Book of Proceedings

FEBRUARY 21 - 23 , 2018

2018 Southeast Decision Sciences Institute Meeting

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Accounting, Business Ethics, Business Law, Information Privacy & Security

Security Risk Learning in Cybersecurity: Evidential Reasoning Model

Authors redacted to preserve anonymity

Abstract:

Information security can only be soundly managed based of security risks to system owners. These risks can only be managed if there is an effective process in place to learn risks and plan incident responses accordingly. Such a cybersecurity environment is however full of uncertainties and ambiguities beyond what Bayesian theory can handle. Hence, an evidential reasoning strategy using Dempster and Shafer Theory becomes essential in learning those security risks for planning a business continuity management system and for handling real-time incident responses. We propose an evidential reasoning model that can learn risks based the AIC triad model – availability, integrity, and confidentiality – and express those security risks as the plausibility of failing to assure them. Available evidence throughout the cybersecurity environment is partitioned accordingly and a sequential belief structure is processed to lead to a comprehensive assertion based on which the security risk to owners is expressed. A numerical example is provided to demonstrate the working of the proposed model.

Keywords: cybersecurity, evidential reasoning, security risk, Dempster and Shafer Theory, availability, data integrity, confidentiality.

The risk management life cycle

Security risk management, as shown in Figure 1, consists of set of recurrent and documented phases: risk planning, risk analysis, risk treatment, and risk monitoring. This is also referred to as the risk management life cycle [1]. Risk management is the activity of controlling risk to maintain it within an acceptable range. It includes planning for risk, assessing risk areas, developing risk-treatment options, monitoring risks to determine how risks change, and documenting the overall risk management program. Risk planning is the process of developing and documenting an organized, comprehensive, and interactive strategy and methods for identifying and tracking risk areas, developing risk treatment plans, performing continuous risk assessments to determine how risks change, and assigning adequate resources. Risk assessment is the determination of the level of risk and the potential impact of identified risk by measuring the likelihood and the impact if associated incidents would take place. Risk assessment is needed to prioritize any risk treatment effort devised to protect the system in question. The amount of risk assessed will be compared against expected benefits before any risk treatment is approved.

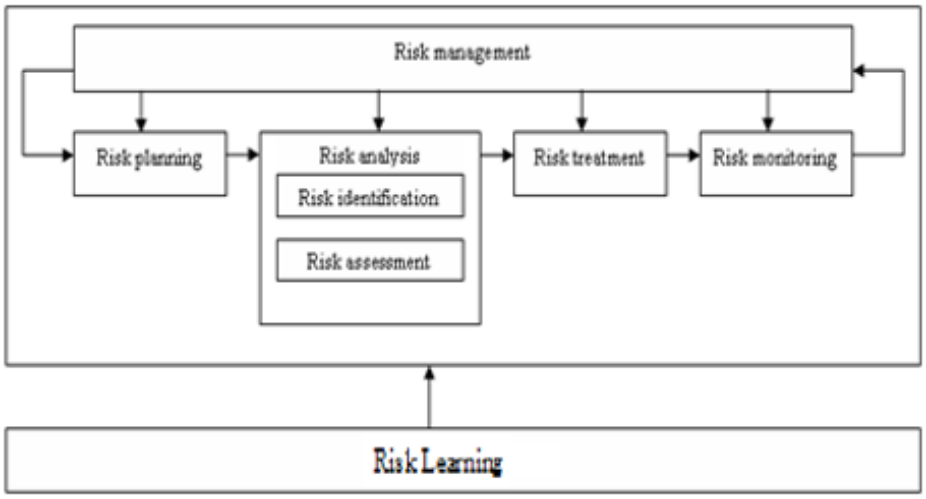


Figure 1: Risk management lifecycle, adapted from the U.S. Department of Energy.

Risk analysis is the process of examining each identified risk area or process to refine the description of the risk, isolating the causes, and determining the effects. It includes risk rating and prioritization in which risk events are defined in terms of their probability of occurrence, severity of consequence/impact, and relationship to other risk areas or processes. Risk treatment is the process of defining, selecting, and implementing security controls in order to bring back risks to acceptable levels as defined in security policy. This includes the terms of what should be done, when it should be accomplished, who is responsible, the schedule, and relevant costs. Risk monitoring is the process that systematically tracks and evaluates the performance of risk treatment actions against established metrics and develops further risk treatment options, as needed. This process revisits back to the other risk management activities of planning, analysis, and treatment as shown in Figure 1. This represents the cycle in the risk management process. Lastly, risk learning is the capturing of any available evidence on the behavior of the cybersecurity environment that effects available information on security risks.

Assets may be exposed to a chance of 'loss;' that is, loss of availability, confidentiality, or integrity. If the asset is exposed to a chance of loss of this type, then the owner is exposed to a chance other types of loss: loss of business and loss of non-economic benefits (or social benefits). The loss of confidentiality, integrity, or availability of an asset will translate into loss of business value to the organization [1]. The organization will also lose its reputation, the trust of its partners and customers, in addition to many other undesirable social outcomes. If the loss is realized, because of an undesired even that we failed to prevent from occurring, then the organization will lose all the revenues generated by the normal operations of the victim asset throughout the asset recovery period, in addition to social benefits. Unless those undesired events are prevented and asset vulnerabilities are mitigated there is always a chance that losses would take place.

Evidential model for learning security risks

Information security management of a system is the assurance that its total security risk remains continuously within the security risk range imposed by its own security policy. Let us write overall system security risk R_s in terms of all effecting factors. In general, one can always think of a set of major components C_i, i=1,N for which we can assess risks R_i, i=1,N. The overall system security R_s can then be written in terms of the risks R_i, i=1,N. These latter risks can in their turn be expressed in terms of all known assets' vulnerabilities $E_3=\{\{E_{11}, \ldots, E_{1M1}\}, \ldots, \{E_{1M}, \ldots, E_{1MM}\}\}$, as shown in Figure 2. The

evidence processing mechanism will first produce the components' assertions $\{a_1, \ldots, a_N\}$ based on evidence E_3 on assets' vulnerabilities and existing threats then the main assertion a_s in terms of components assertions $\{a_1, \ldots, a_N\}$ and available evidence on the current information security management process E_0.

