling hit from the effects of COVID-19. Worldwide shortages occurred, remote work skyrocketed, and company policies and procedures had to be reconsidered. Amid the chaos that COVID-19 wreaked on the supply chain industry, the changes in supply chain internships have not been thoroughly analyzed. Many companies were required to cancel internships, others transitioned their programs to a virtual environment, and others were still able to keep internships on-site. In the supply chain management field, internships are an essential part of preparing the next generation of industry leaders. This is a unique field, and it is one in which practical and hands-on internship experience is often essential for students to truly learn. The concepts students learn in supply chain classes will only get them so far; textbook problems and textbook solutions do not always translate well to real-world applications. Thus, it is vitally important for students to have the opportunity to taste what a real-world supply chain job would look like and to attain applicable and relevant experience. COVID-19 produced both challenges and hindrances to company internship programs. As this is a recent phenomenon, little research has been conducted on the changes implemented in supply chain internship programs, on the challenges and successes of virtual, on-site, and hybrid work environments, and on the future of these programs going forward. This paper will dive into some of these difficult questions and seek to provide useful answers. The following topics will be researched and discussed herein: the necessity of supply chain internships, COVID-19 effects on the supply chain industry and internships, how internship programs have changed, the successes and challenges of virtual, on-site, and hybrid internships, and finally, the future of supply chain internship programs.

LITERATURE REVIEW

As COVID-19 is a relatively recent phenomenon, any works concerning its impact on the workforce will be few in number and newly written. There are several sources, however, that are relevant to this research and important in the development of this paper. This literature review will discuss the general impact of COVID-19 on global supply chains, virtual internships prevalent during COVID-19, virtual internships before COVID-19, the importance of internships for business students, and how supply chains will adapt post-COVID-19.

COVID-19's Impact on Global Supply Chains

In March of 2020, COVID-19 took center stage all across the globe and led to an unprecedented disruption to our economy and society. Hospitals were quickly overrun, millions of workers were sent home to work, and thousands of colleges and universities adjusted to a virtual learning environment. One area that took a particularly hard hit was our supply chains. All across the globe, supply chains were disrupted as many workforces transitioned to remote work, consumer needs shifted, and certain resources unexpectantly became in high demand. Several pieces of literature have examined such effects and how companies dealt with these global disruptions. Many have found that the COVID-19 pandemic, unlike other disruptions supply chains have faced in the past, presented significantly adverse effects throughout all stages of the supply chain, from manufacturing to processing to transportation [12]. "In contrast to other natural or manmade disasters or infections pandemics, COVID-19 not only disrupted the local supply chains, but it profoundly affected GSCs [Global Supply Chains] at all stages" [12]. It is clear that COVID-19 has impacted supply chain in a unique and pervasive way. Other literature has suggested that the pandemic has affected supply chain management operations through unprecedented demand and global shortages; such adverse effects have made clear the necessity of collaboration within supply chains and the adoption of new practices such as digital transformation [6]. These two sources, among others, prove that COVID-19 had an immense impact on global supply chains resulting in a plethora of problems with a far-reaching effect.

Virtual Internships During COVID-19

Another major area COVID-19 disrupted was the ability of college students and young professionals to partake in internships. Amid the global pandemic, many internships shifted to remote work. While there is not much research specifically on supply chain internships during COVID-19, there have been several pieces of literature published describing virtual internships in general. One article explored the idea that virtual internships are viable alternatives to outright cancellations and could be utilized outside of a global pandemic [1]. This author suggests that virtual internships may provide unique access to students who were beforehand hindered by geographic location as well as allow students to practice teleworking. As our workforce has begun to implement more teleworking approaches, "virtual internships may provide training for virtual careers" [1]. Another source found similar results suggesting that virtual internships provide students unique opportunities "to gain and enrich their relevant transferable skills…These transferable skills include…adapting to learning virtually, being flexible and able to adjust well to new situations, working independently, meeting deadlines, [etc.]" [5]. While COVID-19 may have negatively impacted much of our world and our workforce, the adaption of internships to a virtual environment seems to have produced certain positive benefits.

Virtual Internships Pre-COVID-19

The concept and application of remote work are not new phenomena. Though COVID-19 necessitated a sharp increase in the remote workforce, it has been increasing steadily over the past decade. Reed et al. [8] reference surveys that suggest that 75% of companies surveyed have been hiring virtual workers since 2010. This source continues to point out that, due to an increasingly virtual workforce, virtual internships will naturally follow suit. Interestingly, another survey referenced by Reed et al. [8] mentioned that only 33% of employers hired virtual interns in 2011. This is a surprisingly low number compared to the increasingly remote workforce. Further research of my own hasn't yielded much further data on virtual business internships in recent years. Pittenger [7] attributes this lack of virtual internships in recent years to company preference. Most companies prefer to have onsite interns to better showcase the company culture, to give interns better access to mentors, to eliminate technology package expenses, and to keep certain projects confidential. While remote work has been steadily increasing, it seems to be that remote internships are only recently catching up.

Importance of Business Internships

A key part of this research will focus on whether supply chain internships during COVID-19 were completed, canceled, or adapted remotely. In considering this, it is helpful to evaluate the importance of internships in general and why it is vital that they should be continued, despite global pandemics. One study [3] found that experiential education is vital in preparing students for their careers. Many undergraduate students with internship experience were found to obtain their first jobs more quickly, be better prepared for those jobs, earn higher salaries, and experience higher overall job satisfaction compared to those students without internship experience [3]. Internships also are shown to be a great investment for the company; students with internship experience are truly valuable to a company in a number of ways, particularly in assessing and filling any gaps in the company workforce [2].

Supply Chains Post-COVID-19

Though this paper is being written as COVID-19 continues to rage on, certain strategies and theories on what our supply chains will look like post-COVID are already emerging. Yossi Sheffi has authored a new book in which he explores the chaos businesses endured during the pandemic and how companies are to move forward once the pandemic wanes. He argues that a major adjustment is now being required as we continue to see new government mandates, a new normal of working from home, new technologies being adopted, new forms of communication, and new uncertainties [10]. COVID-19 has truly changed our global supply chains forever. The global pandemic has also opened many company's eyes to supply chain vulnerabilities, particularly our excessive reliance on China; these current events have forced businesses to both rethink and re-engineer their supply chains [4]. It is clear that supply chains going forward will look distinctly different than they once were, and many companies are having to take steps to adjust accordingly.

METHOD

The best method to conduct this research will be through utilizing individual narrative interviews. The sample will consist of two main groups: supply chain major students who have had a supply chain internship during COVID-19 (March 2020-present), and supply chain managers who have had an intern or been involved in their company's internship program during COVID-19. These two groups will be the most well-versed in knowledge and insight applicable to this study.

To begin the study, participants will be emailed an invitation to participate in this research and will be asked to fill out a consent form to accept the invitation. Once accepted, a Zoom meeting link will be sent to them. Zoom will be the best method for conducting these interviews as it will allow me to speak with a wide range of people across many locations; Zoom also enables the meeting to be recorded. An outline of some interview questions will be sent to the participants beforehand if they wish to prepare. During the interview, I will utilize a pre-prepared list of questions to initiate conversations. This list of questions was developed from preliminary conversations with several fellow students, from considering the extent and scope of the research question, and from an analysis of current literature on the topic. The list of questions used to guide each interview can be found in Appendix D.

The narrative interview technique will be most helpful for this research. The narrative technique, as described by one sociologist, "exploits the…subjects' skill to verbally express themselves. However, not giving them choice-answers in interrogative research situations, but allowing them to speak freely and in an unguided manner" [9]. This method can best be utilized by asking an initial question, giving time to let the subject open up and share, and asking follow-up questions on key points the subject has made. I will be using a base list of interview questions to ask each participant; however, I will cater follow-up questions based on each individual's responses. After the interviews are complete and the data gathered, I will analyze the data for key themes and patterns. Having asked the same base questions to each interviewee, I should be able to notice patterns in the responses. I will use categorization methods to organize the data based on key themes, ideas, concepts, and repeated phrases. The data will then be interpreted based on the categorization and analysis.

RESULTS AND DISCUSSIONS

Overview of Survey Results

Through this research process, I was able to interview eleven supply chain students and four supply chain managers. Though this was a relatively small sample, each participant was able to delve into their unique experiences and offered exceptionally valuable insight into supply chain internships during COVID-19. Out of the eleven students interviewed, three had an internship canceled, yet they were all able to find a last-minute internship to replace it. Out of the fifteen total participants, a surprising eleven participated in on-site programs, two in virtual programs, and two in hybrid programs. The results and conclusions of this research are discussed in detail below and the key takeaways are summarized in Appendix A and B.

The Necessity of Supply Chain Internships

In a number of fields across countless industries, internships have proven to be essential to a student's learning curve and an excellent opportunity to apply class concepts in a real-life setting. Whether you are a nursing major, elementary education major, or accounting major, there is an intrinsic value to being able to apply knowledge in a practical way. The same is true for supply chain majors. Supply chain is such a broad field, and a college or university classroom will never instruct a student on all they ought to know. While projects, simulations, and practice can be conducted in the classroom, there is something unique about being able to see how things actually run in a real-life workforce. Internships for supply chain students can take abstract knowledge and transform it into concrete wisdom. Through my research, this fact was emphasized by nearly every student participant. There were three main reasons why supply chain internships are necessary that resulted from the interviews.

The first reason is the opportunity to both witness and apply class concepts in a practical, authentic way. One student noted how they didn't understand real-world implications in class but was able to see them in the workforce throughout their internship. Another student discussed their application of project management concepts to their job over the summer. They were able to take their foundation of project management principles learned in class and use it practically throughout their internship. Other students were able to deal directly with inventory, backorder reports, shipping reports, cost-savings analyses, data collection, purchasing, ERP systems, time studies, billing processes, and more. As many of these student interns indicated, the ability to step over the threshold from the classroom to the workforce was a vital process.

A second reason why supply chain internships are so essential is the ability for students to grasp more fully a professional business workforce and the supply chain industry at large. Several students had the opportunity to work on projects that provided an up-close look into a variety of different departments throughout their internship; they were able to see each process, talk to individuals in each area, and analyze the data they gathered. A student who worked in the transportation industry during their internship noted how complex and fast-paced the environment was; they noted that something is always changing and how "there is not a textbook answer for everything." Other interns got a taste into the more analytical side of supply chain and enjoyed that particular aspect of it. One of the managers interviewed noted how their interns were paired with buddies on the teams, invited to supplier meetings, and were able to get a feel of the day-to-day operations. "It was cool to understand how each system works and how everything is incorporated," noted one intern working in a distribution center. Overall, there were numerous stories of students emphasizing the benefits of their integration into their particular company. The opportunity for students to be immersed in the business world and into the supply chain industry during their internship is an advantage not to be lightly regarded.

A third and important reason supply chain internships are a necessity is because they offer a foundation and a guiding hand for a student's future career. A majority of the students interviewed expressed an enthusiastic interest in pursuing supply chain full-time upon graduation. One person noted that working in supply chain "really showed me that that's what I want to do." This student is now pursuing a supply chain career after graduation. Another student, having had completed both an accounting and a supply chain internship, realized that supply chain was something they enjoyed a lot more than accounting; they are now actively pursuing supply chain careers. In a question asking about how the student's internship shaped

their career goals, one answered, "[I] got a holistic look at the streamline of a company and seeing where I really fit into it." Being able to be immersed in a company and to see how the supply chain world operates is essential for a student in determining their future. Though one may fall in love with the concept of managing inventory in a class setting, the ability to see the reality of this process may alter their perspective. As a student looks into potential full-time jobs, the company size, industry, and environment all play important roles. Many students fell in love with the environment of their company and are thus pursuing full-time positions at the same company they interned at. Other's experiences pointed them in different directions. One particular student worked at a very small company over the summer and recognized they didn't want to work full-time there. They realized they wanted to be able to have room to move around in a company and decided to pursue a larger company. In a similar vein, not all students concluded that supply chain was the field for them at all. One student remarked how, "After being exposed to the supply chain side, I realized how unpredictable it is" and continued to describe how messy they thought it is. This student had also completed two internships, one in accounting and one in supply chain. As a result, they realized they enjoyed the accounting industry better. It may be tempting to desire all supply chain interns to pursue supply chain full-time, but that is not necessarily the purpose of the internship. The purpose of a supply chain internship is to grant students the ability to apply class concepts in a meaningful and relevant manner, to grasp the nature of the supply chain industry, and to acquire a sample and an example of potential full-time careers. Whether the student proceeds to choose supply chain after graduation or to embark on a different path, the internship could still have served its purpose. This is another reason why supply chain internships are so essential; students may realize they do not enjoy the work or recognize another direction may be best for them.

Overall, it is abundantly clear that supply chain internships provide students unique access to classroom concept application, a survey of the supply chain field, and a clearer career pathway. It also should be noted that each of these students' thoughts come from their internship experiences during COVID-19. The benefits of supply chain internships were distinctly emphasized, even amidst a global pandemic. Companies ought to consider the importance of these internship experiences; internship programs have a profound significance in shaping a student's career. Though COVID-19 brought havoc and chaos to many companies, we should not let COVID-19 stand in the way of delivering these valuable experiences to willing and able students. Supply chain internships are essential. But they can only happen if companies are willing to hire and teach. Supply chain students are knocking; will companies open the door?

COVID-19 Effects on the Supply Chain Industry

COVID-19 was a phenomenon that truly uprooted our lives. Nothing in our lifetime can compare to the effects and repercussions that COVID had on the world. The business world was particularly impacted as global shortages commenced, plants were shut down, international travel was limited, and a large majority of the workforce was sent home. As the business world was forced to regroup and reorganize, the supply chain industry took a blow. Some companies suffered tremendously due to the limitations and strain on their supply chains. Others faced a unique wave of growth. Depending on the industry you were in and the product or service your company sold, some companies flourished during COVID while others flailed in an ocean of unknowns. Supply chain students who participated in internships during COVID-19 were forced to work during a very unique, and often frustrating time. Yet their perspectives are truly

valuable. For some students, their first supply chain internship took place during COVID, and thus, they had no benchmark for comparison. Others had a previous internship pre-COVID and were able to see how their two experiences sharply contrasted. Each student and manager interviewed were able to share their distinct perspectives and contributed to a wider understanding of the types of effects COVID-19 had on the supply chain industry.

In each interview, all the participants were asked how they saw the effects or impacts of COVID-19 on their company. Though many different answers resulted, one common theme was present: COVID-19 impacted their company in some way. It seems that no company was immune to the rampant effects of this global pandemic. However, the manner and the particular way each company was affected varied based on industry, type of product sold, and company size. One intern shared how their company's product experienced a high increase in sales and revenue; because of this massive explosion in demand, the student witnessed how the company struggled to keep deadlines as they were running out of inventory and lacked the appropriate manpower. Whereas other companies had to lay off a number of people, some companies actually had to hire more people to help facilitate the increase in demand. Students who worked in the transportation industry expressed how important transportation was, especially during COVID-19. This was an essential industry, one student noted, even though the company didn't service its normal customers.

On the other side of this, some companies experienced more adverse effects on their supply chain. One student shared how their company experienced high employee turnover due to stimulus checks prompted by COVID-19. Other students saw the effects that shortages in one area of the company trickled down the chain. One manager noted that many of their customers disappeared thus challenging their ability to buy supplies. Lack of manpower in some of our vendors led to price increases for our company, a second manager explained. Others saw problems with inventory backorders, shortages in materials, delays in stock availability, and unexpected costs. It is clear from the evidence presented in each participant's experience that COVID-19 drastically impacted supply chains in many different industries in many different ways. Students were able to witness and be a part of each company's response to both the challenges and successes generated by COVID-19.

COVID-19 Effects on Internships

Just as COVID-19 greatly impacted a company's supply chain, the effects of COVID-19 on supply chain internships did not go unnoticed. Whether a student was on-site or working from home, the global pandemic impacted them in one way or another. Interestingly, the majority of students interviewed were able to remain on-site during COVID. Even with this sense of normality, many things looked different on-site amidst the pandemic. The biggest effect of on-site internships was the implementation of masks or face-coverings. Many students shared how mask requirements wavered throughout the summer of 2020 and 2021. Early 2020, as companies were still figuring out the gravity of the virus, many students noted how masks weren't required. As the summer went on, more interns saw mask mandates come into place. For the interns that completed internships in the summer of 2021, students saw mask requirements slowly fade, or the conditions change. For instance, as time went on, companies implemented a variety of policies ranging from requiring masks only for the unvaccinated, recommending but not requiring masks for anyone, requiring masks if in hallways but not in personal spaces, etc.

When asked about the impact that mask requirements had, students provided several different responses. One student noted how masks weren't too much of a hassle, but they kind of killed morale. Another noted that it was more difficult to talk to people in masks, but not having to wear masks while social distancing helped offset the inconvenience. Mask requirements affected other students in a way that was more than just an inconvenience. One intern shared how difficult and frustrating having to wear a mask was while shadowing people for extended periods of time. This person even went so far as to say they would probably be less likely to reach out to someone in person because of the hindrance of a mask, and instead just solve the problem online. Another intern had the opportunity to work in the company's warehouse but having to wear a mask in a hot warehouse "made it miserable;" in fact, it limited the time they spent on the floor. Though all the interns didn't believe that mask mandates or social distancing requirements prevented them from accomplishing or completing their projects, these additional COVID-19 procedures certainly affected them in some way.

For both on-site interns and virtual interns, the broad transition of the workforce to more remote work impacted them in both environments. "The majority of people I worked with I never met in person," one intern remarked. Though this intern was working on-site, many other full-time employees were still working from home. Almost all interns used some sort of communication platforms, such as Skype, Zoom, and Microsoft Teams, throughout their internship. Whether they were working in a cubicle on-site or a desk in their bedroom, the use of instant messaging, emails, and video calls was prevalent. Several interns who worked hybrid throughout their internship noted how the reliance on virtual communication looked the same whether they were in-person or at home. This has certainly been a unique result of COVID-19 and is one with consequences not likely to dissipate anytime soon.

How Internship Programs Have Changed

It is clear that COVID-19 has affected supply chain internships in many ways. Because of this, many companies realized that the internship programs themselves had to change. Diving deeper beyond simply the effects of COVID, we shall examine the changes to internship programs that became essential. One of the biggest changes to supply chain internships has been the increased reliance on virtual communication. Whether the intern was on-site or at home, the utilization of online chatting, video conferences, phone calls, and email seems to have grown remarkably. Many interns noted how team meetings over Skype or Microsoft Teams were a day-to-day activity. Very few people were actually in the office as many were still working from home, two different interns shared. They were thus very reliant on virtual communication to connect with and work alongside them. One intern described how they reported to two managers, one of whom was on-site while the second was hybrid (half on-site and half online). They shared how, throughout their internship, they had to learn to navigate not having an answer if a manager wasn't there all the time. This is an important change in how internships are set up. Rather than having a manager always on-site and very easily accessible, interns noted a change in how communication had to be accomplished. One manager who worked with fully virtual interns recognized that, in a fully remote environment, managers may not always be available. Therefore, this particular manager decided to implement a weekly check-in with all the interns and their managers. This would ensure interns would have time to share any questions or concerns in a stress-free environment, and it would also give each manager the chance to receive updates on the intern's work and projects. Through many different intern and manager responses,

it is clear that one of the most impactful ways these programs have changed is a shift into a more online environment, even for those who remained on-site. The ability for a company to adapt to the increased application of virtual platforms is essential for supply chain internships going forward.

Another way supply chain internship programs have changed is in the type of projects offered. The manager of a fully remote intern described how, in the past, interns were given projects that often didn't last beyond the extent of their internship. COVID-19 forced their team of managers to think through more quality projects interns could work on that would contribute directly to their business. As a result, they received products from interns that they are still using today. This company was able to move beyond the projects that filled immediate needs and onto ones that were more strategic and long-term. Several other participants interviewed had transitioned from their internships to full-time roles at the same companies. They thus noted how they were able to see the projects they had worked on during their internship still be functioning and utilized day-to-day. Though this may not be a direct result of COVID-19 in all cases, this potential shift to more meaningful projects is one that did not go unnoticed by either manager or intern.

A final way internship programs have changed is in the implementation of the hybrid work method. Several participants interviewed described how they worked both on-site and at home throughout their internship. As mentioned previously, COVID-19 introduced a great shift to more remote environments. Several companies, however, still recognized the value of on-site work. Many intern's jobs allowed them to work partly in the office and partly in their homes. Previous to COVID-19, hybrid supply chain internships were uncommon. Working hybrid gives interns more flexibility, as many have recently discovered. This was a very unique change in internship programs that would be unlikely to have taken place if not for this global pandemic.

Successes and Challenges of Virtual Internships

As previously mentioned, one of the many changes COVID-19 brought upon supply chain internships was the move to more fully virtual environments. As the global pandemic forced hundreds of employees to transition to remote work, internships for many students also followed suit. Instead of coming to work on-site for a company, many students were shipped an IT package and required to set up workstations at their kitchen tables and bedroom desks. Though most of the students interviewed had on-site internships, there were several that were able to provide insight into their virtual experiences. Even for the on-site interns, their thoughts on the value of on-site versus remote work are invaluable.

One of the successes of virtual supply chain internships is a more flexible and accessible work environment. Being at home, a student is allowed a more comfortable and safe atmosphere to accomplish internship tasks and projects. They are still able to receive a valuable experience, and yet do not have to worry about a commute, about adjusting to a new work environment, and about the distractions of a busy office. One intern mentioned, "Accessibility of virtual work is a lot easier; you can reach someone a lot easier than if you had to walk across a campus." Others mentioned being virtual is more convenient, grants more freedom, is more flexible with location, provides more comfortability, and offers an opportunity to simply sit down and crank out work. Another success is simply the enhancement of one's quality of life. One manager noted, "There's

quality of life benefits for people being able to be at home and have a flexible schedule and being able to manage their life." For interns and full-time employees alike, the demands of daily life are often more easily managed when given the flexibility of remote work. Supply chain internships are a unique field in which virtual work is not only possible but can also be quite effective. Concerning their company's transition to remote work, the same manager went on to say, "Frankly, I think we have proven as a workforce to be pretty good at adapting and keeping the mission going without significant setbacks or detriments." Virtual internships for supply chain students can often be valuable alternatives to fully on-site work.

There are certain elements, however, that interns lose when sent online. For many, working from home is often more distracting. One intern mentioned, "I'm much less productive virtually, I have less initiative to walk over and [ask for help]. I'm more motivated on-site." Another intern, describing the downsides of fully virtual internships, said, "You don't always learn what is expected of you." Being on-site, a student can more easily pick up on expectations, have the opportunity to talk to more individuals in various areas, and can create deeper relationships. When fully virtual, interns oftentimes lose this. One of the biggest advantages to working on-site, as many interns reiterated, is the people. Creating relationships, interacting with managers, communicating efficiently, and shadowing coworkers are benefits that are often lost when translated to remote atmospheres. One manager describes the challenge of training virtual interns: "When there is a point when someone gets stuck…it takes more time to resolve now because you either have to struggle through and research it on your own or you have to wait for someone to become available and to help you." Other managers have harked on this point, explaining how training in a virtual environment is much more difficult. In-person, managers can see whether the light-bulb turns on for an intern; virtually, this is more difficult. Students also noted that certain projects and tasks they completed on-site would not be possible if online. Many noted that some aspects of their responsibilities could perhaps be done from home, but not nearly to the full extent they experienced in person. Another challenge is simply the exhaustive nature of working 40 hours a week in front of a screen in one's home. "Telecommute days are great for what they are, but it's non-stop. You are mentally drained by the end of the day," a manager pointed out. A final challenge many saw was an inadequate overview of the supply chain field. As another manager put it in describing an intern's experience, "You [the interns] don't know what's out there. That's the beauty of being an intern; you should come in and you should see things; you meet other people, and you ask lots of questions…You get to see all that a lot more when you're in the building." This particular manager had been working with virtual interns the past two summers and evidently witnessed many lost opportunities when comparing the on-site versus virtual experience. Virtual supply chain internships can be useful in some scenarios, but these numerous challenges must be considered.

Successes and Challenges of On-Site Internships

The value of the hands-on experience for a supply chain internship is immense. For a student to experience the application of class concepts to real-life problems, to more fully understand the supply chain business world, and to grasp an idea of potential careers, the on-site learning environment is often essential. All of the interns interviewed who worked on-site loved their experience and claimed to have gained much from it. Even amidst COVID-19, the innate value of being on-site for many of these students was immense. For companies working to shape the

future of their internship programs, it is helpful to analyze both the advantages and disadvantages of working in person.

The biggest advantage noticed by each on-site intern was the ability to be with people. An atmosphere in which one can interact with, communicate with, and learn from people in person contributed to a beneficial and successful experience for all. Working on-site for one intern was a, "very interactive environment that I really would have missed out on if I was online or virtual." When asked about their experience being able to communicate on-site, they went on to say, "[It was] really cool to get to meet people. I grasped the job much better by being with people in person." The experience of "being able to connect with the people around you makes the work environment better," another intern explained. Others described how being on-site gave them a chance to meet people they wouldn't normally meet, to learn who their resources are, to experience company culture, to attain a level of comfortability with coworkers, and to establish friendships. "You can only make so much of a relationship over Zoom and Teams," one student stated. In a field that is very much centered around people, the ability to build relationships with those around you is essential. While relationships can be built online, being face-to-face with your manager and your colleagues provides deeper and more meaningful connections. One intern shared some unique insight about this. To paraphrase them: On-site, someone can come in and be having a bad day, and you can see they're having a bad day; if working virtually, you can't really see that; in-person, you can celebrate with people, can talk with others, and can share joy with others - this was a meaningful part of my internship. The ability to connect with and share in life with other people was a significant success of in-person internships for many students.

A second advantage to working on-site is the opportunity to learn. One intern noted, "When I'm in the office and talking to people…it's a lot easier to understand." Another stated, "[There's] a lot less misunderstanding of what's going…better goals of what you are trying to accomplish." Several mentioned that being able to look at a process and follow it all the way through was extremely helpful. Even several managers noted that from a training standpoint, being on-site is almost essential. The ability for a student to put two-and-two together and to connect the dots is almost always easier when in person. The learning curve for a student expands when they can obtain hands-on training. Many interns were able to go onto a production floor, to see how their product is built, to witness the machinery in action, and to follow a process all the way through. This type of learning cannot be replicated in a virtual environment.

One of the questions asked to all participants who were part of an on-site internship was, "How do you think your internship experience/work assignments/communication would have looked if you had been virtual?" Many interns described how they didn't believe their projects would have been able to be accomplished if forced to work fully-virtually. "I don't think we would have completed our project if we were virtual," said one intern. Another one mentioned that "I still would have been able to learn a lot, but I don't think it would have been the same. So much of what I did was physical and working with the people on my team." Others explained how they wouldn't have been able to shadow people, they wouldn't have been able to learn the same lessons, and they wouldn't be able to complete the same type of work. To expand on this last point, many interns described their projects and daily responsibilities and added that it would have looked completely different if they had been virtual. Many projects these students were given were designed specifically for an on-site environment. Working in the warehouse, interacting with various departments, collecting on-site data, and tracking different processes

would have been much more difficult, if not impossible, if transferred to a fully virtual workplace. One intern summarized their thoughts on this subject by saying, "[It's] possible to have virtual internships, but they wouldn't have gotten the most out of me and I wouldn't have gotten the most out of them." This is a unique and valuable insight. As companies look to shape the future of their internship programs, this is an important concept to keep in mind. While much can be transferred to a virtual environment, there are certain dimensions of on-site work that simply cannot be translated to an online world.

The successes and advantages of remaining on-site for a supply chain internship, even during COVID, have been clearly emphasized by many. However, in an increasingly virtual world with a greater ability to accomplish more online, there are some challenges to remaining on-site. The disadvantages described by these interns, however, are highly based on personal preference. One intern described the lows of working on-site by saying, "I got less done than I could have. I was less productive than if I was fully virtual." They explained how, in the office, there was more of a social aspect present, and the ability to talk and interact with people socially often took up time. When asked if they believed they would have accomplished more, less, or the same amount of work if virtual, this same student mentioned, "I think it would have been more productive volume-wise… [But] the quality of work would have been a lot lower. More quantity, but less quality." For others, however, distractions were greater when working at home. Several noted that in their experience of working virtually, the distractions of being at home made work more difficult. Other disadvantages mentioned about working on-site included the inconvenience of a daily commute, a less productive atmosphere, and difficulty in balancing communication between remote and on-site coworkers. One other intern mentioned that if fully in-person, they would've missed out on the chance to join virtual meetings with higher executives. This is an exclusive opportunity and a great occasion for more learning. All in all, though the successes of the in-person work environment are plenteous, there are still challenges to be considered.

Hybrid Internship Method

From the evidence presented by each of these students and managers, there are undoubtedly benefits and drawbacks to both virtual and on-site supply chain internships. COVID-19 truly impacted each of these environments in different ways with different outcomes. Companies all across the world, however, have analyzed and evaluated these impacts. What has resulted is a third internship method: hybrid. As mentioned previously, the introduction of the hybrid method is one of the changes COVID-19 brought upon supply chain internships. Both students and managers have recognized the value that the hybrid method can produce for an internship experience. The ability to work a few days from the comfort of home and a few days alongside coworkers in an office is a truly viable alternative to fully on-site or fully virtual. When asked in the interviews what their thoughts were on the hybrid method, each student and manager shared excellent feedback.

"Hybrid is probably the best route," shared one intern who had the chance to experience working in both an on-site and off-site setting. Other interns praised the flexibility, the freedom, and the independence of working hybrid. One manager shared their love for this method by describing how they loved being home and they loved being in the office but for different reasons. They went on to say, "I really think the hybrid model is the way to go in the future because I think you'll get happier employees that way." This model, in a perfect world, can maximize the

benefits and minimize the downsides of both on-site and virtual internships. There is a strong appeal to the implementation of the hybrid method for supply chain internships. It provides interns the flexibility of getting work done from their home on certain days and valuable training opportunities when on-site the other days. Supply chain is a unique profession in which, in many cases, the work required can often be accomplished in both environments. For interns, certain pieces of a project can be worked on from home, and those pieces can then be put together when brought back on-site.

Not wanting to paint in broad strokes, it is also essential for companies to consider the positions and the specific jobs required of each intern. Supply chain is a very broad field, and so we must not assume all supply chain internship programs will fit the conditions of the hybrid method. For some supply chain jobs, interns are needed on the production floor, in a distribution center, or daily contact with other on-site employees. For other supply chain jobs, there may be no need or benefit to come on-site at all, except for perhaps the occasional opportunity to interact with fellow employees. When considering each of these methods, companies ought to evaluate and consider all aspects of what will be expected of the intern and how the environment will affect their learning. One intern wisely stated, "Hybrid works depending on the person, on their efficiency, and their reason for needing to be hybrid." Many of the other interns and managers, when asked about hybrid as an alternative method, pointed out that it depends on the individual, depends on the position, and depends on the projects. Hybrid is undeniably a practical and effective method, but one size does not fit all. As the hybrid model is only a recent product resulting from COVID-19, it will be important for companies to consider all these options carefully going forward.

CONCLUSIONS

Future of Supply Chain Internship Programs

If COVID-19 has taught us anything, it's how to adapt. Though masks and social distancing hindered some students' on-site experiences, and though it was frustrating for some to learn and engage in a fully virtual world, supply chain internship programs were still largely successful. COVID-19 is oftentimes seen only as an agent of chaos and disorder when, in reality, growth and new opportunities have sprouted all around us. The future of supply chain internship programs is an important topic to consider for company executives and managers, university professors and advisors, and students looking to make their way in the corporate world. Based on the evidence produced in this research, several predictions and evaluations of change can be made regarding the future of supply chain internship programs alongside certain challenges for both companies and students going forward.

The first change evaluated in the context of future supply chain internships is an increased reliance on virtual platforms. Though Skype, Microsoft Teams, and other online platforms have taken the stage over the past few years as digital transformation has grown, the use of these platforms skyrocketed when a large majority of the workforce was sent home during COVID. Even those still working in the office were required to utilize these platforms in one way or another. As supply chain internships are completed in the future, there will undoubtedly continue to be a dependence on these applications. A challenge for companies, both small and large, would be to invest in and utilize these platforms well. We live in a technology-driven age.

COVID-19 only accentuated this drive. As companies shape plans for their next supply chain internships, the emphasis and utilization of these tools will be essential. For students, a challenge is to increase their knowledge of many of these virtual platforms. Entering a company already possessing a familiarity and a skill in these tools could very likely set them above their peers. COVID-19 has certainly pushed us into a more digital world; supply chain internships will likely continue to see this push played out in many ways.

Taking this idea of digitization a step further, the second prediction that can be made based on the evidence before us is an increase in virtual supply chain internships. Though there are immense benefits to being on-site and many challenges when working from home, COVID-19 has shown many companies that work can still get done when online. The wheels of the supply chain world have kept turning, despite the mass influx of employees working from home. The same is true for internships. The companies that implemented virtual supply chain internships continued to witness great benefits. Valuable products were still being turned out by interns, even in a virtual atmosphere. Not only are they still benefiting from the interns, but the execution of virtual supply chain internships is often a cost-saving for a company. Besides the cost of shipping technology packages, a company does not have to pay much for a virtual intern: no relocation fee, no extra office space and supplies, no additional heating, cooling, and lighting costs, etc. Based on simply the monetary advantage alone, the appeal for more virtual internships is likely. Combining cost savings with quality work still being accomplished, it is probable that many companies will be considering fully remote supply chain internships in the future. A challenge to companies as they consider this alternative is to evaluate the pros and cons. Though virtual environments may be cheaper and more convenient, are they truly offering the best experience for a student? Are they truly showcasing the culture and community of a company? Are they truly challenging students in the most meaningful way? For supply chain students as they consider virtual internships, a challenge is to evaluate what type of environment they will thrive the most in. Some students have found on-site work is more distracting; others are less productive and less motivated when working from home. When seeking out these opportunities, students ought to consider carefully the type of environment in which they know they will both learn and contribute the most.

While virtual internships are attractive to many companies, others have recognized the value of being on-site. A third evaluation of the future of supply chain internships is the likelihood that many companies will be returning to, or remaining, on-site. COVID-19 has shown companies and students alike that there is an intrinsic value and a greater learning curve when working in an office. The interns that completed their internship on-site, even during COVID, adamantly praised the benefits and learning opportunities present. Having tasted the importance of the on-site work environment, it is doubtful students will desire to be transferred online when seeking full-time jobs. Even though COVID-19 made working on-site more complicated, no student interviewed would have traded their experience for a fully virtual one. And for the interns that worked fully remote during COVID, though their experiences may have been successful, many came away hungering for the chance to be on-site. To companies contemplating the future of their supply chain internships: consider carefully and thoroughly the benefits of on-site work. As evidenced by these interviews, the importance and value of on-site internship experiences are overwhelmingly rich. To students seeking supply chain internships: pursue companies that recognize the value of the on-site environment; pursue companies that give you the opportunity

of being on the floor, of seeing production lines, of interacting with fellow employees. These will likely be the companies offering the most rewarding experiences.

One final prediction for the future of supply chain internships is the application of more hybrid models. As described previously, the hybrid method often offers the best of both worlds. COVID-19 was the main influencer in the introduction of this method. The restrictions and complications of a global pandemic forced many companies to reevaluate their processes and programs. The result for many was the establishment of this hybrid model. This new model offered both company and intern more flexibility and more positive results. From the evidence gathered through this research, it has been made clear that a hybrid scenario is a feasible and valuable alternative. Moving past COVID, one could modestly predict that the hybrid model will continue to be utilized for supply chain internships. A challenge for companies is to consider the viability of this method for their internship programs. There are many benefits to be reaped and successes to be had. However, companies should consider this method with a grain of salt. For some supply chain internship positions, hybrid may not be the best method. There could be scenarios where an intern should remain fully on-site, or where fully virtual is more cost-effective. It will be important for companies to evaluate carefully the specific jobs, positions, and requirements for each internship program before making decisions. A challenge for supply chain students: if they find themselves working in a hybrid internship, take advantage of both environments. The supply chain field is brimming with learning opportunities, and these can be taken advantage of both virtually and in person. Interns should be challenged to avoid slacking in one atmosphere versus the other; there are significant rewards within both. All in all, the hybrid method is a noteworthy product of COVID-19 and it is unlikely to be forgotten or neglected.

These predictions and challenges are summarized in Appendix C.

Conclusion

Winston Churchill once said, “To improve is to change; to be perfect is to change often.” COVID-19 opened the door for such change. No matter the size, product, or industry of a company, no one was completely immune to the changes induced by the pandemic. In fact, the corporate world at large was remarkably united in its struggle to face these challenges. What made these companies distinct, however, was their ability to not only overcome but to seize the opportunities for growth and change amid the present trials. In the context of supply chain internships, many companies did just that. While some companies were forced to cancel internships, others were determined to take advantage of the value interns could bring to their organization and desired to offer guidance and valuable experiences to eager students. Whether the company offered a virtual, on-site, or hybrid experience, all interns during COVID-19 certainly expanded their knowledge and widened their horizons. Going forward, companies ought to consider the methods, processes, and programs that will benefit both the organization and the intern in the most effective and efficient ways. It is worth repeating: one size does not fit all. COVID-19 has opened the doors for these different alternatives to a traditional on-site internship. However, companies should consider the needs of the organization and the requirements of each specific supply chain role. One method may work well for one organization and be a failure for another. No matter the method, internships are essential in training the next generation of supply chain professionals. COVID-19 has shown us that the world needs supply chain professionals. In a post-COVID world, it will become essential for companies to evaluate

the successes and failures of their supply chain internship programs when determining and shaping the future.

COVID-19 has opened the door for change, and thus, the door for improvement. The future of supply chain will be determined by the decision companies make on whether to act on shrink from such change. There is a window of opportunity here as we slowly make our way out of this pandemic. The changes to supply chain internships that COVID-19 has prompted have inadvertently provided companies a chance to significantly improve their programs. Let us not be too eager to move past the trauma of COVID-19 without capitalizing on the many lessons it has taught us and the changes it has generated. To supply chain students, to supply chain professors, and to supply chain professionals, I ask this: how will you respond?

Topics for Further Investigation

The scope and magnitude of the research were, of little surprise, limited by time and resources. There is plenty of room, therefore, for the development and expansion of these results. For further research, I would suggest the following strategies. Firstly, this research was conducted on a relatively small sample size. The insight and expertise gained, however, was immense. If this research was expanded to a larger population, the outcome would undoubtedly be extremely valuable. Secondly, given the opportunity to interview a greater number of supply chain students and supply chain managers, one would gain a more in-depth look at a variety of topics. Such topics that would be beneficial to delve deeper into include the following: how company size affects a company's decision to implement virtual or in-person programs, how company industry shapes the type of project work given to supply chain interns during COVID, whether the personality of the intern influences their success or failure in virtual and in-person environments, and the general cost benefits/detriments of the hybrid model for companies. Each of these topics would be helpful to know more about. Taking this a step further, there are three specific propositions I would recommend for further testing and investigation.

Proposition one: *The implementation of the hybrid model for supply chain internships will lead to improved internship outcomes*. Hybrid models have seen great success in the past two years of COVID-19; this model will undoubtedly continue to be a worthwhile option with incredible outcomes for both company and student.

Proposition two: *Fully virtual internships for supply chain students will hinder their ability to transition efficiently to an on-site workforce upon graduation*. While remote work has shown to be successful in many cases, nothing compares to the lessons and experiences of being on-site. As students transition from college to the workforce, those who have only experienced remote internships may be a step behind those who were able to learn on-site.

Proposition three: *The individual personality traits of each intern influence their successes or difficulties in on-site, virtual, or hybrid environments.* Many interns referenced their personal preferences when describing whether they enjoyed or struggled in virtual and on-site environments during COVID-19. Going forward, giving interns a choice in the environment they work in during a supply chain internship may lead to greater success.

This research is only a small stepping stone to understanding a business world turned upside down by COVID-19. There are certainly many more steps to be taken and topics to explore to fully comprehend the effects and impacts the pandemic has had on supply chain internships.

REFERENCES

[1] Feldman, E. (2021), "Virtual Internships During the COVID-19 Pandemic and Beyond." *New Horizons in Adult Education and Human Resource Development* Vol. 33(2), 46-51. doi:10.1002/nha3.20314

[2] Formby, S. & Crandall R. (2013). "The talent supply chain," *Industrial Management*, September/October 2013.

[3] Gault, J., Redington, J., & Schlager, T. (2000). "Undergraduate Business Internships and Career Success: Are They Related?", Sage Publications, Inc., *Journal of Marketing Education*, Vol. 22, No. 1, April 2000.