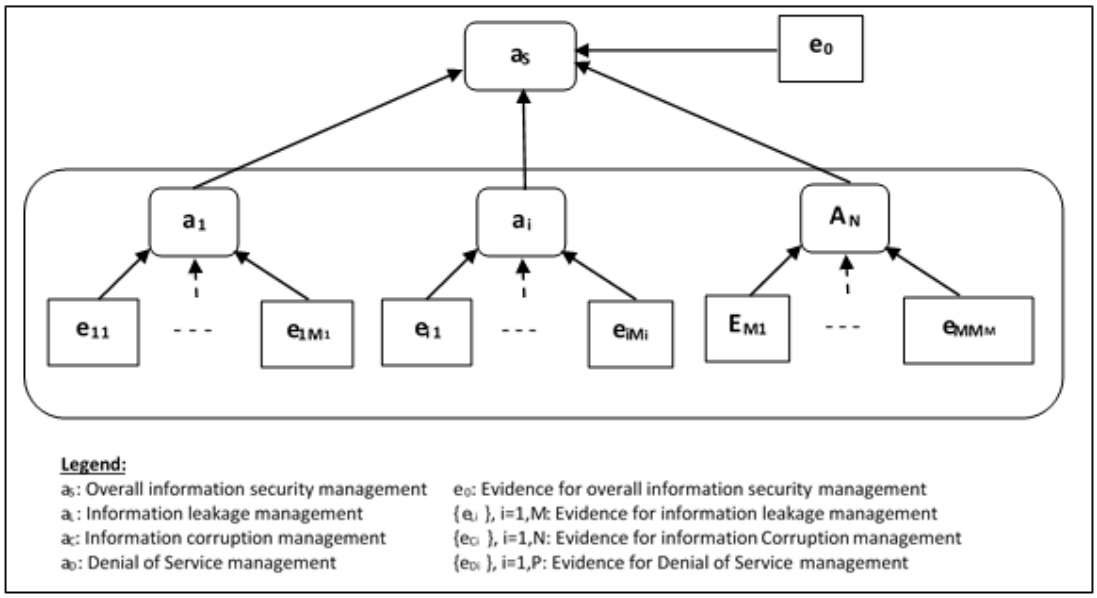


Figure 2: General evidence structure for risk learning

The security policy of a system defines both its real-time and its general acceptable computing behavior, as defined by its owners [1]. In this article, we are only concerned with three classes of security disruptions, as in Raggad taxonomy [1]: information leakage, information corruption, and denial of service.

We assume the information security manger conducts it security management role based on 4 information security resources: E_L: evidence related to information leakage, E_C: evidence related to information corruption, E_D: evidence related to denial of service, and E_0: evidence related to the independent activity of managing the system according to system security policy.

The resources of evidence E_L, E_C, and E_D collect their own evidences from their own sources: E_L acquires its own evidence from M sources $\{E_{Li}\}$, i=1,M; E_C acquires its own evidence from N sources $\{E_{Ci}\}$, i=1,N; and E_D acquires its own evidence from P sources $\{E_{Ci}\}$, i=1,P;. The independent resource of evidence E_0 is articulated by information security management based on what they know they are doing to protect their computing environment according to their owners' security policy. Figure 2 depicts the evidence structure just discussed above and processed for the purpose of learning the system security risk in a continual manner.

The overall security risk of the computing environment R_s is computed in terms of the individual risks R_L, R_C, and R_d, and R_0 representing respectively system risk of information leakage, system risk of information corruption, denial of service risk, and ineffective system security management risk. While we are processing the evidential scheme above, there are many quantities of interest that propagate from the higher nodes of evidence at the leaves of the tree, to lower layers representing the individual information security risks, until the main assertion defining the overall information security management root where the overall system security risk is evaluated, as depicted in Figure 3.

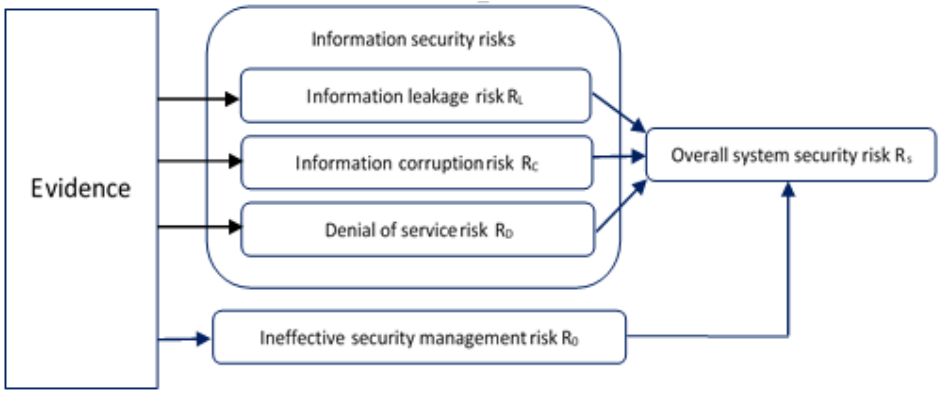


Figure 3: Limited Structure for learning risks based on the AIC triad.

Evidential reasoning

Belief functions, used in this article to construct our evidential reasoning model, were introduced in the 70's under a more extended framework called Dempster and Shafer Theory (DST) [3]. In the situations of poor or incomplete data, uncertainty management in Dempster and Shafer took a more intuitive approach and deviated from the conventional formalism adopted in Bayesian theory. In a DST setting, we start with the delineation of propositional space called a frame of discernment that contains all possible states, in an exhaustive and mutually exclusive way, so that only one of them can take place in one given time. Let us denote this space as $\Omega=\{w_i\}_{i=1,|\Omega|}$ where w_i, $i=1,|\Omega|$ denotes a possible state of the our frame of discernment Ω.

Uncertainties are represented through a basic belief assignment that produces the m-values given the information on hand [4]. The m-values are only assigned to subsets of the elements for which we have information. We then have:

$m: 2^{\Omega} \rightarrow [0, 1]$
$Bel(A) = \sum X \in A\ m(X)$ for any A in 2^{Ω}

The plausibility function on a sunset A is defined as the degree to which A is plausible in light of the evidence, or alternatively, the degree to which A is not disbelieved [6]. The evidential security management risk scheme may be presented using the belief structures used to capture the individual information security risks and the security management risk that we combined to produce the overall system security risk R_s [2, 4]:

E_L= {
$m_L: 2^{\Omega L} \rightarrow [0, 1]$;
Ω_L= {w^+_L='adequate information leakage management',
w^-_L='inadequate information leakage management'};
$e_L = (e^+_L = m_L(w^+_L); e^-_L = m_L(w^-_L); m_L(\Omega_L) = 1 - e^+_L - e^-_L)$
}

E_C= {
$m_C: 2^{\Omega C} \rightarrow [0, 1]$;
Ω_C= {w^+_C='adequate information corruption management',
w^-_C='inadequate information corruption management'};

e_C = (e^+_C=m_L(w^+_C); e^-_C=m_C(w^-_C); m_C(Ω_C)=1 - e^+_C - e^-_C)
}

E_D= {
m_D: $2^{\Omega D}$ →[0, 1];
Ω_D= {w^+_D='adequate denial of service management',
w^-_D=' 'inadequate denial of service management'};
e_D = (e^+_D=m_L(w^+_D); e^-_D=m_D(w^-_D); m_D(Ω_D)=1 - e^+_D - e^-_D)
}

E_0= {
m_0: $2^{\Omega 0}$ →[0, 1];
Ω_0= {w^+_0='adequate overall system security management',
w^-_0=' 'inadequate overall system security management'};
e_0 = (e^+_0=m_L(w^+_0); e^-_0=m_0(w^-_0); m_0(Ω_0)=1 - e^+_0 - e^-_0)
}

E_s= {
m_s: $2^{\Omega L}$ →[0, 1];
Ω_s= {w^+_s='adequate system security', w^-_s=' 'inadequate system security'};
e_s = (e^+_s=m_s(w^+_s); e^-_s=m_s(w^-_s); m_s(Ω_s)=1 - e^+_s - e^-_s)
}

The evidence propagation process

According to the AIC triad model for availability, integrity and confidentiality, we know that any security disruption encountered in a computing environment will add risk to one of these menaces, respectively associated with denial of service, information corruption, and information leakage. That is, all evidence accumulated on information security risks will lead to a revision of all their belief structures that are processed to produce main (lower level in the evidential hierarchy) assertions on the hierarchic evidence scheme discussed above. The propagation of the processed evidence is computed as shown in Figure 4. As an example, suppose we have two pieces of evidence on the risk of information leakage:

E_L={$e_{L1}$and e_{L2}}
{m_{L1}: $2^{\Omega L1}$ →[0, 1];
Ω_{L1}= {w^+_{L1}='adequate information leakage software',
w^-_{L1}='inadequate information leakage software'};
e_{L1} = (e^+_{L1}=m_{L1}(w^+_{L1}); e^-_{L1}=m_{L1}(w^-_{L1}); m_{L1}(Ω_{L1})=1 - e^+_{L1} - e^-_{L1}).}

{m_{L2}: $2^{\Omega L2}$ →[0, 1];
Ω_{L2}= {w^+_{L2}='adequate budget for information leakage management',
w^-_{L2}='inadequate budget for information leakage management'};
e_{L2} = (e^+_{L2}=m_{L2}(w^+_{L2}); e^-_{L2}=m_{L2}(w^-_{L2}); m_{L2}(Ω_{L2})=1 - e^+_{L2} - e^-_{L2}).}

These are two independent sources of evidence that we can combine to produce the belief structure of the assertion on information leakage management, as follows:

{m_L: $2^{\Omega L}$ →[0, 1];
Ω_L= {w^+_L='adequate information leakage management',
w^-_L='inadequate information leakage management'};
$m_L(w^+_L)$ =[m_{L1}(w^+_{L1}) m_{L2}(w^+_{L2}) + m_{L1}(w^+_{L1}) m_{L2}({w^+_{L1}, w^-_{L1}}) + m_{L1}({w^+_{L1}, w^-_{L1}})m_{L2}(w^+_{L2})]/(1-k_L)
$m_L(w^-_L)$ = [m_{L1}(w^-_{L1}) m_{L2}(w^-_{L2}) + m_{L1}(w^-_{L1}) m_{L2}({w^+_{L1}, w^-_{L1}}) + m_{L1}({w^+_{L1}, w^-_{L1}})m_{L2}(w^-_{L2})]/(1-k_L)
Where: k_L= m_{L1}(w^+_{L1}) m_{L2}(w^-_{L2}) + m_{L1}(w^-_{L1}) m_{L2}(w^+_{L2})}

We start learning system security risks as early as at the leaves of evidence at the highest level of the hierarchic evidence scheme. The original sources of risks are found at asset vulnerabilities, as shown in Figure 3. The ability of the existing threats to exploit these vulnerabilities will shape the amounts of risks. Risk develops when we become capable of acquiring information on how current threats exploits asset vulnerabilities and the impact on the business value an asset can generate. In this example, there are plenty of threats that can produce information leakage, and plenty of threats that will produce information corruption, and also plenty will produce denials of service.