[4] Javorcik, B. (2020). "Global supply chains will not be the same in the post-COVID-19 world," *COVID-19 and Trade Policy: Why Turning Inward Won't Work.* Centre for Economic Policy Research, 2020.

[5] Klein, L. & Scott, C. (2021). "Managing Virtual Internships During the Covid-19 Pandemic Era: Implications for Academic Instructors and Business Leaders," *Journal of Higher Education Theory and Practice,* Vol. 21(7), 2021.

[6] Micheli, P., Johnson, M., & Godsell, J. (2021), "How the Covid-19 pandemic has affected, and will affect, operations and supply chain management research and practice." *International Journal of Operations & Production Management*, Vol. 41, No. 6, 2021.

[7] Pittenger, K. (2021). "Virtual Internships – A New Reality," *Developments in Business Simulations and Experiential Learning,* Vol. 48, pp. 149-152.

[8] Reed, L., Whitten, C., Swank, A., Gioia, J., Marr, M., Woods, W., Jeremiah, J., Westerman, L. (2018). "The Changing Landscape of Experiential Learning in Higher Education," *Developments in Business Simulations and Experiential Learning*, Vol. 45, pp. 234-239, Association for Business Simulation and Experiential Learning.

[9] Scârneci-Domnişoru, F. (2013). "Narrative Technique of Interviewing," Bulletin of the *Transilvania* University of Braşov, Series VII, Vol. 6 (55) No. 1.

[10] Sheffi, Y. (2020). *The New (Ab)Normal : Reshaping Business and Supply Chain Strategy Beyond Covid-19,* Transoft Inc., 2020.

[11] Taylor-Powell, E., Renner, M. (2003). "Analyzing Qualitative Data," University of Wisconsin-Extension, *Program Development & Evaluation*.

[12] Xu, Z., Elomri, A., Kerbache, L., & Omri, A. E. (2020), "Impacts of COVID-19 on Global Supply Chains: Facts and Perspectives." *IEEE Engineering Management Review*, Vol. 48, No. 3, Third Quarter, September 2020.

APPENDIX A – KEY TAKEAWAYS FOR MANAGERS

On-site Supply Chain Internships	Virtual Supply Chain Internships	Hybrid Supply Chain Internships
Benefits - ability for interns to interact with people and to develop meaningful relationships - opportunity for interns to learn in a hands-on manner - completion of certain projects that can't be done online	*Benefits* - more flexible and accessible work environment - enhancement of an intern's quality of life - a valuable and effective alternative to on-site internships	*Benefits* - opportunity to experience and learn from both on-site and off-site workplaces - can maximize the benefits and minimize the downsides of each environment - offers flexibility and freedom
Challenges - distracting office setting - inconvenience of a daily commute - difficulty in balancing communication with both remote and on-site coworkers	*Challenges* - less productive - less interaction with people - difficult to train interns - limits the scope of projects that could be completed - exhaustive by nature - inadequate overview of supply chain field for interns	*Challenges* - may not be effective or practical based on the requirements and expectations for specific internship programs - some supply chain intern positions and jobs can only be done on-site while others can be accomplished solely online
Recommendations Examine both the advantages and disadvantages of on-site work for your supply chain program. On-site experiences are typically most beneficial for a student's learning and their ability to complete projects. In some cases, however, a virtual workplace can be more effective and efficient for both intern and company.	*Recommendations* Consider the extent of your internship program, the technology available, the jobs and projects needing to be completed, your ability to train interns effectively, and whether a virtual experience can offer comparable learning opportunities to being on-site.	*Recommendations* Analyze the scope and needs of your internship program and the specific positions of your supply chain interns before implementing. Hybrid is often a viable method, particularly in the supply chain industry, but it does not work in every situation.

APPENDIX B – KEY TAKEAWAYS FOR STUDENTS

In considering supply chain internship opportunities, the following aspects should be considered:

	On-site Supply Chain Internships	Virtual Supply Chain Internships	Hybrid Supply Chain Internships
Personality	- people-oriented - ability to connect well with people and develop meaningful relationships - desire for collaboration - hands-on learning style	- strong initiative capability - organized - independent - excellent communication skills - ability to be proactive in learning	- able to adapt to different work environments - ability to connect and communicate well with people both remotely and in-person - desire for flexibility - can work well alone and alongside others
Location	- must relocate if not in the same area as the company - factor in your daily commute	- can work from anywhere - no commute necessary	- must relocate if not in the same area as the company - commute necessary but not daily
Learning	- hands-on - see processes and procedures enacted in real-time - shadowing others in-person - potentially more distracting in a busy office setting	- more distanced learning - shadowing others through virtual platforms - potentially less productive in a home full of distractions - necessity to learn more on your own	- hands-on - learn concepts on-site and apply them when remote - shadowing others when in-person and when online - potential for distractions in both environments
Projects	- opportunity to complete more hands-on projects, i.e. working with inventory, being on production floor, interacting with many different departments	- limited in scope to what can be accomplished solely online - company may offer more quality, strategic projects that will enable you to learn more deeply	- combination of hands-on projects and tasks that can be completed virtually - projects that may require a certain amount of time on-site and a certain amount of time solely on a computer

APPENDIX C – KEY PREDICTIONS AND CHALLENGES

Predictions	A Challenge to Companies	A Challenge to Supply Chain Students
(1) Increased reliance on virtual platforms within supply chain	Invest in and utilize these platforms effectively	Increase knowledge of and familiarity with these virtual platforms
(2) Increase in virtual supply chain internships	Evaluate the benefits and disadvantages of virtual work before implementing	Evaluate the type of environment you will learn and perform the best in
(3) Returning to, or maintaining, on-site supply chain internships	Consider thoroughly the benefits and importance of on-site internships	Pursue companies that offer on-site experiences and opportunities
(4) Application of hybrid models	Assess the viability of the hybrid method for your specific supply chain internship program	If in a hybrid internship, take advantage of the opportunities in both environments

APPENDIX D – INTERVIEW QUESTIONS

Questions for Students:

1. What was your internship position at the company you interned at?
2. Were you able to complete an internship during COVID-19 (March 2020-Present)?
3. Was your internship virtual or in-person or hybrid?

IF VIRTUAL

4. Tell me about the timeline of your internship. What date did you begin and end?
5. Describe your onboarding process. Was it a smooth process? Do you believe it would have been better/worse/no difference had it been in-person? Why?
6. Were you sent a technology package (laptop, monitor, etc.)? Describe your at-home setup.
7. How did you communicate with your manager and other co-workers? Outlook, Skype, Zoom, Teams? Were you familiar with the communication platforms your company used? Were you well-instructed and informed on communication expectations? How often were you in contact with your manager and co-workers? Describe some of your successes and any downfalls of communicating in a virtual environment.
8. Describe some of your internship responsibilities. Did you work on projects, perform daily tasks, shadow other employees? Do you believe you would have been able to accomplish more/less/the same amount of work if you were in person?
9. What did you learn about the Supply Chain industry in your internship? Were you able to apply concepts learned from school to your job?
10. Did you see or experience the effects of COVID at the company you worked for? If so, describe the impact you believe COVID had on the company.
11. Based on your experience, what are some of the biggest advantages of working virtually? Disadvantages? What is the biggest lesson you learned working virtually?
12. What are your career goals? Do you plan to pursue a Supply Chain career? How beneficial was your internship in shaping those goals?
13. If you could repeat your internship over again, would you choose to work virtually or in person? Why?
14. What was the most rewarding part of your Supply Chain internship?

IF ON-SITE

4. Describe your onboarding process. Was it a smooth process? Do you believe it would have been better/worse/no difference had it been virtual? Why?
5. Were given an office to work in? Describe your work environment.
6. What COVID policies were required (masks, social distancing, etc.)? How did those affect your daily work?
7. How did you communicate with your manager and other co-workers? Were you familiar with the communication platforms your company used? Were you well-instructed and informed on communication expectations? How often were you in contact with your manager and co-workers? Describe some of your successes and any downfalls of communicating while on-site.

8. Describe some of your internship responsibilities. Did you work on projects, perform daily tasks, shadow other employees? Do you believe you would have been able to accomplish more/less/the same amount of work if you were working remotely?
9. What did you learn about the Supply Chain industry in your internship? Were you able to apply concepts learned from school to your job?
10. Did you see or experience the effects of COVID at the company you worked for? If so, describe the impact you believe COVID had on the company.
11. Based on your experience, what are some of the biggest advantages of working on-site? Disadvantages? What is the biggest lesson you learned working on-site?
12. What are your career goals? Do you plan to pursue a Supply Chain career? How beneficial was your internship in shaping those goals?
13. If you could repeat your internship over again, would you choose to work virtually or in person? Why?
14. What was the most rewarding part of your Supply Chain internship?

Questions for Managers:

1. What is your position at your company?
2. Did you have one or more interns, or were you directly involved in your company's internship program, during COVID-19 (March 2020-Present)?
3. Was your intern/internship program virtual or in-person or hybrid?
4. How was the recruiting process? If recruiting took place during COVID, describe any changes that took place in the recruiting process.
5. How many interns did your company place in a Supply Chain position? Is the number of Supply Chain interns smaller/larger/no difference from years before COVID? Did your company cancel any internships due to COVID?
6. How did your company's internship program change? In what ways?
7. Describe the impact you believe COVID had on your company. How did your business area/department/team transition?
8. What are your predictions for the future of Supply Chain internships? Are virtual or on-site internships preferred?

IF VIRTUAL

9. Was transforming your internship program to a virtual environment feasible for your company? What were some of the successes of a virtual internship program? What were some of the challenges? Was there a cost-benefit/detriment to a virtual internship program?
10. What did communication look like between you and your intern? Were expectations made clear from the start? How often were you in contact with your intern? Describe some of your successes and any downfalls of communicating virtually.
11. Was your intern able to work on projects, perform daily tasks, shadow other employees? Do you believe your intern would have been able to accomplish more/less/the same amount of work if they were working on-site?
12. Based on your experience, what are some of the biggest advantages of a virtual Supply Chain internship program? Disadvantages? What is the biggest lesson you learned working with a virtual intern?

IF ON-SITE

9. What COVID policies were required (masks, social distancing, etc.)? How did those affect your work? How do you believe those affected the work of your intern?
10. What were some of the successes of remaining on-site during COVID and having an on-site intern? What were some of the challenges?
11. What did communication look like between you and your intern? Were expectations made clear from the start? How often were you in contact with your intern? Describe some of your successes and any downfalls of communicating while on-site.
12. Was your intern able to work on projects, perform daily tasks, shadow other employees? Do you believe your intern would have been able to accomplish more/less/the same amount of work if they were working virtually?
13. Based on your experience, what are some of the biggest advantages of an on-site Supply Chain internship program? Disadvantages?

OVERVIEW OF THE APPLICATIONS OF AMAZON WEB SERVICES (AWS) IN PROFESSIONAL SPORTS

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ABSTRACT

This paper discusses the main Amazon Web Services used in sports, analyzing the specific applications in four professional organizations (Bundesliga, F1, NFL, and PGA Tour). Most of the applications used rely on machine learning models that were developed using Amazon SageMaker. These models produce predictive and descriptive statistics that are presented to fans in real-time during sporting events, which has resulted in higher fan engagement – one of the key motivations for adopting AWS by these organizations. While using cloud computing services poses some degree of risk, the benefits of these applications suggest that the use of AWS will continue to grow in professional sports.

INTRODUCTION

Over the past decade, Amazon Web Services (AWS) has become the most widely used cloud computing platform in the world, with millions of customers across the globe. AWS offers over 200 different services, some of which are a key part of the operations of companies such as Netflix, Facebook, or Adobe.

Like in every industry, organizations in professional sports are adopting AWS to enhance their operations, improve performance, and provide a more engaging fan experience. Organizations embracing AWS have unlocked a new world of possibilities and are experiencing major benefits right away.

First, this paper outlines the key cloud services commonly used in professional sports, and then explores the specific applications of AWS in four professional organizations from different sports: Bundesliga (soccer), Formula 1 (motorsport), NFL (football), and PGA Tour (golf). Then, an evaluation of the key benefits and issues is conducted, illustrating relevant points with examples from the sport organizations analyzed. Finally, a conclusion summarizes the overall use of AWS in professional sports and potential future trends.

TECHNOLOGY OVERVIEW

Many Amazon Web Services are used to enhance the experience of fans, players, teams, and organizations involved in professional sports. The most prominent web services used in this context include:

- **Amazon SageMaker:** This tool helps data scientists and developers to prepare, build, train, and deploy high-quality machine learning models by bringing together a broad set of capabilities specifically suited for machine learning [1].
- **Amazon S3:** Amazon's Simple Storage System is a cloud-based object storage service that offers industry-leading scalability, data availability, security, and performance [2].
- **Amazon Kinesis:** This tool helps to collect, process, and analyze real-time streaming data which can be used to obtain relevant insights in a timely manner [3].
- **Amazon EC2:** Amazon Elastic Compute Cloud provides secure and adjustable computing capacity in the cloud [4].
- **Amazon Rekognition:** This service allows users to access pre-trained customizable computer vision capabilities to extract information from images and videos [5].

Many of the cloud computing models applied in professional competitive sports rely on the combination of multiple Amazon Web Services. These services are compatible and easy to integrate, which facilitates the scale-up of operations.

AWS IN THE BUNDESLIGA

The Bundesliga is the top-tier soccer division in Germany and is one of the most competitive soccer leagues in the world. The Bundesliga first established a partnership with AWS in January 2020 and since then, there have been several applications into the sport [6].

Expected Goals (xG)

The expected goals (xG) metric is a predictive model that assesses each goal-scoring opportunity providing a score that measures the likelihood of scoring [7]. The scale for the xG model ranges from 0 to 1, and the values are calculated by a machine-learning model developed using *Amazon SageMaker*. To maximize accuracy, over 40,000 shots on goal were used to train the expected goals model [8]. The key variables integrated into the calculation of the xG score include distance to goal, player speed, angle to goal, number and positioning of defenders, and goalkeeper coverage [8]. An important note about the calculation of the xG values is that it does not take into account the quality of the player taking the chance. Instead, it estimates the goal-scoring probability of an average player in that situation.

The xG individual values can also be aggregated to provide the number of expected goals in a match. This value no longer suggests a probability of a single event, instead, it indicates the expected outcome given a set of events. This is the key concept used to calculate *Shot Efficiency* (Actual Goals – Expected Goals), another important metric adopted by the

Bundesliga and powered by AWS [9]. Overall, all the information generated by the xG model is used by teams to evaluate multiple parameters such as player efficiency and team expected outcome [10].

Average Positions

The *Average Positions* metric uses around 3.6 million geographical data points to track every player's position during a game [11]. This information can be used to discover relevant trends or patterns related to the positioning of a team in different scenarios. For example, this technology allows to compare the average position of a team before and after a key event in a game such as a goal scored or conceded. This information can be exploited by the teams because it helps to better understand their own patterns of play as well as the opposition's.

Other useful information derived from measuring the movement of the players throughout the game is their live speed. The Bundesliga has incorporated a *Speed Alert* graphic into games which signals the fastest player on the field, as well as any speed records noted during the match [12].

Passing Profile

The *Passing Profile* metric is also developed using Amazon SageMaker to create a machine learning model trained by analyzing videos of almost 2,000,000 passes [13]. The algorithm generated evaluates multiple factors such as player positioning, pass distance, and opposition pressure. All this information is combined into a score that indicates the difficulty of completing a given pass. Passes with a score of less than 75 percent are considered difficult. Like with expected goals, teams can compare the actual pass completion percentage of a player with the generated completion probability score to determine above and lower than average players. The Passing Profile can also indicate a player preference for long versus short passes or vice versa, which can be used by coaches to generate favorable scenarios in a game for that particular player.

Most Pressed Player

The *Most Pressed Player* metric is also based on a machine learning model that examines pressure that each player is under when in possession of the ball. The factors taken into account in this model include the number of opposition players, the distance to the player in possession of the ball, as well as the direction of the movement from every player [14]. The outcome of this model compares the number of significant pressure situations that a player experiences in a game versus the average of those experienced by teammates. For example, the most pressed player in the team has been significantly pressed 34 percent more than the team's average.

AWS IN FORMULA 1

Formula 1 racing is one of the most popular motor racing sports in the world and is the highest class and most technologically advanced, single-seater formula racing cars. The

word “Formula” refers to the set of rules that each of the competing teams needs to adhere to. F1 is a technology-centered competition, and these rules are changed frequently to push the technological development thresholds, ensure driver and spectator safety, and ultimately, ensure the continuous evolution of the sport.

Formula 1 began its partnership with Amazon in 2018, migrating the majority of its information systems’ infrastructure from on-premises data centers to AWS cloud computing services. During each race, 300 sensors in each car generate 3 GB of data with over 1 million data points captured every second [15]. This partnership with AWS was established to enhance scalability, reliability, and security of F1’s data processing and analytics needs, while enhancing fan experience [16].

F1 Insights are different metrics presented to fans in-real time through TV broadcast and digital platforms. They include a variety of relevant information that can be used by both, fans and teams, to better understand diverse situations in a race. F1 Insights can be divided into three groups: Race Strategy, Competitor Analysis, and Car Performance.

Race Strategy

These metrics rely on the live timing information to provide an accurate view of a driver’s strategy. Key insights include:

- **Battle Forecast:** Predicts the number of laps before the chasing car is within striking distance of the car in front based on track history and projected car pace. This graphic also illustrates the overtake difficulty based on the drivers’ pace and circuit characteristics [17].
- **Pit Lane Performance:** Analyzes the performance of each car during different phases of the pitting process: entry, pit lane, and exit [18].
- **Pit Window:** Shows the estimated ideal lap range for a pit stop based on tire compound, lap times, and positioning of cars on track [18].
- **Pit Strategy Battle:** Indicates the probability of a driver staying in front of a competitor after making a pit stop, taking into account the average time lost in the pit lane and the current on-track pace [18].

Competitor Analysis

These metrics rely on data analysis to compare cars, teams, and drivers’ performances. Key indicators include:

- **Start Analysis:** Uses the acceleration and live speed data generated by the many sensors in a car to illustrate the performance of a driver at the start of the race. The output includes the driver’s reaction time and time taken to accelerate from 0 to 200 km/h [19].
- **Driver Performance:** This metric compares a driver’s performance with the theoretical maximum performance of the car in a given scenario. Ultimately, it shows

the driver's performance as a percentage of the car limit through the acceleration, braking, and corners phases of the lap [20].
- **Car Analysis and Development:** This insight removes the effect of the driver and focuses only on the car's performance. It tracks the development of the car throughout the season, analyzing its performance in three key areas: power, downforce, and drag [21].
- **Qualifying Pace:** Takes into account a variety of data points such as fuel levels, tire compounds, lap times, and engine modes to predict the qualifying pace of each car [22].

Car Performance

These insights examine aerodynamics, tire performance, car power unit, dynamics, and optimization to evaluate multiple aspects of car performance.

- **Braking Performance** – Through advanced data analysis, this F1 insight shows the exact initial braking point, top speed just before reaching the braking point, speed decrease, maximum G-force experienced by the driver, and total braking power required to slow the car down [23].
- **Corner Analysis** – Shows how a particular car handles the four key components of a corner (braking, turn in, mid-corner, and exit) and gives a normalized score out of 10 for each of them [24].
- **Tire Performance** – Indicates how much of a tire has been used out of its total competitive performance life [15].

AWS IN THE NATIONAL FOOTBALL LEAGUE (NFL)

The National Football League (NFL) is the most popular professional sports league in the United States. The NFL first started using Amazon Web Services in 2017 and has used this technology to improve the sport from the perspective of fans, players, and organizations [25].

Player Performance

The NFL has worked closely with AWS to provide fans with unprecedented information in real-time during live games. The Next Gen Stats includes information about every player's location, speed, and acceleration in any given moment of the game. The data is collected by sensors located throughout the stadium that track the radio frequency identification (RFID) chips that are installed into the players' shoulder pads [26]. This information is also fed into a machine-learning model built using Amazon SageMaker, where it is combined with historical data and with other relevant information (e.g., the football's speed and location). The results of this model are different metrics that measure key aspects of the game such as pass completion probability or expected rushing yards.

Player Safety

The NFL and AWS are currently working on creating the *Digital Athlete* platform, a simulation model that tests a multitude of scenarios to better understand how to treat and rehabilitate injuries, and eventually to predict and prevent them [27]. The technology used in this model involves the application of artificial intelligence and machine learning.

Another application of AWS to improve player safety includes the use of computer vision models, which is used by the NFL to better detect and understand the underlying forces and factors that cause concussions [28].

AWS IN PGA TOUR

PGA Tour is the official organizer of the major golf tours played in the United States. The partnership with AWS was announced in March 2021, with the goals of simplifying content delivery, creating new digital experiences, and providing enhanced access to broadcast footage [29]

The two main technologies that the PGA Tour utilizes are Amazon S3 and Amazon Rekognition. The purpose of Amazon S3 in PGA Tour is to process data in objects and buckets. This system allows users to access 93 years of data from historic tournaments and watch recorded events [30]. Amazon Rekognition is used mainly for labeling and tagging videos and images. This application is used by PGA Tour to identify players. Amazon Rekognition combined with S3 allows fans to search for clips of their favorite golfers.

PGA Tour also offers a service called Every Shot Live, a streaming platform powered by AWS, that gives fans live access to every shot from every player in a tournament. For instance, at major tournaments such as The Players Championship, fans will be able to access over 32,000 shots from nearly 150 players [30]. The feature TOURCast, also powered by AWS, gives unprecedented access to multiple camera angles, course overview, and player statistics [30] This newly established partnership is the latest in Amazon's attempt to expand its services to the professional sports industry.

EVALUATION OF AWS IN SPORTS

Although each sport competition is unique, the applications of AWS often bring similar benefits and issues between the different sports.

Key Benefits

The most common benefit resulting from the application of AWS in professional competitive sports is fan engagement. This is not a surprise given that this is one of the main reasons why AWS are adopted by these organizations in the first place. While fans see sports as entertainment, professional sports organizations have business models that focus on maximizing profit. Maximizing the engagement of fans is crucial for these organizations, as it results in higher revenue. The application of AWS is successful in increasing fan engagement because it reveals hidden insights that were not visible before. This is illustrated by metrics such as expected goals in the Bundesliga, start analysis in Formula 1, pass completion probability in the NFL, and detailed statistics in PGA Tour.

In addition to increasing fan engagement, AWS also play a key part in moving the sport forward. For example, Formula 1 is using the cloud computing capabilities offered by AWS to design the technical specifications of the new generation of cars [31]. AWS also plays a key role in making the NFL a safer sport for players by running simulations that provide a better understanding of injuries and how to prevent them.

Finally, one of the reasons why AWS is successful in professional sports is because of the numerous cloud computing services offered by Amazon, which allows entities to select only the services that fit their needs. At the same time, it is easy for organizations to scale up their operations through AWS, given the compatibility of their services.

Potential Issues

While AWS have brought countless benefits to the different professional sports competitions, there will always be inherent risks in any use of technology for personal consumption or for corporate purposes [32]. Some of the more widely known and applicable to any industry are as follows:

- Loss or theft of intellectual property
- Compliance violations and regulatory actions
- Loss of control over end-user actions
- Malware infections that unleash a targeted attack
- Contractual breaches with customers or business partners
- Diminished customer trust
- Data breach requiring disclosure and notification to victims
- Revenue losses

Some of these issues are more applicable to some specific sports than others. For instance, malware infections are inherently dangerous in every industry, but particularly for Formula 1, where they could disrupt the flow of information from the car to the team's pit wall. This could have catastrophic consequences if there is an issue with the car, which jeopardizes the security of the drivers.

In the case of the NFL, one of the biggest risks regarding the use of cloud computing services is the loss or theft of intellectual property. Teams in the NFL work daily with sensitive data such as players' physical status, contracts, or their playbook. Any leaked information could have damaging consequences for the team involved and would give opponents an advantage against them.

Lastly, an often-undetected issue with AWS is information overload for fans. As previously described, AWS gives access to massive amounts of data. This information is crucial for internal use by teams and players, as it often provides them with a competitive advantage. However, the same data is not always suitable for consumption by the fans. The information exposed to the fans should be carefully selected and presented in a non-intrusive way, ensuring that the viewing experience of the sport is not negatively affected.

CONCLUSION

The growth of AWS over the past decade has risen dramatically, entering almost every industry. Professional sports organizations have turned to AWS to enhance their operations, with a focus on three key aspects: fan engagement, streamlining of operations, and development of the sport. There are multiple examples of successful AWS applications in different sport competitions, as shown throughout this paper. While there are some key issues that should be taken into consideration before adopting AWS, they are outweighed by unprecedented benefits that come with the successful integration of these services. The presence and importance of AWS in professional sports will likely continue to increase as technological advances keep pushing the boundaries of what is possible.

REFERENCES

[1] Amazon. (2021). *PM*. Amazon SageMaker. Retrieved November 16, 2021, from https://aws.amazon.com/pm/sagemaker/

[2] Amazon. (2021). *PM*. Amazon S3. Retrieved November 16, 2021, from https://aws.amazon.com/pm/serv-s3/

[3] Amazon. (2021). *PM*. Amazon Kinesis. Retrieved November 16, 2021, from https://aws.amazon.com/kinesis/

[4] Amazon. (2021). *PM*. Amazon EC2. Retrieved November 16, 2021, from https://aws.amazon.com/pm/ec2/

[5] Amazon. (2021). *PM*. Amazon Rekognition. Retrieved November 16, 2021, from https://aws.amazon.com/rekognition/

[6] Veth, M. (2021, August 11). *Bundesliga and AWS 'are still at the beginning' of their partnership*. Forbes. Retrieved November 16, 2021, from https://www.forbes.com/sites/manuelveth/2021/08/11/bundesliga-and-awsrolfes-we-are-only-at-the-beginning/?sh=216678050a49.

[7] Bundesliga. (n.d.). *Bundesliga match facts powered by AWS*. bundesliga.com - the official Bundesliga website. Retrieved November 16, 2021, from https://www.bundesliga.com/en/bundesliga/news/new-real-time-match-analysis-dfl-and-amazon-web-services-11246.

[8] *Bundesliga match facts powered by AWS: Xgoals - youtube*. (n.d.). Retrieved November 16, 2021, from Bundesliga Match Facts powered by AWS: xGoals

[9] Bundesliga. (n.d.). *DFL and AWS to debut two new Bundesliga match facts for the 2021-22 season*. bundesliga.com - the official Bundesliga website. Retrieved November 16, 2021, from https://www.bundesliga.com/en/bundesliga/news/dfl-and-aws-to-debut-two-new-match-facts-for-the-2021-22-season-17237.

[10] *XG explained*. FBref.com. (n.d.). Retrieved November 16, 2021, from https://fbref.com/en/expected-goals-model-explained/.

[11] Bundesliga. (n.d.). *Bundesliga match facts powered by AWS*. bundesliga.com - the official Bundesliga website. Retrieved November 16, 2021, from https://www.bundesliga.com/en/bundesliga/news/new-real-time-match-analysis-dfl-and-amazon-web-services-11246.

[12] *Bundesliga match facts powered by AWS: Speed alert - youtube*. (n.d.). Retrieved November 16, 2021, from Bundesliga Match Facts Powered by AWS: Speed Alert

[13] Bundesliga. (n.d.). *DFL and AWS to debut two new Bundesliga match facts for the 2021-22 season*. bundesliga.com - the official Bundesliga website. Retrieved November 16, 2021, from https://www.bundesliga.com/en/bundesliga/news/dfl-and-aws-to-debut-two-new-match-facts-for-the-2021-22-season-17237.

[14] *Bundesliga match facts powered by AWS: Most ... - youtube*. (n.d.). Retrieved November 16, 2021, from https://www.youtube.com/watch?v=zSkpUgfMTOE.

[15] Amazon. (2021). *PM*. Amazon F1. Retrieved November 16, 2021, from https://aws.amazon.com/f1/

[16] F1. (2018, September 4). *Formula 1 selects AWS as Official Cloud and Machine Learning*

Provider. Formula 1. Retrieved November 16, 2021, from https://www.formula1.com/en/latest/article.formula-1-selects-aws-as-official-cloud-and-machine-learning-provider.3thFUei8926UA28csUs0EQ.html.

[*17*] F1 Battle Forecast Powered by AWS - youtube. (n.d.). Retrieved November 16, 2021, from https://www.youtube.com/watch?v=LTOTl_wdzAg&t=1s.

[18] F1 Insight Pit Lane Performance - Powered by AWS | Amazon Web Services - youtube. (n.d.). Retrieved November 16, 2021, from https://www.youtube.com/watch?v=nUxkqA1gBOU

[19] F1 Insights "Start Analysis" - Powered by AWS | Amazon Web Services - youtube. (n.d.). Retrieved November 16, 2021, from https://www.youtube.com/watch?v=XKwZfBRBShI

[20] F1 Insights Powered by AWS: Driver Performance - youtube. (n.d.). Retrieved November 16, 2021, from https://www.youtube.com/watch?v=tl8fdv0uYTo

[21] F1 Insights Powered by AWS: Car Analysis/Car Development - youtube. (n.d.). Retrieved November 16, 2021, from https://www.youtube.com/watch?v=Ta8iOMRAYrg

[22] AWS re:Invent 2019 – Rob Smedley From Formula 1 Talks About Using AWS to Improve the Fan Experience. Retrieved November 16, 2021, from https://www.youtube.com/watch? v=RezSBUZkTBk&t=134s

[23] F1 Insights Powered by AWS: Braking Performance. Retrieved November 16, 2021, from https://www.youtube.com/watch?v=58oQdV9EPsM&t=1s

[24] F1 Insights Powered by AWS: Corner Analysis. Retrieved November 16, 2021, from https://www.youtube.com/watch?v=YW3q6EPD3Ck&t=1s

[25] Nfl. (2021, January 5). *Powering the next generation of athlete safety*. NFL.com. Retrieved November 16, 2021, from https://www.nfl.com/playerhealthandsafety/equipment-and-innovation/aws-partnership/powering-the-next-generation-of-athlete-safety.

[26] Amazon. (2021). *PM*. Amazon - NFL. Retrieved November 16, 2021, from https://aws.amazon.com/nfl/

[27] *NFL and Amazon Web Services team up to transform player health and safety using cloud computing and artificial intelligence // .* NFL Communications. (n.d.). Retrieved November 16, 2021, from https://nflcommunications.com/Pages/NFL-and-Amazon-Web-Services-Team-Up-to-Transform-Player-Health-and-Safety-Using-Cloud-Computing-and-Artificial-Intelligence.aspx.

[28] Nfl. (2021, January 5). *Using artificial intelligence to advance player health and safety*. NFL.com. Retrieved November 16, 2021, from https://www.nfl.com/playerhealthandsafety/equipment-and-innovation/aws-partnership/using-artificial-intelligence-to-advance-player-health-and-safety.

[29] Sean Martin, P. G. A. T. O. U. R. C. O. M. (2021, March 1). *New Aws Partnership to Transform PGA Tour Media Business*. PGATour. Retrieved November 16, 2021, from https://www.pgatour.com/company/2021/03/02/new-aws-partnership-to-transform-pga-tour-media-business.html.

[30] Amazon. (2021). *PM*. Amazon - PGATOUR. Retrieved November 16, 2021, from https://aws.amazon.com/sports/pgatour/

[31] Staff, A. (2021, July 14). *Formula 1 uses AWS to develop Next Generation Race Car*. US

About Amazon. Retrieved November 16, 2021, from https://www.aboutamazon.com/news/aws/formula-1-uses-aws-to-develop-next-generation-race-car.

[32] *9 cloud computing security risks every company faces*. McAfee Blogs. (2020, December 9). Retrieved November 16, 2021, from https://www.mcafee.com/blogs/enterprise/cloud-security/9-cloud-computing-security-risks-every-company-faces/

QUALITATIVE BENEFITS OF LANGUAGE CAPABLE INDIVIDUALS

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ABSTRACT

In the melting pot that is the United States, communities and workplaces have naturally become more diverse, due to globalization, immigration, education opportunities, and job changes. This pattern of increased diversity has noticeably brought along larger talent pools, new perspectives, ideas, and has created new industry expectations of workplace diversity, and the desire for even more. These workplace expectations have led to the search for the highest quality and experienced individuals in areas more than their local communities. What may be considered during the search to find these diverse and culturally exposed individuals would be the recruitment language capable individuals or individuals with personal experience in the learning of a foreign language. For this research, a language capable individual is considered one that is proficient in languages other than their native tongue. Through what is the language learning process to become a language capable individual, individuals experience enough communication in all mediums, possess a reason to learn, and are typically interested in the language or culture, which may translate to many beneficial things in other areas of their lives. The desire to learn or maintain a language may be personally or organizationally incentivized through financial compensation, travel, and increased professional and social opportunities. The responses of interviews and prior research combine to acknowledge many considerations in benefits that are associated with the social, personal, and workplace aspects of language capable individuals. These individuals also agree that their professional and personal cultural experience as well as practice in learning a language may have directly provided them more opportunities, increased their quality of life, and is prevalent in their current environments.

LITERATURE REVIEW

The analysis of quantitative language benefits and workplace diversity has been ongoing for many years with empirical data being recorded for efficiency, productivity, profits, and communication effectiveness [4] – this paper aims to examine the social and qualitative benefits of individuals, employers, and other organizations cultivating their internal language capabilities. In the 1950s, individuals and organizations in the United States believed that learning another language was too difficult of an endeavor [7]. Now, behind the phenomenon of globalization [17] as well as following mass international commerce and travel, nearly 20% of US citizens may be considered bilingual [29], with second language use occurring in professional and personal settings.

Individuals that are considered bilingual or language capable inherently possess an understanding of communication practices and contextual interpretations being presented [19]. This is to say that when conversations are being had, language capable individuals are better at understanding the tone or the passion of the individual, as well as in the language being used. Contextual understanding of specific words used is extremely relevant across languages, with

words having different cultural meanings when translated, as well as the meanings of cultural idiomatic phrases - heavily prevalent in languages like Chinese Mandarin and English - not being completely understood by non-native speakers. However, language capable individuals may likely have a slight sense of the meaning, be aware of the communication gap, or possess the resources to navigate communication issues.

In an article for Language Magazine, a publication for those learning or teaching languages, one author writes that “the capacity to understand and appreciate the viewpoints of others is a steppingstone for success” [13]. The learning of another language creates an opportunity for the individual to understand the context from a new perspective completely [16]. Watching, listening, or reading in another language can completely remove the individual from their own society, and create exposure to all sorts of different ideas and thoughts. The intake of second-language material also may reinforce the ability of one’s mother tongue [5]. Monitoring of grades and scores of elementary students in Kansas as well as Louisiana in the late 1990s has shown that students that participated in the learning of a second language elevated their scores in English, Math, History, and Science, higher than those students not learning a second language [14]. The working memory of Dutch-Turkish speaking children has shown to be much better than those of children that speak only one of the languages [2]. There is also evidence to back the claim that language-studied students also do better on standardized tests, such as the SAT and ACT than their peers that do not study a second language. In the early stages of a structured learning environment, things like grammar and parts of speech are typically prioritized. Learning these things in a completely new language can naturally enhance one’s native tongue by repetition and practice. Knowing how parts of speech operate in one’s own language allows the learner to reposition parts of speech for different sentence structures - making learning easier. The enhancement of one’s native tongue creates a more confident and professional communicator in multiple languages and mediums [13]. Knowing how to communicate ensures all points are clearly understood by both parties in the transfer of information, deterring potential misunderstandings while ultimately saving time and/or money.

Angela Gallagher-Brett published a document containing “Seven hundred reasons for studying languages” and notes that many individuals that take on learning another language for what seems to be enhancements in personal quality-of-life [6]. Gallagher-Brett acknowledges the soft-skills gained from language learning, as well as the opportunities for business and travel that are created, but cumulatively notes that all things create a better life for those learning. Some of these quality-of-life improvements can be considered higher rates of pay, travel opportunities, higher quality professional and personal relationships, as well as growth opportunities in the workplace [1]. Learning a second language opens the individual up to a completely new culture and environment, where creativity and risk may lead the individual in a different direction.

Language capable individuals are more tolerant of differences in those around them [3]. Workplace diversity is sought after in many organizations for several reasons. One main reason is because the mutual collaboration of individuals with different backgrounds can lead to a wider array of positive outcomes [11]. Another reason is that ethnically diverse teams may “positively affect mutual learning and outcome of teams” [10]. Diversity goals may be reached much easier with those that are already familiar and aware that the various needs of others must be maintained. It must be understood that this language diversity and ethnic diversity are not the

same things, however, this request of diversity may be fulfilled by language capable individuals, presenting many other positives that non-diverse areas may lack [9].

Endogenous Growth Theory is the idea that internal organization cultivation and growth reflect external economic advancement. This theory originates from empirical analyses of local and foreign growth in the 1980s [18]. This theory heavily focuses on the idea that investment in human capital for organizations is pivotal for economic advancement [12]. The investment in human capital has been researched and has shown positive outcomes from investment in organizations with many low-skilled laborers to increase efficiency but can be positive outcomes also come from the quality of investment in human capital [8]. Language learning has already been discussed as cause for higher quality of life and can also create better outcomes in the workplace. Organizations that conduct affairs abroad may internally increase the cultural understanding of employees by offering language learning opportunities to their teams and individuals, opening a window to allow them to appreciate their international counterparts, produce better relationships, and better understand their business practices [15]. Employer investment in language capable individuals can be financial incentivization, travel opportunities, and even learning opportunities.

INTERVIEWS

A total of 9 individuals were interviewed in 8 sessions with one married couple participating together. All interview candidates were considered for either their extensive exposure to multicultural or language-diverse workplace environments, or their experience in language learning. Individuals had either prior connections to the researcher or research advisor, or suggested candidates were from other personal connections. Interviews were consented to and were conducted as informal conversations with an outline of predetermined questions. Individuals were encouraged to speak openly, anonymously, and without fear of personally identifiable information being used in results, with things to be refrained or omitted from results if desired; Table 1 below outlines subject demographics without sacrificing anonymity. Interviewees will be referenced as Subject A through Subject I, however, may be referred to as interviewees, subjects, candidates, and individuals.

TABLE 1 – INTERVIEWEE DEMOGRAPHIC SUMMARY

Total Subjects	9 Subjects
Average Age of Subjects	43.7 Years
Gender	2 Female Subjects, 7 Male Subjects
Non-US Born	3 Subjects
Non-English-Language Native:	4 Subjects
Education:	-
No College / AA	2 Subjects
Bachelors	3 Subjects
Masters	3 Subjects
PhD	1 Subject

Interview questions are listed in the Appendix. Questions were developed to consider individual demographics, education and work history, personal experience, observed characteristics, and opinions. Questions were left open-ended to allow for subjects to elaborate on points and experience. Although the interviews were not published, they will be referenced like other references.

RESULTS

Interview results were used to compare as well as support literature reviewed prior to conducting interviews regarding the benefits of language capable individuals. Interview question responses are subjective opinions provided by the consenting subject with information summarized categorized for analysis. Results are categorized as either being individual benefits, social and communal benefits, or workplace benefits and are as follows. Some benefits may be referenced in multiple categories.

Personal and Individual Benefits

All 9 of the subjects were exposed to language learning environments from a young age. These environments were either first-generation US Citizens' early years, learning English as a second language overseas, or learning Latin, German, or Spanish in high school in the United States. All 9 of these individuals, to some degree, attribute their language learning endeavors to the exposure they had in their early years, with one individual specifically attributing their passion for learning and culture due to their early language courses growing up in Europe [24].

Of the internal benefits seen in these individuals, most agreed or elaborated on their belief in personally learning a foreign language being a reason they are more patient and empathetic towards those that are attempting or struggling to communicate in a language other than their own native tongue. Multiple interviewees also believed that learning a language to a level of working proficiency to be quite an accomplishment or personal achievement. Subject I, having leadership and management experience in multiple diverse environments with mixes of capable and non-language capable teams, regards learning a language in high regard because they are proud of their own advancements in foreign languages [28]. Subject E strongly believes that like themself, those with language skills may become more "curious and inquisitive learners", and even become more adaptable and comfortable individuals in varying environments [24]. Subject C reinforced this notion by using their 2-year travel to the country of Portugal as an example of a mindset-changing experience. Not only was Subject C exposed more to Portugal's native dialect of Portuguese, rather than their Brazilian dialect, but was able to greatly progress their English at an all-English university. During the two years of school and work, this individual also saw growth in their intangibles such as communication, presentation, and conversational skills in both English and Portuguese, which they claim to be the start of their journey that has led to their career with a Global 500 company and successful collaboration with organizations on 5 continents, as well as their upcoming relocation to the US [22].