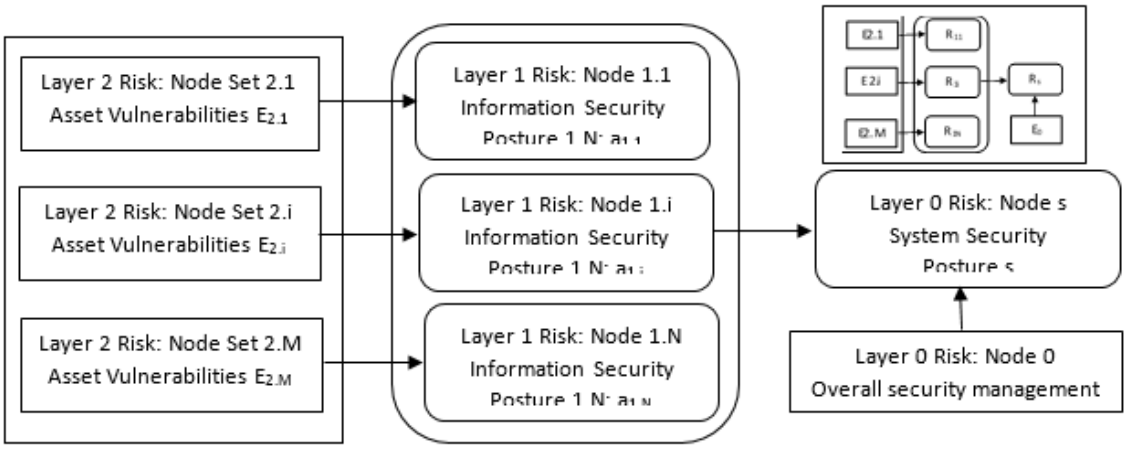
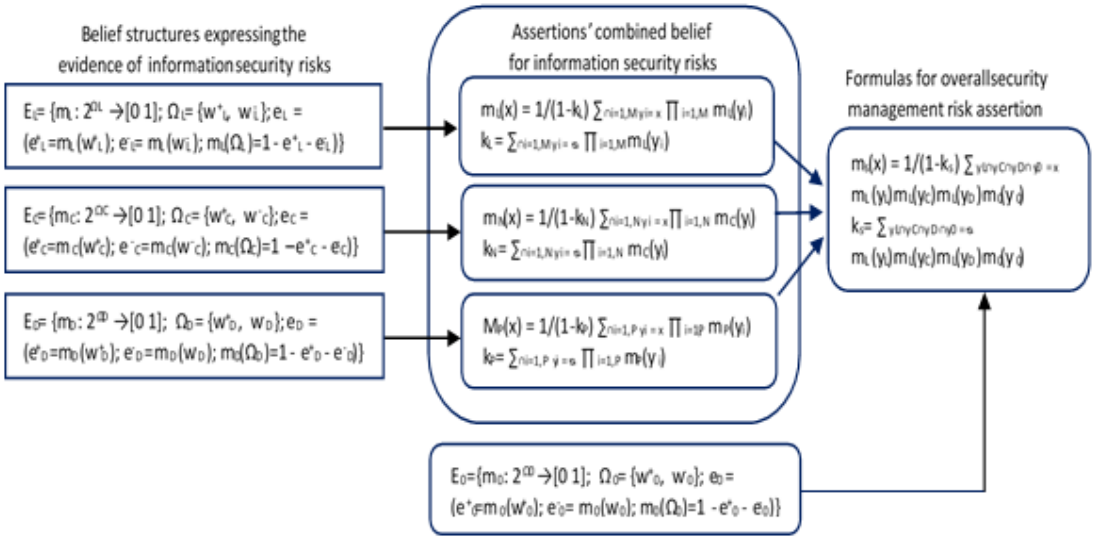


Figure 4: Risk evidential scheme.

That is, there are three subsets of evidence E_L for information leakage, E_C for information corruption, and E_D for denial of service that are available to the respective information security managers to process and produce information on the state of information security in their departments. The information leakage manager will process the evidence subset at hand E_L to produce the assertion a_L. At the same time, the information corruption manager will process all the evidence E_C at hand and produce his/her assertion a_C on the state of information corruption management. On the other hand, the denial of service manager will process all the evidence E_D at hand and produce his/her assertion a_D on the state of denial of service management.



Fog 5. Evidence belief structure expressing overall security management.

Numerical Example

In this numerical example, we assume that we obtained factual evidence as belief structures on the management of information confidentiality, personal training programs, data integrity management, the enforcement of security policy, security planning, and security auditing, as follows:

E_L= {
{m_{L1}: $2^{\Omega L1}$ →[0, 1]; Ω_{L1}= {w^+_{L1}: 'Adequate Management of Information Confidentiality', w^-_{L1}: 'Inadequate Management of Information Confidentiality'}; e_{L1} = (e^+_{L1}=.6; e^-_{L1}= .3; $m_{L1}(\Omega_{L1})$=.1)}

{m_{L2}: $2^{\Omega L2}$ →[0, 1]; Ω_{L2}= {w^+_{L2}: 'Adequate Personnel Training Programs', w^-_{L2}: 'Inadequate Personnel Training Programs'}; e_{L2} = (e^+_{L2}=.7; e^-_{L2}= .2; $m_{L2}(\Omega_{L2})$=.1)}
}

E_C= {
{m_{C1}: $2^{\Omega C1}$ →[0, 1]; Ω_{C1}= {w^+_{C1}: 'Adequate Management of Data Integrity', w^-_{C1}: 'Inadequate Management of Data Integrity'}; e_{C1} = (e^+_{C1}=.6; e^-_{C1}= .1; $m_{C1}(\Omega_{C1})$=.3)}

{m_{C2}: $2^{\Omega C2}$ →[0, 1]; Ω_{C2}= {w^+_{C2}: 'Adequate Enforcement of Security Policy', w^-_{C2}: 'Inadequate Enforcement of Security Policy'}; e_{C2} = (e^+_{C2}=.5; e^-_{C2}= .1; $m_{C2}(\Omega_{C2})$=.4)}
}

E_D= {
{m_{D1}: $2^{\Omega D1}$ →[0, 1]; Ω_{D1}= {w^+_{D1}: 'Adequate Security Planning', w^-_{D1}: 'Inadequate Security Planning'}; e_{D1} = (e^+_{D1}=.4; e^-_{D1}= .3; $m_{D1}(\Omega_{D1})$=.3)}

{m_{D2}: $2^{\Omega D2}$ →[0, 1]; Ω_{D2}= {w^+_{D2}: 'Adequate Security Auditing', w^-_{D2}: 'Inadequate Security Auditing'}; e_{D2} = (e^+_{D2}=.5; e^-_{D2}= .3; $m_{D2}(\Omega_{D2})$=.2)}
}

These subsets of evidence, as depicted in Figure 5, are related to the assertions of information security management in terms of information leakage management, information corruption management, and denial of service management. The evidential propagation process is shown in Figure 6 which produced a security risk of 0.031. Computations may be requested through email from one of the authors of the article.

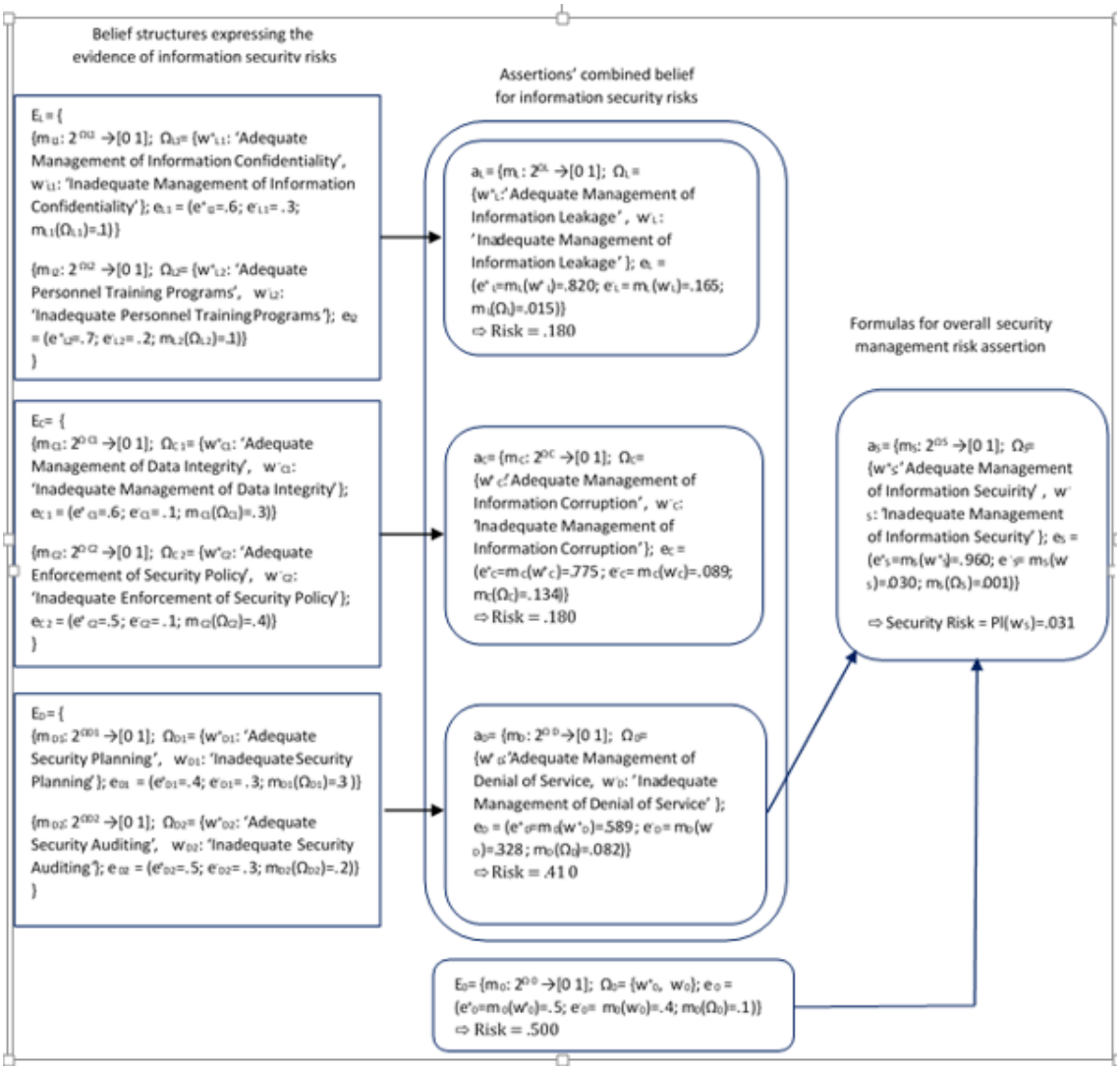


Figure 6: Numerical example to demonstrate the risk learning model.

Conclusion

This article proposed a security risk learning model using evidential reasoning that tracked risks using three layers of risk management. The first layer aimed at capturing evidence at the vulnerability level. The captured vulnerably evidence subsets were processed to produce belief structures on information security management assertions processed at the second layer. The third layer was concerned with the computation of the overall security risk in terms of individual risks associated with information leakage management, information corruption management, and denial of service management. A numerical example, Figure 6, was processed to demonstrate the working of our security risk learning model.

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ARE EACH OF THE INDIVIDUAL COUNCIL MEMBERS OF THE TOWN OF OAK ISLAND, N.C. PERSONALLY LIABLE FOR THE SEWER DISTRICT FEES/TAXES REFUNDED TO DEVELOPED PARCEL OWNERS OF SAID TOWN?

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Francis Marion University

ABSTRACT

This author has written extensively about the implications of a recurring, annual Sewer District Fee/Property Tax ('SDF property tax") levied by the Town of Oak Island, N.C. ("Town") against owners of developed and undeveloped properties within the boundaries of a Sewer Treatment District.

a. "Has the Town of Oak Island, N.C. Imposed a Recurring, Annual Sewer District Fee/Tax Against 11,433 Property Owners of Developed and Undeveloped Sewer District Parcels in Violation of the Equal Protection Clause of the Fourteenth Amendment to the U.S. Constitution?"
b. "The Surprising Federal Income Tax Consequences of a Recurring, Annual Sewer District Fee/Tax, Levied by the Town of Oak Island, N.C., Against Developed and Undeveloped Sewer District Parcels, Wherein said Town Issues a Credit to Developed Parcels."
c. "Does the Recurring, Annual Sewer District Fee/Tax, Levied by the Town of Oak Island, N.C. against Owners of Undeveloped Sewer District Parcels, Constitute a Fifth Amendment Taking of Property?"