Subject A attributes their now progressive mindset and empathy towards those of different backgrounds to their work with a foreign corporation and the inherent language and cultural influence that follows, as well as their own personal language learning experience gained while

attending high school [20]. Through their awareness and broadened perception through experience collaborating with individuals of different languages and ethnicities, Subject A has been able to personally make changes in their work settings to create safe resources in the workplace for those that don't know how to get them. Another interviewee, Subject D, has used their bilingual abilities to personally create translated copies of safety forms for laborers with struggling English in a majority Spanish speaking area of the United States. Subject D believes because of their bilingual upbringing and English-lacking relatives that they were conscious of the needs of their ethnically similar colleagues as well as safety negligence from Human Resources in an extremely hazardous industry. Also, because of their experience as the "communication conflict resolution specialist" of non-English-speaking parents in an English-speaking country, they believe they are more selfless and have become a more optimistic individual with a passion for helping and teaching others [23].

Social and Communal Benefits

Many of the internal individual benefits described above could also be mentioned with the social benefits. Socially, learning a language opens the door to whatever number of speakers also know that language – simply put as "language is the gateway to learning culture" [21]. Subject E takes pleasure in knowing multiple languages and making connections between the cultures that follow each language. This individual also believes that their quality of life is greatly impacted because of the various connections made using multiple languages in their personal life and enjoy the social and mutually beneficial aspect of communication between two individuals that are attempting to learn the native language of the other through mutual bilingual communication [24]; essentially a "pen-pal", with mutual growth in the others' language.

To Subject B, to be capable of discerning similarities and differences in opinions and beliefs, rather than 'similar equals good' and 'different equals bad', is a quality of an emotionally intelligent person. Subject B considers the process of learning a new language as a facilitator to gaining that ability because of the repetition required to grasp grammar patterns, word usage, as well as social queues and social interactions noticed in target language communication from various sources of instruction, conversation, and media [21].

When asked about whether they celebrate other cultures (other than their own heritage) in their daily lives or social lives, all participants agreed that they are frequently exposed to multiple aspects of different cultures, with some referencing the Internet of Things and access to information being an obvious reason for modern cultural diffusion. Also, most of the participants claim they have some form of current connection to the culture(s) of the language(s) they have learned or been immersed in, whether it be food, music, holidays, or traditions. These types of lingering cultural aspects are as simple as Subject C growing up in South America in the early 2000s and developing a passion for music while watching popular music videos from the television channel MTV as a tool to help learn English. For Subject D, however, it is much easier for them to notice these characteristics in their personally connected cultures because of their previously mentioned non-English-speaking parents in the United States. Two individuals consider the cuisine associated with their learned language to be their favorite type of food [27] [28], which they consider to be minor now yet was very impactful for their personal language learning experiences. More impactful than the lingering impacts mentioned above, of the non-

US-born subjects, all consider English to be their primary language used at their place of work and even in their social lives.

Workplace and Team Benefits

Regarding English, all 9 Subjects agreed that English could unofficially be considered the language of the world, and specifically in business settings where parties reside in different regions. After newly becoming an employee at what is their current company, Subject A frequently attended executive-level meetings held in a completely foreign language. This participant lost almost all context during meetings without means of immediate translation and was unable to contribute until the extra effort was made by colleagues to ensure things were understood after the meeting. This participant notes that it took multiple meetings and some individual effort, however, Subject A eventually was able to perceive the tone of dialogue in meetings and begin to cling to patterns after the constant post-meeting communication from his helpful colleagues. Whether it be from understanding less than what is being presented [20] or by not being able to wholly explain the presentation given to a team of foreign executives in the native language of the executives [21], all interview candidates agree that there is context that is lost when expressing or perceiving communication in a non-native language. Subject E however adds that more and more workplace exposure and practice may create links and connections between various sorts of cultural and language context, producing a more informed individual, even aside from language ability [24].

All subjects agree that the process of learning another language may help individuals become more comfortable with uncertainty. Subject H and Subject I both specifically mentioned to not only feel they are now capable of adapting to ever-changing work environments, but also believe they both perform well under pressure after attending formally structured language programs [27] [28]. Subject I was forced to use their language ability with their foreign industry counterparts and along the way built mutual trust and respect, but also fostered the growth between organizations [28]. Subject H had also created relationships that eventually led to their invitation and attendance of a multinational “language retreat” hosted by the employer of their foreign counterparts. Furthermore, Subject H believes there are unnoticed benefits in diverse workplace settings that lie in the lower likelihood (in their own observation) of traditional workplace issues and insensitivities arising, such as discrimination, harassment, miscommunication, and low workplace morale [27]. Subject G, being of European descent, is proficient in six languages and has had the opportunity to travel the world for various careers throughout his life, creating global connections and opportunities. He attributes his enjoyed quality of life to the work opportunities that he’s taken that have been made available through his abilities in multiple European and Middle Eastern languages [26].

Workplace diversity is still a desired goal for Human Resources in many areas, and supporting their corporate desire, all interviewees distinctively prefer diverse and multicultural work environments compared to an environment with individuals that are like themselves.

Subject E believes that their position working directly with numerous European businesses heavily impacts the relationship between executives and the labor force of those organizations. Due to his capabilities in four languages and extended residency in many areas of the world,

including areas without language capability, he has the experience and prior knowledge to make connections between these groups of multiple backgrounds to create better working environments and facilitate more cohesive teams. These skills are not only successful when consulting or in a business environment but may also translate to other industries and their traditional management processes [24]. Subject F, who may sit at the highest of the traditional corporate ladder of these participants, deliberately hired their team of global reaching individuals to be primarily made up of people that do not originate from the home country of the organization's corporate headquarters. Subject F requests that members bring as much value to the team as possible through their inherent cultural differences, experiences, and learned behaviors. This participant acknowledges the importance of the personal background, wellbeing, and quality of life of everyone, while at the same time assumes the widely diverse team members to be extremely qualified and has high yet achievable expectations for them [25].

LIMITATIONS

Following research involving interviews used for research, there are notable limitations that must be mentioned. First, the questions were carefully deliberated after initial research, however the questions may have been too simple. Higher quality research may come from an increased number of interview subjects, covering more variety in languages and ethnicities in interview subjects. All interviews were conducted in English and may have different results were individuals from other origins conducting similar research.

Qualitative research may include many non-measurable opinions and beliefs, which may make comparisons more subjective. Were an individual to believe that communication skills, language abilities, and relationship building are not as important as other measurable skills, results may vary. Also, candid interviews may not produce the answer that individuals may give were they given the interview questions prior to the interview and prepared. These limitations need to be considered for research and future research; however, they do not invalidate the answers, beliefs, and results taken from interviews.

FUTURE OPPORTUNITIES

As well as more research to be considered on the topic of qualitative benefits of language learned individuals, there may also be considerations for research on topics: such as counter-productive and non-beneficial outcomes of language use and knowledge transfer between sociopolitical boundaries; the impact of nationalism and pride on diversity and culture; as well as potential research on the psychology of individuals and communication habits.

CONCLUSION

Through the research of published literature on the topic of qualitative benefits exemplified in the process of learning a non-native language, utilization of a non-native language, and growth of communication skills overall, there are many benefits to be found whether they be personal, social, or workplace oriented that may be supported through the interviews and responses provided by the subjects. Most notably, the individuals interviewed that are considered language capable (all but Subject A) have all noticed a quality of life increase they believe the language

learning experience is responsible for. This increase can be noticed in any aspect of life – as simple as a greater appreciation of cultural aspects that may follow the language learning process like food, music, customs, or holidays; higher quality interactions and relationships with close family/friends, colleagues, or connections made during or after the language learning process; as well as growth, opportunities, or achievements that were directly related. Another point to be drawn specifically from the responses of the subjects interviewed is not the openness and willingness of all nine individuals, but rather the personal preference to collaborate and be members of groups comprised of ethnically/culturally diverse, language learned, and culturally sensitive persons. Lastly, it must be noticed that the confidence, patience, and emotional intelligence that may develop during or after the constant communication practice, exposure, and repetition of new material are extremely valuable in any team of colleagues and common characteristics of high-quality individuals.

APPENDIX

Interview Questions

1. Personally Identifiable Information will be excluded from all findings. Do you consent to being interviewed?
2. Name?
3. Age?
4. What is your nationality or country of origin?
5. What is your education history like?
6. Do you have any experience with foreign languages?
7. Occupation?
8. Did you enjoy working there?
9. How long did you work there?
10. What was your role or task?
11. Did you ever work with individuals from other countries?
12. How did you communicate?
13. Have your language abilities helped you in any areas?
14. Have you been able to leverage for more pay or opportunity because of language ability?
15. Have you noticed a quality of life increase from your language abilities in any aspect?
16. Have you used your language professionally?
17. How proficient were your language abilities when using your language professionally?
18. How many members were on your working team?
19. What was the cohesion like on your team?
20. Was the team diverse?
21. Were there ever any language barriers?
22. How were they resolved?
23. Were there on-site individuals that emigrated from a foreign country that were being collaborated with?
24. Were the off-site collaborating organizations language capable?
25. Did they enjoy working there?
26. At work, were other cultures (holidays, music, food) celebrated?
27. Was language capability incentivized?

28. Was there opportunity for travel for language capable?
29. Non-language capable travel?
30. What was the workplace culture like?
31. Were there country-specific cultural differences observed through business settings?
32. Do you consider yourself culturally aware or sensitive?
33. What has the progression of your communication skills been like?
34. Do you enjoy working with others from different backgrounds or ethnicities?
35. More than nondiverse groups?

REFERENCES

[1] Bilingua. (2017). 6 benefits of learning a foreign language for career growth, accessed September 18, 2021, available at https://bilingua.io/benefits-learning-a-foreign-language-career.
[2] Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. The benefits of being bilingual: Working memory in bilingual Turkish–Dutch children. *Journal of Experimental Child Psychology.* 2014, 105–119.
[3] Carpenter, J., A. and Torney, J., V. Beyond the melting pot. *In Childhood and Intercultural Education: Overview and Research.* 1974, 14-24. Washington DC: Association for Childhood Education International.
[4] Clarke, L. (2021). 8 amazing benefits of cultural diversity in the workplace, accessed October 29, 2021, available at https://inside.6q.io/benefits-of-cultural-diversity-in-the-workplace/.
[5] Devlin, T. M. (2019). How learning a new language can help you learn about your native tongue, accessed September 18, 2021, available at https://www.babbel.com/en/magazine/understand-english-better.
[6] Gallagher-Brett, A. (2004). Seven hundred reasons for studying languages, accessed September 19, 2021, available at https://www.researchgate.net/publication/255613164_Seven_hundred_reasons_for_studying_languages.
[7] Gaudin, L. S. Foreign Languages and Job Opportunities. *The Modern Language Journal*. 1951, 35(8), 602–608.
[8] Grossman, G. M., & Helpman, E. Endogenous innovation in the theory of growth. *Journal of Economic Perspectives.* 1994, 8(1), 23–44.
[9] Hamilton, B. H., Nickerson, J. A., & Owan, H. Diversity and productivity in production teams. *Advances in the Economic Analysis of Participatory and Labor-Managed Firms*. 2004, 99–138.
[10] Hoogendoorn, S. & Van Praag, M. Ethnic diversity and team performance: A field experiment. *Tinbergen Institute Discussion Paper.* 2012, 12-68.
[11] Lee, W., & Cunningham, G. B. Group diversity's influence on sport teams and organizations: A meta-analytic examination and identification of key moderators. *European Sport Management Quarterly.* 2019, 19(2), 139-159.
[12] Liberto, D. (2020). What is endogenous growth theory? Accessed September 18, 2021, available at https://www.investopedia.com/terms/e/endogenousgrowththeory.asp.
[13] Mehdi, L. (2021). The bilingual advantage in the global workplace, accessed September 18, 2021, available at https://www.languagemagazine.com/2018/06/07/the-bilingual-advantage-in-the-global-workplace/.

[14] NEA. (2007). The benefits of second language study, accessed September 18, 2021, available at https://portal.ct.gov/-/media/SDE/World-Languages/BenefitsofSecondLanguage.pdf.
[15] Oakden, R. (2019). Cultural influences on supply chains and trade, accessed September 20, 2021, available at https://www.learnaboutlogistics.com/cultural-influences-on-supply-chains-and-trade/.
[16] QAA. (2015). Languages, cultures and societies: Draft for consultation, accessed September 19, 2021, available at https://dera.ioe.ac.uk/22859/1/SBS-consultation-Languages-Cultures-Societies-15.pdf.
[17] Rumbaut, R. G., & Massey, D. S. Immigration & language diversity in the United States. *Daedalus.* 2013, 142(3), 141–154.
[18] Romer, P. M. The origins of endogenous growth. *The Journal of Economic Perspectives*. 1994, 8(1), 3–22.
[19] SCRC SME. (2005). Cultural effects on the global supply chain, accessed September 18, 2021, available at https://scm.ncsu.edu/scm-articles/article/cultural-affects-on-the-global-supply-chain.
[20] Subject A, conducted September 30, 2021.
[21] Subject B, conducted October 3, 2021.
[22] Subject C, conducted October 7, 2021.
[23] Subject D, conducted October 4, 2021.
[24] Subject E, conducted October 5, 2021.
[25] Subject F, conducted October 4, 2021.
[26] Subject G, conducted October 1, 2021.
[27] Subject H, conducted October 3, 2021.
[28] Subject I, conducted October 3, 2021.
[29] Zeigler, K., & Camarota, S. A. (2019). 67.3 million in the United States spoke a foreign language at home in 2018, accessed September 28, 2021, available at https://cis.org/Report/673-Million-United-States-Spoke-Foreign-Language-Home-2018.

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THE RELATIONSHIP BETWEEN ENVIRONMENTAL PERFORMANCE OF FIRMS AND PROFITABILITY: EXPLORING THE EFFECT OF OPERATIONAL PRODUCTIVITY

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ABSTRACT

Despite the number of extant studies done on environmental performance of organizations, the relationship between firm environmental and financial performance remains ambiguous. Given the lack of consistent results about this relationship, it has become difficult for businesses to gauge the feasibility of engaging in sustainable operations while they are being increasingly pressurized by stakeholders to be environmentally concerned. Hence the research objective of this study lies in answering the managerial question, "is it financially worthwhile to invest in improving environmental performance?". The study leverages data on 220 firm-year observations from 2015 to 2019. Data on GHG emission levels to measure environmental performance is extracted from Bloomberg and data from Compustat is used to measure financial performance operationalized through operating ROA. Analysis of the data through hierarchical regression revealed that higher GHG emission levels lead to lower profitability of the company. When exploring the moderating effect of operational productivity (OP) on the main relationship, it was found that companies controlling for GHG emissions can achieve substantial profitability only in the presence of high OP levels. Accordingly, a company should be operationally productive to achieve substantial financial benefits on profitability which are expected from controlling for GHG emissions.

Keywords: environmental performance, operational productivity, profitability

1 INTRODUCTION

Corporate social responsibility (CSR) and its main tenants of environmental, social and governance (ESG) factors are areas of business research that have blossomed in academic and practitioner interest over the past 50 years. Beyond the fundamental imperative of corporations to generate capital returns to shareholders, the moniker CSR stresses the onus on corporations to also carry the mantle of being mindful of their performance in all ways ESG. Milton Friedman's Capitalism and Freedom (1962) articulates how CSR can be subversive to free markets by distracting from "the one and only social responsibility of business—to use its resources and engage in activities designed to increase its profits so long as it stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud." Put another way, by splintering the purpose of corporations to perform well on the triple-bottom line of people, planet and profits, the driving purpose of corporations to provide economic returns to

shareholders is diluted. Furthermore, Orlitzky (2015) argues that the arc of CSR research has evolved from a positivist perspective to ideological, collectivist, political perspectives as a way to influence corporate performance by adopting stakeholder interests rather than shareholder interests. For example, Orlitzky (2015) notes that attributes provided in KLD Research and Analytics, Inc.'s widely used KLD data frame much of the research on CSR, and that many KLD qualities express specific political views on corporate characteristics while other KLD qualities are "merely good management practices".

Nonetheless, companies and national governments are speaking to and taking action on environmental and social initiatives to explicitly address organizational performance in these areas. For example, Exxon recently committed that its oil and gas production operations would reduce its intensity of emissions by 15% to 20% over the next four years (Matthews, 2020). As a way to hear from investors and also receive feedback on its efforts with respect to carbon emissions, Unilever has pledged to poll its shareholders every three years via a vote on its efforts to mitigate its impacts on the natural environment (Chaudhuri, 2020).

At a macro-economic level, Germany and other European governments are planning via legislation to require companies to screen and police suppliers to assure their supply chains are not violating environmental and social rights standards (Boston & Boston, 2021). Firms affected by the proposed Supply Chain Law in Germany argue that they will be at a competitive disadvantage due to the costs of being held accountable for supply chain actions beyond their immediate operations (Jennen, 2021). On the other hand, Unilever CEO, Alan Jope, observed recently that oftentimes companies experience short-term expenses from efforts to improve the sustainability of its sourcing, but that in the long-run these investment expenses enable long term savings. For example, from 2008-2020, Unilever has saved $1.5 billion via sourcing sustainably (Brown, 2021). Of course, organizational communications might not provide an objective view or clear accounting of the economic costs and benefits of meeting organizational goals in the areas of environmental and social performance.

Our research effort seeks to use audited and verified, well-defined and quantitative data on two of the three dimensions of the triple-bottom line, planet and profit, to provide a positivist perspective on firm performance. We examine the relationship between greenhouse gas (GHG) emissions and operating return on assets (OROA) due to the fundamental relationship of productive output on both GHG and OROA. Given regulatory reporting requirements for manufacturers with regard to pollutants and the corporate ownership of many manufacturers, we specifically examine the relationship between green-house gas (GHG) emissions of manufacturing organizations and operating return on assets (OROA) via publicly disclosed, secondary data. The study also looks into operational competitiveness of firms via the effect of operational productivity (OP) on the relationship between GHG emissions and OROA.

Academic literature to-date finds the relationship between the level of emissions reported by an organization and its financial performance is ambiguous. A lack of consistent results about the

relationship between environmental and economic output resulting from operational efforts makes it difficult for organizations to gauge the feasibility of engaging in sustainable processes. Therefore, a data-driven empirical examination of the relationship between direct GHG emissions and OROA can inform responses to managerial questions with respect to sustainability like: “Is it financially worthwhile to invest in controlling GHG emissions?’’.

Since this study measures the impact of the absolute levels of GHGs released during plant level operations, which is a direct indicator of environmental performance of the company, the interplay of emissions to financial returns will be conveniently decipherable by all managerial levels of the organization, and inform efforts from the production line to senior level decision-makers. Furthermore, measuring the moderating role of OP involves the influence of the competitiveness of operations practices on the degree to which an organization’s financial performance is tied to its environmental performance. Inclusion of OP in the analysis provides deeper insights into how an organization’s operational competitiveness can work in concert to enhance or detract from the relationship between GHG and OROA.

Our research approach begins with reasoning a base model with the independent variable, GHG emission level and the dependent variable, OROA. This basic model in extended by introducing moderating effects of OP on the relationship between GHG and OROA. To test our model, GHG emission data from manufacturing organizations of the United States for the period 2015 to 2018 published by Bloomberg.org are collected for the study. We include control variables of market capitalization, advertising intensity, R&D intensity, leverage and industry. All of the financial data required to calculate the variables used in the study are obtained from Compustat.

In the next section, we review the extant literature on the key elements of our analysis. In section three, details of measuring variables are provided. Section four presents the methodology employed to collect and analyze the data, leading to results and interpretations in section five. A discussion based on the findings, managerial implications, conclusion and areas for future work finalize our study.

2 LITERATURE REVIEW

2.1 Environmental Performance

Klassen and Vachon (2003) study how supply chain collaboration and evaluation can help organizations improve their environmental management. Using data gathered from a sample of Canadian plants, they find that collaborations initiated by both organization and customer have a significant impact on the form and level of investments in environmental technologies used in regulating environmental impact across different segments of the supply chain. They find only limited evidence to support the argument that evaluation activities influence investment in environmental management. Similar to our study, Klassen and Vachon (2003) consider organizational environmental performance as the independent variable in their study, but they

use evaluative activities and legal compliance to conceptualize the construct by leveraging a survey based research design.

Hart and Ahuja (1996) study the impact of a reduction of selected chemical pollutants on the financial performance of companies. They collect data from the Toxic Release Inventory Program and use the percentage change in the emissions efficiency index, which is the ratio of reported emissions in pounds to the revenue of companies, as the independent variable. They measure financial performance using ROA, and include control variables: R&D intensity, leverage and advertising intensity. The results of the study suggest that the positive impact of efforts invested in pollution control on a firm's financial performance starts to deteriorate with time after the initiation period. Similar to the study conducted by Hart and Ahuja (1996), we investigate the environmental, operating and financial performance of organizations, but different from our study, Hart and Ahuja (1996) operationalize the environmental performance as a reduction in emissions, and operational and financial performance are both dependent variables. Additionally, in our study we examine the moderating role of competitively derived operational productivity.

A common operational measure of environmental performance of organizations is gauged by the level of toxic emissions of organizations such as GHG released by companies into the environment (Jacobs 2014; Hart and Ahuja, 1996). Jacobs (2014) explores whether or not there is a change over time in the direction or magnitude of the effect of emissions reductions by firms on their financial performance as well as market reactions to GHG emission reductions versus market reactions to non-GHG emissions reductions. An event study methodology is employed to examine the effect of voluntary emissions reduction announcements on stock market reaction. Jacobs (2014) finds that the market reaction to voluntary emission reductions decreases significantly over time and that for GHG emission reductions, the market reaction is more positive than for non-GHG emission reductions. Jacobs (2014) considers the effect of voluntary announcements on GHG emission reductions by companies on their financial performance, which is operationalized via ROA similar to how we operationalize our dependent variable. Otherwise, our study's focus is on how financial and environmental performance of manufacturers relate, especially with respect to operational dimensions within an organization's control.

Chen and Delmas (2011) conduct a study on measuring corporate social performance of companies which incorporates measuring corporate environmental performance. They state that there is no universally agreed upon scale or prioritization of environmental performance indicators existing for different stakeholders in the context of varying situations due to the diversity and dynamism of stakeholder attributes such as stakeholder preferences and perceptions. Accordingly, it is noted that many studies utilize directly observable indicators like energy consumption, greenhouse gas emissions and pollutant emissions for the measurement of a firm's environmental performance. Using data envelopment analysis Chen and Delmas (2011) leverage KLD measures to establish environmental performance scores. However, GHG emissions are not a dimension included in scores. Our study also utilizes DEA, but not for establishing environmental performance. Instead, we establish competitiveness or operational

productivity via DEA and rely on the direct measure of GHG emissions as the gauge environmental performance of firms.

2.2 GHG Emissions and Financial Performance

By benchmarking the CSR activity of firms against their industry peers in a given year and thereby recognizing the best in the industry and the worst, Awaysheh, Heron, Perry and Wilson (2020) examined the relationship between CSR and firm financial performance. The inconsistency of the results obtained from studies which explored the link between CSR and firm financial performance is attributed to the difficulty in measuring the elements of CSR accurately, finding data on CSR engagement by firms at the firm level and the non-convergence of data published by third party organizations due to the non-disclosure of all relevant information by firms (Awaysheh et al., 2020). Hence Awaysheh et al. (2020) propose that comparing best in class firms against the worst in class firms will provide a better analogy of the CSR-financial performance link since it will account for the industry differences, time trends, clustering and the potential for the existence of a nonlinear relationship between engagement in CSR activities and financial performance of firms. Awaysheh et al. (2020) show that the top 10% firms in an industry in terms of CSR performance or which are the best-in-class firms, have higher operating performance levels (measured via operating income before depreciation divided by total assets) and higher relative market valuations (measured via Tobin's Q). The results suggest that more profitable firms can invest more in CSR without compromising the interests of the shareholders, and the high operating performance can result in the high market valuation (Awaysheh et al., 2020). At first the study considers operational performance of the firm as a dependent variable along with financial performance of the firm. Using KLD data for seven dimensions, Awaysheh et al. (2020) show that best in class performers of CSR activities have high operational and financial performance levels, hence they raise the concern whether it is doing good (engaging in CSR) leads to doing well (firm financial performance) or is it the other way round since high profits give managers more liberty to invest in CSR activities without shirking their responsibility towards the shareholders. Therefore, Awaysheh et al. (2020) next consider operational performance as a control variable and reexamine the link between CSR and firm financial performance, to see that best-in-class firms, ceteris paribus are having high financial performance compared to their industry peers, showing that top CSR performers are not doing good just because they are doing well.

Researchers in the area of operational sustainability theorize via the resource-based view (RBV) that resources employed by a firm to control GHGs can constitute VRIN (valuable, rare, inimitable, non-substitutable) characteristics and lead to a competitive advantage for the firm (Jacobs, 2014). Emission reductions in firms can result from labor intensive efforts such as total quality management practices like continuous improvement projects (Hart and Ahuja, 1996). These practices can embed in organizational routines and depend on the knowledge of employees. Thus, resources used to control GHG emissions have aspects of inimitability. Russo and Fouts (1997), find that the technology used by a company to reduce GHG emissions will not be easily available to its competitors, because they require specialized skills to operate. Hence, the resources associated with controlling GHG emissions can yield a competitive advantage to a company and generate returns in the form of increased profitability. Transportation of raw materials to the manufacturing plant, conversion of raw materials to finished products, storage of

raw materials, work-in-progress and finished goods at the plant are some of the business processes which result in releasing GHGs to the atmosphere. These processes happen at the expense of organizational assets or resources like human capital, property, plant and equipment. These productive processes are leveraged to create a value to the customer which will generate financial returns for the organization in terms of sales and profits. Organizational resources involved in business processes which emit GHGs, will be used to generate financial returns for the company, where they will also result in costs for the company in terms of energy inefficiencies. Thus, it is reasonable to model the relationship between GHGs and OROA of a company. Additionally, several variables like plant size, investment in R&D, advertising intensity, capital intensity will have to be controlled for, to blunt the effect from differences in firm resources, commitments, and strategies (Hart and Ahuja, 1996). Relationally, we expect firm GHG emission levels to have a negative impact on firm financial performance and that firms which reduce their GHG emissions will be able to reap beneficial impacts associated with the financial performance.

2.3 Role of Operational Productivity

Operational productivity measured as the ratio of an output like sales of the firm to an input resource like inventory or employees or property, plant and equipment is found to elicit a condition for the relationship existing between corporate social performance and financial performance of companies. Jacobs, Kraudee and Narayanan (2016) find that only the companies which excel in both OP and corporate social performance, which is the adoption of management practices to minimize the negative impact that firm operations have on the society, can drive better financial performance than companies excelling in only one of them.

Productive companies have the necessary resource and technological base needed to enhance employee performance and leverage management practices which are needed to improve business performance (McKone et al., 2001). Smith and Reece (1999) explored relationships between business strategy, productivity and firm performance. They consider productivity as a mediating variable between business strategy and performance. Particularly, they find that productivity mediates a positive relationship between customer service strategy and firm performance.

The reduction of the negative impact of operations on the environment via the efficient usage of natural resources and materials in manufacturing is termed as environmental efficiency (Rothenberg, Pil and Maxwell, 2001). Elements of lean production which encompass maintenance of minimal levels of inventory or buffer minimization, management practices and policies which enable human resource management are examined in previous literature for their role on improving the operational efficiency which then impacts the environmental performance of the firm (MacDuffie, 1995; Rothenberg et al., 2001). Buffer minimization, which entails producing the maximum output using the minimum level of inventories, enables minimum end-of-process rework areas and work-in-process compared to plants without inventory efficiency. The reduction in the likelihood of producing large batches of faulty products via the efficient management of inventory results in higher operational productivity of the firm (Rothenberg et al., 2001). Employee efficiency, which is another component of operational productivity that we

consider in our study, includes worker commitment, motivation and skills, which are crucial for the operational success of the firm (Rothenberg et al., 2001). Human resource management practices like compensation linked to performance, high levels of skill development and training for employees, efforts to reduce the power gap between management and employees are found to be important for improving labor productivity which improves the operational efficiency of the firm. (Pill and MacDuffie, 1999). These types of material efficiency and labor efficiency practices are deemed a part of pollution prevention technologies and management. In contrast to pollution prevention technologies, pollution control technologies improve the environmental performance of plants by minimizing the toxic emissions via treatment or disposal of harmful by-products or pollutants at the end of manufacturing processes (Rothenberg et al., 2001).

It has been found that through material usage reduction, combined with increased efficiency of plant equipment, manufacturing plants are able to reduce the emission of toxic volatile organic compounds (Aragon-Correa, 1998). Firms with high environmental performance are found to combine both pollution prevention technologies with pollution control technologies, rather than depending solely on pollution prevention mechanisms. Evidence for this can be found in observing a 50% decrease in volatile organic compound emissions by introducing material usage reduction, where another 15% reduction in emissions was achieved by increasing the efficiency of the equipment used by an automobile assembly plant (Rothenberg et al., 2001).

According to the resource-based view of the firm, organizations gain competitive advantage by exploiting their internal strengths, which possess the VRIN characteristics of being valuable, rare, not imitable and non-substitutable (Barney,1991). Firms with high productivity, which generate more outputs from a unit of input compared to a firm with less productivity, will likely possess VRIN resources, such as skillful employees who are capable of implementing activities related to environmental management, support from organizational management in training and educating the workforce on green orientation of organizations, and organizational knowledge and technology (Paiva et al., 2008) needed to leverage GHG emission reduction practices effectively and efficiently.

These resources employed by efficient organizations will yield superior returns as compared to less efficient organizations. Hence even if a firm with low OP engages in GHG emission reduction efforts, any financial return associated will be limited, since they do not utilize resources efficiently and effectively like firms with high OP do. Therefore, when firms are operationally productive, they leverage inputs including those which aid in reducing GHG emission levels. This efficiency capability helps the firm to derive returns from engaging in GHG emission reduction practices, and slack resources that can be used to counter the costly inputs needed for engaging in GHG reductions (Jacobs et al; 2016). Based on this we can expect firms with low OP to be less effective than high OP firms in terms of financial performance through the reduction of their GHG levels. Thus, high OP companies can gain financially while emitting lower levels of GHGs.

3 MEASURES

The data to form the measure for this study are collected from two main sources. Bloomberg is used to collect data on the independent variable which is GHG scope 1 emissions, and all other financial data including the measures used to calculate the dependent variable operating return on assets (OROA), control variables, and operational productivity (OP) are collected from Compustat.

3.1 Independent Variable

The independent variable of our study is GHG scope 1 emissions, the direct GHG emissions of a company, emitted from sources controlled or owned by the company. These emissions are given in metric tonnes of carbon dioxide equivalent. Bloomberg collects and lists the data on GHG emissions from financial reports of companies. Utilizing this source, GHG scope 1 emissions from 44 manufacturing firms from the United States for the period from 2015 to 2019 are collected.

3.2 Dependent Variable

To compare as directly as possible returns due to the production function of firms, we use operating return on assets (OROA) as the dependent variable in our study. OROA is calculated as operating income after depreciation divided by total assets of the firm. Data for these variables are obtained from Compustat.

3.3 Moderating Variable

Operational productivity (OP) is modeled as the moderating variable in this study. The measure standardizes across firms the output produced per a given input. Since firms can take multiple approaches to improve their operational productivity, by using different types of inputs like labor, inventory and fixed assets, we consider all three types of inputs in calculating the operational productivity for each firm. To quantify this variable we employ a data envelopment analysis (DEA) approach similar to the method used by Jacobs et al. (2016) for each firm-year.

Data for three inputs: total inventory; number of employees; and plant, property and equipment for each firm year, as well as one output, total sales, for each firm year, are collected from Compustat. For the DEA analysis used in this study, there are 220 decision-making units (DMUs) belonging to three sectors of the manufacturing industry: food manufacturing (NAICS code starting with 31); wood product manufacturing (NAICS code starting with 32); and primary metal manufacturing (NAICS code starting with 33).

Due to the dataset containing three inputs, the DEA approach in this study follows an input oriented, VRS model. This addresses the non-proportional changes in output due to different inputs, by adding a convexity constraint (Jacobs et al., 2016). Considering multiple inputs simultaneously, the CCR model utilized in the study optimizes the output generated for a given set of inputs by assigning weights for the inputs subjected to typical DEA constraints.

Here the measures for the optimal operational productivity results from the maximization of a linear objective function derived from the ratio between the output (sales) and the aggregated inputs can be given as,

$$E_{ks} = \sum_y O_{sy} \,.\, v_{ky} / \sum_x I_{sx} \,.\, u_{kx} \quad (1)$$

where,

E_{ks} = Optimal operational productivity for firm *s*, using the weights of firm *k*
O_{sy} = value of output *y* (sales) for firm *s*
v_{ky} = value of weight assigned to firm *k* for output *y*
I_{sx} = value of input *x* of firm *s*
u_{kx} = value of weight assigned to firm *k* for input *x*
Equation (1) maximizes the operational productivity score by solving for the optimal *u* and *v* values for each firm as denoted below.

$$E_{kk} = \sum_y O_{ky} \,.\, v_{ky} / \sum_x I_{kx} \,.\, u_{kx} \quad (2)$$

Subject to,

$E_{ks} \leq 1$ for all firms *s*, including *k* and
$u_{kx}, v_{ky} \geq 0$

In equation (2), the weights assigned for the output and the three inputs are subjected to two constraints, where all efficiency scores cannot exceed one and each weight assigned to the four variables, the output and the three inputs, is greater than or equal to zero. This decision problem can be converted to a linear programming problem by using Charnes, Cooper and Rhodes (1978) transformation, where the denominator of equation (2) can be set to 1 by introducing an additional constraint which is, $\sum_x I_{kx} \,.\, u_{kx} = 1$

Hence the objective function of maximizing the ratio given in equation (2) can be replaced with maximizing the product of the output and the assigned weight for the output. This is formulation is:

Maximize $E_{kk} = \sum_y O_{ky} \,.\, v_{ky}$ (3)

Subject to,

$E_{ks} \leq 1$ for all firms *s*, including *k*
$\sum_x I_{kx} \,.\, u_{kx} = 1$
$u_{kx}, v_{ky} \geq 0$

The efficiency score calculated in equation (3) will be a value between 0 and 1, where a score of 1 indicates that the firm lies on the efficient frontier, with the maximum achievable operational productivity. Therefore, an operational productivity score of 1 results for a firm which generates sales most efficiently from labor, inventory and fixed assets. Similarly, efficiency scores below 1

show firms with room to improve sales productivity. For example, if a firm has an operational productivity score of 0.85, it has room to improve its efficiency by 15% relative to the competitively determined efficient frontier.

3.4 Control Variables

To mitigate influences of potentially confounding aspects of firms in the study, control variables used in regressions are: 1) firm size measured in terms of market capitalization; 2) advertising intensity; 3) R&D intensity; 4) leverage; and 5) industry. Data needed for these variables are obtained via Compustat.

3.4.1 Firm Size

When a company implements green practices, there will be purchases of intermediate goods and services related to the provision of green products. Large firms can extract scale economies via quantity or bulk purchase savings on input costs. They can also spread costs of using human resources over numerous units of output. (McWilliams, A., D. Siegel. 2001). Large firms will likely be highly conscious of their public image because of the large scale and scope of any negative ramification from bad publicity. Hence large firms might possess economies of scale and also scope that enhance or depress the relationship between green practices and ROA. To account for size related considerations, firm size is included as a control variable in regressions. Firm size is calculated in terms of market capitalization. Market capitalization is the preferred proxy for firm size because previous studies have established that a larger increase in R^2 can be obtained when market capitalization is used in the regression model compared to other proxies like total assets or sales (Dang, Li and Yang, 2018). For each firm-year measure of market capitalization, the number of outstanding shares at the end of each year is multiplied by the average closing share price. Average closing share price is calculated using the quarterly closing share prices to smooth the share price figure versus a one day, end of year share price.

3.4.2 Advertising Intensity

Firms that invest in advertising are found to be more market and customer oriented. Advertising helps to boost sales of the organization by exploiting short-term market opportunities (Guo, Fan and Zhang, 2020). Therefore, firms engaging in promotional activities will enjoy amplified sales revenues due to improved customer awareness which signals that the effect of advertising needs to be controlled when conducting our study. If a company wants to differentiate their products on green practices used in the production process, advertising will play an important role in raising the awareness of potential customers with saliency for green consumption. McWilliams and Siegel (2001), find that there is a positive correlation between advertising intensity and provision of green attributes. Likewise, firms focusing on maintaining public image are found to be more engaged in sustainable development (Yang, Lau and Cheng, 2018). Therefore, advertising intensity of each firm is included as a control variable when measuring the relationship between GHG emissions and OROA. We calculate advertising intensity by dividing advertising expenses by total sales. Firms which did not report their advertising expenses are assumed to have a value of zero for their advertising intensity.

3.4.3 R&D Intensity

Research and Development intensity is considered to be a control measure for firm performance since R&D produces more successful products and higher performing firms tend to spend more on R&D. Product differentiation through the use of green initiatives, such as recycled products or reduction of GHG emissions, may include investment in research and development (R&D). R&D investment can result in both process and product innovations, which are each valued by some consumers. Therefore, product differentiations achieved through R&D can positively affect the provision of green attributes (McWilliams and Siegel, 2001).

Employees of firms with higher investments in R&D are found to be better at learning from customer feedback, thereby increasing sales of the organization (Guo, Fan and Zhang, 2020). Additionally, investments in R&D can enable organizations to improve their greenhouse gas performance (Koh, Gunasekaran and Ebrahimi, 2017).

Therefore, we include R&D intensity as a control variable and calculate it from Compustat as R&D expenses divided by sales.

3.4.4 Leverage

When firms are highly leveraged, they may have a lesser capacity to invest in activities required to implement global environmental standards and green practices, and the R&D projects needed for the development of green initiatives. Therefore, we control for this effect by including leverage as a control variable in our study. Leverage is calculated by dividing the long-term debt by total assets, figures for which are obtained from Compustat.

3.4.5 Industry

Using dummy variables provides a direct method for accounting for potential differences among industries without the trouble of parsing out which particular characteristics are most likely to be relevant (Sharp, Bergh and Li2013). We include two dummy variables for the wood product manufacturing and primary metal manufacturing sectors, which are compared with reference to the base industry sector of food manufacturing. NAICS codes of each company form the delineation of the three sub-sectors.

4 METHODOLOGY

For manufacturers in the United States, we obtained data for GHG scope 1 emissions from Bloomberg. To obtain financial data for the firms, Compustat was used. Due to newness of GHG data and lags in most recent reporting periods, we had to restrict the analyzed period of time to five years covering 2015-2019. The final dataset contains data for 44 individual firms comprising 220 firm-year observations.

In developing the OP efficiency scores, we consider three sectors of the manufacturing industry to allow a finer-grained investigation of firms within a specific industrial sector. We compare efficiency scores for OP within each sector; food, wood and primary metal product manufacturing for five years from 2015 to 2019. The recommended number of DMUs for a DEA is generally two times the sum of inputs and outputs or three times the sum of inputs and outputs if considered on a more stringent basis (Jacobs et al., 2016). Employing the more conservative three times as the threshold, with one output and three inputs, we require a minimum number of twelve DMUs for the OP score calculation. The number of firms from the wood and primary metal sectors is fourteen and twenty-four, respectively. Thus, the three times threshold for DEA analysis is satisfied for these two sectors. However, the number of firms in the food manufacturing sector is only six, and does not even meet the two times threshold. To address this issue, we calculated the correlation between the three inputs and found that the number of employees and property, plant and equipment for the firms in the food manufacturing sector have a high correlation of approximately 0.9 in each year. As such, we dropped the number of employees as an input for the food manufacturing sector and for this sector the DEA calculation of OP scores used only two inputs.

To analyze the direct effect between GHG scope 1 emissions and OROA and the impact of OP scores on that direct relationship, we implement a hierarchical regression analysis. In model 1 we included only the control variables and in model 2 we included the independent variable GHG scope 1. In model 3 we included the OP score and in model 4, the interaction effect between GHG scope 1 and OP score was included.

5 ANALYSIS AND RESULTS

The descriptive statistics for the key variables, GHG Scope 1, OROA and OP, for each industry sector, and year are given in Table 1. Table 2 provides the correlation matrix for the variables considered in the study.