In these articles, this author has successfully argued that the Town has levied a recurring, annual SDF property tax on Sewer Treatment District parcels that unconstitutionally discriminates in favor of 7,974 property owners of developed Sewer Treatment District parcels and against 3,459 property owners of undeveloped Sewer Treatment District parcels (because undeveloped parcel owners paid less in prior years), all in violation of the Equal Protection Clause of the Fourteenth Amendment to the U.S. Constitution. Within this context, these articles have also successfully argued that the recurring, annual SDF property tax, as levied by the Town, is unlawful because such recurring fee/tax directly opposes its enabling legislation (i.e., S.L. 2004-96, as amended by S.L. 2006-54) and the N.C. Constitution.

In the instant article, this author extends his analysis by focusing upon one aspect of the Town's execution of its enabling legislation, i.e., since 2009 and by resolution for each year thereafter, each member of the Town Council has adopted a resolution to impose a SDF property tax on all parcels within the Town's Sewer Treatment District, but then, without any authority to do so, each member of the Town Council by resolution refunded said SDF property tax for developed parcel owners by issuing an equivalent credit to each of them on their property tax statements. In general, fund revenue from a levy of property tax (e.g., the SDF property tax) is recognized by an increase (credit) to a fund account. However, since 2009, SDF property tax revenue is recognized from actual levies of SDF property tax against undeveloped parcels only. SDF property tax revenue is not recognized for actual levies of SDF property taxes against developed parcels, which is allowed under the *modified accrual basis of accounting* (with a current resources measurement focus), but only if the Town never intends to collect the SDF

property taxes from the developed parcel owners. Since 2009, the Town has employed the *modified accrual basis of accounting* (with a current resources measurement focus) in accounting for its enterprise funds, including the SDF Fund. As shown in the Town's audited financial statements: "Under this method, revenues are recognized when measurable and available." The bottom line - since the inception of the SDF property tax, each member of the Town Council by resolution has given a total gift (in the form of refunded SDF property taxes), to each developed parcel owner of $4,781.91, which aggregates across developed parcel owners to over $38,000,000. As a consequence, this article argues that, under G.S. § 105-380, each of the individual council members of the Town is personally liable for the SDF property taxes refunded to developed parcel owners of said town, where the aggregate amount to date is over $38,000,000.

Accordingly, the three primary objectives of this article are:

(1) To establish the factual background surrounding the imposition by the Town of a recurring, annual SDF property tax, including the refunding of said SDF property tax to developed parcel owners.
(2) To establish the law at issue, i.e., G.S. § 105-380.
(3) To apply the law at issue to the factual background, wherein this author concludes that each member of the Town Council by resolution who refunded SDF property taxes to developed parcel owners becomes personally liable for said refunded SDF property taxes to developed parcel owners under G.S. § 105-380.

This article asserts that if these objectives are met, the General Public [including (1) the citizens of the Town, (2) owners of developed and undeveloped parcels within the boundaries of the Sewer Treatment District, (3) the N.C. Office of the Attorney General, (4) the N.C. General Assembly, and (5) the Town's Council and administration] will have a greater understanding of the personal liability of the individual council members of the Town for the SDF property taxes refunded to developed parcel owners, where the aggregate amount to date is over $38,000,000.

In a case study approach that employs an IRAC (**I**ssue, **R**ule, **A**pplication, **C**onclusion) structure, similar to that of an I.R.S. revenue ruling, this article accomplishes its purpose and objectives in a stepwise fashion, as follows.

- In Part I, the factual background surrounding the imposition by the Town of a Sewer District Fee/Tax is presented.
- In Part II, the law at issue, i.e., G.S. § 105-380, is presented.
- In Part III, the law at issue, as presented in Part II, is applied to factual background, as presented in Part I, for the purpose of establishing the personal liability of the individual council members of the Town for the SDF property taxes refunded to developed parcel owners.
- In Part IV, implications for the Town are presented.

Analytics, Business Intelligence, Data Mining, & Statistics

COMPARING THE FAIRNESS OF TWO POPULAR SOLUTION CONCEPTS OF COALITION GAMES: SHAPLEY VALUE AND NUCLEOLUS[1]

AUTHORS REDACTED TO PRESERVE ANONYMITY

ABSTRACT

An analytics model is developed to compare two popular solution concepts of coalition games, and to determine which one is fairer and more appropriate to use in real life applications of coalition games. Coalition games have found wide application in economics, finance, politics, and computing. When applications are developed using coalition game theory, designers have the option of choosing from several solutions concepts and the effectiveness of the solution depends on the accuracy of the underlying solution concepts. The algorithm presented sheds light on the effectiveness and fairness of the solution concepts and, in particular, is used to compare the fairness between Shapley Value and Nucleolus solution concepts. When imputations for coalitions are expressed in a barycentric triangle, they create a core, and larger core areas leave room for more competition among the coalitions which can create instability. Smaller core areas are desirable because they leave little room for further collaboration and come to a quick resolution. An example supports the idea of smaller core comparisons, and imputations have been calculated using Shapley Value and Nucleolus expressed in a barycentric triangle for comparison to show, at least in this example, that the Shapley Value solution concept method had a fairer distribution of the payoffs.

INTRODUCTION

Game theory has its foundations in applied mathematics. The mathematical models and built-in consistency of game theory make it a suitable framework and basis for modeling and designing of automated bargaining and decision-making software systems in interactive negotiation. For example, a game theory framework can serve as the most efficient bidding rule for Web Services, e-commerce auction website, or tamper-proof automated negotiations for purchasing communication bandwidth [10-12]. Research in these applications of game theory is the topic of many recent conferences, journals, and scientific papers. The application of game theory to automated negotiation is still in a nascent stage. The automation of strategic choices enhances the need for these choices to be made efficiently.