Table 1: Descriptive statistics for the key variables

			2019	2018	2017	2016	2015
Food Manufacturing	**GHG Scope 1**	**Mean**	3254133	3199892	3243374	3254133	3199892
		STD	5806299	5703889	5739966	5806299	5703889
	OROA	**Mean**	0.081	0.099	0.119	0.103	0.104
		STD	0.035	0.036	0.061	0.042	0.043
	OP	**Mean**	0.914	0.894	0.885	0.885	0.885
		STD	0.119	0.154	0.111	0.127	0.143
Wood Manufacturing	**GHG Scope 1**	**Mean**	7803874	8297779	8004508	11302510	11352977
		STD	15829146	17318592	16584086	20108509	20488876
	OROA	**Mean**	0.100	0.117	0.094	0.095	0.089
		STD	0.053	0.057	0.062	0.078	0.077
	OP	**Mean**	0.606	0.576	0.607	0.656	0.734

		STD	0.230	0.244	0.228	0.209	0.188
Primary Metal Manufacturing	**GHG Scope 1**	**Mean**	1071374	1093613	1032917	1063977	1341655
		STD	3571903	3612285	3331850	3575284	4894267
	OROA	**Mean**	0.100	0.108	0.090	0.087	0.089
		STD	0.048	0.055	0.040	0.042	0.056
	OP	**Mean**	0.483	0.510	0.503	0.469	0.480
		STD	0.233	0.235	0.236	0.245	0.242

Table 2: Pearson Correlation values

	Op ROA	Market cap	R & D intensity	Advertising Intensity	Leverage	Wood	Metal	Year 2019	Year 2018	Year 2017	Year 2016	GHG scope 1
Op ROA	1											
Market cap	0.327***	1										
R & D intensity	0.243***	0.152**	1									
Advertising Intensity	0.336***	0.009	0	1								
Leverage	0.155**	-0.08	0.12**	0.29***	1							
Wood	0.025	-0.04	-0.1**	-0.1	0**	1						
Metal	-0.045	0.078	0.3***	-0.4***	-0***	-0.7***	1					
Year 2019	0.002	0.043	0	-0	0	0	0	1				
Year 2018	0.116**	0.024	0.01	0	-0	0	0	-0***	1			
Year 2017	-0.016	0.005	-0	0	-0	0	0	-0***	-0.3***	1		
Year 2016	-0.047	-0.04	0	0.01	0	0	0	-0***	-0.3***	-0.3***	1	
GHG scope 1	-0.36***	0.09*	-0.2***	-0.2**	-0**	0.36***	-0***	-0	-0	-0	0.01	1
OP Score	0.111*	0.365***	-0.1	0.36***	-0	0.12**	-0***	-0	-0	-0	-0.01	0.3

*** p < 0.005 ** p < 0.05 * p < 0.1

We tested for multicollinearity between the variables using VIF values. All VIF values (given in Table 3) are below 10, and thus, indicate multicollinearity is not an issue.

Table 3: VIF values

Variable	Standardized Coefficients	t	Sig.	VIF
Market cap	0.334	5.466	0	1.336
R & D Intensity	0.092	1.495	0.137	1.344
Advertising Intensity	0.389	4.893	0	2.262
Leverage	-0.028	-0.453	0.651	1.322
Wood manufacturing	0.402	3.569	0	4.555
Metal manufacturing	0.258	1.862	0.064	6.903
Year 2019	0.026	0.384	0.701	1.629
Year 2018	0.119	1.776	0.077	1.613
Year 2017	0.02	0.292	0.771	1.608
Year 2016	0.01	0.15	0.881	1.607
GHG scope 1	-0.199	-1.951	0.052	3.736
OP Score	0.007	0.094	0.925	2.069
ZGHG_ZOP	-0.217	-2.318	0.021	3.142

Hierarchical regression results are provided in Table 4. Only the control variables are included in Model 1 and the independent variable GHG Scope 1 is introduced in Model 2. As shown, there is a 10.6% increase in adjusted R^2 value in Model 2 as compared to Model 1. The impact of GHG Scope 1 on OROA is found to be negative and significant at p = 0.005. In Model 3, OP score is introduced and surprisingly, the impact of OP score is found to be not statistically significant though positive. In Model 4, the interaction effect between GHG Scope 1 and OP score is introduced which results in a 1.3% increase in R^2 value, yielding a R^2 value of 39% for the full model. The effect of this moderation is significant at p = 0.05 level. The direct effect between GHG Scope 1 and OROA remains negative but not significant at p =0.05 level, but is significant at p =0.1 level. Cluster robust standard errors are used in all models.

Table 4: Hierarchical regression results

	Model 1	Model 2	Model 3	Model 4
(Constant)				
Market cap	0.29***	0.337***	0.327***	0.334***
R&D intensity	0.124*	0.086	0.082	0.092
Advertising intensity	0.497***	0.402***	0.401***	0.389***
Leverage	0.054	-0.032	-0.029	-0.028
Wood manufacturing	0.359***	0.396***	0.411	0.402***
Primary metal product manufacturing	0.385***	0.239*	0.264*	0.258*
Year 2019	0.028	0.026	0.027	0.026
Year 2018	0.124*	0.12*	0.122*	0.119*

Year 2017	0.023	0.019	0.02	0.02
Year 2016	0.004	0.008	0.009	0.01
GHG scope 1		-0.378***	-0.384***	-0.199*
OP Score			0.029	0.007
GHG scope 1* OP Score				-0.217**
Adjusted R^2	0.273	0.379	0.376	0.389
Change in adjusted R^2		10.6%	-0.3%	1.3%

*** p < 0.005 ** p < 0.05 * p < 0.1

According to model 1, market capitalization which is a proxy for the size of the firm, has a significant (p=0.005) positive correlation with financial performance, OROA. This indicates that larger the firm, higher will be the financial success of the firm. Therefore, by including firm size as a control variable, we are effectively isolating the tendency for firms to perform better financially due to the larger scale of the organization. Surprisingly, the relationship between R&D intensity and firm financial performance is not significant, though the direction of the correlation is positive. The relationship gives a positive and significant coefficient in model 1 where only the control variables are included, but once the main variables are included, the coefficient becomes insignificant. As expected, the impact of advertising intensity on financial performance is positive and significant at p=0.005. The relationship between leverage and OROA is negative as anticipated but not significant. The sub-industry category of wood manufacturing has a significant positive relationship with financial performance compared to the base sub-industry category of the food manufacturing sector. Similarly, the primary metal product manufacturing sub-industry has a significant positive effect on financial performance compared to the food manufacturing sector. But the significance of the primary metal product manufacturing sub industry category is not as strong as that of the wood manufacturing sector. Coefficients for both the industry sub sectors compared to the base industry sub sector are positive and significant at p=0.005 in model 1 where only the controls are included but the significance of the coefficient for metal manufacturing diminishes when main variables are included.

For a graphical interpretation of the results including moderation, a two-way interaction plot is provided in Figure 1. The effect of different levels of OP on the relationship between GHG emission and OROA is given in Figure 2. Accordingly, for all firms, the relationship between GHG emissions and OROA is negative. Hence higher the GHG emissions, lower will be the profitability of the company. But for firms with high OP, controlling the GHG emission levels will have a greater impact on their OROA. Reducing the emissions or being green oriented will yield lesser financial benefits in the presence of low OP. Therefore, in the presence of high OP, companies which control their GHG emissions can perform very well financially. Companies with low OP levels and mitigated GHG emissions can expect to experience muted benefits to financial performance. Therefore as hypothesized, when OP is high, lower GHG emissions will be associated with higher financial returns, whereas when OP is low, there will be little or no financial gain achieved by lower GHG emissions. As a robustness check, the industry and year

control variables were removed and the same regression results were obtained. The best model fit was obtained with the inclusion of all of the remaining control variables.

Figure 1: Plot for the interaction effect between GHG Scope 1 and OP on OROA.

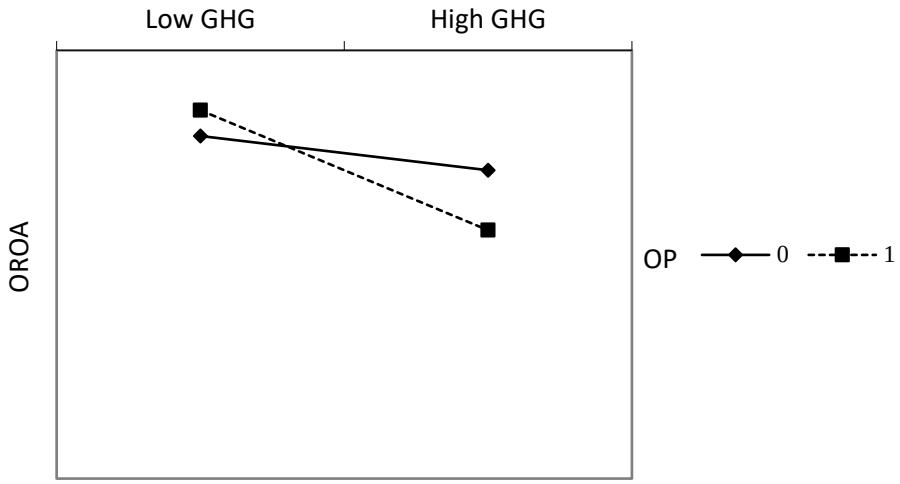
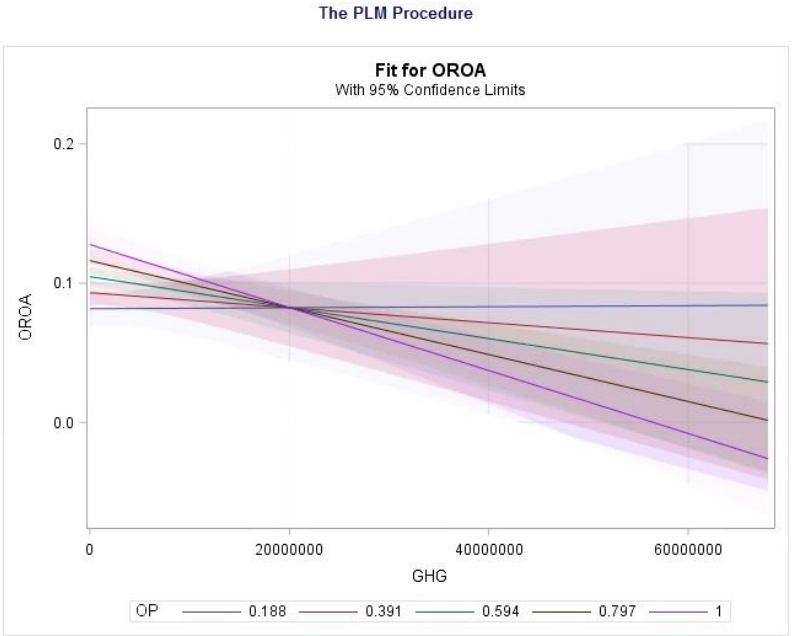


Figure 2: Effect of different levels of OP on the relationship between GHG emission and OROA.



Considering the possible effect of time-invariant, firm specific, unobservable characteristics which might be correlated with the explanatory variable considered in our study, we also include a firm- level, fixed-effects regression model in our analysis. Dummy variables for time account for any possible exogenous year specific characteristics on firm performance. Inclusion of time

dummies assumes the estimation of coefficient of standard errors to have no correlation across the firms in idiosyncratic disturbances (Suarez, Cusumano and Kahl, 2011).

A random effects regression was also run to account for unobserved heterogeneity at the sub-industry level. However, results from the Hausman (1978) test suggest that the fixed effects model is the most appropriate for our study. The regression results from the fixed effects model (model 5) using robust standard errors is given below in table 5.

Table 5: Results of Fixed Effects estimations for firm financial performance.

	Model 5
Market cap	0.342
R&D intensity	0.032
Advertising intensity	0.501
Leverage	-0.0121
Wood manufacturing	0.397
Primary metal product manufacturing	0.149
GHG scope 1	-0.0072** (0.00618)
OP Score	0.0836*** (0.02025)
GHG scope 1* OP Score	-0.0018** (0.00122)
Year Dummies	Yes
Number of observations	220
Number of groups	44
R2	21.20% (Overall)

Note: Standard errors are included in parentheses, except where indicated

*** p < 0.005 ** p < 0.1

Ultimately, for the main variables, GHG Scope 1, OP Score and the interaction term, the results obtained from fixed effects estimation are similar to those from hierarchical OLS regression. GHG scope 1 has a negative correlation with financial performance (p=0.10). Operational productivity has a positive relationship with financial performance of the firm and the correlation is significant at p=0.005. The moderating effect of operational productivity of the firm, on the relationship between firm environmental performance and firm financial performance, as indicated by the interaction term, is negative and significant at p=0.1.

Hence the results from fixed effects estimation further validate our conclusion that higher the GHG emissions, lower will be the operational returns or financial performance of the company, and that for firms with high operational productivity, controlling the GHG emission levels will have a greater positive impact on their financial performance.

6 DISCUSSION

We initiated our study with a motivation of managerial actions toward sustainability pressures from various stakeholders on the efforts of manufacturers to meet financial performance expectations of shareholders. A key question of our study: “Is it financially worthwhile to invest in controlling GHG emissions?” is addressed in results of our analysis.

Our findings indicate that manufacturers can satisfy stakeholder concerns about environmental issues while also being financially successful for its shareholders. However, the tension between environmental effects from business operations to achieve positive financial outcomes are governed by how well firms manage other operational aspects of production. Firms need to be operationally productive to achieve financial benefits in relation to lowering its direct GHG emissions. In particular, efforts to reduce GHG emissions will yield high financial returns for companies while in the presence of high operational productivity levels. Companies with low operational productivity tend to miss out on financial benefits associated with controlling GHG emissions. Thus, threats to financial outcomes of firms by initiatives to improve environmental performance targets on firms via elective action, activist shareholders or government policies can be mitigated in part when firms are operationally productive as compared to industry peers.

Our data-driven empirical examination of the relationships between GHG emissions and financial performance in light of operational productivity provides a positivist approach for organizations interested in the feasibility of pursuing returns for shareholders and sustainable practices. From an emissions mitigation perspective, high GHG emission levels of manufacturers are associated with poor financial performance. Therefore, environmental effects of productive processes should be considered by operations managers because it is a responsible attitude both environmentally and financially. A key take-away is that when engaging in green practices, whether due to stakeholder pressures, policies of the governments or to acquire high financial returns, firms should focus on achieving competitively high operational productivity. Green-oriented initiatives to control GHG emissions are only truly sustainable if the firm remains a going-concern, and the firm’s financial benefits associated with this friendlier environmental practice is limited by the firm’s operational productivity. Therefore, operations managers and executives should be mindful in maintaining high OP levels when trying to achieve low GHG emissions and also perform well financially.

Since our study includes a direct measurement of environmental performance of the firm, in the form of absolute levels of GHGs emitted during scope 1 firm operations, our results can be conveniently comprehended across all hierarchical levels of the firm and inform all employees about how environmental performance of the company impacts the operational returns of the company. Operational managers can stress the point that increases in GHG emissions lower the profitability of the company. Strategic managers can interpret the results of our study and understand that no matter the efforts invested in working towards improving the environmental performance of the company, or the sustainability agenda followed by the company, in order to encourage returns from such investments in the form of improved financial performance, the

company should have high operational productivity levels. Therefore, our study signals to strategy makers that inventory, labor and fixed asset productivity levels of the company should be high if the company is seeking financial returns from their sustainability agenda. With the resource-based view grounded in competitiveness of operational productivity, the firm will garner the optimal conditions for reduced GHG levels to provide financial benefits for the company.

Our analysis of the main effect between firm's environmental performance and its profitability, which turns out to be positive and significant, since a firm with lower GHG emissions or higher environmental performance will have a high financial performance, suggests that firms with greater environmental performance can attract skilled workers, improve their reputation as a 'green' organization, resulting in a greater market presence for the firm (Jacobs, 2016). Firms with high environmental performance and operational productivity may also be able to attract greater customer attention via positive advertising. Hence this suggests that greater productivity of green entities can be translated to improved bottom lines which include People, Planet and Profit (Jacobs, 2016). The fundamental contribution of our moderation results to the existing literature on green performance of firms is the identification of the crucial role of operations in leveraging green or environmental performance of the company for its financial benefit.

Considering the limitations of our study, we included only the manufacturing plants in U.S. given our focus on OP which considered labor, inventory and fixed assets as the different types of inputs. This limited our sample to only the manufacturing firms hence we are not able to arrive at conclusions on service sector firms. Our DEA approach needs a larger sample size to have a comprehensive comparison between different firm groups and to yield a sufficient number of DMUs. Hence the availability of greenhouse gas emission data restricted our sample to the manufacturing industry with only three sub industry categories.

7 IMPLICATIONS

Even if the common agreement is that the main role of operations managers is improving the operational productivity of the company, many of the managers might not understand how OP facilitates performance gains for the firm via the environmental-financial performance link. Therefore, our findings illuminate the important role played by operations management in garnering a healthy relationship between a firm's environmental performance and its financial livelihood.

An important advantage of the DEA methodology is that it enables flexibility in how firms approach or reach the efficiency frontier (Jacobs, 2016). Table 6 indicates how some firms in our sample used different input efficiencies year-to-year, along with the corresponding OP score and OROA. The examples given in the table are firms which increased their inputs, and based on the respective OP (given by DEA score) achieved: (i) inefficient and unchanged OP score; (ii) OP score improved, but did not reach the frontier for the sub industry-year; (iii) OP score improved

and efficiency frontier for the sub industry- year was reached; (iv) Remained to be on the efficiency frontier for the sub industry-year.

Table 6: Example on firms which improved the OP inputs with the corresponding change in OP score and OROA.

		OP score inefficient and did not change	OP score improved but below the frontier	OP score improved and reached the frontier	OP scores remain on the frontier
ID	Firm	General Motors	Westrock Co	General Mills	PepsiCo Inc
	Sub industry category	Primary Metal	Wood	Food	Food
	Year t	2018	2016	2019	2019
1 Year Change in Inputs	Sales/Inventory	9.72%	49.2%	12.84%	-2.67%
	Sales/PPE	-2.90%	29%	14.50%	-12.40%
	Sales/Employees	5.90%	32%	7.15%	3.87%
DEA scores for OP	OP_{t-1}	0.42	0.41	0.85	1
	OP_{t}	0.43	0.48	1	1
	Change in OP	-2.5%	15.71%	17.62%	0.00%
OROA	$OROA_{t-1}$	6.19%	4.38%	9.46%	13.40%
	$OROA_{t}$	3.23%	5.10%	9.62%	13.60%
	Change in OROA	-47.7%	16.49%	1.71%	1.49%

According to the above table 6, we can see that each firm took a different approach to achieve efficiency improvements. General Motors improved both its Sales per Employees and Sales per Inventory but yet its OP score did not improve compared to the rest of the firms of the sub industry category. Westrock made improvements in all three categories of efficiency: Sales per Inventory, PPE and Employees. Accordingly Westrock improved its OP score. General Mills also made improvements in all three categories and reached the efficiency frontier. Pepsi made improvements only in Sales per Employees and managed to remain on the frontier. Therefore, this indicates the different approaches leveraged by firms to achieve improvements in productivity and these results signify the benefit of adopting a DEA-based methodology to calculate OP (Jacobs, 2016). Further, the year to year increments and decrements in efficiency values highlight the value of utilizing an overall OP score for efficiency rather than being solely based on an individual input. Looking at the performance of General Motors, we can see that even if it improved both its employee and inventory efficiencies, the other firms in the sub industry category of primary metal manufacturing improved even more, and thus as a result General Motors' OP score decreased, and their financial performance also decreased.

Even if one might find it difficult to understand the important relationships between environmental performance, firm financial performance and operational productivity of the firm given that the operational productivity, examples like the ones provided in Table 6 makes it easier for the managers to easily realize the implications of using different approaches to efficiency improvements, and their impact on the overall OP score. Table 6 suggests that managers should not only be focusing on improving efficiencies of various inputs, but they also should be mindful of how these different variables relate to the other firms in their same industry category. Therefore, it is important for the managers to be cognizant that even if they improve all kinds of input efficiencies, when compared to the rest of the firms of the industry, they might still not have improved in terms of their overall OP score. Thus, as indicated by table 6, managers should also note that firm level efficiency improvements are not sufficient enough to improve their financial performance, but instead the efficiency improvements compared to the rest of the industry will be crucial (Jacobs, 2016). Most important managerial implication in terms of OP score of the firm is, as Table 6 suggests, managers can choose between different approaches to become the industry leaders in firm efficiency by concentrating on different aspects of operations. Table 6 shows that even if the efficiency of rest of the inputs decreases but if you manage to improve the efficiency of one input compared to the industry, you will be able to reach the frontier. Hence it should also be noted that rather than focusing on one type of input efficiency, managing trade-offs between input efficiencies will be the key to reach or maintain the position on the efficiency frontier. This yields a flexibility to the managers in how they can approach operations in their endeavor to improve the financial performance of the firm (Jacobs, 2016).

Another key managerial implication of our study is that it is not viable to pursue environmental performance of firms at the expense of OP. Our results show that a financial benefit from controlling for GHG emissions can be obtained only in the presence of high OP. Hence firms with high green performance but low OP did not do well in terms of their profitability. Therefore, it would be advisable for the managers to set a threshold OP level (Jacobs, 2016), at least on par with the other firms in the industry before indulging in associating environmental performance with firm's financial performance.

8 CONCLUSION

Our research has several important findings. We highlight the critical nature of OP to the financial performance and green performance of the firm. We find that better financial performance can be achieved by controlling for GHG emissions only in the presence of high OP levels. We also indicate that even if a firm improves their different types of input efficiencies, they might still yield decreased OP scores and profitability levels, if they lag behind the other firms in the industry. We show that firms have the flexibility to tackle operational productivity of the firm by considering different approaches for improving efficiency, and that rather than focusing only on one type of input efficiency, firms should manage a trade-off between different efficiencies to achieve high OP scores. Most importantly, we conclude that firms should not indulge in improving the environmental performance at the expense of the OP, since a positive relationship between firm's environmental performance and financial performance can only be achieved under high levels of OP.

9 FUTURE WORK

Our study considered only OROA as a proxy for firm financial performance. Therefore, as future work we suggest the incorporation of different metrics for the measurement of financial performance like Altman Z and Tobin's Q. Since Tobin's Q incorporates the intangible assets as well, the utility of this measure will enable understanding of how firm's green performance can improve the brand image and reputation; and attract high caliber workforce. Stemming from our study which included the moderating role of OP on the link between green or environmental performance and firm's financial performance, future studies can extend our study to incorporate the other aspects of ESG metrices, by addressing Social and Governance aspects of the firm. As Rothenberg et al. (2009) indicated, input efficiency improvements include practices like buffer minimizations, management systems and human resource management practices which are the elements of lean management. In our study we discussed how such practices result in different efficiencies like inventory and labor efficiencies which improve the firm's overall OP score. Therefore, future researchers can design a study which evaluates the relationship between the elements of lean management, OP of the firm and firm financial performance. Further, in our study we included only GHG emissions for the measurement of firm environmental performance. Future work can involve different metrices under the environmental performance like KLD measures, which can be aggregated to achieve a DEA score (Chen and Delmas, 2011), similar to how we calculated the OP score in our study. Due to limits of available, verified and audited data for production intensive firms, our study focused on U.S. manufacturing companies. Another area for future work includes testing the generalizability of our results with sample data from various countries as well as with variables that reach beyond the firm (eg. other scopes of GHG). Extending our work to include service sector organizations will require a different approach for the operationalization of OP since the inputs used by service organizations will likely differ from that of the manufacturing plants.

10 REFERENCES

[1] Aragón-Correa, J. (1998). Strategic proactivity and firm approach to the natural environment. *Academy of Management Journal*, *41*, 556-567.

[2] Awaysheh, A., Heron, R.A., Perry, T., & Wilson, J.I. (2020). On the relation between corporate social responsibility and financial performance. Southern Medical Journal, 41, 965-987.

[3] Bailey, J. (1992), "VOC Regs Drive Auto Paint Line Design," Industrial Finishings, 59

[4] Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*, 99-120.

[5] Boston, P., & Boston, W. (2021). Germany to Make Firms Responsible for Policing Abuses by Global Suppliers. Retrieved 18 March 2021, from https://www.wsj.com/articles/germany-to-make-firms-responsible-for-policing-abuses-by-global-suppliers-11614780088

[6] Brown, A. (2021). Unilever finds short-term sustainability costs lead to long-term savings. Retrieved 18 March 2021, from https://www.supplychaindive.com/news/unilever-supplier-sustainability-costs-savings/595388/

[7] Charnes, A., Cooper, W. W., and Rhodes, E. 1978. "Measuring the efficiency of decision making units." *European Journal of Operational Research* 2(6): 429-444.

[8] Chaudhuri, S. (2020). Unilever to Give Investors Advisory Vote on Climate-Change Plan. Retrieved 28 May 2021, from https://www.wsj.com/articles/unilever-to-give-investors-advisory-vote-on-climate-change-plan-11607971421

[9] Chen, C., & Delmas, M. (2010). Measuring Corporate Social Performance: An Efficiency Perspective. *Corporate Governance: Social Responsibility & Social Impact eJournal*.

[10] Dang, C., Li, Z. and Yang, C (2018). Measuring firm size in empirical corporate finance. *Journal of Banking & Finance*, 86, 159-176.

[11] Friedman, Milton (1962). *Capitalism and Freedom.* University of Chicago Press.

[12] Guo, Y., Fan, D., & Zhang, X. (2020). Social media–based customer service and firm reputation. International Journal of Operations & Production Management.

[13] Hart, S., & Ahuja, G. (1996). Does it pay to be green? An empirical examination of the relationship between emission reduction and firm performance. *Business Strategy and the Environment*, *5*(1), 30-37. doi: 10.1002/(sici)1099-0836(199603)5:1<30::aid-bse38>3.0.co;2-q

[14] Hausman, J. (1978). Specification tests in econometrics. *Applied Econometrics*, *38*, 112-134.

[15] Jacobs, B. (2014). Shareholder Value Effects of Voluntary Emissions Reduction. *Production and Operations Management*, *23*(11), 1859-1874. doi: 10.1111/poms.12201

[16] Jacobs, B., Kraude, R., & Narayanan, S. (2016). Operational Productivity, Corporate Social Performance, Financial Performance, and Risk in Manufacturing Firms. *Production and Operations Management*, *25*(12), 2065-2085. doi: 10.1111/poms.12596

[17] Jennen, B. (2021). German Companies to Face Fines If Suppliers Abuse Human Rights. Retrieved 18 March 2021, from https://www.bloomberg.com/news/articles/2021-02-12/german-companies-to-face-fines-if-suppliers-abuse-human-rights

[18] Klassen, R., & Vachon, S. (2009). Collaboration and evaluation in the supply chain: the impact on plant-level environmental investment. *Production and Operations Management, 12*, 336-352.

[19] Koh, S., Gunasekaran, A., Morris, J., Obayi, R., & Ebrahimi, S.M. (2017). Conceptualizing a circular framework of supply chain resource sustainability. I*nternational Journal of Operations & Production Management*, 37, 1520-1540.

[20] Macduffie, J.P. (1995). Human Resource Bundles and Manufacturing Performance: Organizational Logic and Flexible Production Systems in the World Auto Industry. *Industrial & Labor Relations Review*, *48*, 197 - 221.

[21] Matthews, C. (2020). Exxon Promises to Cut Greenhouse-Gas Emissions, End Flaring by 2030. Retrieved 18 March 2021, from https://www.wsj.com/articles/exxon-promises-to-cut-greenhouse-gas-emissions-end-_laring-by-2030 11607957820

[22] McKone, K.E., Schroeder, R., & Cua, K.O. (2001). The impact of total productive maintenance practices on manufacturing performance. *Journal of Operations Management, 19*, 39-58.

[23] McWilliams, A. and Siegel, D. (2001). Corporate Social Responsibility: a Theory of the Firm Perspective. *Academy of Management Review*, 26(1). https://doi.org/10.5465/amr.2001.4011987

[24] Orlitzky, Mark (2015). The politics of corporate social responsibility or: why Milton Friedman has been right all along. *Annals in Social Responsibility*, 1(1): 5 – 29

[25] Paiva, E., Roth, A., & Fensterseifer, J. (2008). Organizational knowledge and the manufacturing strategy process: A resource-based view analysis. *Journal of Operations Management, 26,* 115-132.

[26] Pil, F., & Macduffie, J.P. (1996). The Adoption of High-Involvement Work Practices. *Industrial Relations, 35,* 423-455.

[27] Rothenberg, S., Pil, F., & Maxwell, J. (2009). Lean, Green and the quest for superior Environmental Performance. *Production and Operations Management, 10,* 228-243.

[28] Russo, M. V., P. A. Fouts. 1997. A resource-based perspective on corporate environmental performance and profitability. *Academy of Management Journal,* 40(3): 534–559

[29] Sharp, B.M., Bergh, D.D., & Li, M. (2013). Measuring and Testing Industry Effects in Strategic Management Research. *Organizational Research Methods,* 16, 43 - 66.

[30] Smith, T.M., & Reece, J.S. (1999). The relationship of strategy, fit, productivity, and business performance in a services setting. *Journal of Operations Management,* 17, 145-161.

[31] Suarez, F.F., Cusumano, M., & Kahl, S.J. (2013). Services and the Business Models of Product Firms: An Empirical Analysis of the Software Industry. *Management Science, 59,* 420-435.

[32] Yang, Y., Lau, A., Lee, P.K., Yeung, A., & Cheng, T. (2019). Efficacy of China's strategic environmental management in its institutional environment. *International Journal of Operations & Production Management,* 39, 138-163.

THE ROLES OF AI-BASED TECHNOLOGIES IN HELPING MOBILIZE THE COLLECTIVE TACIT KNOWLEDGE (CTK)

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ABSTRACT

The application of artificial intelligence in all aspects of life is the current trend in the era of information and advanced technology, in which artificial intelligence provides machines with human knowledge and intelligence. Moreover, these machines have become able to learn and manage tacit knowledge, which is a type of knowledge, as tacit knowledge is complex and cannot be recorded and results from the exchange of experiences and personal experiences and is closely related to social interaction among people. The domain of knowledge can be represented by a continuum, which includes three types of tacit knowledge in addition to explicit knowledge. AI applications currently used in knowledge management only help explicit and tacit knowledge in the form of relationships and bodies [15]. The problem is that there is no AI machine capable of dealing with collective tacit knowledge because it is based on experience and practice that is socially acquired and is mostly activities related to human consciousness. Hence, this study will investigate what are the mechanisms of artificial intelligence and their interaction with community-based knowledge management mechanisms that help gathering tacit collective knowledge.

INTRODUCTION

The current trend in the age of information and advanced technology is the application of artificial intelligence in all aspects of social, economic life, industries, medicine, and other various aspects of life. Artificial intelligence focuses on giving machines the knowledge and mental abilities of human [12]. Furthermore, artificial intelligence is multidisciplinary and includes many areas such as expert systems, robots, speech recognition, virtual reality, natural language processing, and more that rely on neural networks [4].

In recent technological developments, machines can learn and manage tacit knowledge. Through a range of technologies, organizations can manage and leverage knowledge from different sources as knowledge is divided into explicit knowledge and tacit knowledge [11]. Explicit knowledge means "knowledge that can be formally expressed using the system of symbols or formal systemic language [11]. Examples of explicit knowledge include products, patents, computer databases, technical drawings, photographs, sound recordings, films, documents, pictures, stories, diagrams, and narratives [11]. Polany (1962) noted that explicit knowledge is personal knowledge that written or organized formally and systematically, which can be illustrated in words, images, and printed numbers and can be easily transmitted [14]. On the other hand, Obermayer and Toth (2019) explained that tacit knowledge is "personal and embodied, which makes it difficult to codify and disseminate because it is considered to be participatory in a specific context and closely related to social identity." [11].

Sanzogni et al. (2017) also pointed out that the field of knowledge can be represented through a continuum that includes, besides explicit and tacit knowledge, three types of tacit knowledge. These types are collective tacit knowledge (CTK), which is found in society and acquired within the social environment, relational tacit knowledge (RTK) that results from emergencies related to human interaction, and the somatic tacit knowledge (STK) that is embodied within the self and revealed through physical energy [15]. Polany (1962) stated that most of the tasks performed by humans are considered forms of the tacit knowledge, in which they are difficult to record and automate [14].

According to Sanzogni et al. (2017), although AI supports knowledge management in terms of explicit knowledge and some forms of tacit somatic and relational tacit knowledge, no AI machine is capable of handling collective tacit knowledge so far.

PROBLEM STATEMENT

There are collective activities that human beings undertake, learn, and apply, which are activities that are based on experience and practice that cannot be codified and which are a form of tacit knowledge. These activities are also components of human awareness and understanding. Consequently, there are some limitations to both AI and knowledge management about the extent to which different forms of implicit knowledge can be created, acquired, disseminated, and effectively applied [15]. Current AI applications used in knowledge management help explicit knowledge and tacit knowledge only in its relational and somatic forms. As for collective tacit knowledge, no AI machine understands collective tacit knowledge [15].

Within AI / KM developments, an evolutionary approach can be identified that currently serves knowledge management. This approach refers to the development of machines that complement human behaviors and skills. For example, through this approach, humans perform tasks that require wisdom and cognitive awareness of collective tacit knowledge, and devices are assigned and implemented that need clear jobs [16]. This is a collaborative approach between man and machine, but artificial intelligence techniques that follow the idea of this approach are few, according to fanuc.eu, the world's largest robotics company.

PUROPSE OF STUDY

As it mentioned earlier, the problem is that there is no AI machine capable of dealing with collective tacit knowledge because it is based on experience and practice that is socially acquired and is mostly activities related to human consciousness. Therefore, this study will investigate what are the mechanisms of artificial intelligence and their interaction with community-based knowledge management mechanisms that help gathering tacit collective knowledge.

RESEARCH QUESTIONS

The suggested research questions will be as following:

1. What are the roles that AI-based technologies that play in helping to mobilize the CTK?
2. What are the limitations of AI technologies to assist CTK learning?
3. What are the effects of AI-based technologies built to renovate human efforts on the accomplishment of knowledge management related tasks by humans?
4. How do AI-based technologies designed to complete social activities affect the performance of human knowledge management tasks by people?

LITERTURE REVIEW

The field of using artificial intelligence techniques is an attractive field for research. Because of the power of computing to facilitate tacit knowledge codification, the current trend is to study the application of various AI technologies in collective tacit knowledge research. The lack of research published in this field has led to a review of the literature currently available in electronic information sources. Therefore several studies relevant in the field of using artificial intelligence and collective tacit knowledge were selected for review.

According to a study by Sanzogni et al. (2017) led to complete the investigation of this study. Knowledge can only be attained through practical experience. Because specialized knowledge representation in a variety of Relational Tacit Knowledge (RTK), Somatic Tacit Knowledge (STK), and Collective Tacit Knowledge (CTK), the research problem is involves the possibility of identifying the interaction between the AI and social conceptual knowledge management mechanisms capable of effecting experience. Based on the proposal of Sanzogni et al. (2017) that practice-based methods can be beneficial for studying the interaction of artificial intelligence techniques with community-based KM tools.

One of the types of research involved in the field of collective tacit knowledge is a research paper whose purpose is to contribute to the literature; by examining the generation of collective tacit knowledge (CTK) in organizations through overhead social activities (SLAs) as a particular form of micro-practice by employees. Spraggon and Bodqqolica (2017) stated that managers should become more supportive of the fun group activities in their organizations by building an appropriate institutional climate to round up CTK in the workplace as understanding SLAs as a soft set contributes to the completion of the task of other devices provided by information systems [17].

Besides, another research paper aims to stimulate understanding of tacit knowledge, what are the effects of technological advances on the codification of tacit knowledge, and how organizations can do to improve their use of tacit knowledge available. Kabir (2012) also emphasized the importance of organizations needing a clear recognition of tacit knowledge, their

place within organizational knowledge requirements, and how to utilize this vital resource. Additionally, this paper explains the interrelationship between technological advances and the potential of tacit knowledge transfer [7].

According to a study by Dzekashu (2009), the problem of failure to focus on the quality of knowledge leads to a reluctance of knowledge workers to use the knowledge stored in repositories. This problem, therefore, affects the enthusiasm of knowledge users to use knowledge repositories because they believe that the knowledge captured is sub-optimal. He also noted that the quality of knowledge and the use of knowledge are an integral part of ensuring the success of knowledge management initiatives. On the other hand, the author stated that in designing knowledge capture programs, many companies tend to focus on technology (software and hardware) but fail to ensure that the required human interface is considered in the design, resulting in a gap in performance and quality. The results of this study concluded that tacit knowledge is very internal and difficult to articulate, making it challenging to develop appropriate processes for capturing knowledge. Many institutions focus on the development of technologies to promote the process of obtaining knowledge, and therefore lack of attention to the role of human interface [3].

There is also a research paper that reveals the relationship between tacit knowledge held by learning and Developers and performance measurement systems in postmodern institutions. As well as assess the applicability of implied, its importance, and practical knowledge in the Internet age for the daily work life of employees of training and industry development. The main question of the study is whether these professionals are still able to take advantage of their tacit knowledge and use it without reducing it through concurrent systems. This study revealed that there is a strong interaction between tacit knowledge and performance systems that are now supported by digital-age technologies, including advances in artificial intelligence (AI) [5].

A study by Panahi et al., (2013) was conducted to show current discussions in the literature on implicit knowledge sharing using information technology; what are the main research gaps that lay the foundations for future research in tacit knowledge sharing using information technology? The results of this paper show that there are schools of thought regarding the ability of information technology to share tacit knowledge. Some difficulties have also demonstrated the sharing of tacit knowledge through the use of information technology. Finally, the potential and risks of social network tools have been presented [13].

In another research study by Jokonya (2018), a descriptive analysis of the content of some of the literature in knowledge management research was conducted. The application of artificial intelligence in knowledge management appeared with the advent of deep learning and machine learning. In addition, machine learning helps organizations address tacit and codified knowledge as part of knowledge transfer in processes. On the other hand, he illustrated the methods of the Fourth Industrial Revolution, such as natural language processing, which could process tacit knowledge for the benefit of organizations [6].

Amin and Roberts (2008) point out that knowledge management is partly dependent on information technology and partly on social interactions, and is capable of dealing with some forms of tacit scientific, physical and collective knowledge. However, it should contribute that the developers of artificial intelligence technology enable the appropriate human interaction of the computer. For example, the use of new interactive machines associated with F2F contacts allows relational communication, which in turn enables the facilitation of sharing some forms of collective implicit knowledge [1].

Specter (2006) mentioned a pathway that points to the development of machines that perform as human behaviors or skills. Through this approach, humans perform tasks that require wisdom and cognitive awareness that are considered as an example of collective tacit knowledge, and machines that require precise tasks are set in tacit somatic and relational tacit knowledge [16].

CONCEPTUAL FRAMEWORK

The SECI model was chosen because it is related to the research problem in this study. The SECI model was developed by Nonaka et al. (2000) who developed the first comprehensive model of knowledge creation. This model consists of two main types of knowledge: explicit knowledge and tacit knowledge, where "explicit knowledge is knowledge that can be expressed in natural or symbolic language and transmitted in verbal or written communication in any social context" [10]. On the other hand, tacit knowledge is personal, embodied, and informal and cannot be expressed and shared with other people because it is based on practical and experience [2].

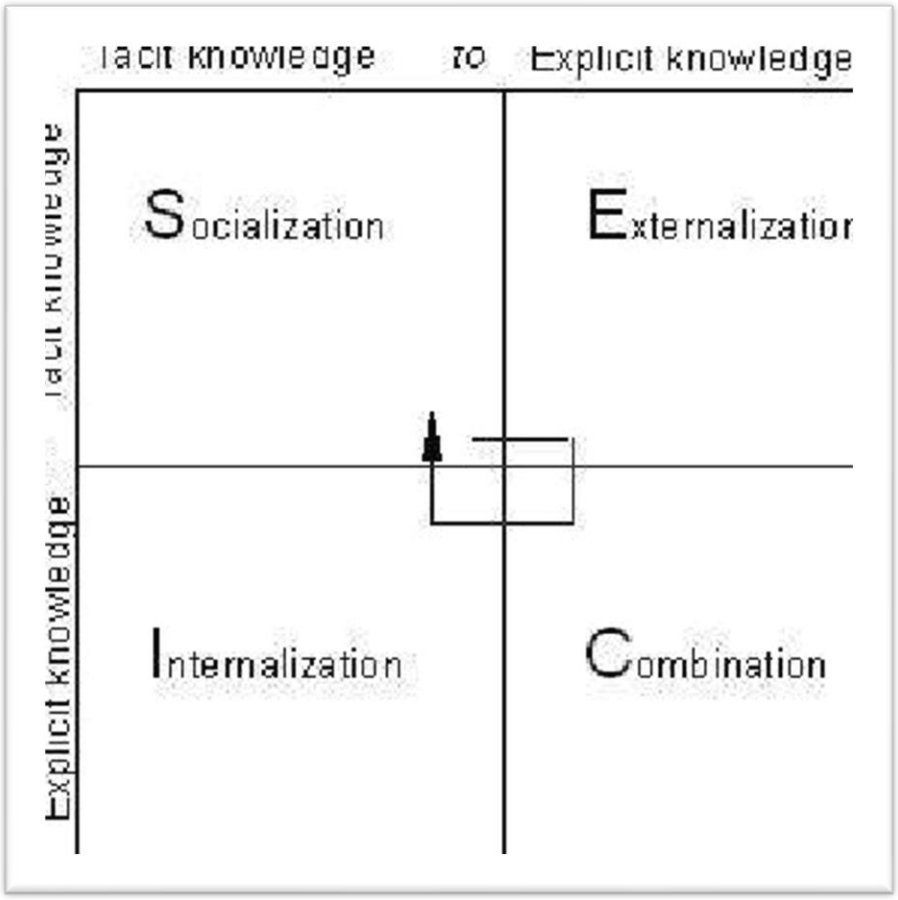

Figure 1: The 'engine' of knowledge creation (Retrieved from [10]).