Game theory is the formal study of conflict and cooperation [2]. These are decision problems with multiple decision makers, whose decisions impact one another and the outcome. Game theory is a bag of analytical tools designed to help us understand the phenomena that we observe when decision-makers interact [3]. The basic assumptions that underlie the theory are that decision-makers pursue well-defined exogenous objectives (they are rational) and take into account their knowledge or expectations of other decision-makers' behavior (they reason strategically). An important characteristic of games is that the actions of one person have influence on the outcomes of other people in the game and vice versa.

Coalition Games, also called Cooperative Games, have found application in economics, finance, politics, computing, and problem resolution of various kinds [2, 3, 14]. Coalition game theory studies and models the joint activities of a group of decision makers who cooperate and take joint actions in a coalition to

[1] This paper is a summary of a doctoral dissertation by the first author as it nears completion.

increase their stakes. The problem of distributing the jointly-earned wealth in a fair way as payoffs or cost sharing among the coalitions remains a challenge till now. The game theoretic researchers have deduced a good quantity of methods of distribution, or solution concepts; and only a few of these solution concepts have been well accepted in the real life applications [14].

In this paper we discuss the coalition model extensively. Game theory requires that the conflict is modelled through proper analysis to find a proper solution to any conflict. We will highlight the differences between decision making of a single agent and interactive decision making, namely, a game. One of the differences is that in the first case we are aiming at getting an optimal decision. Optimality in games does not always apply, and the result of games can be dismal even when all parties behave rationally [10].

This study investigates two important Solution Concepts of coalition games, and compares them to understand their accuracies in their calculation of imputations and in their fairness in application. The coalition games have several of these Solution Concepts, and among them Shapley Value and Nucleolus have found wide applications in computing, finance, economics, biology etc. Efforts have been made to understand the accuracy of these Solution Concepts in allocating of imputations gained by the Agents, participating in coalitions [14].

Solution Concepts of coalition games become complex as more than two players join a coalition, and each agent try to maximize their gains; so, when multiple coalitions try to compete and win, proper distribution of gains is important to hold the coalition in place. When software applications are developed using coalition game theory, the fairness of imputation is the key for accurate outcomes. While fairness generally means equal treatment without favoritism, in coalition game theory fairness is typically specified as a well-defined metric or measure.

This study focuses on the coalition game for more than two players and extends the established work in this area. More specifically, it extends methods to compare and examine the properties of Shapley Value and Nucleolus Solution Concepts to calculate imputations to determine which values form the smaller core in barycentric coordinates, because when the area of the core is small the Solution Concept is defined here as being more accurate and fair.

THE PROBLEM

Game theory provides formal tools and mathematical models to study strategic interactions among players. In strategic interaction situations, the assumption of common knowledge known as solution concepts holds [10]. To study these situations and corresponding solution concepts we must resort to computational methods. Software is now available for coalition games, handling its underlying mathematical models and solution concepts. When applications are developed, designers have the option of choosing models and solutions concepts, and the effectiveness of the software depends on the accuracy of the underlying solution concepts.

In coalition game theory the modeler often must choose one of several substantively different solution methods, or solution concepts, which can lead to different game outcomes. Often one is chosen because it leads to a unique prediction [14]. In cooperative game theory, by defining solution concepts, one tries to characterize the set of outcomes that are, seen from a viewpoint of fairness and rationality. In this study we will describe and discuss the main solution concepts that have, in the course of time, been proposed by different game theorists [14]. In the discussion we will also establish the relationship between two different concepts and their usefulness and limitations in real life applications.

An example will explain the necessity for using a fair solution concept. The New York City (NYC) public school system had a problem matching incoming freshmen to high schools where the school district students

used to mail in a list of their five preferred schools in rank order to the Board of Education which then mailed a photocopy of that list to each of the five schools. The schools could then tell whether or not students had listed them as their first choice, and because many schools only wanted first-choice students this meant that some students really had a choice of only one school rather than five. To resolve this matching problem the school district went to experts and subsequently accepted the suggested Shapley's solution concept as the method of selection for NYC public school students [6]. But what would have happened if the experts selected the Nucleolus solution concept instead? Which solution concept would produce a fairer matching system? To answer such questions this study compares the level of fairness between these two solution concepts. In general, coalitions are outcomes of cooperation between players and these coalitions are usually goal-oriented, short-lived, formed with a purpose in mind, and dissolved when that purpose no longer exists or when players stop cooperating among themselves.

LITERATURE REVIEW

A game "is a competitive activity in which players contend with each other according to a set of rules" [10]. A game theory model can be designed to model any kind of conflict which is an interactive situation among the parties involved. If a conflict situation exists, there are multiple ways to resolve that conflict, and only few of them will be efficient. The application of game theory guarantees efficient resolution of the conflicts always, and also gives accurate mathematical reasoning of the situation. The nature and course of the conflict as well as its resolution depends on the decisions made by the various parties involved. Each party involved in the conflict, when considering its decisions, should take into account the decisions made by all the other parties. Game theory is the formal study of conflict and cooperation [12]. Games are decision problems with multiple decision makers, whose decisions impact one another. Game theory is a bag of analytical tools designed to help us understand the phenomena that we observe when decision-makers interact [11].

Professor Bruce Bueno de Mesquita of New York University recently made a handful of very impressive and accurate political predictions (https://www.newscientist.com/article/mg20527520-500-the-predictioneer-using-games-to-see-the-future/): in May 2010, he predicted that Pervez Musharraf, the Pakistani president had to leave his office by the end of summer of that year. Pervez Musharraf was forced out of his office before the end of the year. Bruce also successfully predicted the fall of Egyptian president, Hosni Mubarak. Approximately five years before the death of Ayatollah Khomeini in 1989, Bruce accurately predicted the name of his successor, and, since then, Bruce has made many dozens of consistent forecasts as a consultant to State Department, Pentagon and intelligence agencies and few foreign governments. The secret behind his success is the application of game theory and related mathematical models.