In Figure 1 of the "The Engine of Knowledge" model or the Knowledge Creation model, there are four ways to transfer knowledge: "tacit to tacit (socialization); tacit to explicit (Externalization); explicit to explicit (Combination) and explicit to tacit (internalization)" [10]. This model describes in the first process that socialization is the primary stage of knowledge

creation through learning that arises through the exchange of tacit knowledge in society. Then comes the externalization that converts the tacit knowledge acquired by the individual into explicit knowledge through mental skills such as concepts, metaphors, and assumptions. The third stage is the combination through which explicit knowledge is shared using natural or symbolic language in a particular social context. At this point, individual knowledge becomes group-level knowledge. The last stage is the internalization, which causes explicit knowledge to become tacit knowledge in the individual, and it is the opposite process of externalizations [2].

REFERENCES

[1] Amin, A., & Roberts, J. (2008) Knowing in Action: Beyond Communities of Practice. *Research Policy, 37*(2), 353.

[2] Bratianu, C. (2016). Knowledge dynamics. *Management Dynamics in the Knowledge Economy, 4*(3), 323-337.

[3] Dzekashu, W. G. (2009). Integration of quality management into the tacit knowledge capture process (Order No. 3355037). Available from ABI/INFORM Global. (305080805).

[4] Elsevier Artificial Intelligence Program (2018). *Artificial Intelligence: How knowledge is created, transferred, and used Trends in China, Europe, and the United States*. [online] Elseveir. Available at: https://www.elsevier.com/connect/resource-center/artificial-intelligence [Accessed 11 Dec. 2018].

[5] Garrick, J. (2018). A critical discourse on tacit knowledge management and the performative agenda. *European Journal of Training and Development, 42*(3), 210-225. http://doi.org/10.1108/EJTD-12-2017-0107.

[6] Jokonya, O. (2018). Descriptive content analysis on knowledge management research. Kidmore End: Academic Conferences International Limited. https://doi.org/docview/2158170288?accountid=7113.

[7] Kabir, N. (2012). Effects of advances in technology on tacit knowledge transferability. Kidmore End: Academic Conferences International Limited. Retrieved from https://doi.org/docview/132796

[8] Kebede, G. (2010). Knowledge management: An information science perspective. *International Journal of Information Management*, 30, 416-424.

[9] Mohajan, H. (2016). Sharing of Tacit Knowledge in Organizations: A Review. *American Journal of Computer Science and Engineering*. 3. 6-19.

[10] Nonaka, I., Toyama, R., and Konno, N. (2000). SECI, Ba and leadership: A unified model of dynamic knowledge creation. *Long Range Planning, 33*(1), 5-34

[11] Obermayer, N., & Tóth, V. E. (2019). *The future of human knowledge and artificial intelligence*. Kidmore End: Academic Conferences International Limited. http://doi.org/10.34190/KM.19.129.

[12] OECD (2019). Artificial Intelligence in Society. OECD Publishing, Paris, https://doi.org/10.1787/eedfee77-en.

[13] Panahi, S., Watson, J., & Partridge, H. (2013). Towards tacit knowledge sharing over social web tools. *Journal of Knowledge Management,* 17(3), 379-397. http://doi.org/10.1108/JKM-11-2012-0364?

[14] Polany, M. (1962). The republic of science: Its political and economic theory. Minerva 1:54–73.

[15] Sanzogni, L., Guzman, G., & Busch, P. (2017). Artificial intelligence and knowledge management: Questioning the tacit dimension. *Prometheus*, 35. 1-20.

[16] Spector, L. (2006). Evolution of artificial intelligence. *Artificial Intelligence*, *170*(18), 1251-1253.

[17] Spraggon, M., & Bodqqolica, V. (2017). Collective tacit knowledge generation through play: Integrating socially distributed cognition and transactive memory systems. *Management Decision*, *55*(1), 119-135. http://doi.org//10.1108/MD-05-2015-0173.

Sustainability, SCM, Quality Management, Logistics, Hospitality, Recreation and Sports - Abstracts

A TWO-ECHELON LOGISTICS MODEL FOR EMERGENCY RELIEF SUPPLY CHAIN SYSTEM WITH CROSS-EVALUATION METHOD BASED ON SUPER EFFICIENCY SCORES

Oral Presentation

Prof. Hong Jae-Dong [1], ***Dr. Judith Mwakalonge*** [1]

1. *South Carolina State University*

This paper studies a multi-objective emergency relief supply chain system (*ERSCS*) model, which would play a critical role in providing timely disaster relief items. The data envelopment analysis (DEA) method identifies efficient *ERSCS* configurations among the proposed schemes. This study presents a process of combining the two most popular DEA methods, super efficiency and cross-efficiency methods, for designing efficient *ERSCS* configurations. Through a case study, we demonstrate the applicability of the proposed procedure. The proposed methods can be an essential tool to efficiently and effectively design various supply chain network schemes.

Achieving Supply Chain Visibility with a Supply Chain Control Tower Solution

Oral Presentation

Prof. Markus Gerschberger [1], ***Prof. Christoph Bode*** [2], ***Prof. Scott Ellis*** [3], ***Prof. Franz Staberhofer*** [4]

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This study proposes a guiding framework that helps practitioners and researchers to understand how supply chain control tower solutions can be used to achieve supply chain visibility (SCV). We first motivate the importance of SCV and discuss boundary conditions in terms of business requirements and critical success factors. Next, we use a design science approach coupled with a longitudinal case study of a leading, global automotive OEM to develop a nine-step framework that describes the design and implementation of an SCV-facilitating supply chain control tower solution. Finally, we highlight the practical relevance and the benefits that the case company was able to realize by leveraging this framework. Most notably, our findings show that the case company substantively reduced inventory in each stage of its automobile distribution network.

Decision Theory Applied to Supply Chain Attack

Oral Presentation

Dr. Donald Costello [1]

1. *University of Nebraska-Lincoln*

The continual attacks on supply chains causes an increase in efforts to manage Risk Assessment for each entity in a particular industry setting. This assessment is of course different for each entity depending on its business profile and Risk Adverse Posture. It has almost always been the case that attackers outwit defenders on a regular basis. The defender attack vector is limited if the defender is provided with limited information on the opponent's strategy and decisions.

Game theory appropriately enhances the ability to anticipate the actions of the attacker. While this is true new strategies involving approved or at least sanctioned attacks on attackers has become commonplace.

Decision Theory has long played a large role in situations of this variety but turning a theory into a practice is far from a simple task. Nevertheless, it is incumbent on faculty with real consulting experience to set up a paradigm that demonstrates new paradigms to meet the urgency of the current and future assessment of attacks of this nature. This approach takes into consideration the cybersecurity requirements in many if not most International Supply Chain environments.

Demand Point Estimates in Capacitated Multi-Item Dynamic Lot Sizing Problems with Uncertain Demands

Oral Presentation

Dr. Hadi Farhangi [1], ***Ms. Karen Perez*** [2]

1. *Savannah State University,* ***2.*** *Amazon*

Dynamic Lot Sizing problem and its variations has been widely used for the scheduling of the productions and inventories. When demands are uncertain, one can use the mean of historical data or the expected value, which is a point estimate of demand. In addition to the mean, this work considers another point estimate, which is called median. We show that the total backorders, as the result of capacity limitation and uncertain demand, can be lower when median is used instead of the mean. It is shown that for an asymmetric distribution, the total backorder is lower significantly when median is used. Furthermore, when demand follows a symmetric distribution, the total backorder do not differ significantly between the two point estimates.

DEVELOPMENT OF A REACTIVE SUPPLY CHAIN STRATEGY FRAMEWORK

Oral Presentation

Dr. Kimberly Deranek [1], ***Dr. Edie Schmidt*** [1]

1. *Nova Southeastern University*

This study examined supply chain strategy best practices and key factors impacted by COVID-19 used to develop an improved framework for implementing a comprehensive supply chain strategy. The framework consists of evaluating key components and critical factors typically included in developing a reactive supply chain strategy. Each of the critical factors were identified throughout a thorough literature review and comparative analysis to define commonalities among them. This research leverages a Design Science Framework to identify critical factors relevant to a comprehensive SC strategy and describes the process needed to validate and implement.

Environmental, Social, and Governance (ESG) Sustainability Disclosures: Evidence from E.U. and U. S.

Oral Presentation

Prof. Zabihollah Rezaee [1]

1. *The Uiversity of Memphis*

We examine whether higher levels of environmental, social, and governance (ESG) sustainability disclosures are attained under voluntary or mandatory disclosure regimes. We use the regulatory differences between the United States (US) and European Union (EU) settings, as firms in US are currently disclosing ESG information on a voluntary basis, whereas their counterparts in EU are required to disclose such information starting fiscal year 2017. Drawing on a sample of 2563 firm-year observations from US and EU in the 2007-2019 period we report three main findings: (1) for the full sample period, EU firms have an overall higher ESG disclosure relative to US firms; (2) EU firms outperform US firms under voluntary disclosures requirements (2007-2016); (3) after 2017, the ESG disclosure of EU firms further improves relative to US firms. Taken together, our results suggest that the 2017 adoption of disclosure guidelines in the EU is associated with improvements in EU firms' ESG disclosure. We contribute to the literature by examining ESG disclosure under voluntary and mandatory regimes and whether the EU disclosure guidance has influenced disclosure of non-financial ESG sustainability information. Our results are robust after performing additional analyses in addressing potential endogeneity concerns. Overall, our findings have policy, practical, and research implications, as they underscore the importance of more rigorous and uniform ESG sustainability disclosures.

Experiential Learning, Retention, Graduation, and Job Placement: Observations and Perspectives of Culinary Arts Education Programs in the United States of America

Oral Presentation

Dr. David Fowler [1], ***Dr. Jon Musgrave*** [2]

1. *Lander University,* ***2.*** *Morehead State University*

Experiential learning has achieved a paramount appointment in higher education as an effective way for students to acquire and enhance beneficial skills and abilities while preparing for post-graduation employment. The hospitality industry is reliant upon potential personnel who are well-prepared for this competitive and demanding field of endeavor. Colleges, universities, technical institutions, and trade schools have embraced culinary arts as enticing offerings to a multitude of students who desire to enter the fascinating world of food preparation. An explosion of programs has been realized over the past few decades, as culinary students fill higher education classrooms, kitchens, bakeries, and dining rooms as they aspire to become the next generation of admirable chefs.

Many culinary arts programs offer experiential learning in the form of dining room service offered to the public as a component of the required curriculum. This study considers personal observations through active participation as consumers of culinary school dining room service. The qualified researchers exhibit extensive relevant practitioner and scholarly knowledge in hospitality, public service, and general business fields. The authors include a graduate of a vocational culinary program and former executive chef, a former fire chief and small food service business owner, and doctoral graduates in organizational development and change. Both authors currently hold assistant professorship assignments of teaching graduate and undergraduate business and hospitality management classes for AACSB accredited institutions.

Engagement with culinary students, faculty, and administrators took place over a few years during observational qualitative data gathering. Themes were discovered consisting of similar hospitality skills that were utilized by those participating in experiential learning dining service. Functional necessary hospitality industry abilities including soft skills, safety, sanitation, customer service, management, and leadership were realized during the observation period. The study provides specific examples of these skills and thematic congruency between culinary arts programs.

The study also associates the qualitative observations with quantitative data concerning retention, graduation, and employment rates of selected culinary schools that use live dining room service as part of the curriculum, and a comparison to those that do not advertise offering this experiential learning.

Experiential learning in the culinary arts field demonstrates positive correlations with retention, graduation, and employment rates with regard to these educational programs. These observed measurable aspects in participatory programs surpass those that do not accentuate live dining service in their curriculums.

The inquiry provides a high-level overview of observed hospitality developmental skills and an analysis of public domain quantitative information concerning retention, graduation, and job placement rates within selected culinary programs.

Food Hub Networks: a Literature Review

Oral Presentation

Dr. Keli Feng [1], ***Mr. Mohamed Selim Ben Ali*** [1], ***Mr. Omer Gorgun*** [1]

1. *South Carolina State University*

A food hub network is an emerging and innovative business model through which food hubs across a state or region collaborate formally or informally to trade and distribute local produce and share best practices and other business services. However, limited research has been conducted to review the existing scholarly literature and best practice, identify the research gaps, and recommend future research on food hub networks. This study surveys and summarizes the recent scholarly research and practical studies on food hub networks in the United States. The research also discusses the research gaps in the literature and directions for future research.

Functions and actors of inland ports: Insights for Southern California

Oral Presentation

Ms. Jieping Mei [1]***, Dr. Nasrin Mohabbati*** [2]

1. *Information and Decision Sciences Department, California State University, San Bernardino,* ***2.*** *Assistant Professor of Information and Decision Sciences Department, California State University, San Bernardino*

Coastal and inland ports significantly contribute to the economy, job growth, and total GDP in the United States. Investments are focused on capacity and efficiency enhancements due to the increase in the vessel sizes as well as the tonnage shipments. The increasing number of international trades has also resulted in dramatic increases in import volumes. To transport the imports to regional and international destinations, heavy-duty diesel trucks have been used from seaports to final destinations, which significantly contribute to the region's poor air quality, noise pollution, and congested freight corridors. In this research, we investigate the role of inland ports (also known as dry ports) as intermediate terminals distant from the seaports in minimizing the cost of operations and the air pollution as well as maximizing the capacity usage of resources. Studying several real cases of inland ports in the United States such as the Georgia, Chicago, and New York inland ports, we present the essential factors in building, developing, and managing inland ports. We also propose the inland port concept for Southern California which is the house of the two largest seaports in the United States. The proposed framework provides shared resources for the industrial parties involved in the region, reduces the cost of operations, improves product delivery, and reduces air and noise pollution levels in the region.

Green Supply Chain Management: Motivations and Outcomes for Sustainable Packaging Initiatives

Oral Presentation

Mr. John Noblitt [1], ***Prof. Johnny Ho*** [1], ***Mr. Joshua Checa*** [2], ***Mr. Steven O'Neill Santiago*** [1]

1. *Columbus State University,* ***2.*** *Davis & Associates CPA*

Companies pursue resource conservation initiatives for a number of reasons, including government mandate, customer mandate, cost improvement, market penetration, and social responsibility. The objective of reducing waste or increasing recyclable content can involve detailed investigations of all supply chain modes to fully understand what resources are consumed at each packaging point, and evaluations of a series of alternatives each with different costs, logistical considerations, sourcing issues, and inherent environmental impacts. Initiatives are then undertaken based on a particular assessment of the expected costs and benefits of each program, while the actual costs and benefits may be quite different post-implementation. The degree of variation between expectation and outcome is a subject for further understanding.

Implications of Government Environmental Policies for Supply Chain Performance: A Cross-National Study

Oral Presentation

Prof. Hokey Min [1]

1. *Bowling Green State University*

Continued environmental degradation prompted many governments to play an active role in protecting our living environments. As such, the government often intervenes with a way that private enterprises conduct business through many different forms of environmental regulations and business incentives. However, the efficiency and effectiveness of such government intervention are still unknown and unclear at best. Many skeptics still think that economic growth and environmental protection are in conflict with each other and subsequently the firm's environmental performance and export performance cannot be achieved simultaneously even with active government intervention over the firm's environmental management. To clarify this pre-conceived notion, this paper aims to examine whether government intervention leads to the affected firm's both environmental and export (sales) performance. In addition, it investigates whether the extent of impact of government intervention on firm performance varies depending on country-specific policies. In so doing, this paper verifies the ecological modernization theory and institutional theory using the empirical analysis of the survey data obtained from both the Korean and Chinese small and median sized enterprises (SMEs).

Incorporating Drones in Humanitarian and Healthcare Delivery Logistics

Oral Presentation

Dr. Emre Kirac [1]

1. *Christopher Newport University*

Disasters cause significant social, cultural, and environmental damages with large economic impacts. Humanitarian agencies and nongovernmental organizations play a critical role in saving lives and minimizing human suffering by providing relief supplies. Drones have the potential to reduce the response time of delivering relief supplies and discover the requests by visiting disaster locations. In this study, a routing problem with a drone is presented to reduce the route of the truck and make use of drones to save important resources. Here, we would like to maximize the usage of drones, as it is apparently a superior mode of delivery when compared to trucks especially for delivering smaller packages by weight or volume for isolated populations. The problem that is solved here uses disaster scenarios quantitatively assessing the value of incorporating drones when making resource allocation decisions. While the search-and-rescue truck still remains a primary vehicle to all the rescue efforts, drones can be used to deliver necessary items in smaller quantities after the accuracy of locations have been identified

Key Supply Chain Management Components & Challenges for USA: Perspectives from Recent Studies

Oral Presentation

Dr. Matthew Waritay Guah [1]

1. *South Carolina State University*

This paper draws on recent studies about Supply Chain Management (SCM), along with the economic and social problem in Fall 2021, caused by temporary delay in goods delivery to the high street, highlighting several aspects of the USA's current SCM challenges. Such challenges include high inequality, partly related to historical relations between ship workers and mainstream businesses but reinforced by a continuing dualism between the formal and informal sectors. The paper also emphasizes areas where SCM suffers from a serious "secondary deficit" and weak educational quality. Finally, a business climate, which exhibits continuing problems with inappropriate regulation, while infrastructure provision has suffered from cutbacks to public provision, is only partly compensated for by increased private investment. The author suggests a framework for reforming SCM in the USA and concludes that SCM is the USA's future source of international comparative advantage. Whether in natural resource-based exports or in manufacturing, the USA needs to improve performance in mobilizing knowledge and technology for SCM optimization.

Last Mile Delivery by Air: A Changing Paradigm

Oral Presentation

Dr. david swanson [1], ***Dr. Nathan Kunz*** [1], ***Dr. Chris Baynard*** [1], ***Dr. Robert Richardson*** [1]

1. *UNF*

Air travel traditionally has been faster and more expensive than ground transportation. However, this paradigm is changing due to technological advances of unmanned aerial vehicles (UAVs). Whenever using UAVs, air transportation is no longer necessarily the most expensive or fastest mode of travel. Information is needed to inform transportation decisions between UAVs and ground modes of travel (e.g., delivery vans or robots). This research analytically demonstrates that circuity – the ratio of road distance over air distance – is correlated with the speed and cost of transportation. Knowing the circuity in an area is therefore important because it allows comparing air and ground transportation options. This is becoming more important since the decision to travel by air or road is no longer primarily based on time and cost, but also the characteristics of the road network in an area (i.e., the circuity). This research further investigates the characteristics of circuity. Using empirical data from a set of 4477 routes from 90 cities in the United States, it develops a multilevel linear regression model to test the relationship of circuity with demographic and geographic variables, including route elevation change, average altitude, population, and proportion of land (i.e., total area minus waterbodies). The findings of this research will help logisticians make strategic decisions between UAVs and ground travel modes in specific areas, based on the demographic and geographic characteristics of those areas.

Operational Response to Market Entry

Oral Presentation

Dr. Ata Karbasi [1]***, Dr. Mark Hanna*** [2]

1. *Valparaiso University,* ***2.*** *Georgia Southern University*

Due to high competition nowadays firms frequently encounter competitors attempting to enter their market. Market entry has become a growing challenge to incumbent firms and is considered one of the most important factors in the evolution of industries. Prior literature primarily focuses on marketing mix and primarily price-based response to market entry. As incumbents' operational capability adjustments have received relatively little attention, in this study, we utilize data from the US airline industry to investigate how incumbent firms react to a rival's entry by adjusting their operational strategies. Results indicate that incumbents become more operationally focused after a new rival enters their market. In other words, rather than prioritizing multiple operational capabilities simultaneously, incumbents focus their operational capability development strategies on a single capability in response to a market entry. We address the contributions to the marketing and operations management literature and provide practical advice to managers and policymakers.

Keywords: market entry, operational capability, focus vs. combinative, resource allocation, airline industry

STAYING ALIVE: EXPLORING THE EVOLUTION OF ADAPTIVE CAPABILITIES

Oral Presentation

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Twenty Twenty's Covid-19 pandemic has demonstrated the need for rapid response in a discontinuous, disruptive environment. Hesitant and/or misguided responses have increased the costs Covid-19 has imposed on society, both in terms of lives lost and economic damage. Research that discerns why so many decision makers were paralyzed by the onset of Covid-19 is timely and relevant. This study evaluates why a few companies were able to respond quickly and effectively, while others were not. Specifically, we ask, "What does a rapid adaptation response capability—one that can help a company survive now and evolve to thrive in a new normal—look like?" We rely on evolution theory, systems design, and the capability development literature and take an inductive, case-based approach to gain insight into how organizational DNA evolves to enable or hinder rapid adaptation. This study contributes to theory and practice in two important ways. First, we find, and document, that the organizational DNA of the fastest adapters is different from that of merely fast-response companies. Second, we develop a systems diagram to explicate the dynamics of a rapid adaptation capability. Ultimately, we identify specific roles managers must perform to genetically modify their organizations to achieve a rapid adaptation capability. Overall, findings suggest that organizational DNA is critical to surviving and thriving in what appears to be a pandemic-prone environment. Given we are likely to see future pandemics, it is essential that organizations start the process of evolving their DNA.

Supply Chain 4.0 in Small to Medium Sized Enterprises: A Supply Chain Resource Orchestration Model

Oral Presentation

Dr. Matthew Jenkins [1]

1. *East Tennesse State University*

Supply Chain 4.0 is generating a lot of interest from both academics and practitioners. The Supply Chain 4.0 concept encompasses disruptive supply chain technologies and practices that will radically change how competitive advantage is earned. However, implementation of these technologies is often out of reach for Small to Medium Sized Enterprises (SMEs) due to lack of resources, size, and scope. Supply chain resource orchestration (SCRO) could be a game changer for these organizations. This research uses a case study approach to examine how SMEs use SCRO to generate Supply Chain 4.0 capabilities and improve competitive advantage despite lacking the apparent means to do so. Consequently, the purpose of this research is to: (1) develop SCRO theory identifying common strategies that SMEs use to implement Supply Chain 4.0 technologies (2) provide insight into how SMEs use SCRO to generate new Supply Chain 4.0 capabilities; and (3) discover theoretical mechanisms that link Supply Chain 4.0 capability creation with competitive advantage in SMEs. This research sheds light on opportunities for future scholars to examine Supply Chain 4.0 in SMEs, and provides useful knowlegge on how SMEs can orchestrate a successful Supply Chain 4.0 strategy.

Supply chain resilience and firm innovativeness: an empirical investigation

Oral Presentation

Dr. Sergey Ponomarov [1]

1. *The Citadel*

A dynamic capabilities theory facilitates the discussion on the nature of firm innovativeness and supply chain resilience and informs the development of the proposed conceptual model. Firm innovativeness and supply chain resilience are explored and empirically tested within a supply chain disruptions context. The moderating role of supply uncertainty and interdependence in the focal relationship was also hypothesized and tested. Findings suggest that firm innovativeness is positively associated with supply chain resilience, and supply uncertainty negatively moderates this relationship. This research has both theoretical and managerial implications.

Technology Planning in the Hospitality Industry

Oral Presentation

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1. *Clark University,* ***2.*** *Drexel University*

The hospitality industry has turned to technology as a strategic weapon to improve operational efficiency, support employees, enhance service quality, gain competitive advantages, and maintain customer relationships. Hence, this paper is about technology planning in the hotel industry. We propose a prescriptive model to strategically select technologies to invest in the hotel. By implementing Hyperlink Induced Topic Search (HITS) and PageRank algorithms, we construct a network connecting "hotel selection criteria," "activities," and "technologies." The results present the ranking of the technologies based on the HITS or PageRank weights, utilizing a network analysis. Considering the technologies' costs and the hotel's budget, we formulate an optimization model using the Knapsack problem. We demonstrate how our model can be applied to plan technology investments in a hotel with a numerical example.

The Heisman Hype – Are Heisman Winners Worth the Price of a Top Draft Pick?

Oral Presentation

Dr. Jim Mirabella [1], ***Dr. Wendy Gillis*** [1]

1. *Jacksonville University*

In the National Football League, there is an annual draft in which teams choose college football players to join their teams the next season. The order is determined by team records the previous season, with the worst record going first and the Super Bowl champion going last. The Heisman Trophy is awarded each year to the supposedly best player in college football, and that winner is usually one of the most desired players in the draft. Teams will normally have to pay a higher salary to players drafted #1, and they are especially expensive if they are Heisman winners. Can these high-priced players really make a difference or are they likely to fizzle? Is the worst team better off trading away their top pick to draft extra players at a lower price? Was Trevor Lawrence really the best decision for the Jacksonville Jaguars? And what about the marketing value of a player to a city? Tim Tebow jerseys were the best-selling in the NFL, even though he didn't have the best statistics; he brought in fans and increased viewership, which translates to money for the team. In this paper, we will analyze the top drafted players for the past 30 years, using team statistics as well as Fantasy Football data to determine player value. We will also look at ticket and merchandise sales to evaluate how fans value the player. Ultimately we will create a model to determine whether the team with the #1 pick should pay the price for a Heisman winner or take a more value-based approach to the draft.

The Impact of Industry 4.0 Information Technologies Driven Digital Supply Network Pillars on the Operational Performance Improvement of Firms: An Empirical Study

Oral Presentation

Dr. ABIRAMI RADHAKRISHNAN [1], ***Dr. Sanjay Bapna*** [1], ***Dr. Gregory Ramsey*** [1], ***Mr. David Burton*** [2]

1. *Morgan State University,* ***2.*** *Diverse Manufacturing Supply Chain Alliance*

Many U.S.-based manufacturing and logistics firms pursue “smart manufacturing practices” (i.e., Industry 4.0 practices). But extant literature reveals a lack of research on the extent of smart manufacturing practices adopted by U.S.-based manufacturing and logistics firms and operational performance improvements achieved. This study examines the impact of six digital supply network pillars (i.e., supply chain processes such as product design and development, supply chain planning, strategic sourcing, smart manufacturing, dynamic order fulfillment, and connected customer service facilitated by Industry 4.0 information technologies) on operational performance improvements at the firm level. We conducted a large-scale empirical study using data from 179 firms. We find that the six digital supply network pillars directly significantly impact firm-level operational performance improvements. These results will guide supply chain managers and IT managers to effectively use Industry 4.0 Information technologies to digitalize the supply chain processes.

Traveling Salesman Problem with Location-dependent Time-varying Profits and without a Depot Condition: Case of Grocery Delivery Service

Oral Presentation

Dr. Haibo Wang [1]

1. *Texas A&M International University*

This study considers grocery delivery service as a use case due to the COVID-19 pandemic. Businesses can deploy several types of fee schedules to defuse the surge by allowing customer to choose receiving service for free based on the annual membership or with a fee per order for priority. In solving the above problems often researchers cast the problem as an integer programming (IP) model then apply some procedures to solve the problem. When IP formulation modeling is used, some TSP subtour elimination scheme is needed. Although a variety of subtour elimination procedures have been proposed for IP applications of TSP, formulating the above problems using appropriate subtour elimination can be complicated in practice. This study presents new mathematical models for traveling salesman problem (TSP) with location-dependent time-varying profits and without a depot condition in the real-world setting. To evaluate the results by comparing methods in the literature, this study tests the new models and algorithms to handle very large-scale data from different real-world operations using data sets generated by the combinations of stores and products on grocery delivery service. The analysis of the solutions produced by this study provides insights and future direction on developing effective optimization models for delivery services.

Sustainability, SCM, Quality Management, Logistics, Hospitality, Recreation and Sports - Papers

A TWO-ECHELON LOGISTICS MODEL FOR EMERGENCY RELIEF SUPPLY CHAIN SYSTEM WITH CROSS-EVALUATION METHOD BASED ON SUPER EFFICIENCY SCORES

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ABSTRACT

This paper studies a multi-objective emergency relief supply chain system (*ERSCS*) model, which would play a critical role in providing timely disaster relief items. The data envelopment analysis (DEA) method identifies efficient *ERSCS* configurations among the proposed schemes. This study presents a process of combining the two most popular DEA methods, super efficiency and cross-efficiency methods, for designing efficient *ERSCS* configurations. Through a case study, we demonstrate the applicability of the proposed procedure. The proposed methods can be an essential tool to efficiently and effectively design various supply chain network schemes.

Keywords: Data envelopment analysis, Emergency relief supply chain system, Super efficiency, Cross efficiency

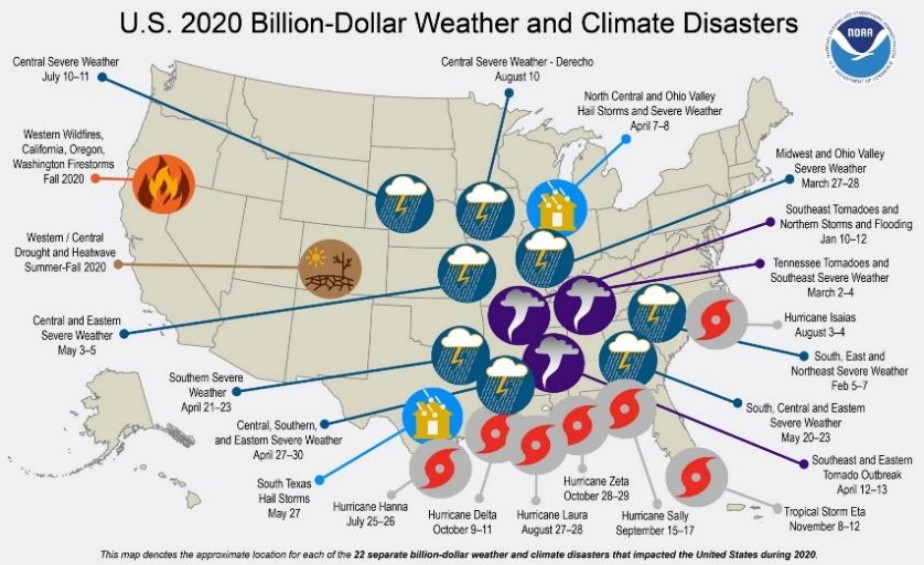
INTRODUCTION

The emergency relief supply chain system (*ERSCS*) plays a critical role in providing disaster relief items such as first aids, drinking water, food, and daily commodities to alleviate people's suffering. These two terms, *ERSCS* and disaster relief supply chain system, are frequently used interchangeably. In 2017, the U.S. experienced a historic year of weather and climate disasters. In total, the U.S. was seriously affected by 16 separate billion-dollar disaster events, including three tropical cyclones, eight severe storms, two inland floods, a crop freeze, drought, and wildfire. During 2018 and 2020, the U.S. experienced a very active year of weather and climate disasters (see Figure 1), letting alone the COVID-19 pandemic. The U.S. was seriously affected by 14 separate billion-dollar disaster events: two tropical hurricanes, eight severe storms, two winter storms, wildfire, and drought. The past four years (2017-2020) have been historic, with the annual average number of billion-dollar disasters being more than double the long-term average. The number and cost of disasters are increasing over time due to a combination of increased vulnerability, exposure, and the fact that climate change is increasing the frequency of some types of extremes, which lead to billion-dollar disasters (https://www.climate.gov/news-features/blogs/beyond-data/2018s-billion-dollar-disasters-context)

In this respect, an *ERSCS* design has become an important strategic decision due to the significant damage inflicted by several natural disaster events (Hong and Jeong [12]). The weather-related emergencies have brought issues of emergency relief planning again.

Indeed, after emergencies, it is critical through emergency response facilities (ERFs) to distribute humanitarian aid to the affected areas efficiently and effectively to save human lives and alleviate suffering for a rapid recovery. van Wassenhove [24] emphasizes that since disaster relief is 80% logistics, emergency relief planning should be through slick, efficient, and effective logistics operations and, more precisely, supply chain management. Logistics planning in emergencies involves the quick and efficient distribution of emergency supplies from ERFs to the affected areas via supply chains. Boonmee et al. [2], Habib and Sarkar [10], Noham and Tzur [17], Petrudi et al. [19], and Sarma et al. [21] consider various problems related to *ERSCS* design and analysis. Cao et al. [3] propose multi-objective programming models of relief distribution for sustainable *ERSC*.

FIGURE 1: U.S. 2020 Billion-Dollar Weather and Climate Disasters



The *ERSCS* considered in this study is a two-echelon supply chain system, where there are three distinctive ERFs. They are (i) Central Warehouses (*CWHs*) or Distribution Warehouses (*DWHs*), where emergency relief commodities are stored, (ii) intermediate response facilities termed Relief Distribution Center (*RDC*) or Commodity Distribution Point (*CDP*), where people can more effectively gain access to relief goods, and (iii) neighborhood sites (*NBSs*) in need of humanitarian items. The chief objective of the strategic level is to strengthen emergency preparedness as well as to select the most cost/distance-effective location of *CWHs* and *RDCs* among a set of candidate locations, to establish the distribution of emergency supplies throughout the *ERSC*, and to assign *NBSs* to *RDCs* and *RDCs* to *CWHs*. Determining such location-allocations is a critical area in the design of an effective *ERSC.* However, traditional cost-based facility location models implicitly assume that located facilities will always be in service or be available and do not consider an associated risk of disruption. Due to natural disasters, accidents, breakdowns, weather, or strikes, all facilities are susceptible to disruptions. Such disorders would be worsened due to a lack of flexibility and interdependency, commonly presented in the general supply chain systems.

Evaluating various *ERSCS* alternatives and identifying the most efficient options would be essential for efficient *ERSC* planning. The reason is that each network scheme is related to ERF location-allocation decisions, which are very difficult to be changed later due to the expensive fixed costs and operating costs of locating *CWHs* and *RDCs*. No typical procedure is available to assign specific values to the weight factors to ensure the decision-makers find the most desirable solution. Evaluating alternatives generated by solving the G.P. model can be viewed as a multiple-criteria decision-making (MCDM) problem, requiring a systematic solution evaluation system. The question is how to evaluate these network schemes without any biased preferences or decision maker's subjective judgment and how to identify the most efficient *ERSCS* configurations for the decision-makers to make a final decision

The typical multi-objective programming (MOP) model allows the decision-maker to assign weights to the objective function's deviational variables. It would be necessary for them to reflect on the importance and desirability of deviations from the multiple goals. However, the actual efficiency of the resulting *ERSCS* is not known. No standard procedure is available for assigning values to the weight factors to guarantee we will find the most desirable solution to a MOP problem. Ragsdale [20] suggests that an iterative procedure should be followed, using a particular set of weights, concluding that it is essential for us to repeat this process several times to find the most desirable solution for decision-makers. Thus, it is unavoidable for the decision-makers to use some of their subjective judgment. The question is how the best alternative option is selected if the most desirable solution is different among the decision-makers. Hence, it is imperative to answer how to evaluate the efficiency of all alternatives generated by the model and select the most desirable one(s) without any subjective assessments.

Data envelopment analysis (DEA) is one of the methodologies that have been widely used to evaluate the relative efficiency of decision-making units (DMUs) that have multiple inputs to use and outputs to produce. The classical DEA (C-DEA) was proposed by Charnes et al. [4], who developed how to use a linear programming model to change a fractional linear measure of efficiency score. DEA produces a single, comprehensive measure of performance for each of the DMUs. The best ratio among all the DMUs would identify the most efficient DMU, and every other DMU would be rated by comparing its ratio to the best one. However, as the numbers of inputs and output variables increase, DEA generally finds more efficient DMUs. That would be the reason why it may suffer from a lack of discrimination particularly.

The C-DEA allows each DMU to be evaluated with its most favorable weights due to its nature of self-evaluation. Consequently, the C-DEA model may even ignore unfavorable inputs/outputs to maximize self-efficiency. To remedy this deficiency of C-DEA, the two most popular methods are cross-efficiency (C.E.) DEA and the supers-efficiency (S.E.) DEA method. CE-DEA, suggested by Sexton et al. [22], ranks DMUs with the main idea of peer evaluation rather than DMU's usual pure self-evaluation. Sexton et al. [22] construct a C.E. matrix consisting of two evaluation results: self-evaluation and peer-evaluation. Due to its enhanced discriminating power, especially for the simple DMUs with fewer inputs and outputs, the C.E. evaluation has found a significant number of applications (see Gavgani and Zohrehbandian [8]; Hong and Jeong [11]; Hou et al. [13]; Paryzad et al. [18]; Lee [15]; Liu et al. [16]).

The first issue for applying the C.E. method is the proportion/percentage of self-evaluation in computing the C.E. score (E.S.). Some literature suggests that the portion of self-evaluation be 1/ *N*, where '*N*' denotes the number of DMUs being evaluated. Thus, as *N* increases, the weight for self-evaluation decreases. As Doyle and Green [7] note, the second issue is the non-uniqueness of C.E. scores due to the often-present multiple optimal DEA weights. The third issue is that the C.E. method frequently ranks inefficient DMUs ahead of the fully efficient DMUs. Wang and Chin [23] propose the **neutral** DEA model for C.E. evaluation to avoid choosing between the two different formulations, aggressive and benevolent C.E. formulations. There has not been much literature that considers, compares, and applies all three C.E. models to evaluate the units.

The idea of super-efficiency (S.E.), which is mainly developed by Anderson and Peterson [1], is that a DMU under evaluation is not included in the reference set of the C-DEA model. Notably, the SE-DEA model has significance for discriminating among efficient DMUs, as Anderson and Peterson [1] demonstrate. Charnes et al. [5] use the SE-DEA model to study the sensitivity of the efficiency classification. But the critical issue of using the model is that the adjacent DMUs decide the S.E. score (SES) of an efficient DMU, so it would be unreasonable for DMUs to be ranked by the SESs. This paper proposes a procedure for integrating these three DEA methods to eliminate each method's weaknesses.

This paper aims to evaluate the *ERSCS* configurations generated by the multi-objective programming models by utilizing the proposed DEA method, which integrates the three DEA techniques. The procedure proposed by this study could provide a valuable tool that would help the decision-makers evaluate various *ERSCS* alternatives better than each DEA method and identify robust and efficient configurations.

FORMULATION OF *ERSCS* MODEL

See Hong and Jeong [11] for detailed formulation. The first goal is minimizing the related logistics costs, which is the traditional objective of most facility location-allocation models. We call it the total logistics cost (*TLC*). The second goal is related to the demand-oriented objective, which focuses on measuring the 'closeness' of the *ERFs*. The second goal is to minimize the maximum coverage distance (*MCD*) such that each *NBS* is covered by one of the *RDCs,* and each *RDC* is covered by one of the *CWHs* within the endogenously determined distance. ERFs should be located at the least likely locations to be disrupted to enhance supply chain resilience to disasters. The third goal is to maximize the expected amount of demands covered (*EDC*) by the *ERFs*. Deckle et al. [6] consider the problem of minimizing the total number of disaster recovery centers (DRCs) in Alachua County, Florida, on the condition that each county resident being close to a DRC must be less than a given threshold. It implies that each location should be within a certain distance of the nearest DRCs to be served in case of emergency. Besides, there may be some environmental constraints or difficulties such as weather issues and road damage/construction, limiting the maximum coverage distance given by *MCD* in (3). Thus, the maximum effective coverage distance (*MECD)*, denoted by D_c, may be shorter than the *MCD*. However, it would be desirable to

maximize the covered demands within D_c, while minimizing the *MCD*. The next goal is to maximize the covered demands in case of emergency, *CDE*.

Let the nonnegative deviation variables, $\delta^+_{TLC}, \delta^-_{TLC}, \delta^+_{MCD}, \delta^-_{MCD}, \delta^-_{EDC}, \delta^+_{EDC}, \delta^-_{CDE}$, and δ^+_{CDE} denote the amounts by which each value of *TLC, MCD, EDC,* and *CDE* deviates from the target values. Then, let $\boldsymbol{\alpha} = \{\alpha_1, \alpha_2, \alpha_3, \alpha_4\}$, $\sum_{\kappa=1}^{4} \alpha_\kappa = 1$, denote relative weights attached to the corresponding goal. The objective function is to minimize the maximum weighted percentage deviation (WPD), subject to each WPD is less than or equal to the objected value itself. The complete constraints for the *ERSC* design problem are found in Hong and Jeong [11]. Solving the multi-objective model for a given set of weights generates one *ERSCS* scheme with a group of optimal four-performance metrics. There will be multiple schemes for various values of the weights. This paper applies DEA by considering these generated schemes as DMUs, and each DMU can be considered to have two inputs, *TLC* and *MCD*, to produce two outputs, *EDC* and *CDE*.

DATA ENVELOPMENT ANALYSIS METHODS

Classical DEA (C-DEA) & Cross Efficiency (CE-DEA)

Note that each DMU represents an *ERSCS* scheme generated by solving the MOP model given in (7)-(27) for a given value of each weight. The mathematical model of C-DEA for DMUs with two inputs, *TLC* and *MCD*, would be stated to produce two outputs, EDC and CDE. The cross-efficiency (C.E.) method consists of two phases (see Zhu [26]). The first is the self-evaluation phase, where DEA scores are calculated using the C-DEA model. In the second Phase, the weights/multipliers generated in Phase I are applied to all DMUs to get the cross-efficiency score (CES) for each DMU. In Phase I, let E_{kk} represent the DEA score for DMU_k, which will be obtained from

$$Max\ E_{kk} = u_{1k}EDC_k + u_{2k}CDE_k, \tag{1}$$

subject to

$$v_{1k}TLC_k + v_{2k}MCD_k = 1, \tag{2}$$

$$\left(u_{1k}EDC_j + u_{2k}CDE_j\right) - \left(v_{1k}TLC_j + v_{2k}MCD_j\right) \leq 0, j = 1, \dots, N, \tag{3}$$

$$u_{1k}, u_{2k}, v_{1k}, v_{2k} \geq 0.$$

N = number of DMUs being compared in the DEA analysis
θ = efficiency rating of the DMU_k being evaluated by DEA
i = number of inputs used by the DMUs
r = number of outputs generated by the DMUs
u_r = coefficient or weight assigned by DEA to output r
v_i = coefficient or weight assigned by DEA to input i

Now, the C.E. for DMU_j, using the weights that DMU_k has chosen in the model by (1)-(3), is given by

$$E_{kj} = \frac{u^*_{1k}EDC_k + u^*_{2k}CDE_k}{v^*_{1k}TLC_k + v^*_{2k}MCD_k}, k\ and\ j = 1, \dots, N, k \neq j. \tag{4}$$

DMU_j is called a rated DMU, whereas DMU_k is called a rating DMU. Then, Doyle and Green [7] use Eq. (4) to set up the C.E. matrix that consists of the self-evaluation value, E_{kk}, in the leading diagonal and peer-evaluation value, E_{kj}, in the non-diagonals. By averaging E_{kj} in (4) without the leading diagonal, Doyle and Green [7] propose the CES for DMU_k, which is defined as

$$\bar{E}_{k(p)} = \frac{1}{N-1}\sum_{j\neq k}^{N} E_{jk}. \tag{5}$$

In (5), 'p' stands for peer evaluation. In the meantime, Zhu [26] and Hong and Jeong [11] include self-evaluation value in averaging the appraisals by itself and peers as follows:

$$\bar{E}_{k(s+p)} = \frac{1}{N}\sum_{j=1}^{N} E_{jk}. \tag{6}$$

In (6), 's' stands for self-evaluation. No literature explicitly has suggested the appropriate proportions of self-evaluation and peer-evaluation in deciding the C.E. scores. To solve the dilemma between the above two equations, let β denote the proportion of self-evaluation evaluation. We propose the following equation to combine (5) and (6):

$$\bar{E}_{\kappa} = \beta * E_{\kappa\kappa} + \frac{(1-\beta)}{N-1}\sum_{\substack{\omega=1,\\ \omega\neq\kappa}}^{N} E_{\omega\kappa}. \tag{7}$$

We call the above model the **regular** CE-DEA. As mentioned before, Wang and Chin [23] developed the neutral CE-DEA model to avoid choosing between the two different formulations. The neutral CE-DEA model determines one set of input and output weights for each DMU without being aggressive or benevolent to the others. Thus, **the neutral C.E. scores** will be more neutral, and its model is formulated as follows:

$$Maximize\ w \tag{8}$$

Subject to

$$v_{1k}TLC_k + \ v_{2k}MCD_k = 1, \tag{9}$$
$$u_{1k}EDC_k + u_{2k}CDE_k = E^*_{kk}, \tag{10}$$
$$\left(u_{1k}EDC_j + u_{2k}CDE_j\right) - \left(v_{1k}TLC_j + v_{2k}MCD_j\right) \leq 0, j = 1, \dots, N, k \neq j, \tag{11}$$
$$u_{1k}EDC_k \geq w, \tag{12}$$
$$u_{2k}CDE_k \geq w, \tag{13}$$
$$w, u_{1k}, u_{2k}, v_{1k}, v_{2k} \geq 0.$$

Super Efficiency DEA

The super-efficiency score (SES) is obtained from the C-DEA model after a DMU under evaluation is excluded in the C-DEA models' reference set. The SE-DEA has significance for discriminating among efficient DMUs. In the S.E. model, efficient DMUs are not compared to the same standard since the frontier constructed from the remaining DMUs changes for each efficient DMU to be rated. Consequently, the SESs of efficient DMUs are allowed to have

higher values than 1. Jeong and Ok [14] and Yu and Hou [25] maintain that the self-evaluation efficiency would not discriminate efficient DMUs and propose a modified cross-evaluation method using the SES. They demonstrate that their approach can determine efficient DMUs better than the CE-based methods. Now, the C.E. approach based on the SES is expressed as

$$Max\ SE_{kk} = u_{1k}EDC_k + u_{2k}CDE_k, \tag{14}$$

subject to

$$v_{1k}TLC_k + v_{2k}MCD_k = 1, \tag{15}$$

$$\left(u_{1k}EDC_j + u_{2k}CDE_j\right) - \left(v_{1k}TLC_j + v_{2k}MCD_j\right) \leq 0, j \neq k, \tag{16}$$

$$u_{1k}, u_{2k}, v_{1k}, v_{2k} \geq 0.$$

Now, the cross efficiency of DMU_j based on SES that is called **super-cross efficiency** (SCE) in this paper, is given by

$$SCE_{kj} = \frac{u_{1k}^* EDC_k + u_{2k}^* CDE_k}{v_{1k}^* TLC_k + v_{2k}^* MCD_k}, k\ and\ j = 1, \ldots, N, k \neq j. \tag{17}$$

Then, the cross-evaluation matrix consists of the self-evaluation value, SE_{kk}, in the leading diagonal and peer evaluation value, SCE_{kj} in (17), in the non-diagonals. The following equation for the average SCE score for DMU_κ is proposed:

$$\overline{SCE}_\kappa = \beta * SE_{\kappa\kappa} + \frac{(1-\beta)}{N-1} \sum_{\substack{\omega=1, \\ \omega \neq \kappa}}^{N} SCE_{\omega\kappa}. \tag{18}$$

Now, this study extends the SE-DEA model to the neutral CE-based method. C-DEA and two models, regular and neutral, for CE-DEA and SCE-DEA, are applied to solve the following numerical example for a case study.

CASE STUDY AND OBSERVATIONS

The case study applies major disaster declaration records in South Carolina (S.C.) to illustrate the proposed procedure. Forty-six counties are clustered based on proximity and populations into twenty counties. Then, they choose one city from each clustered county based on a centroid approach and assume that all population within the clustered county exists in that city. The Federal Emergency Management Agency (FEMA) database (FEMA, 2015), South Carolina (S.C.) database provides a list of counties where a major disaster was declared. It is also assumed that when a major disaster is declared, the emergency facility in that county is damaged and shut down. Based on the historical record and the assumption, each neighborhood's risk probability (a county or a clustered county) is calculated in Table 1.

TABLE 1: Data for Locations of ERFs

No	City	County	Population (K)	Risk Probability
1	Anderson	Anderson/Oconee/Pickens	373	0.125
2	Beaufort	Beaufort/Jasper	187	0.063
3	Bennettsville	Marlboro/Darlington/Chesterfield	96	0.375
4	Conway	Horry	269	0.375
5	Georgetown	Georgetown/Williamsburg	93	0.438
6	Greenwood	Greenwood/Abbeville	92	0.125
7	Hampton	Hampton/Allendale	33	0.188
8	Lexington	Lexington/Newberry/Saluda	318	0.313
9	McCormick	McCormick/Edgefield	35	0.250
10	Moncks Corner	Berkeley	178	0.313
11	Orangeburg	Orangeburg/Bamberg/Calhoun	123	0.375
12	Rock Hill	York/Chester/Lancaster	321	0.313
13	Spartanburg	Spartanburg/Cherokee/Union	367	0.313
14	Sumter	Sumter/Clarendon/Lee	157	0.375
15	Walterboro	Colleton/Dorchester	135	0.250
16	Aiken†	Aiken/Barnwell	184	0.313
17	Charleston†	Charleston	350	0.250
18	Columbia†	Richland/Fairfield/Kershaw	461	0.375
19	Florence†	Florence/Dillon/Marion	203	0.438
20	Greenville†	Greenville/Laurens	521	0.125

†potential locations for *CWH*

Finding four performance metrics' target values is necessary to set up the objective function and constraints. These target values can be obtained by solving the mathematical programming problem with the objective function of the corresponding equations of each metric. Each of these target values could be obtained by setting the corresponding weight equal to 1 and solving the MOP model. We hypothetically set the maximum effective coverage distance in case of emergency equal to 35 miles to find CDE_{max}.

Using the target values, the MOP model is formulated and solved for various values of the weight set, $\boldsymbol{\alpha}$, where each weight changes between 0 and 1 with an increment of 0.1. There are 286 configurations for each model arising out of the combinations of the setting of $\boldsymbol{\alpha}$ under the condition $\sum_{v=1}^{4} \alpha_v = 1$. After 286 runs, we reduce 286 configurations into 148 consolidated schemes after grouping them with the same four-performance metrics' values. Each of the 148 network schemes is considered a DMU, representing the optimal locations of *ERFs* and their supply chain schemes. Considering *TLC* and *MCD* as inputs and *EDC* and *CDE* as outputs, we apply the C-DEA model and find thirteen (13) efficient DMUs out of 148 with a perfect E.S., θ_k= 1, which are called "a best-practice frontier."

In Table 2, we present all 13 efficient DMUs, along with the value of each performance metric, E.S., θ_k, for C-DEA and cross-efficiency scores (CESs) for **Regular** and **Neutral** models. Similarly, super-cross efficiency scores (SCESs) for **Regular** and **Neutral** models for these efficient DMUs are also reported. The DMUs with the top three greatest CESs/SCESs are denoted by '***', '**', and '*,' respectively. From Table 2, we observe that the **Regular** CES finds DMU #57 as the most efficient DMU, whereas the **Neutral** CES ranks DMU #53 as #1. In contrast, DMU #58 is ranked #1, DMU #57 is ranked second, and DMU #53 is ranked third by both SCESs. We observe that DMU #57 and DMU #58 yield almost identical inputs and outputs, while DMU #57 yields slightly less *TLC* and *EDC* than DMU #58. DMU #53 results in fewer inputs, TCL and MCD, and fewer outputs, *EDC* and *CDE*, than DMU #57 or DMU #58. In other words, DMU #53 is more efficient in terms of inputs but less efficient in terms of outputs than DMU #57 or DMU #58. Based on these results from Table 2, we depict the two highly-ranked DMUs, DMUs #53 and #58, in Figure 2.

SUMMARY AND CONCLUSIONS

The classical DEA (C-DEA) estimates DMUs in terms of self-evaluation only, allowing each DMU to rate its efficiency score with the most favorable weights. Consequently, problems related to weak discriminating power have arisen because multiple DMUs frequently turn out to be efficient. Lack of discrimination power is the major weakness of C-DMU. The cross-efficiency (C.E.) evaluation was introduced to increase the discrimination power. The two models, **Regular** and **Neutral,** were introduced a long time ago to compensate for the critical weaknesses of CE-DEA. But only a few references have applied these methods to show the increased discriminating power. Most of the references on the C.E. methods use the **Regular** model only. Also, no literature explicitly has suggested the appropriate proportions of self-evaluation and peer-evaluation in deciding the C.E. scores. The super-efficiency DEA (SE-DEA) method was developed to enhance the discrimination power. This paper combines CE-DEA into SE-DEA methods, using the two models, **Regular** and **Neutral**, which are also integrated into this cross-evaluation method based on the super efficiency scores.

Using the actual data available for South Carolina, this paper demonstrates the proposed methods to evaluate various ERSCS configurations generated by the MOP model. Surprisingly, the proposed methods reveal some hidden efficient network configurations that the regular C.E. model alone can't identify. We observe that the proposed approach can be an essential tool for designing *ERSCS* and other supply chain network systems with multiple inputs and multiple outputs.

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REFERENCES

References are available upon request.

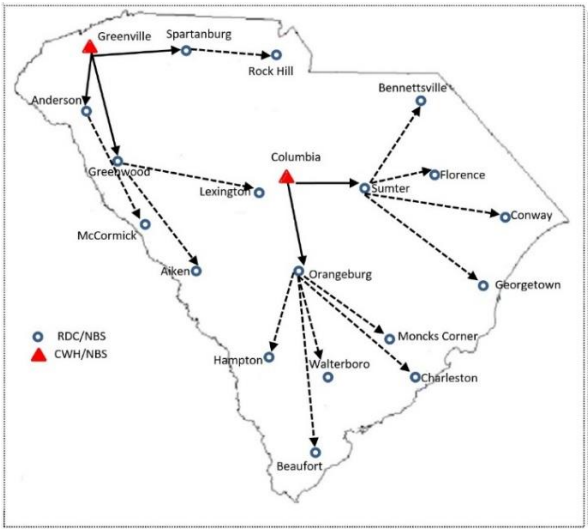
TABLE 2: Efficient DMUs, Their Performance Metrics, and Efficient Scores

No	DMU #	*TLC($)*	*MCD (miles)*	*EDC (K)*	*CDE (K)*	*ES*	*CES (R)*	*CES (N)*	*SES (R)*	*SES (N)*
		Input	Input	Output	Output					
1	25	397,904	100.9	2119	3361	1.0000	0.8566	0.8812	0.8494	0.8501
2	26	338,510	85.5	2754	2139	1.0000	0.8406	0.8840	0.8611	0.8613
3	53	294,084	83.9	2637	2094	1.0000	0.8837*	0.9157***	0.8989*	0.8991*
4	56	329,360	130.0	2411	3040	1.0000	0.8205	0.8041	0.8075	0.8077
5	57	300,062	116.0	2862	2736	1.0000	0.9079***	0.9001*	0.9023**	0.9023**
6	58	300,608	116.0	2868	2736	1.0000	0.9078**	0.9002**	0.9024***	0.9024***
7	59	308,864	116.0	2996	2049	1.0000	0.7782	0.7830	0.7837	0.7834
8	60	335,001	93.9	3031	2057	1.0000	0.8283	0.8645	0.8493	0.8493
9	62	293,234	176.0	2600	2725	1.0000	0.7417	0.6909	0.7165	0.7161
10	78	425,988	100.9	2094	3361	1.0000	0.8248	0.8548	0.8189	0.8197
11	79	434,507	100.9	2090	3361	1.0000	0.8163	0.8478	0.8108	0.8116
12	95	363,088	94.0	3075	2038	1.0000	0.7964	0.8394	0.8209	0.8210
13	142	388,104	100.9	2115	3361	1.0000	0.8670	0.8893	0.8591	0.8599

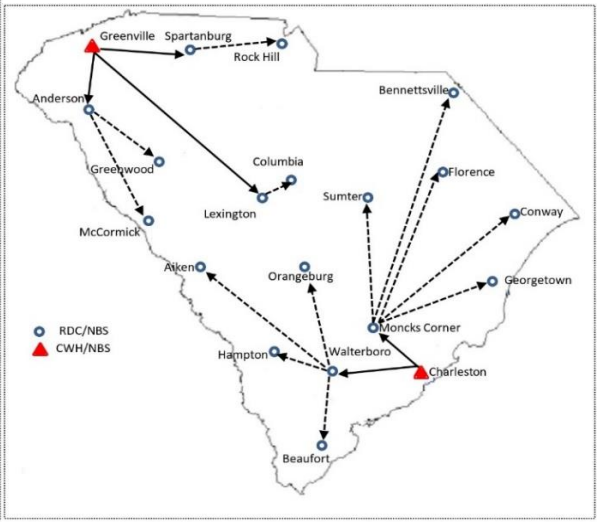
E.S.: Efficiency Score, **CES:** Cross-Efficiency Score, **SES**: Super-Efficiency Score, **R**: Regular Model, **N**: Neutral Model
***: Ranked First, **: Ranked Second, *: Ranked Third

FIGURE 2: Most Efficient Emergency Relief Supply Chain Network Schemes

DMU #53



DMU #58



Achieving Supply Chain Visibility with a Supply Chain Control Tower Solution

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Achieving Supply Chain Visibility with a Supply Chain Control Tower Solution

This study proposes a guiding framework that helps practitioners and researchers to understand how supply chain control tower solutions can be used to achieve supply chain visibility (SCV). We first motivate the importance of SCV and discuss boundary conditions in terms of business requirements and critical success factors. Next, we use a design science approach coupled with a longitudinal case study of a leading, global automotive OEM to develop a nine-step framework that describes the design and implementation of an SCV-facilitating supply chain control tower solution. Finally, we highlight the practical relevance and the benefits that the case company was able to realize by leveraging this framework. Most notably, our findings show that the case company substantively reduced inventory in each stage of its automobile distribution network.

Introduction

"*The supply chain of the future will increasingly be self-aware, think by itself and require minimum, if any, human intervention to manage risks. … will continuously monitor supply chain performance by analyzing quintillion bytes of data generated by objects; …; and automatically take actions to prevent risks before they materialize. The supply chain will autonomously learn from these activities and use such knowledge in future decisions.*" (Calatayud et al. 2019, pp. 22-23). The ongoing impacts of the COVID19 pandemic on the global automotive supply chain, which include shortages of supplied parts, transportation delays, OEM plant shutdowns, and rapid fluctuations in demand (Garsten, 2020), suggest the practical utility of this vision for future supply chains. However, given the relatively low digital supply chain maturity levels in many industries, the difficulty of achieving this vision might have a discouraging rather than an inspiring effect on many practitioners.

In the academic literature, current research primarily explores the isolated impacts of an individual, new digital technologies, such as blockchain, internet of things (IoT), or artificial intelligence (AI), on supply chain performance (Calatayud et al. 2019). Yet, few studies provide guidance on how to systematically raise the overall digital supply chain maturity level. Moreover, despite more than 20 years of research in SCV, most studies have focused on simplified supply chains (i.e. dyads, two-tier supply chains, and linear supply chains), which provide a limited representation of realistic, complex environments (Caridi et al., 2013) and address only select aspects of

SCV. More specifically, existing SCV studies do not provide guidance on how to exploit the large amount of data available within the company, lack clarification on how to develop user-friendly visuals, and fall short on validating the results of their analysis. Swift et al. (2019) found that most studies claim that SCV is important, but only show that its complete absence leads to severe consequences. Furthermore, they highlighted that it is difficult for researchers to assess the benefits obtained from SCV because companies are reluctant to share the details of their supply chains.

Our study aims to address these gaps in extant literature in two important ways. First, we seek to provide a step-wise framework for the implementation of a control tower solution in order to achieve the needed SCV. Second, we analyze the benefits created by a higher level of SCV. Rather than inferring benefits indirectly (e.g., from financial performance variables retrieved from secondary data sources), we delineate concrete benefits (e.g. reduced lead-times, higher planning accuracy) that companies may attain when making decisions based on the resulting control tower solution and associated supply chain visualization capabilities. Hence, using case study data and the pragmatic research paradigm, we build on the fundamental principles of supply chain traceability (Hastig and Sodhi, 2020) and transparency (Sodhi and Tang, 2019) to systematically develop and empirically validate a supply chain a control tower solution that facilitates visibility on a supply chain-wide, real-time basis.

Theoretical Background

This study builds mainly on the SCV stream of literature (Srinivasan and Swink, 2018; Barrat and Oke, 2007), but also lies at the intersection of literature streams on supply chain traceability (Hastig and Sodhi, 2020), focusing on RFID and blockchain applications, and on supply chain transparency (Sodhi and Tang, 2019). For all three literature streams, we identify and analyze existing studies (roughly 100 studies) in order to identify business requirements of why companies decided to initiate SCV projects and what steps were undertaken to increase traceability, transparency, or visibility.

Method

As shown in Figure 1, we motivate the practical importance of SCV by integrating the company needs identified through a series of semi-structured field interviews with the business requirements and success factors identified

in the academic and practitioner literature (cf. Hastig and Sodhi, 2020). Interview participants were either selected because of a known maturity in SCV (e.g., companies having successfully implemented control tower solutions) or a described need in SCV (e.g., companies willing to start a SCV project but not knowing how). Next, we use a design science approach following the guidelines proposed by Peffers et al. (2007) to develop and practically apply our artefact. Our artefact is a step-wise guiding framework for the implementation of a supply chain control tower solution in order to achieve SCV. Finally, we provide evidence in a detailed use-case that describes how our artifact can be practically applied (practical relevance) and how business benefits were generated for the case company (pragmatic validity) (van Aken et al., 2016).

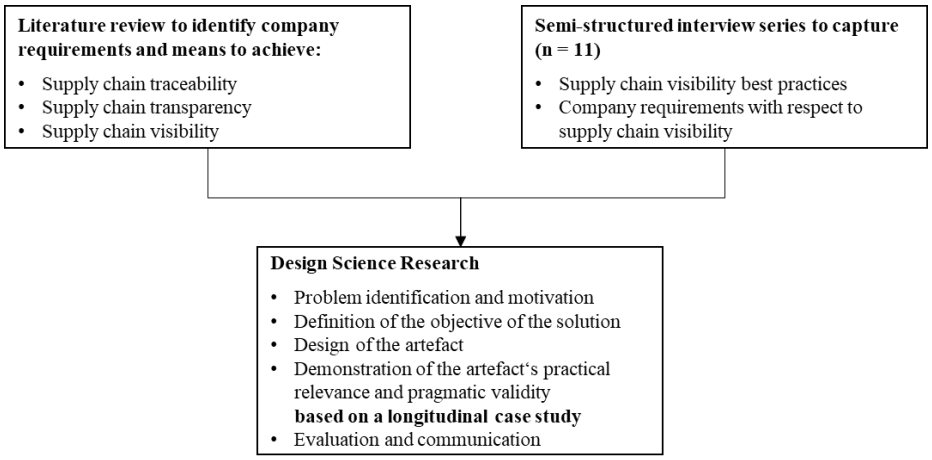

Figure 1 - Research Design

Findings

Integrating the design science methodology with literature review and semi-structured interview findings, we advance a framework that details how to implement a SCV-facilitating control tower solution (see Figure 2). This framework was prototypically applied within a longitudinal case study. A snapshot of the realized dashboards in the control tower is shown in Figure 2. For each of the framework's nine steps, we describe the critical action items, existing reference materials, and publicly available tools (e.g., Gephi for network visualization; Tableau for visuals) that can be consulted for successful implementation. Practical relevance and pragmatic validity are continuously evaluated by checking whether the business requirements derived from theory and practice are met.

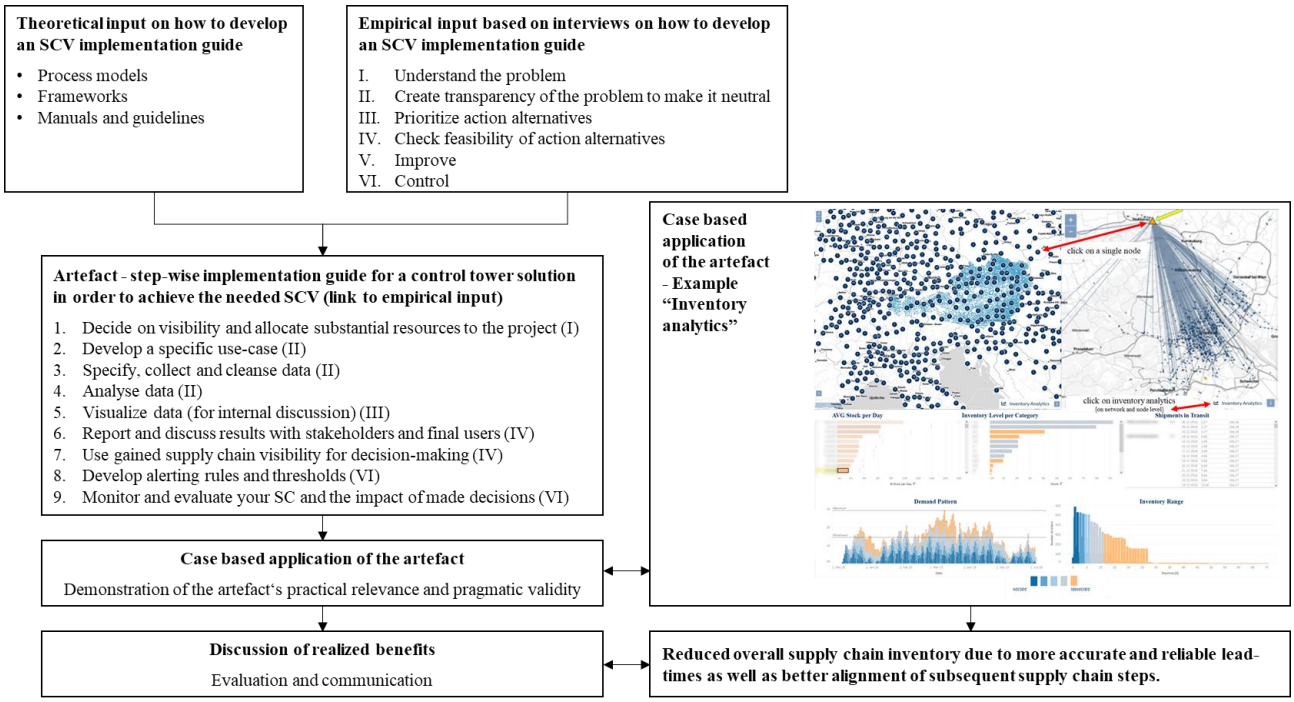

Figure 2 - The artefact and its case based application

Conclusion and Implications

We advanced a nine-step framework that demonstrates, for researchers and practitioners, how to realize and implement a control tower solution in order to achieve SCV independent of a company's current digital supply chain maturity level. SCV is key for identifying critical network nodes and for planning supply chain processes that enable inventory, lead-time, and delay reductions as well as enhanced monitoring. All of these benefits potentially reduce costs, generate superior customer value, and eventually support competitive advantage. We highlight the practical relevance of the developed framework through its prototypical implementation and by showing its direct business benefits, which include significantly reduced overall inventory due to more accurate and reliable lead-times and improved alignment of sequential supply chain stages.

Scientific contribution - SCV is of paramount importance in many industries; notably, our study details how SCV can systematically be achieved through the rigorous application of a design science methodology. By testing and assessing our artefact in an application setting, we show that our control tower solution addresses a problem of great practical relevance and that our design methodology is practically useful. Our artefact therefore provides a

foundation for a novel stream of subsequent research focused on systematically designing and/or improving SCV. Future research can apply and refine our framework through the evaluation and redesigning steps of the design science methodology.

Managerial implications - In general, our study provides managers with an effective guide on how to increase SCV, which enables evidence-based decision-making and improvements to misaligned departure and arrival schedules in consecutive stages of complex, high volume supply chains. Further, SCV enables more accurate target lead times for specific shipments; this improves planning accuracy and, subsequently, reduces inventory days-on-hand and working capital.

In this study, we discussed how companies might increase SCV by applying our artefact. We are fully aware that our designed artefact is still in its very early stages and requires refinement and ongoing application to reach the next maturity level. Nevertheless, we hope that it spurs discussion on how to achieve SCV and exploit data in the supply chain on an end-to-end basis. The mutual exchange between practitioners and scholars will reveal several further research opportunities for OM and SCM scholars.

References

Barrat, M., & Oke, A. (2007). Antecedents of supply chain visibility in retail supply chains: a resource-based theory perspective. *Journal of operations management*, 25(6), 1217-1233.

Garsten, E. (2020). https://www.forbes.com/sites/edgarsten/2020/03/16/study-predicts-prolonged-covid-19-pandemic-could--sharply-reduce-vehicle-sales/#1b7b063355c2 [retrieved April 30th 2020].

Caridi, M., Perego, A., & Tumino, A. (2013). Measuring supply chain visibility in the apparel industry. *Benchmarking: An International Journal*.

Hastig, G. M., Sodhi, M. S.. Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors. *Production and Operations Management* (2020).

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems*, 24(3), 45-77.

Sodhi, M. S., Tang, C. S. (2019). Research Opportunities in Supply Chain *Transparency. Production and Operations Management*, 28(12), 2946-2959.

Srinivasan, R., Swink, M. (2018). An investigation of visibility and flexibility as complements to supply chain analytics: An organizational information processing theory perspective. *Production and Operations Management*, *27*(10), 1849-1867.

Swift, C., Guide Jr, V. D. R., & Muthulingam, S. (2019). Does supply chain visibility affect operating performance? Evidence from conflict minerals disclosures. *Journal of Operations Management*, 65(5), 406-429.

van Aken, J., Chandrasekaran, A., & Halman, J. (2016). Conducting and publishing design science research: Inaugural essay of the design science department of the Journal of Operations Management. *Journal of Operations Management*, 47, 1-8.

DEMAND POINT ESTIMATES IN CAPACITATED MULTI-ITEM DYNAMIC LOT SIZING PROBLEMS WITH UNCERTAIN DEMANDS

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ABSTRACT

Dynamic Lot Sizing problem and its variations has been widely used for the scheduling of the productions and inventories. When demands are uncertain, one can use the mean of historical data or the expected value, which is a point estimate of demand. In addition to the mean, this work considers another point estimate, which is called median. We show that the total backorders, as the result of capacity limitation and uncertain demand, can be lower when median is used instead of the mean. It is shown that for an asymmetric distribution, the total backorder is lower significantly when median is used. Furthermore, when demand follows a symmetric distribution, the total backorder do not differ significantly between the two point estimates.

KEYWORDS: Dynamic Lot-Sizing, Multi-Item, Uncertain Demand, Point Estimate

INTRODUCTION AND LITERATURE REVIEW

Since it was first conceived by [16], DLS problem has remained in the center of attention to manage supply chains. This problem considers the production and inventory levels for multiple periods of planning. In this work, we concentrate on the multi-item extension of this problem, i.e. Multi-item Dynamic Lot Sizing (*MIDLS*), and we consider a variation of this problem that considers the backorders and uncertain demands.

To present the formulation of *MIDLS* problem, we use the same notation as [6]. We show the set of items by $\mathscr{I} = \{1, ..., |\mathscr{I}|\}$ which is indexed by i and we show the set of periods by $\mathscr{T} = \{1, 2, ..., |\mathscr{T}|\}$ which is indexed by t. We assume the unit holding cost, set up cost, production cost, and start up cost of item i in period t is h_i^t, s_i^t, p_i^t, and o_i^t respectively. The demand of item i in period t is d_i^t. In addition, we have four variables in the problem. The production of item i in period t is shown by x_i^t. The inventory level of i at the end of period t is shown by q_i^t. Binary variable $y_i^t = 1$, if there is a production of item i in period t and otherwise, $y_i^t = 0$. Finally, $z_i^t = 1$ when we have a production of i in period t and no production of i in previous period. Given $M^t = \sum_{i \in \mathscr{I}} d_i^t$, we can formulate *MIDLS* problem as follows, which is similar to [1, 10, 2, 6]:

$$\textit{MIDLS}: \quad \min \quad \sum_{t\in\mathscr{T}}\sum_{i\in\mathscr{I}}(h_i^t q_i^t + p_i^t x_i^t + s_i^t y_i^t) + \sum_{t\in\mathscr{T}\setminus\{1\}}\sum_{i\in\mathscr{I}}(o_i^t z_i^t) \tag{1}$$

$$\text{s.t.} \quad q_i^{t-1} + x_i^t \geq q_i^t + d_i^t \qquad \forall i \in \mathscr{I}, \forall t \in \mathscr{T}\setminus\{1\} \tag{2}$$

$$x_i^t \leq M^t y_i^t \qquad \forall i \in \mathscr{I}, \forall t \in \mathscr{T} \tag{3}$$

$$z_i^t \geq y_i^t - y_i^{t-1} \qquad \forall i \in \mathscr{I}, \forall t \in \mathscr{T}\setminus\{1\} \tag{4}$$

$$x_i^t, q_i^t \geq 0, y_i^t \in \{0,1\} \qquad \forall i \in \mathscr{I}, \forall t \in \mathscr{T} \tag{5}$$

$$z_i^t \in \{0,1\} \qquad \forall i \in \mathscr{I}, \forall t \in \mathscr{T}\setminus\{1\} \tag{6}$$

Objective (1) is set to minimize the total cost of inventories, productions, set ups, and start ups. Constraints (2) are the inventory balance constraints. These constraints guarantee that in each period, the total previous inventory and production for each item is greater than or equal to the demand plus the ending inventory. If there is a production in a period, constraints (3) guarantee the corresponding binary variables will be equal to one. If there is a new production in a given period, constraints (4) force the corresponding z_i^t variable equal to one. Constraints (5)-(6) represent the definitions of variables. Upon solving this problem, variable x_i^t decides on the production of each item in each period; variables q_i^t shows the end of period inventory level; variable y_i^t shows whether there is a production of each item in a period; and, variable z_i^t decides if we have a new start-up for a product in a given period.

In the*MIDLS* problem, demand d_i^t is assumed to be stationary through all periods [16]. When demand is not stationary, i.e. fluctuating and/or uncertain, the problem may render infeasible. This means no solution considering the constraints can be found to satisfy the realized demand. To overcome this issue, one may add backorder variables to the constraints (2). The backorder variables will act as catalysts that absorb the additional demand or backorders. In the literature, backorder has been included in inventory balance constraints [3, 5] or as stochastic variables [7, 15]. It is worth noting that service-level has been widely used to address demand uncertainty, which is beyond the scope of this research. For example, the work of [4] studies the probability of having in-hand inventory as a constraint and [8] connects the backorders and service-levels. More similar studies related to the service-levels can be found in the work of [14, 15, 13].

To solve optimization problems with uncertain parameters, such as the *MIDLS* problem, there are several approaches utilized in the literature. One of the popular approaches is to solve the expected value problem [11]. The expected value problem substitutes the uncertain parameter of the problem with its mean. Note that the mean is a point estimate of the uncertain parameter. Alternatively, one can substitute the uncertain parameter with its median. For an uncertain parameter that has a symmetric distribution, it should not affect the backorders, largely. However, if the distribution is asymmetric, backorders should change more compared to using the median of the uncertain parameters. The comparison of the point estimates median and mean when approximating the uncertain parameters is the focus of this work.

In the next section alternative formulations including backorders are presented. In the later section, we analyze different point estimate solution approaches and we show which solution approach

leads to a lower backorder through a statistical analysis. We conclude the research and hints on future directions of this research in the last section.

DLS PROBLEMS WITH UNCERTAIN DEMANDS AND BACKORDERS

When demand fluctuates high and the capacity in production/inventory is limited, constraints (2) may become infeasible. The infeasibility lies in the possibility of having a large enough demand that cannot be satisfied due to the limited capacities. To overcome this problem, we use backorder variables and update inventory balance constraints. In the work of [3, 5, 9, 12], the inventory balance constraints are updated by including backorder variables u_i^t. Assuming r_i^t is the backorder cost, we have the Capacitated MIDLS with Backorder (*CMIDLS-BO*) as follows:

$$\textit{CMIDLS-BO}: \quad \min \quad \sum_{t\in\mathscr{T}}\sum_{i\in\mathscr{I}}(h_i^t q_i^t + p_i^t x_i^t + s_i^t y_i^t + r_i^t u_i^t) + \sum_{t\in\mathscr{T}\setminus\{1\}}\sum_{i\in\mathscr{I}}(o_i^t z_i^t) \tag{7}$$

$$\text{s.t.} \quad q_i^{t-1} + x_i^t + u_i^t \geq q_i^t + d_i^t + u_i^{t-1} \quad \forall i \in \mathscr{I}, \forall t \in \mathscr{T} \tag{8}$$

$$x_i^t \leq M^t y_i^t \quad \forall i \in \mathscr{I}, \forall t \in \mathscr{T} \tag{9}$$

$$z_i^t \geq y_i^t - y_i^{t-1} \quad \forall i \in \mathscr{I}, \forall t \in \mathscr{T}\setminus\{1\} \tag{10}$$

$$\sum_{i\in\mathscr{I}} x_i^t \leq C_P \quad \forall t \in \mathscr{T} \tag{11}$$

$$\sum_{i\in\mathscr{I}} q_i^t \leq C_Q \quad \forall t \in \mathscr{T} \tag{12}$$

$$x_i^t, q_i^t, u_i^t \geq 0,\ y_i^t \in \{0,1\} \quad \forall i \in \mathscr{I}, \forall t \in \mathscr{T} \tag{13}$$

$$z_i^t \in \{0,1\} \quad \forall i \in \mathscr{I}, \forall t \in \mathscr{T}\setminus\{1\} \tag{14}$$

Objective (7) is set to minimize the total cost of inventories, productions, set ups, start ups, and backorders. Constraints (8) are the inventory balance constraints. These constraints guarantee that in each period, the total previous inventory, production, and backorder for each item is equal to the demand plus summation of previous backorder and the ending inventory. The rest of constraints (9)-(14) are similar to (3)-(6), except that capacity constraints (11) and (12) are added and the definition of backorder variables is included in constraints (13).

Next, we use two point estimates, i.e. mean and median, to have two solution approaches to solve the *CMIDLS-BO* problem. We compare the solution approaches in terms of their backorders and we show the median is a better point estimate with demand asymmetrically distributed.

SOLUTION ANALYSIS

Solution Approaches

Before analyzing the solution methods, we first write *CMIDLS-BO* into its compact form. Let's show all variables by λ, the cost coefficients of all variables by C, demands by D, Matrix of left-hand-side of constraints (8) by A, and the feasible space of the rest of constraints by $\mathscr{X}$. The compact form is:

$$\begin{aligned} \mathscr{P}\text{:} \quad & \min \quad C\lambda \\ & \text{s.t.} \quad A\lambda \geq D \\ & \qquad \lambda \in \mathscr{X} \end{aligned}$$

Based on the historical data $D^k, \forall k \in \mathscr{K}$, we develop two approaches to solve $\mathscr{P}$ given the uncertain demand D. One approach is based on the mean of historical data $\bar{D}$ and the other approach is based on the median of historical data or $\widehat{D}$. We call the corresponding problems $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\widehat{D}}$. The purpose is to understand which approach results in a lower total backorder through a numerical analysis. This analysis is repeated for demands that have a Normal distribution, a Uniform distribution, and a Poisson distribution. In each case, the total backorder of each approach is computed and compared.

Numerical Analysis

In the numerical analysis, parameters are generated uniformly as integers within a lower bound and an upper bound that is shown by $IU[lb,ub]$. Particularly, $h_i^t \in IU[1,5]$, $p_i^t \in IU[10,20]$, $s_i^t \in IU[20,40]$, $o_i^t \in IU[15,25]$, and $r_i^t \in IU[100,200]$. Note that vector D of demands is available for the past $|\mathscr{K}| = 100$ time horizon. In another word, we have D^k for all $k \in \mathscr{K}$. If demands follow a Uniform distribution, we generate historical demands as $D^k \in [800,1000]$. If demands follow a Normal distribution, we generate historical demands as D^k as a normal random variable with a mean of 900 and standard deviation of 100. If demands follow a Poisson distribution, we generate historical demands as D^k (d_i^{tk}) as a Poisson random variable with a mean of 900 ($\mu = 900$). Note that if we use the mean as the point estimate, we set $D = \bar{D^k}$ and if we use median as the point estimate, we set $D = \widehat{D^k}$.

Additionally, initial inventory and capacity of production and inventory should be calculated. For this purpose, we assume the initial inventories are all zeros, i.e. $q_i^t = 0$. To find C_P and C_Q we first generate an array of $D^k \in [800,1000]$. Then, given γ being a random number between 2 and 3, these capacities are calculated as:

$$C_Q = \frac{1}{\gamma \times |\mathscr{K}|} \sum_{k \in \mathscr{K}} \sum_{i \in \mathscr{I}} d_i^{1k} \tag{15}$$

$$C_P = \frac{1}{|\mathscr{T}| \times |\mathscr{K}|} \sum_{k \in \mathscr{K}} \sum_{t \in \mathscr{T}} \sum_{i \in \mathscr{I}} d_i^{tk} \tag{16}$$

The number of items belongs to $|\mathscr{I}| \in \{10,20,30,40\}$ and the number of periods belongs to $|\mathscr{T}| \in \{40,60,80,100\}$. For every $i \in \mathscr{I}$ and $t \in \mathscr{T}$, we generate 10 problem instances according to the above settings. Note that the average of these instances are presented in this paper. These instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\widehat{D}}$ are implemented in Python 7 and run on computer with 2×2.4 GHz CPU, 4 GB RAM, and 64-bit Windows operating system. Instances are solved using Gurobi 9.0.3 academic solver. The computational time is shown by *cpu* and the difference between total backorders of problems $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\widehat{D}}$ is shown by Δ. This difference is divided by the minimum backorder among $\bar{U}$ and $\widehat{U}$ to be shown by percentages. We define this measure as:

$$\Delta = \frac{\mathbb{1}(\bar{U} - \widehat{U})}{min\{\mathbb{1}\bar{U}, \mathbb{1}\widehat{U}\}} \tag{17}$$

where $\mathbb{1}$ is a vector of 1's of an appropriate size. Table 1 in the APPENDIX summarizes the numerical analysis of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\widehat{D}}$ instances, when D is Uniformly distributed. Despite the choice of point estimate, $\bar{D}$ or $\widehat{D}$, all instances are solved in less than 6 seconds with an average being less than 1.5 seconds. The Δ or the percentage of relative difference between $\bar{U}$ or $\widehat{U}$ is sometimes negative and sometimes positive. On average, it is $\Delta = 0.09\%$.

Table 2 summarizes the numerical analysis of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\widehat{D}}$ instances, when D is Normally distributed. Despite the choice of point estimate, all instances are solved in less than 5 seconds with an average being less than 1.5 seconds. The Δ is sometimes negative and sometimes positive. On average, it is $\Delta = -0.11\%$. These results are similar to Table 1.

Table 3 summarizes the numerical analysis of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\widehat{D}}$ instances, when D is Poisson distributed. Despite the choice of point estimate, $\bar{D}$ or $\widehat{D}$, all instances are solved in less than 6 seconds with an average being less than 1.5 seconds. Unlike Uniform or Normal data in tables 1 and 2, here Δ is always positive, and it is $\Delta = 1.27\%$, on average. A positive value of Δ means the point estimate median can return lower backorders. In addition, Δ has increased more than tenfold when data is asymmetric (Poisson distribution). This spike in the value of Δ requires further attention. In the following, we discuss whether the value of Δ shows a significant difference between point estimates $\bar{D}$ and $\widehat{D}$.

Significance of Point Estimates

To test the significance of point estimates $\bar{D}$ and $\widehat{D}$, we conduct a hypothesis test to see if the total backorder changes when we use different point estimates. Tables 4-6 investigate this. Every row of these tables corresponds to a combination of $|\mathscr{I}|$ and $|\mathscr{T}|$, in which 100 instances are generated and solved. This means 1,600 instances are solved for the significance study.

In Table 4, parameter D assumes a Uniform distribution. When comparing point estimates of this parameter, i.e. $\bar{D}$ and $\widehat{D}$, we see there is no significant change as the p_{value}'s are very large. The minimum p_{value} is 0.47 which makes the difference between backorders when using different point estimates insignificant. Similar results have been observed when D assumes a Normal distribution in Table 4. We can conclude that the difference between backorders when using different point estimates is insignificant.

Note that both Uniform and Normal distributions are symmetric. When the distribution of demand is asymmetric, such as Poisson distribution, the difference between point estimates becomes more apparent; $\Delta = 1.27\%$. Particularly, Table 6, for a Poisson distribution, shows that p_{value}'s are very small, the maximum being 0.0021. This shows that when D follows a Poisson distribution, we are more than 99.79% confident that the backorders return by mean and median demands differ from each other. Note that the setting of the hypothesis test is for the difference. If we change the setting to the smaller backorders, the p_{value}'s will become even smaller. This means we will have even more confidence that the median point estimate reduces the backorders.

CONCLUSION AND FUTURE RESEARCH

This study investigates the use of two point estimates to reduce the backorders in Capacitated Dynamic Lot Sizing problems with uncertain demands. The two point estimates are the mean and median. It is shown that median can reduce total backorders significantly when demand distribution is asymmetric, i.e. it has a Poisson distribution. However, since service levels are not studied, further analysis is needed to assure demands are satisfied.

One possible future research is to study the effects of the median point estimate using real world data. Moreover, one can investigate more point estimates and more distributions. It is very important to incorporate service levels in the study to assure demands are met at the desired level. Finally, comparison of point estimates and other stochastic optimization approaches can be another future direction of this research.

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REFERENCES

[1] Panayotis Afentakis, Bezalel Gavish, and Uday Karmarkar. Computationally efficient optimal solutions to the lot-sizing problem in multistage assembly systems. *Management Science*, 30(2):222–239, 1984.

[2] Semra Agrali. A dynamic uncapacitated lot-sizing problem with co-production. *Optimization Letters*, 6(6):1051–1061, 2012.

[3] Christian Almeder and Bernardo Almada-Lobo. Synchronisation of scarce resources for a parallel machine lotsizing problem. *International Journal of Production Research*, 49(24):7315–7335, 2011.

[4] James H. Bookbinder and Jin-Yan Tan. Strategies for the probabilistic lot-sizing problem with service-level constraints. *Management Science*, 34(9):1096–1108, 1988.

[5] Nadjib Brahimi, Stephane Dauzere-Peres, Najib M. Najid, and Atle Nordli. Single item lot sizing problems. *European Journal of Operational Research*, 168(1):1–16, 2006.

[6] Hadi Farhangi and Suman Niranjan. Inventory balance formulations and extensions of the deterministic dynamic lot sizing problem. In *2019 Annual Conference of the Decision Sciences Institute Proceedings*, pages 370–386, 2019.

[7] Stefan Helber and Florian Sahling. A fix-and-optimize approach for the multi-level capacitated lot sizing problem. *International Journal of Production Economics*, 123(2):247–256, 2010.

[8] Stefan Helber, Florian Sahling, and Katja Schimmelpfeng. Dynamic capacitated lot sizing with random demand and dynamic safety stocks. *OR spectrum*, 35(1):75–105, 2013.

[9] Yi-Feng Hung and Kuo-Liang Chien. A multi-class multi-level capacitated lot sizing model. *Journal of the Operational Research Society*, 51(11):1309–1318, 2000.

[10] Behrooz Karimi, S. M. T. Fatemi Ghomi, and J. M. Wilson. The capacitated lot sizing problem: a review of models and algorithms. *Omega*, 31(5):365–378, 2003.

[11] Anton J. Kleywegt, Alexander Shapiro, and Tito Homem de Mello. The sample average approximation method for stochastic discrete optimization. *SIAM Journal on Optimization*, 12(2):479–502, 2002.

[12] Chung-Yee Lee, Sila Cetinkaya, and Albert P. M. Wagelmans. A dynamic lot-sizing model with demand time windows. *Management Science*, 47(10):1384–1395, 2001.

[13] Jafar Rezaei, Mansoor Davoodi, Lori Tavasszy, and Mohsen Davarynejad. A multi-objective model for lot-sizing with supplier selection for an assembly system. *International Journal of Logistics Research and Applications*, 19(2):125–142, 2016.

[14] S. Armagan Tarim and Brian G. Kingsman. The stochastic dynamic production/inventory lot-sizing problem with service-level constraints. *International Journal of Production Economics*, 88(1):105–119, 2004.

[15] Horst Tempelmeier. *Stochastic lot sizing problems*, pages 313–344. Springer, 2013.

[16] Harvey M. Wagner and Thomson M. Whitin. Dynamic version of the economic lot size model. *Management science*, 5(1):89–96, 1958.

APPENDIX: TABLES

Table 1: Instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\hat{D}}$ problems when D has a Uniform distribution

$\lvert\mathscr{I}\rvert$	$\lvert\mathscr{T}\rvert$	$cpu\,(\mathscr{P}_{\bar{D}})$	$cpu\,(\mathscr{P}_{\hat{D}})$	$\Delta\%$
10	40	0.102	0.106	0.16
	60	0.176	0.173	0.79
	80	0.281	0.277	0.3
	100	0.402	0.383	0.29
20	40	0.33	0.269	0.29
	60	0.575	0.523	0.37
	80	1.004	0.83	-0.18
	100	1.482	1.273	0.12
30	40	0.58	0.513	-0.06
	60	1.447	1.025	-0.1
	80	2.315	1.757	-0.46
	100	3.209	2.68	-0.01
40	40	0.906	0.842	0.27
	60	1.888	1.712	-0.33
	80	3.644	2.851	0.54
	100	5.354	4.229	-0.55
Average		1.481	1.215	0.09

Table 2: Instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\hat{D}}$ problems when D has a Normal distribution

$\lvert\mathscr{I}\rvert$	$\lvert\mathscr{T}\rvert$	$cpu\,(\mathscr{P}_{\bar{D}})$	$cpu\,(\mathscr{P}_{\hat{D}})$	$\Delta\%$
10	40	0.13	0.106	-0.27
	60	0.188	0.173	-0.15
	80	0.29	0.284	-1.4
	100	0.418	0.393	-1.13
20	40	0.405	0.281	0.52
	60	0.623	0.525	0.15
	80	1.003	0.83	0.2
	100	1.457	1.221	-0.04
30	40	0.585	0.52	-0.03
	60	1.225	1.044	-0.06
	80	1.911	1.638	0.14
	100	3.273	2.407	-0.28
40	40	1.025	0.827	-0.03
	60	2.004	1.632	0.24
	80	3.297	2.704	0.34
	100	4.888	4.177	0.04
Average		1.42	1.173	-0.11

Table 3: Instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\hat{D}}$ problems when D has a Poisson distribution

$\lvert\mathscr{I}\rvert$	$\lvert\mathscr{T}\rvert$	$cpu\,(\mathscr{P}_{\bar{D}})$	$cpu\,(\mathscr{P}_{\hat{D}})$	$\Delta\%$
10	40	0.096	0.105	0.5
	60	0.188	0.181	1.05
	80	0.288	0.291	1.23
	100	0.432	0.42	1.8
20	40	0.319	0.283	0.72
	60	0.607	0.529	1.41
	80	0.872	0.852	1.5
	100	1.313	1.281	2.02
30	40	0.66	0.527	0.74
	60	1.151	1.024	1.05
	80	1.933	1.761	1.44
	100	2.975	2.627	1.89
40	40	0.913	0.835	0.64
	60	2.087	1.752	1.34
	80	3.61	3.113	1.27
	100	5.165	4.794	1.78
Average		1.413	1.273	1.27

Table 4: p_{value} comparison of instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\hat{D}}$ problems, when D has a Uniform distribution

$\lvert\mathscr{I}\rvert$	$\lvert\mathscr{T}\rvert$	p_{value}
10	40	0.98
	60	0.77
	80	0.06
	100	0.10
20	40	0.87
	60	0.70
	80	0.48
	100	0.68
30	40	0.31
	60	0.98
	80	1.00
	100	0.71
40	40	0.74
	60	0.70
	80	0.47
	100	0.73

Table 5: p_{value} comparison of instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\hat{D}}$ problems, when D has a Normal distribution

$\lvert\mathscr{I}\rvert$	$\lvert\mathscr{T}\rvert$	p_{value}
10	40	0.93
	60	0.54
	80	0.95
	100	0.89
20	40	0.89
	60	0.58
	80	0.61
	100	0.71
30	40	0.96
	60	0.72
	80	0.47
	100	0.60
40	40	0.83
	60	0.64
	80	0.93
	100	0.87

Table 6: p_{value} comparison of instances of $\mathscr{P}_{\bar{D}}$ and $\mathscr{P}_{\hat{D}}$ problems, when D has a Poisson distribution

$\lvert\mathscr{I}\rvert$	$\lvert\mathscr{T}\rvert$	p_{value}
10	40	2.10E-03
	60	7.50E-07
	80	1.63E-05
	100	6.25E-09
20	40	1.39E-06
	60	1.61E-07
	80	2.86E-09
	100	1.09E-12
30	40	2.89E-07
	60	1.25E-13
	80	1.94E-14
	100	6.96E-17
40	40	8.66E-12
	60	2.36E-13
	80	3.41E-16
	100	2.73E-19

DEVELOPMENT OF A SUPPLY CHAIN MANAGEMENT FRAMEWORK

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ABSTRACT

This study examined supply chain strategy best practices and key factors impacted by COVID-19 used to develop an improved framework for implementing a comprehensive supply chain strategy. The framework consists of evaluating key components and critical factors typically included in developing a reactive supply chain strategy. Each of the critical factors were identified throughout a thorough literature review and comparative analysis to define commonalities among them. This research leverages a Design Science Framework to identify critical factors relevant to a comprehensive SC strategy and describes the process needed to validate and implement.

INTRODUCTION

The COVID-19 pandemic has had a detrimental impact on supply chains throughout the world. The need for data reliability, transparency, and accessibility throughout the extended supply chain (SC) is paramount to facilitate strategic and tactical decisions supported by scientific evidence. As far back as 1973, supply chain resilience has been described as the ability of a supply chain to either resist disruptions or recover operational capability after disruptions occur (Holling, 1973). According to Ivanov (2019a), the ripple effect impact causes disruption on supply chain (SC) performance, and the disruption is propagated downstream throughout the SC network. Unlike the bullwhip effect which triggers small variation in demand, this deterioration on the structural dynamics of a SC is severe and causes the downstream propagation of degradation in demand fulfilment that has a high impact on performance (Ivanov, 2019b). The ripple effect is enhanced by the fact that SCs act in isolation; stakeholders only allow other stakeholders that are immediate members of their SC access to information and product visibility.

Melnyk, Closs, Griffis, Zobel and Macdonal (2015) address SC resilience, and use the term resistance capacity to refer to the ability of the system to minimize disruption impact by avoiding it entirely or by minimizing the time between the onset of the disruption and beginning of containment. Alternatively, the term recovery capacity refers to the system's ability to return to functionality once disruption occurs (Melnyk et al., 2015). In either instance, both would require a period of containment, stabilization, and return (Figure 1).

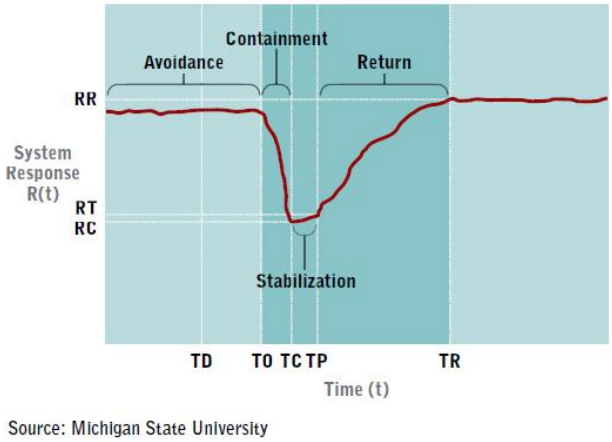

Figure 1: Time Series Display of SC Resilience Factors
Source: Melnyk et al., 2015, p. 36

Because supply chain members operate within their individual value chain, pivoting outside of their network can be difficult during a time of disruption. Ivanov and Dolgui (2020) point out that in response to disruption however, SC resistance should be evaluated at the intertwined supply network level of viability (Figure 2) defined as "a systems ability to meet the demands of surviving in a changing environment" (p. 2906). This will help mitigate SC collapse and market degradation and ensure the steady flow of goods and services.

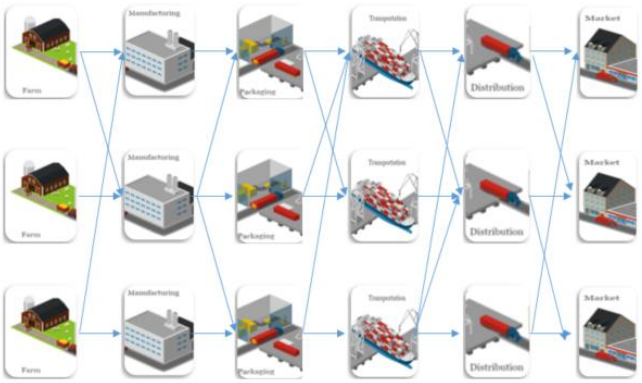

Figure 2: Intertwined SC Network
Adapted from: Ivanov & Dolgui, 2020, p. 2905

BACKGROUND

Supply chains (SC) are complex in nature due to the inter-connectivity and inter-dependencies that exist amongst a distributed network. Without a comprehensive *SC Strategy,* members of diverse supply chains are struggling to manage disruptions caused by the Covid-19 global pandemic. A *SC Strategy* ensures coordination, cooperation, and collaboration of partners throughout the extended SC.

A sound *SC Strategy* is dependent upon a unified view within a complex ecosystem that starts with the creation of a multi-tier SC Network Map. Identification of first tier partners is not enough. Visibility of alternative supply and demand of second and third tier partners is essential. Forging a unified and centralized vision of the extended supply chain allows for preparedness and response in a cohesive and expeditious fashion and allow for SC agility and resilience. Transparency and communication amongst strategic alliance partners will provide access to critical information and foster dynamic decision-making during times of crisis.

PROBLEM

Due to the labor, cost, and time limitations, many organizations do not have a comprehensive list of members within their SC network. Furthermore, many SCs do not leverage a common communication platform to foster communication with members of their extended SC. As a result, when crises disrupt the existing SC, its partners often revert to manual and anecdotal mechanisms to react and respond. Without a comprehensive SC Strategy and transparency across the SC, members throughout the extended SC remain disconnected. They are slow to regain access to their customers due to lack of visibility and collaboration. Integrated SC networks, on the other hand, enable fast reconfiguration to cope with chaotic environments that result from natural and human-made disasters. Integrated SCs are strategic and therefore more resilient than organizations acting in isolation.

VISION

This research proposes a framework for the development of an integrated SC Strategy that would reduce the complexity and vulnerability throughout the extended supply chain. This proactive solution will maximize visibility within and between members. In essence, it would enhance the economic

security of firms through the initiation of a proactive technique. This will ensure preparedness through the design and use of management strategies that will lessen knowledge gaps during times of disruption.

The development of a Supply Chain Strategy will help stakeholders within global supply chains to develop strategies and implement solutions to mitigate threats and response to chaos caused by disruptions. The solution would be viable during normal economic conditions and would be essential during a natural disaster or pandemic, minimizing the lag between impact, stabilization, and recovery. This would help minimize destabilization and economic impact.

A supply chain strategy controls the inbound development of suppliers for the procurement of raw materials and subassemblies, logistical decisions including transportation of materials to/within/from suppliers and customers and within the company, the design and manufacturing of products or processes to deliver a service, as well as maintenance decisions. Puica, E. (2021), identifies the following key factors that impact the supply chain efficiency and responsiveness:

a. Facilities
b. Inventory
c. Transportation
d. Information
e. Sourcing
f. Pricing

Sarkis, J. (2020) describes how the COVID-19 crisis created upheaval in supply chains, from the toilet paper and hand sanitizer shortage to the closing of international borders to reduce the potential spread of the virus, impacting the global food supply chain. Recently, the labor shortage in the United States has wreaked havoc in the service, manufacturing, and logistics industries.

METHODOLOGY

The study identifies key strategic criteria to be included in a supply chain strategy tool. Initially, a literature review and discussion with supply chain managers was the starting point for identifying known weaknesses for each supply chain member. The first draft of the criteria will be presented to 30 subject matter experts.

Onofrei, Nguyen, Zhang, and Fynes (2020) investigated how forging a relationship with suppliers and customers enhanced relationship capital and ultimately innovative marketplace performance. Therefore, we propose including the extended supply chain members in the entire Supply Chain Strategy (SCS) development process, not just that of the business case. Additionally, regarding both customer and supplier assessments, the assessment should extend beyond tier 1 to include as many tiers as deemed appropriate and include the six key processes – plan, source, make, deliver, return, and enable (Figure 3).

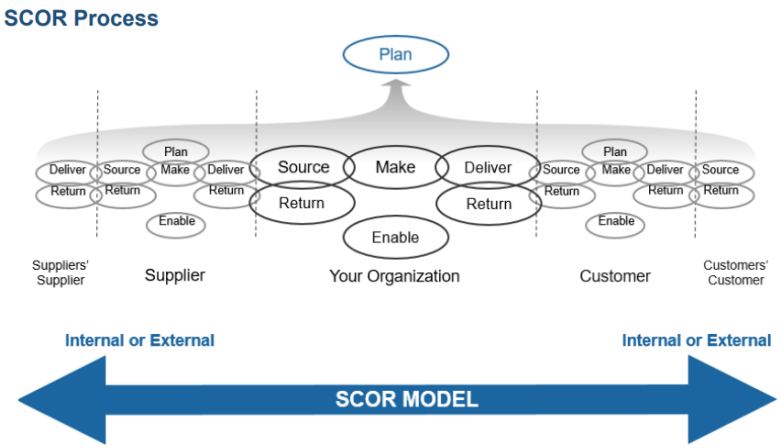

Figure 3
(Source: Supply-Chain Council, 2017)

Because of the disruption of technology, it can also be argued that organizations interested in developing a SCS should constantly scan the marketplace for the latest developments to include in their design. Ardito, Petruzzelli, Panniello, & Garavelli (2019) proport Industrial IoT, cloud computing, Big Data analytics and cyber security are imperative technologies associated with supply chain integration. Because big data analytics now plays a crucial role in creating sustainable supply chains to optimize business processes and simplify decision making across the extended supply chain, we propose a Big Data analytics be consolidated with KPIs in the SCS development process for identifying relevant data required to optimize the supply chain. (Dubey et al., 2018; Ren et al., 2019).

Big Data Analytics (BDA) could play a crucial role in developing a reactive supply chain strategy. BDA can increase communication real-time, and add value to help companies attain operational excellence for their existing supply chain operations. Technologies impact on supply chain strategies and the opportunities they provide are assessed by Puica (2021). Partnerships throughout the extended supply chain should be forged to ensure the delivery of customer value. Articulating partner expectations is a critical component of achieving success when implementing a supply chain strategy.

RESULTS

A literature review was conducted to identify key factors necessary for a successful supply chain strategy (Dittmann, 2013; Onofrei et el., 2020; Supply-Chain Council, 2017; Dubey et al., 2018; Ren et al., 2019). The critical factors were matched to corporate objectives to determine the roadmap that companies need to keep in mind when implementing a supply chain strategy (Figure 4). The identified critical factors will be foundational to the creation of an assessment tool.

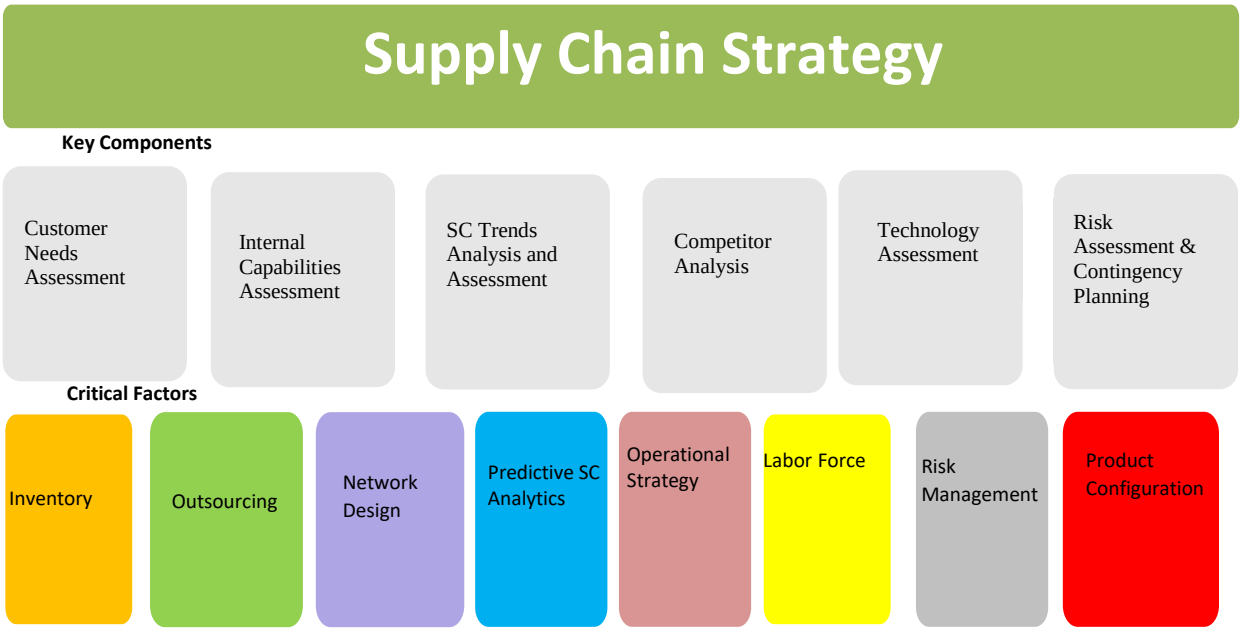

Figure 4: Supply Chain Strategy Key Factors

FUTURE WORK

The detailed analysis of the critical factors will be identified, and Big Data technologies evaluated. The model will be presented to a group of 30 executives to obtain feedback and the next activity is to combine everything into the model. This step requires putting together one template for each of the critical factors, including the best practices defining each one. The combination of the research questions will provide all the elements required to create the supply chain strategy assessment tool. The assessment tool will be used in several enterprises across industries, including the food, wood product, and logistical industries, and analyzed for similarities and differences across the critical factors. The tool will be evaluated using Gap analysis for refinement of the tool and the analytics output.

SUMMARY

Supply chain strategic planning was impacted greatly by the COVID-19 pandemic. Global organizations found themselves addressing challenges never considered previously. Product shortages, closed international borders, and labor shortages caused longer lead times, longer customer responsiveness and changes to customer needs. Supply chain strategies now need to be more reactive and implement key technologies that enhance the ability to communicate quickly and efficiently. Physical facilities became empty from all but essential workers, and adaptive workforce management strategies needed to be implemented. This exploratory research identifies critical factors that will help organizations implement an effective, efficient, and responsive supply chain strategy.

REFERENCES

Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C. (2019). Towards Industry 4.0: Mapping digital technologies for supply chain management-marketing integration. *Business Process Management Journal*.

Dittmann, J. P. (2013). *Supply chain transformation: building and executing an integrated supply chainstrategy*. McGraw-Hill.

Dubey, R., Gunasekaran, A., Childe, S.J., Luo, Z., Wamba, S.F., Roubaud, D., & Foropon, C. (2018). Examining the role of big data and predictive analytics on collaborative performance in context to sustainable consumption and production behaviour. *Journal of Cleaner Production*, 196, pp. 1508-1521

Holling, C.S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systemics, 4*, 1-23. DOI: 10.1146/annurev.es.04.110173.000245

Ivanov, D. & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. *International Journal of Production Research, 58 (10),* 2904-2915. DOI: 10.1080/00207543.2020.1750727

Ivanov D., Dolgui A., & Sokolov B. (2019a). Ripple Effect in the Supply Chain: Definitions, Frameworks and Future Research Perspectives. In: D. Ivanov, A. Dolgui, & B. Sokolov (Eds.), *Handbook of Ripple Effects in the Supply Chain. International Series in Operations Research & Management Science* (Vol. 276, pp. 1-33). https://link.springer.com/book/10.1007/978-3-030-14302-2

Ivanov D., Tsipoulanidis A., & Schonberger J. (2019b). Global Supply Chain and Operations Management. Springer, 2nd Ed, Cham.

Lambert, D. M., & Knemeyer, M. (2004). We're in This Together. *Harvard Business Review.*

Melnyk, S.A., Closs, D.J., Griffis, S.E., Zobel, C.W. & Macdonald, J.R. (2014). Understanding supply chain resilience. *Supply Chain Management Review*, 18 (1), 34-41. https://www.researchgate.net/publication/285800059_Understanding_supply_chain_resilience

Onofrei, G., Nguyen, H. M., Zhang, M., & Fynes, B. (2020). Building supply chain relational capital: The impact of supplier and customer leveraging on innovation performance. *Business Strategy and the Environment*, *29*(8), 3422-3434.

Puica, E. (2021). A classification predictive model to analyze the supply chain strategies. *Informatica Economica, 25*(2), 29-39. doi:http://dx.doi.org/10.24818/issn14531305/25.2.2021.03

Ren, S., Zhang, Y., Liu, Y., Sakao, T., Huisingh, D., & Almeida, C.M. (2019). A comprehensive review of big data analytics throughout product lifecycle to support sustainable smart manufacturing: a

framework, challenges and future research directions. *Journal of Cleaner Production*, 210, pp. 1343-1365.

Sarkis, J. (2020). Supply chain sustainability: Learning from the COVID-19 pandemic. *International Journal of Operations & Production Management, 41*(1), 63-73. doi:http://dx.doi.org/10.1108/IJOPM-08-2020-0568

Supply-Chain Council (2017), *APICS Supply-Chain Operations Reference Model* (Version 12.0). http://www.apics.org/docs/default-source/scor-training/scor-v12-0-framework-introduction.pdf?sfvrsn=2

Tsai, F. M., Bui, T. D., Tseng, M. L., Ali, M. H., Lim, M. K., & Chiu, A. S. (2021). Sustainable supply chain management trends in world regions: A data-driven analysis. *Resources, Conservation and Recycling*, *167*, 105421.

GREEN SUPPLY CHAIN MANAGEMENT: MOTIVATIONS AND OUTCOMES FOR SUSTAINABLE PACKAGING INITIATIVES

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ABSTRACT

Companies pursue resource conservation initiatives for a number of reasons, including government mandate, customer mandate, cost improvement, market penetration, and social responsibility. The objective of reducing waste or increasing recyclable content can involve detailed investigations of all supply chain modes to fully understand what resources are consumed at each packaging point, and evaluations of a series of alternatives each with different costs, logistical considerations, sourcing issues, and inherent environmental impacts. Initiatives are then undertaken based on a particular assessment of the expected costs and benefits of each program, while the actual costs and benefits may be quite different post-implementation. The degree of variation between expectation and outcome is a subject for further understanding.

1. INTRODUCTION

Across the globe companies, governments, social service organizations, and individual citizens are supporting the adoption of "green" initiatives to aid in the transition to a more sustainable global existence. Many current manufacturing, energy generation, agricultural production, and transportation practices are perceived to be overly harmful to the environment and wasteful of valuable scarce natural resources. The following are various reasons that changes may be implemented:

- To comply with legal requirements
- To pursue operating cost reductions
- To appeal to a particular target market of consumers
- To comply with customer product specifications
- To demonstrate commitment to a popular societal movement
- To gain the support of a particular political constituency
- To satisfy an internal objective to "do the right thing"
- To improve the form, function, or quality of a product or process

Over the past several decades the specialized field of Green Supply Chain Management (GSCM) has developed in response to the increasing emphasis being placed on resource conservation, sustainability, and corporate social responsibility. The green supply chain consists of analyzing every element of material flow in an industry including supplier selection, material specification/composition, transportation and logistics, packaging, and disposal. Each step in the process is studied to identify opportunities for improvements in resource conservation. It may be less fuel used in the transport of products, less non-recyclable material used in manufacturing, reductions in the amount of single-use packaging required in value chain processes, or reductions in the amount of material inputs used in the manufacturing process.

This paper focuses on the particular subset of GSCM known as "green packaging." Packaging is described as not simply a carton or a box, but it is a system that enables the safe, cost-effective and efficient storage, handling, transportation, and marketing of goods along the supply chain [3]. Green packaging, then, is packaging which is designed, constructed, and used in a manner that generates the least amount of waste and/or maximizes recycle or reuse opportunities at some or all positions along the supply chain.

Green packaging has received such a significant amount of attention as an opportunity for resource conservation due to the vast amount of packaging used in manufacturing, distribution, and commerce. To give some scale to the subject consider that data collected from FedEx, UPS, and USPS reveals that 165 billion packages are shipped in the U.S. per year which use up cardboard packaging made from approximately 1 billion trees [12]. Figure 1 shows a simplified value chain structure and examples of the multiple different packaging types required to progress through the supply chain from raw material to end consumer. Only the steel intermodal shipping container is considered reusable in this scenario. The rest of the modes are at best recyclable and more likely to be disposed of as waste streams.

This paper reviews several initiatives to measure reductions in resource consumption related to packaging, primarily focusing on the manufacturing sector. Manufacturing supply chains can be quite elaborate, consisting of the packaging and transportation of materials ranging from raw natural resources like iron ore or platinum, to highly processed finished goods such as artificial hips for surgical implantation, which require special sterilized packaging for safe transport and delivery to the point of use. Packaging materials used in these processes can include paper, corrugated cardboard, glass, various types of plastic, wood, steel, aluminum, rubber, and chemicals such as disinfectants, rust inhibitors, and lubricants.

While the motivations for implementing sustainability-enhancing initiatives may be clearly understood, the anticipated outcomes as compared to the realized outcomes offer an intriguing opportunity for further investigation. Was the initiative successful in achieving its conservation goals? Was there an unanticipated favorable or unfavorable cost impact to the initiative? Was there an unanticipated favorable or unfavorable impact to the organization's image or reputation as a result of the initiative? These and other questions will aid in constructing a framework for properly evaluating a more comprehensive picture of the costs and benefits of undertaking "green" initiatives.

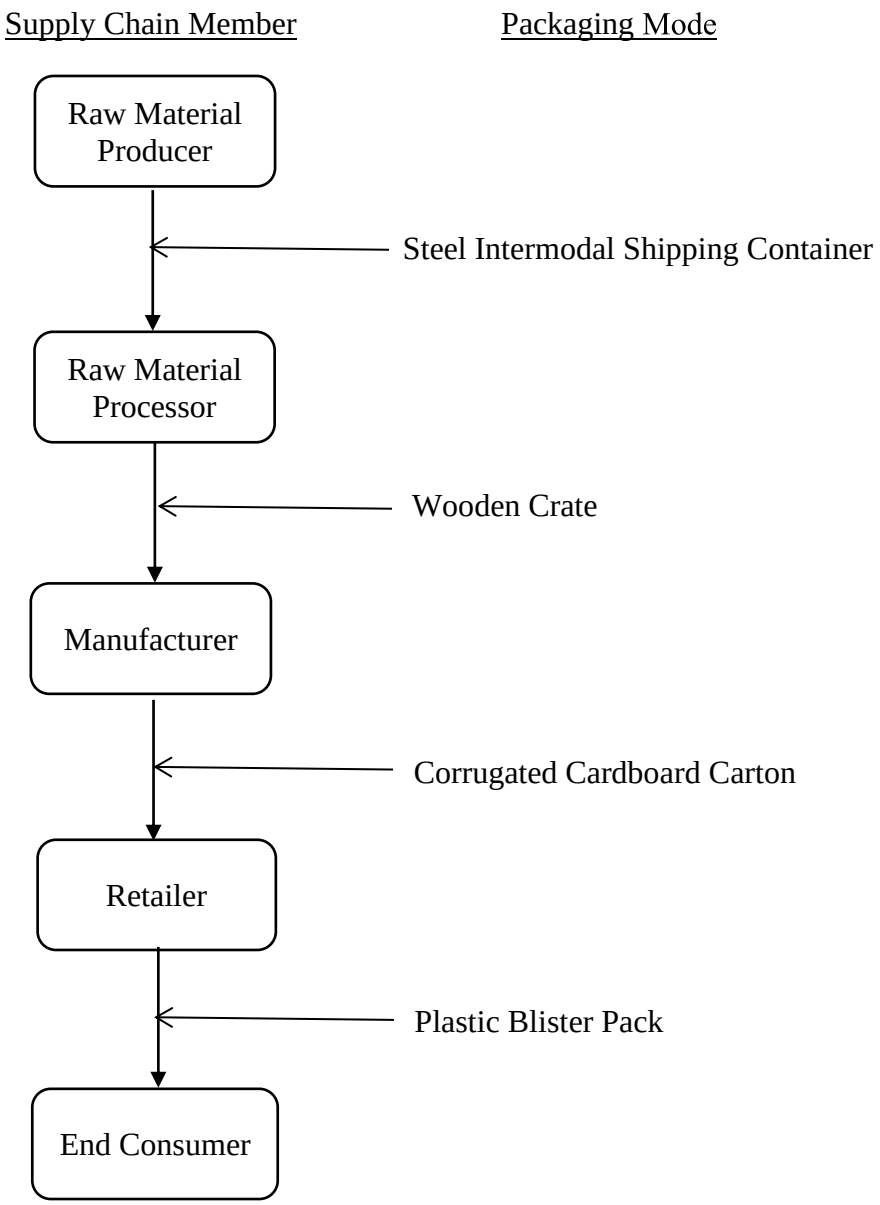

FIGURE 1. REPRESENTATIVE SUPPLY CHAIN PACKAGING MODES

2. LITERATURE REVIEW

Three primary stratifications have been identified to facilitate the review of existing published studies of green supply chain and green packaging implementations:

- Customer/Consumer-oriented adoption assesses the preference or loyalty-enhancing attributes of green packaging initiatives by the customer base and whether other attributes may outweigh "greenness."

- Financial/Performance-oriented adoption involves the impact on the bottom line of companies based on their adoption of GSCM principles in general, with associated applicability to packaging improvements.

- Process-oriented adoption specifically reviews initiatives to replace expendable packaging with returnable/reusable packaging, and evaluates the net overall benefit/cost to the company.

A summary of research papers on green supply chain and green packaging is given in Table 1.

TABLE 1. LITERATURE REVIEW ON GREEN SUPPLY CHAIN AND GREEN PACKAGING IMPLEMENTATIONS

Reference	Focus	Keywords
Customer/Consumer		
Orzan, Cruceru, Balaceanu, and Chivu [10]	Consumer behavior in sustainable packaging	Sustainable consumer behavior, environmental protection
Rokka and Uusitalo [13]	Consumer behavior in product attributes including sustainable packaging	Consumer preference, product choice, environmental packaging and labels, conjoint analysis, segmentation
Martinho, Peres, Portela, and Fonseca [7]	Factors affecting consumers' choices in sustainable packaging	Sustainable packaging, theory of planned behavior, environmental awareness, packaging features, demographics, recycling behavior
Financial/Performance		
Tavares, Vanalle, and Camarotto [14]	Economic, environmental, and operational outcomes of green initiatives in packaging supply chain	Green supply chain, packaging, green packaging, green initiatives, environmental outcomes, economic outcomes, operational outcomes
Vijayvargy and Agarwal [15]	GSCM practices and their impact on organizational performance	Green supply chain, organizational performance, operational performance, financial performance, environmental performance, green purchasing
Liu [6]	Relationships between environmental and financial performance	Environmental performance, financial performance, green operations, sustainability, multilevel
Process		
Accorsi, Cascini, Cholette, Manzini and Mora [1]	Environmental and economic impacts of reusable packaging container implementation	Packaging, food supply chain (FSC), life cycle assessment (LCA), sensitivity analysis, sustainability
Menesatti, Canali, Sperandio, Burchi, Devlin and Costa [8]	Comparison of cost and waste between reusable and disposable containers	Cut flowers, reusable containers, supply chain, net present value, waste reduction
Palsson, Finnsgard and Wanstrom [11]	Packaging system alternatives and sustainability	Automotive, logistics, model, packaging, sustainability

2.1. Customer/Consumer-Oriented Adoption

Many companies pursue environmentally-friendly packaging schemes because their customers have made it clear that they would prefer to buy a product that comes in sustainably-produced packaging over a product that does not. But when the sustainable packaging comes at a price penalty to the consumer, it has been found that even if the perceived costs exceed the perceived benefits, the consumer will not act to conserve the environment even if they are sympathetic towards environment [10]. This study used an online survey of 268 consumers in Romania to assess their attitudes about packaging types, availability of information, sensitivity to price differences, and motivations for buying products in sustainable packaging. While a relatively small study confined to a single country outside of North America, it does highlight the importance of providing a sufficient level of information to the consumer about the overall benefits of the sustainable packaging in order to offset a portion of the cost concerns.

Another consumer-based study, based on survey responses of 330 consumers in Finland, found that given choices among multiple product attributes such as price, resealability (for a drink product), environmentally-friendly packaging, and brand, a not insignificant portion of the respondents ranked the recyclability of the packaging as a primary attribute for product selection, even over the relative price attribute [13]. These findings give some hope to the marketers of green-packaged products that they may not be at such a severe competitive disadvantage based solely on price. Rokka and Uusitalo [13] conclude in their findings that companies can benefit from helping consumers concretely, for example, by offering new environmental product alternatives, green packaging, and labels.

A third study in the area of consumer choice relative to packaging sustainability, this one using data from an online survey of 215 respondents in Portugal, also highlights the significance of the price attribute relative to the green packaging attribute: The price of a product is the main aspect that must be considered to make sustainable packaging influence the consumers' choice in a substantial way [7]. This study also pointed to the importance of informational efforts in the marketing campaign as a means to elevate the importance of the sustainable packaging attribute in the minds (and consciences) of the consumers.

2.2. Financial/Performance-Oriented Adoption

The broad adoption of GSCM principles and practices across global industries leads many companies to believe they must implement sustainability measures simply to remain competitive in the global marketplace. This implementation comes at a cost, either in additional capital assets, higher unit production costs, or alternative material sourcing. Companies still expect a "return on investment" for their expenditures, but in this context the return may be difficult to correlate to a specific green initiative, and/or difficult to quantify. Several studies have undertaken the objective of correlating sustainability with improved financial, operating, and market performance.

Tavares et al. [14] studied the impact of green initiatives, specifically in the packaging supply chain in Brazil, via an online survey completed by 124 respondents, which was found to be a

statistically sufficient data set. The data was analyzed using statistical methodologies which arrived at the following conclusions:

- "it was not possible to show that the majority of respondents perceive that the green purchasing initiative influences the economic and operational outcomes of companies," [14, p. 12) and
- "The adoption of the green purchasing initiative influences the environmental outcome of the company" [14, p. 11].

This indicates that GSCM initiatives are more likely a cost driver in an organization, but with the intended improvement in environmental performance.

Vijayvargy and Agarwal [15] utilized statistical modeling techniques to assess linkages between GSCM practices and related environmental, operational, and financial performance. A questionnaire was distributed with responses from 161 organizations in Indian industry. The data was compiled and subjected to reliability testing and hypothesis testing. The authors concluded that "the findings indicate that external pressures force companies to adopt GSCM practices enabling environmentally-friendly moves, improving efficiency, enhancing flexibility, and augmenting organizational performance cost effectively" [15, p. 38). This indicates that there are indeed benefits to be realized beyond just the environmental improvement companies initially set out to generate. The question remains, however, of what the magnitude of the improvement may be and in particular what was the improvement as compared to the anticipated improvement.

Liu [6] performed a relatively large-scale statistical analysis on the 500 largest publicly traded companies in the United States using widely available published information to establish their environmental performance (EP) and financial performance (FP). Many studies have proceeded with a similar objective, with mixed results. Some found unfavorable relationships among the two factors, meaning that as environmental performance went up, financial performance declined, and vice versa [4] [9], while others found a positive relationship between the two factors, meaning as environmental performance increased, financial performance also increased [2] [5]. Liu's work sought to establish more concrete causality between EP and FP, given the constraints of industry, firm size, and market differences. Liu [6] concludes that "the company's EP and FP are positively related overall, suggesting that in general a proactive EM strategy is helpful in improving future FP (i.e. it does pay to be green)" [6, p. 336). The data set and methodologies used in this study make it a fairly compelling support for the implementation of EM (environmental management), also described as GSCM (green supply chain management) or at the very least a counterpoint to the argument that EM is only a cost driver.

2.3. Process-Oriented Adoption

A particular implementation mode of GSCM that has gained prominence in the manufacturing and distribution sectors is the adoption of durable, returnable, reusable containers for transport of goods rather than disposable, single-use packaging such as corrugated cardboard. As shown in Figure 1, illustrating that 3 of the 4 distribution modes may consist of single-use disposable packaging (A wooden crate may arguably be reusable but its durability is suspect). Each of these

single-use modes represents a waste stream, which is contrary to the pursuit of increased sustainability, and may be economically disadvantageous to final product cost.

Evaluations of the effectiveness both in terms of environmental and economic benefits from reusable packaging have shown mixed results, however, which indicates that more diligence is required in project planning and implementation in order to preempt any unexpected unfavorable outcomes. Much more is involved in the project scope than simply the purchase price of a disposable container as compared to the purchase price and repeat utilization of a durable returnable container. There is the cost of return and its associated environmental considerations, cost of excess inventory or excess material handling when containers are not returned in a timely manner, cost of storage and cleaning of reusable containers, and repair or replacement costs.

One case study examined the use of durable plastic containers rather than disposable wooden or cardboard containers in the perishable food supply chain in a particular region of Italy (Emilia-Romana). The packaging and transport from farm to distributor to customer and return of containers was analyzed, including quantifications for such activities as cleaning of reusable containers and recycling of single-use containers. The research concluded that "the analysis shows that for the case study in question, adoption of an RPC (reusable plastic container) system will lead to a reduced environmental impact…However, the overall economic return is projected to be negative…" [1].

Another study, also in Italy but this time looking at the distribution of fresh cut flowers, evaluated the costs and environmental impacts of disposable single-use packaging as compared to returnable reusable plastic containers, and found that "the use of an RU (reusable) system assures a production with less waste and less environmental pressures…Moreover, the system is also economically advantageous." [8].

The preceding examples both dealt with uniquely time-sensitive products that required prompt packaging and transport to ensure their viability for market. So another example, from a less perishable (but certainly still time-sensitive) industry is appropriate. A case study was performed on a particular logistics mode at the Volvo Car Company to evaluate the use of returnable packaging compared to disposable packaging. This model used a quite comprehensive set of assessment tools to arrive at an evaluation of the supply chain characteristics and associated costs and benefits beginning from the component product source location and progressing through to its destination at final assembly, including all related transit and return points. In this particular case, which studied transport of a wiring harness from Turkey to Sweden, and the associated environmental and economic impacts, the model found that the one way packaging was favorable both from environmental and economic perspectives [11]. While this is counter-intuitive to the concept of returnable packaging being less harmful to the environment, the strength of the model stems from its incorporation of a more holistic evaluation of the incremental impacts of each supply chain alternative.

3. DISCUSSION AND PROPOSAL

Review of the extant literature has generated several key points about the potential impacts of GSCM initiatives on the environmental, financial, and operational outcomes of organizations seeking to adopt them.

First, the consumer can be a fickle associate to engage in commerce with. While outwardly expressing the level of importance of certain product attributes based on broad societal trends, the consumer may take their buying power in a totally different direction when it comes down to final purchase commitment. It has been found that price is often the overriding product attribute, and the perceived value of corporate environmental or social responsibility engagement is liable to be overestimated.

Second, there can be a misplaced bias against implementing environmental improvement initiatives because they are perceived to be cost drivers without incremental value returned to the organization. Similar to regulatory compliance costs, these initiatives can be characterized as not generating sufficient return on investment to pursue, when in reality there may be compound improvements in environmental, economic, and operational performance. Again, the Liu model [6] is a compelling tool for confirming linkage between environmental and financial performance. The critical factor for organizations is to establish a reasonable range of expected results from an initiative in order to estimate the benefits vs. costs appropriately.

Third, there are multiple models available to support the evaluation of the effectiveness of returnable packaging as opposed to disposable packaging. The results, however, can vary widely by industry, geographic distance, product physical characteristics, and perishability. Our assessment is that the model developed by Palsson et al. [11] has a level of robustness based on including broad dimensions of impacts that give it particular strength in evaluating these projects.

Our proposal for furtherance of the body of research in this area is twofold:

1) Multiple additional case studies utilizing the Palsson model to confirm its applicability to the subject of evaluating the cost/benefit characteristics of returnable vs. disposable packaging in the supply chain. Utilizing different scenarios for product type, package type, geographic distance, and protective qualities would generate an insightful array of data upon which to build additional decision-support criteria.

2) A supplemental study, in the form of a survey of a meaningful population of geographically and industry-diverse manufacturers and distributors. The purpose of this study is to generate a statistical analysis of the organizations' degree of engagement in GSCM principles, and how the results of their improvement initiatives have measured up to their expectations upon implementation.

4. HYPOTHESES

1) Our expectation of the additional data generated by the Palsson model is that given relatively simple and inexpensive disposable packaging, as travel distance increases, the favorability of reusable packaging declines. The return transport costs and environmental impact will exceed the disposal costs (particularly if recycling is prevalent) and environmental impact of single-use packaging.

2) We expect the overall graphical representation of the survey response data to show clusters of organizations that experienced greater cost upon implementation than expected, and clusters that experienced lower than expected favorable consumer response to their green packaging initiatives. The magnitude of the deviations in cost and/or consumer response will be most intriguing.

5. CONCLUSIONS

One of the most important questions faced by a company leadership team and board of directors is "Are we investing the financial resources of the company wisely, in a manner that will generate an adequate return to our shareholders?" Notwithstanding the altruistic motivations for companies' pursuit of environmental resource conservation, there must also be an effective way to determine whether the benefits derived outweigh the costs incurred, or the return on investment.

Many models exist currently, two of which, the Liu model [6] and the Palsson et al. model [11], show particular promise in supporting the "go/no-go" decisions companies face in their pursuit of improved sustainability and financial performance in the area of GSCM. These models enable the justification of projects based on comprehensive evaluations of the resources consumed vs. resources saved, providing useful guidelines for project comparisons. Our proposal seeks to provide a framework for establishing the statistical frequency and degree of outcomes that either surpass or underperform the projected objectives.

REFERENCES

[1] Accorsi, R., Cascini, A., Cholette, S., Manzini, R. & Mora, C. Economic and environmental assessment of reusable plastic containers: A food catering supply chain case study. *International Journal of Production Economics*, 2014, 152, 88-101.

[2] Christmann, P. Effects of "best practices" of environmental management on cost competitiveness: The role of complementary assets. *Academic Management Journal*, 2000, 43 (4), 663-680.

[3] Dixon-Hardy, D.W. & Curran, B.A. Types of packaging waste from secondary sources (supermarkets) – The situation in the U.K. *Waste Management*, 2009, 29(3), 1198-1207.

[4] Jacobs, B.W., Singhal, V.R. & Subramanian, R. An empirical investigation of environmental performance and the market value of the firm. *Journal of Operations Management*, 2010, 28(5), 430-441.

[5] Konar, S. & Cohen, M.A. Does the market value environmental performance? *Review of Economics and Statistics*, 2001, 83(2), 281-289.

[6] Liu, Z. Unraveling the complex relationship between environmental and financial performance – A multilevel longitudinal analysis. *International Journal of Production Economics*, 2020, 219, 328-340.

[7] Martinho, G., Pires, A., Portela, G. & Fonseca, M. Factors affecting consumers' choices concerning sustainable packaging during product purchase and recycling. *Resources, Conservation and Recycling*, 2015, 103, 58-68.

[8] Menesatti, P., Canali, E., Sperandio, G., Burchi, G., Devlin, G. & Costa, C. Cost and waste comparison of reusable and disposable shipping containers for cut flowers. *Packaging Technology and Science*, 2012, 25(4), 203–215.

[9] Ngwakwe, C.C. Environmental responsibility and firm performance: Evidence from Nigeria. *International Journal of Humanities and Social Science*, 2009, 3, 97-104.

[10] Orzan, G., Cruceru, A.F., Bălăceanu, C.T. & Chivu. R.G. Consumers' behavior concerning sustainable packaging: An exploratory study on Romanian consumers. *Sustainability*, 2018, 10(6), 1787.

[11] Palsson, H., Finnsgard, C. & Wanstrom, C. Selection of packaging systems in supply chains from a sustainability perspective: The case of Volvo. *Packaging Technology and Science*, 2013, 26, 289-310.

[12] Peters, A (2018). Can online retail solve its packaging problem? accessed April 20, 2018, available at https://www.fastcompany.com/40560641/can-online-retail-solve-its-packaging-problem.

[13] Rokka, J. & Uusitalo, L. Preference for green packaging in consumer product choices – Do consumers care? *International Journal of Consumer Studies*, 2008, 32, 516-525.

[14] Tavares, A.C.S., Vanalle, R.M. & Camarotto, J.A. Influence of green initiatives on environmental, economic, and operational outcomes: The case of the Brazilian packaging supply chain. *Sustainability*, 2019, 11(2), 430.

[15] Vijayvargy, L. & Agarwal, G. Empirical investigation of green supply chain management practices and their impact on organizational performance. *IUP Journal of Supply Chain Management*, 2014, 11(4), 25-42.

Scholarly Journal Editors' Panel - Abstracts

Decision Sciences Journal

Oral Presentation

Dr. Xenophon Koufteros [1]

1. *Texas A & M University*

Decision Sciences Journal is a premier business research publication with international visibility and impact. Some of the finest research on business decision making appears in our pages, and we specifically invite thoughtful investigations of the decisions of managers in the enterprise from any functional discipline interested in the processes of formulating, evaluating and executing high quality managerial decision making.

The Journal focuses on theoretical, empirical and methodological investigations of managerial decisions that drive business productivity and success. Such research can be methodologically focused on quantitative approaches, on qualitative methods, or can take the form of insightful reviews and commentaries on best practices in business research.

In the tradition of the Institutes interdisciplinary heritage, *Decision Sciences Journal* dedicates itself to the interdisciplinary investigation of managerial decision making in the recognition that important managerial decision making takes place in a range of critical business areas, including Accounting, Economics, Finance, Information Systems, International Business, Logistics, Management, Marketing, Operations, Production and the Supply Chain. We are particularly interested in Analytics as an emerging synthesis of sophisticated methodology and large data systems used to guide managerial decision making in an increasingly complex business environment.

Decision Sciences Journal of Innovative Education

Oral Presentation

Dr. Susan W. Palocsay [1]

1. *James Madison University*

The *Decision Sciences Journal of Innovative Education* (*DSJIE*) is a peer-reviewed journal published by the Decision Sciences Institute. Its mission is to publish significant research relevant to teaching and learning in the decision sciences - quantitative and behavioral approaches to managerial decision making. The journal welcomes submissions relevant to the application and practice of the decision sciences both in business and other domains such as, but not limited to, healthcare, product development, and engineering management. Articles submitted to the journal should offer either proven innovation in classroom instruction/delivery, new insights into pedagogy, program development, delivery, or assessment, or empirically based analysis of the application of the decision sciences in learning and education. The goal of the journal is to not only provide resources that can enhance instruction, but serve as a forum for disseminating best practices and new insights.

Dr Hope Baker

Oral Presentation

Dr. Hope Baker [1]

1. *Kenn*

Dr Hope Baker

Electronic Government, An International Journal

Oral Presentation

Dr. June Wei [1]

1. *University of West Florida*

EG is dedicated to design, development, management, implementation, technology, and application issues in e-government. *EG* aims to help professionals working in the field, academic educators and policy makers to contribute, to disseminate knowledge, and to learn from each other's work through cutting-edge thinking in e-government. The international dimension is emphasised in order to overcome cultural and national barriers and to meet the needs of accelerating technological change and changes in the global economy. *EG* is an outstanding outlet where e-government research can take a shape of its own and results can be shared across institutions, governments, researchers and students, as well as industry.

- Up-to-date, leading edge research to keep readers ahead and maintain a competitive edge best practice in e-government
- Practical guidance on ways to achieve great effectiveness and efficiency in e-government development and implementation.
- In-depth analysis and interpretation to advance our understanding and provide a framework for further study of e-government.
- International coverage that allows us to share information, knowledge and insight on a worldwide scale.

Expert Systems with Applications

Oral Presentation

Dr. Binshan Lin [1]

1. *Louisiana State University Shreveport*

Expert Systems with Applications is a refereed international journal whose focus is on exchanging information relating to expert and intelligent systems applied in industry, government, and universities worldwide. The thrust of the journal is to publish papers dealing with the design, development, testing, implementation, and/or management of expert and intelligent systems, and also to provide practical guidelines in the development and management of these systems. The journal will publish papers in expert and intelligent systems technology and application in the areas of, but not limited to: finance, accounting, engineering, marketing, auditing, law, procurement and contracting, project management, risk assessment, information management, information retrieval, crisis management, stock trading, strategic management, network management, telecommunications, space education, intelligent front ends, intelligent database management systems, medicine, chemistry, human resources management, human capital, business, production management, archaeology, economics, energy, and defense. Papers in multi-agent systems, knowledge management, neural networks, knowledge discovery, data and text mining, multimedia mining, and genetic algorithms will also be published in the journal.

Human Systems Management

Oral Presentation

Dr. Nada Trunk [1]

1. *International School for Social and Business Studies*

Human Systems Management (HSM) is an interdisciplinary, international, refereed journal, offering applicable, scientific insight into reinventing business, civil-society and government organizations, through the sustainable development of high-technology processes and structures. Adhering to the highest civic, ethical and moral ideals, the journal promotes the emerging anthropocentric-sociocentric paradigm of societal human systems, rather than the pervasively mechanistic and organismic or medieval corporatism views of humankind's recent past.

Human Systems Management: Special Issue for SEDSI 2022

Oral Presentation

Dr. Ping Wang [1], ***Dr. Yingying Sun*** [2], ***Dr. Raktim Pal*** [1]

1. *James Madison University,* ***2.*** *Renmin University of China*

Bridging the Gaps in Decision Making under Uncertainty

Human Systems Management (HSM) seeks submissions for a special issue on Bridging the Gaps in Decision Making under Uncertainty. Decision making under uncertainty is always a challenge. We have witnessed an unprecedent level of uncertainty in recent times. The COVID-19 pandemic exposes a series of gaps in decision making in uncertain environment leading to disastrous consequences in businesses, in our society, and in our lives. This calls for further research in theories and applications to deal with uncertainty and mitigate risks from managerial and organizational perspectives. This special issue (SI) aims to contribute to this effort in collaboration with the 51st Annual Conference of Southeast Decision Science Institute (SEDSI). The topics of the SI will be of particular interest in the context of the current pandemic as there have been ongoing efforts to refine and redefine decision making in business and society through the lens of equity, inclusion, and sustainability.

While some of the papers published in this SI are expected to be presented at the 2022 SEDSI conference, we solicit submissions that are not connected with the conference but are within the scope of this SI. Papers are invited from a wide range of fields of research and applications impacting business and society as a whole. Topics of the SI may include (but are not limited to):

• Resilience and disruption management
• Risk management
• Public health
• Humanitarian operations
• Not for profit management
• Global supply chain
• Information systems
• Information security
• Organizational communication
• Innovative use of technology
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• Equity and sustainability

Journal information and manuscript submission:

Human Systems Management (HSM) is an interdisciplinary, international, refereed journal, offering applicable, scientific insight into reinventing business, civil-society and government organizations, through the sustainable development of high-technology processes and structures. Adhering to the highest civic, ethical and moral ideals, the journal promotes the emerging anthropocentric-sociocentric paradigm of societal human systems, rather than the pervasively mechanistic and organismic or medieval corporatism views of humankind's recent past.

Before submission, authors should carefully go through the Author Guidelines

(https://www.iospress.com/catalog/journals/human-systems-management#author-guidelines). The review process will follow the journal's practice. Authors are requested to submit their manuscript electronically to the journal's Editorial Management System (www.editorialmanager.com/hsm). The manuscript should be uploaded as one file with tables and figures included. The submitted files must be editable (e.g. MS word). Please use the journal's manuscript template.

Important dates:

• Manuscript submission deadline: 31st May, 2022
• Notification* of first decision: 31st August, 2022
• Revised version submission deadline: 15th October, 2022
• Notification of final decision: 31st January, 2023
• Expected publication date: Spring 2023

* The author(s) may be notified earlier if the manuscript is not within the scope of the special issue.

If any additional information is needed, please contact the Special Issue guest editors.

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INFORMS Journal of Computing

Oral Presentation

Prof. Paul Brooks [1]

1. *Virginia Commonwealth University*

The theory and practice of computing and operations research are necessarily intertwined. The *INFORMS Journal on Computing* publishes high quality papers that expand the envelope of operations research and computing. We seek original research papers on relevant theories, methods, experiments, systems, and applications. We also welcome novel survey and tutorial papers, and papers describing new and useful software tools. We expect contributions that can be built upon by subsequent researchers or used by practitioners.

International Journal of Accounting & Information Management

Oral Presentation

Dr. Xin (Robert) Luo [1]

1. *The University of New Mexico*

The International Journal of Accounting & Information Management publishes research in accounting, finance and information management with a special emphasis given to the interaction between these areas of research in an international context and in either the private or public sectors. Aiming to bridge the knowledge gap between researchers and practitioners who are conducting research, the journal covers issues arising in:
Information systems
Accounting information management
Innovation and technology in accounting
Accounting standards and reporting
Capital market efficiency

International Journal of Electronic Finance

Oral Presentation

Dr. Jiaqin Yang [1]

1. *Georgia College & State University*

IJEF aims to help professionals working in the field, academic educators and policy-makers to contribute, to disseminate knowledge, and to learn from each other's work through cutting edge thinking in e-Finance. The international dimension is emphasised in order to overcome cultural and national barriers and to meet the needs of accelerating technological change and changes in the global economy. *IJEF* is an outstanding outlet that will enable e-Finance research to take a shape of its own and whose results can be shared across institutions, governments, researchers and students, as well as across the healthcare industry:

- Up-to-date, leading edge research to keep you ahead and maintain a competitive edge best practice in e-Finance
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- In-depth analysis and interpretation to advance our understanding and provide a framework for further study of e-Finance
- International coverage which allows us to share information and knowledge and insight on a worldwide scale

International Journal of Mobile Communications

Oral Presentation

Dr. June Wei [1]

1. *University of West Florida*

The objectives of the *IJMC* are to develop, promote and coordinate the development and practice of mobile communications. The *IJMC* aims to help professionals working in the field, academic educators and policy-makers to contribute, to disseminate knowledge, and to learn from each other's work. The international dimension is emphasised in order to overcome cultural and national barriers and to meet the needs of accelerating technological change and changes in the global economy. *IJMC* is an outstanding outlet that which can shape a significant body of research in the field of mobile communications and in which results can be shared across institutions, governments, researchers and students, and also industry.

International Journal of Sustainable Economy: Special Issue for SEDSI 2022

Oral

Dr. Xiaohui You [1]

1. *Metropolitan State University of Denver*

Guest Editor:
Dr. Xiaohui You, Metropolitan State University of Denver, USA
With disruptions of environmental, social, and governance changes, sustainable growth and development of the economy have been negatively influenced globally. This special issue aims to discuss the achievement of innovations and sustainable development by addressing the current environmental, societal, and economic concerns. We support the innovative research in business, economics, management, financial and industrial organisation of markets; both theoretical and empirical work will be encouraged. The empirical results and applied theoretical and analytical contributions may foster current policy debates and provide evidence and guidance to policy-makers for economic sustainability and innovations.
The Guest Editors will be inviting substantially extended versions of selected papers presented at the Southeast Decision Sciences Institute 51st Annual Meeting (SEDSI-2022) for review and potential publication, but are also inviting other experts to submit articles for this call.
Subject Coverage
Suitable topics include, but are not limited, to the following:

- Economic growth and development
- Econometric/mathematical modelling of economic processes
- Business fluctuation/cycles
- Enterprise development
- Environmental economics
- Finance, finance institutions, corporative finance
- Industrial organisation, market structure, competition
- Innovation, competitive advantage, knowledge management
- International trade and globalisation
- Labour and demographic economics
- Monetary policy, money supply/credit
- Public economics, welfare

Notes for Prospective Authors

Submitted papers should not have been previously published nor be currently under consideration for publication elsewhere. (N.B. Conference papers may only be submitted if the paper has been completely re-written and if appropriate written permissions have been obtained from any copyright holders of the original paper).

All papers are refereed through a peer review process.
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Important Dates

Manuscripts due by: *31 May, 2022*
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Final versions due by: *31 January, 2023*

Journal of Computer Information Systems

Oral Presentation

Dr. Alex Koohang [1]

1. *Middle Georgia State University*

The ***Journal of Computer Information Systems*** (JCIS) aims to publish manuscripts that explore information systems and technology research and thus develop computer information systems globally.
We encourage manuscripts that cover the following topic areas:

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- Computer systems enterprise architecture, enterprise resource planning
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- Health Informatics
- Information Assurance and Security–Cyber Security, Cyber Forensics
- IT Project Management
- Knowledge Management in computer information systems
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Journal of Global Information Management

Oral Presentation

Dr. Zuopeng Zhang [1]

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The **Journal of Global Information Management (JGIM)** provides a forum for researchers and practitioners to share leading-edge knowledge in the global information resource management area. Playing a pivotal role in the discussion of the organizational applications and managerial implications of information resource management technologies, JGIM's contributors include a growing list of 2,400+ industry-leading experts, making the scope and breadth of the research diverse as it provides solutions to concepts like reengineering, rightsizing, network organizations, and the virtual corporation.

As stated by John Naisbitt, in his book **Global Paradox**, "the bigger the world economy, the more powerful its smaller players." While the world is becoming more interconnected, international strategic alliances are increasing due to the reality that no single company and/or country can be a successful player in this new global game. As such, big international companies are deconstructing themselves and creating new structures to survive in the new world order. JGIM is highly indexed, with prestigious placements such as Web of Science® - Science Citation Index Expanded®, Web of Science® - Social Sciences Citation Index®, Scopus®, Compendex®, INSPEC®, and more, placing it well within that global communicative space.

Journal of Operations Management

Oral Presentation

Dr. Tyson Browning [1]

1. *Texas Christian University*

The *Journal of Operations Management* (*JOM*) is one of the leading journals in the ISI Operations Research and Management Science category. *JOM's* mission is to publish original, empirical, operations and supply chain management research that demonstrates both academic and practical relevance.

Journal of Real Estate Research

Oral Presentation

Dr. William G. Hardin III [1]

1. *Florida International University*

The *Journal of Real Estate Research* (JRER) is a publication of the American Real Estate Society (ARES). The Journal's objective is to investigate and expand the frontiers of knowledge that cover business applications through scholarly real estate research. JRER is committed to publishing the highest quality analytical, empirical, and clinical research useful to business decision-makers in the fields of real estate development, economics, finance, investment, law, management, marketing, secondary markets, and valuation.

Theoretical papers without testable or policy implications are discouraged. Data used in empirical research must be thoroughly documented and sufficient details of computations and methodologies must be provided to allow duplication. Authors are encouraged to provide data (at a reasonable cost) for replication purpose should such a request arise.

The Editorial Board of JRER is interested in broadening the reach of scholarly real estate research and is willing to work with any potential author who is developing new and exciting ideas.

Olson

Oral Presentation

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Deans’ Panel - Abstracts

Award presentation

Oral Presentation

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Board, VPs and Council

Oral Presentation

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1. *Georgia Southern University,* ***2.*** *Presbyterian College,* ***3.*** *James Madison University,* ***4.*** *Louisiana State Universith Shreveport,* ***5.*** *University of North Carolina Wilmington,* ***6.*** *Alabama State University,* ***7.*** *Virginia Commonwealth University,* ***8.*** *Roanoke College,* ***9.*** *East Carolina University,* ***10.*** *North Carolina A&T State Univ.,* ***11.*** *William & Mary University,* ***12.*** *Virginia Tech,* ***13.*** *Clayton State University*

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Case Centre

Oral Presentation

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Coggin College of Business, University of North Florida

Oral Presentation

Dr. Richard Buttimer [1]

1. *University of North Florida*

Dr. Richard Buttimer has officially started his position as the new dean of the Coggin College of Business.
He joins UNF after 18 years at the University of North Carolina at Charlotte (UNCC) where he worked in a variety of positions. He served as the director of the Childress Klein Center for Real Estate and the John Crosland, Sr. Distinguished Professor in the Department of Finance in the Belk College of Business at UNCC. He also served as the interim senior associate dean for the Belk College, having served as the full-time senior associate dean from 2011 through 2017.

Coggin Graduate and Executive Programs |Coggin College of Business | University of North Florida

Oral Presentation

Ms. Amy Bishop [1]

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Coggin Graduate and Executive Programs |Coggin College of Business | University of North Florida

College of Business Administration, University of New Orleans

Oral Presentation

Dr. Pamela Kennett-Hensel [1]

1. *University of New Orleans*

Our College of Business Administration at the University of New Orleans develops future business leaders and scholars through an engaging and exceptional educational experience. We are proud to be the largest college of business in Louisiana and the most diverse in terms of students, faculty, and staff in the state.

The renowned academic programs, community-involved faculty, and acclaimed research centers of the College have made it a vibrant place that has prepared over 25,000 graduates for success. As an internationally recognized business college, we have a great critical mass of alumni and partners who serve as successful role models investing their time, expertise, and resources in our programs. Our low cost tuition and excellent degree programs make our College of Business Administration one of the most desired programs in the nation.

Our College is accredited by the Association to Advance Collegiate Schools of Business (AACSB) and the Department of Accounting holds its own AACSB accreditation distinguishing it in the top 3 percent of all colleges of business internationally. Other departments in the College include the Department of Economics & Finance, Department of Management, Department of Marketing, and the Lester E. Kabacoff School of Hotel, Restaurant and Tourism Administration (HRT). Accounting and the School of HRT are Programs of Distinction at the University. Graduate programs include the MBA (the largest graduate program at the University), Master of Science in Healthcare, MS in Accounting and Taxation, MS in Hospitality and Tourism Management, and the Ph.D. degree program in Financial Economics. Executive Education Programs include an Executive Master of Business Administration and the Executive Master of Health Care Management.

In addition to those academic areas, the College also features the AT&T Entrepreneurship Center, the Center for Economic Development, the Institute of Real Estate Research, the Division of Business & Economic Research, and the Hospitality Research Center (a Center of Excellence at the University and the premier hospitality and tourism research center in the nation).

Thank you for visiting the College of Business Administration website. If you haven't already done so, please take the time to explore and learn more about us and all that our College has to offer.

Pamela Kennett-Hensel, Ph.D.
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College of Business, Florida International University

Oral Presentation

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College of Business, Louisiana State University Shreveport

Oral Presentation

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College of Business
Louisiana State University Shreveport
Dr. Mary Lois White
mwhite2@lsus.edu

College of Business, Louisiana Tech University

Oral Presentation

Dr. Chris Martin [1]

1. *Louisiana Tech University*

Louisiana Tech University's College of Business is the ideal environment to develop the skills you need to be a successful and innovative thinker, communicator, and leader. Regardless of the major you select in our College, you'll learn how to leverage technology in business to its fullest and what it takes to lead innovation in any organization. The College offers an array of modern and relevant business programs at both the undergraduate and graduate level. As a student, you will be taught and mentored by dedicated faculty who are leaders in their respective fields. Our goal is to ensure you have every opportunity for academic and professional success.

Strong partnerships within the industry allow us to develop opportunities designed to give you the real-world experience that employers value. Through our co-curricular programming, students expand their knowledge outside of the classroom through insightful conversation on current issues with high-level executives and corporate leaders (many of whom are College of Business alumni).

All of this leads to remarkable placement rates for our graduates—95% of our 2017-2018 undergrads placed in the career or graduate school of choice within six months.

Whether you are beginning to explore universities and majors, or you already know that you are ready to become part of the College of Business at Louisiana Tech, please take a minute to let us know how we can help as you consider your next steps. If I can be of any assistance with your college selection process, please do not hesitate to contact me at **cmartin@latech.edu**.

David B. O'Maley College of Business, Embry-Riddle Aeronautical University

Oral Presentation

Dr. Shanan Gwaltney Gibson [1]

1. *Embry-Riddle Aeronautical University*

Having recently joined the Eagle family as Dean of the David B. O'Maley College of Business, I am thrilled and honored to lead the College of Business going forward. I was seeking a university that understands and values its special niche, offers a well-differentiated, high-quality service to its industry partners, and has a culture that prizes student success and entrepreneurial spirit. I believe I have found this and much more here!

We provide a world-class business education with state-of-the-art curricula at both the graduate and undergraduate levels. We pride ourselves on our deep relationships with, and understanding of, the aviation, aerospace and space industries. And while the O'Maley College of Business offers degree programs specific to these industries, we ensure our students gain a solid business education that applies to all industries, including entrepreneurship. Our deep connections place our graduates on the leading edge of innovation and in some of the world's most transformative organizations.

I joined this team because I was impressed by the exceptional faculty and the student body that we serve. Our current students are the future leaders, our alumni represent the legacy of this institution, and our faculty are the glue that bonds across generations. Working together to support the O'Maley College of Business is essential to our continued success.

We are dedicated to propelling our students to new heights; we exist to Educate. Innovate. And Launch you to success! Business Eagles Take Flight!

Davis College of Business, Jacksonville University

Oral Presentation

Dr. Barbara A. Ritter [1]

1. *Jacksonville University*

The Davis College of Business at Jacksonville is perfectly positioned at the intersection of education and industry. Across the river from the city of Jacksonville, students take advantage of strong industry partnerships that result in practical course work and applied experiences inside and outside of the classroom.

With a world class faculty, we offer a personal, individualized educational experience that prepares students for sustained career success. Our curriculum includes the knowledge and skills most sought after by employers such as critical thinking, ethical reasoning, and communication. Our graduate programs build upon the knowledge of an undergraduate degree to prepare students for enhanced career success. We are proud of the fact that our students are highly in demand as evidenced by exceptional placement rates for graduates at all levels.

Professional development tailored to the personal goals of each student is our objective, achieved through the Davis College Center for Professional Development. Students can speak with a career counselor to explore career options, take advantage of VMock software for resume review and the Big Interview platform for mock interview practice. Internships or practicum experiences are recommended and students can apply to be a part of the Phins Up career mentorship program. Graduate students may have distinct development needs so opportunities are tailored for each program and designed to help grow a professional network for upwards advancement.

I welcome you to the Dolphin family. You will be hard pressed to find a college more dedicated to enabling your success than the Davis College of Business.

Dean Barbara A. Ritter, Ph.D.

britter1@ju.edu

DSI

Oral Presentation

Ms. Vivian Landrum [1]

1. *University of Houston*

MISSION STATEMENT

Decision Sciences Institute provides forums to create, disseminate and use knowledge to improve managerial decision making involving systems and people.

VISION STATEMENT

Decision Sciences Institute will be recognized globally as a scholarly professional association that creates, develops, fosters and disseminates knowledge to improve managerial decisions.

GOALS

The Decision Sciences Institute is a global society guided by the core values of high quality, responsiveness and professional development. The goals of the Institute are:

1. enrich the diverse disciplines of the decision sciences;
2. integrate these disciplines into bodies of knowledge that are effectively utilized for decision making;
3. develop theoretical bases for such fundamental processes as implementation, planning and design of decision systems;
4. improve educational programs and instruction in the decision sciences.

To facilitate these goals, the Institute shall provide for the exchange of information among those who extend, apply and teach the decision sciences.

Parker College of Business, Georgia Southern University

Oral Presentation

Dr. Allen C. Amason [1]

1. *Georgia Southern University*

Allen C. Amason is Dean of the Parker College of Business at Georgia Southern University. He earned his Ph.D. in International Strategic Management from the Moore School of Business, at the University of South Carolina. He served previously on the faculties of Mississippi State and the University of Georgia, and he was Chair of the Management Department at the UGA Terry College of Business.

Dr. Amason's research focuses on strategic decision-making and the role of top management in the strategy process. He is the author of the popular book, *Strategic Management: From Theory to Practice*, and has published more than 40 articles, monographs, and chapters in various scholarly outlets. He has been on several editorial boards and served as Associate Editor for the *Journal of Management Studies* and the *Journal of Management*. He is past-President of the Southern Management Association.

Professor Amason's teaching and consulting focuses on strategic management and decision-making. He has served on the boards of various organizations including Georgia Oak Partners, the Russian Foundation for Population Health & Recovery, and the Ocean Exchange. He has done C-level consulting on issues related to strategy and strategic decision making with a variety of firms including, Exide Technologies, Primewest Energy, the UGA Athletic Association, Rosetta Marketing, Johnson & Johnson, Computer Associates, Novartis, Tenet Healthcare, Schneider Electric, and AMD.

Office Location

Parker College of Business room 2254

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aamason@georgiasouthern.edu

Ryan Hanifin

Oral Presentation

Ms. Ryan Hanifin [1]

1. *Hawkes Learning*

Ryan Hanifin | Event Marketing Specialist
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hawkeslearning.com | Follow Us: Facebook | Twitter | LinkedIn | YouTube

Satish & Yasmin Gupta College of Business, University of Dallas

Oral

Dr. Brett J. L. Landry [1]

1. *University of Dallas*

On behalf of all our faculty, staff and students, welcome to the Satish & Yasmin Gupta College of Business!

As dean of the college, I'm extremely proud of the rich tradition of providing practical, experience-based business education that our college has upheld since its founding. Our business programs prepare our students to become leaders with the moral depth and intellectual intensity necessary to meet the challenges of a time of critical transition in society.

Located in an economic and cultural hub, the University of Dallas offers unique opportunities for our students to engage with DFW's companies and communities. For example, through the Capstone Experience, our MBA students have completed over 3,000 strategic consulting projects for local and national companies, entrepreneurial ventures and not-for-profit organizations. The Capstone Experience has not only benefited the business community, but has provided the perfect opportunity for our students to begin putting their education into action.

Central to the success of our students and over 14,000 Gupta College of Business alumni, has been the decades of leadership and experience-based knowledge that our faculty bring into the classroom. As thought leaders in their industry, the knowledge and research contributions of our faculty continue to drive change both at the university and across the globe.

I would like to cordially invite all of you who are interested in expanding your knowledge and enriching your careers to explore our school further either online or through a visit to campus.

School of Business, College of Charleston

Oral Presentation

Dr. Alan Shao [1]

1. *College of Charleston*

Alan T. Shao has served as the College of Charleston's dean of the School of Business since March 2009. Since then, he has established an MBA degree program, obtained AACSB reaccreditation for the school, developed new majors (in Finance and Marketing), established a Deans Student Forum, dramatically elevated fundraising, created the School of Business "Wall of Honor" to recognize philanthropy and long-term impact, and advanced the culture of global learning throughout the School.

Shao's plans for the School of Business are to build a new building that will house graduate and professional programs, establish a doctoral program in business, offer degrees in foreign countries, and expand degree offerings. Shao came to Charleston after nearly 20 years at the University of North Carolina Charlotte, where he was North Carolina Ports professor of marketing and associate dean of Professional and Global Programs, and received numerous teaching and research awards. While at UNC Charlotte, he created self-supporting graduate business programs in Taiwan, Hong Kong, Mexico and Denmark.

In 2005, the *Journal of Advertising* named Shao one of the most prolific contributors to advertising research. In his career, he has published more than 50 articles in leading journals, made more than 100 presentations on a variety of international business topics and has authored three books, most recently Marketing Research: An Aid to Decision Making, 3rd edition. As a Pacific Cultural Foundation fellow, he has studied foreign culture influences on advertising in Taiwan.

In addition to teaching and research, Shao has worked as an executive director of marketing research and a manager of computer operations, and has developed import businesses that manufactured furniture, motorcycles and crystals in China. He is a frequent traveler, having visited China more than 100 times and lectured in more than 30 countries. Shao has consulted for major companies that include Coca-Cola, Nissan, HSBC, Wachovia, North Carolina State Ports Authority, Hendrick Motor Sports (NASCAR) and the Carolina Panthers football franchise. He is a past-president of the North Carolina World Trade Association, has served on the board of the North Carolina District Export Council and is a past member of the Charleston Metro Chamber.

School of Computing, Middle Georgia State University

Oral Presentation

Dr. Alex Koohang [1]

1. *Middle Georgia State University*

Our Vision

The School of Computing's vision is to be among the nation's premier institutions for providing quality education at both the undergraduate and graduate levels.

Our Mission

The mission of the School of Computing is to educate students in ways that lead to fulfilling careers and enhance the economic vitality of Central Georgia. The School provides its graduates with the analytical and problem-solving skills required to excel within an increasingly interconnected and changing global environment. The School pursues this mission as an educational leader in teaching excellence, scholarship, professional service, and community outreach.

SEDSI Council

Oral Presentation

Dr. Jim Wynne [1], ***Dr. Terry Rakes*** [2], ***Dr. Chris McCart*** [3], ***Dr. Lance Matheson*** [2], ***Dr. Suzie Smith*** [4], ***Dr. Reza Kheirandish*** [5]

1. *Virginia Commonwealth University,* ***2.*** *Virginia Tech,* ***3.*** *Roanoke College,* ***4.*** *Presbyterian College,* ***5.*** *Clayton State University*

SEDSI Council

Authors Index