In 1962, Shapley together with David Gale wrote two papers on two important classes of games: cooperative and coalition games; the paper with title "College Admissions and the Stability of Marriage," authors studied matching games with nontransferable utility (http://www.u.arizona.edu/~mwalker/501BReadings/Gale&Shapley_AMM1962.pdf). The canonical example is the marriage game, where m women are to be matched with m men. A matching is "stable" if there is no woman and man who prefer each other to their current match. Gale and Shapley showed that the set of stable matching is precisely the set of core allocations, proved that there exists a stable matching, and provided an algorithm for finding it. In another 1962 paper, Martin Shubik and Shapley studied a transferable utility version of the matching game, called an assignment game (https://link.springer.com/article/10.1007/BF01753437). These two games have become workhorses in the study of labor markets and other two-sided markets.

In his 1953 paper, "A Value for N-Person Games," Shapley provided a set of axioms that, in every cooperative game, uniquely identified a payoff for each agent (http://www.library.fa.ru/files/Roth2.pdf#page=39). This payoff has come to be called the Shapley value. The paper has been enormously influential, both through the widespread use of the Shapley value, and by inspiring other values obtained through modifications to Shapley's original axioms. The Shapley value has been used to quantify the impact of voting rules on the influence of individual voters, where it is often called the Shapley-Shubik index after a 1954 Shapley and Shubik paper that analyzed the influence of different members of the United Nations Security Council (https://www.cambridge.org/core/journals/american-political-science-review/article/a-method-for-evaluating-the-distribution-of-power-in-a-committee-system/5C4948A19BD4138D855EDA0536496BCE). This measure is of more than academic interest: A related measure (the Banzhof index) has played a role in legal decisions concerning electoral districting and representation. The Shapley value has also been widely applied in accounting to problems of cost allocation.

Von Neumann and Morgenstern who were the originators of multi-person cooperative games proposed their own solution concept, known as the Stable Set [13]. In 1953, Gillies introduced the concept of core as the set of all un-dominated payoffs (i.e., imputations) to the players satisfying rationality properties. Even though the core has been found useful in studying economic markets, it does not provide a unique solution to the allocation problem. Also in 1953, Shapley wrote four axioms which would capture the idea of a fair allocation of payoffs and developed a simple, analytic, expression to calculate the payoffs. Shapley value can be computed easily by using a formula regardless of whether or not the core is empty [4]. However, when the core is non-empty, Shapley value may not be in the core and under some conditions the allocation scheme in terms of Shapley value may result in an unstable grand coalition. An alternative solution concept known as the nucleolus was introduced by another game theorist, Schmeidler. In 1969, Schmeidler defined and introduced the concept of Nucleolus. The nucleolus of a coalition game is the imputation with lexicographically minimal excess, based on ordering of the imputations. The nucleolus solution is defined as an n-tuple of imputation x = (x1, x2,…xn) such that the excess of any possible coalition S cannot be lowered without increasing any other greater excess [1].

Solution concept is the term used to mean the methods used to divide the cost or payoffs fairly amongst the participating players who acted jointly in the coalition. In the process one should choose an allocation scheme that satisfies coalition's joint agreement with natural monotonicity property of the game. Monotonicity of a scheme is defined as when the cost or payoffs incurred by each possible coalition rises, then the cost or payoffs allocation to each entity under the scheme should also be increased accordingly. The nucleolus is not always monotonic [1].

Game theory became a popular area of research due to its mathematical models and wide application in the fields of computing, economics, finance, politics, stock markets, prediction markets, international relationships, and generally any field where multiple parties were involved in making decisions. Application software is available using the underlying principles of coalition game and its underlying mathematical models using solution concepts. Many contributions were made by academicians in this area, some of which are very complicated in nature.

The solution concepts, which are the logical rules of sharing the imputations, play an important role to hold the coalitions and share their worth. Two of the six main solution concepts, namely Shapley Value and Nucleolus, have been widely used by prominent game theoreticians because of their simplicity and accuracy. In coalition games, coalitions stay together when their payoffs are maximum and also fair compared to other possible coalitions. The coalition members act together to maximize their shares, or imputations, and if the imputations are not sufficiently fair, i.e. if members are dissatisfied, the coalition will not exist and fairer methods should be applied in the allocation process. Here, we determine which solution concept is best by comparing their outputs. For comparing, we have used: (1) the deviations, in which the outputs

have been calculated with pro-rata outputs, then compared to see which one produce minimum deviations; (2) more accurately, comparisons by finding the core created by Shapley Value and Nucleolus in barycentric triangles to find a solution concept producing the smaller Core; (3) also comparisons by using lexicographic ordering.

COALITION GAMES AND SOLUTION CONCEPTS

A coalition game is a special case of cooperative games where individual players cooperate among themselves as part of a coalition on some joint activities and decision making. Coalitions are formed for mutual benefit with each agent or player of a coalition trying to maximize their payoffs and the payoffs of the coalition. The central understanding of a coalition game is the formation of the coalitions and the rules governing the existence and activities of coalitions. Coalitions are partitions on the super set of total players in the game. The binding force of a coalition is the worth of the coalition. The solution concept will predict the coalition formations and the final allocation (payoffs) to participants. A coalition game consists of two elements: (i) a group of players who participate in the game and (ii) a characteristic function specifying the value created by different subsets of the players in the game. Formally, let N = {1, 2 … n} be the sets of players and n=|N| the total number of players. The characteristic function is a function, denoted v(S), that associates with every subset S of the n players the value created when the members of S work together. In summary, a coalition game is a pair (N, v), where N is a set and v(S) is a characteristic function [2]. Solution concepts like Shapley Value are used to calculate the worth at the individual marginal level using the characteristic function v(S) of the game (N,v). A set consisting of all the players in a coalition game is known as the Grand Coalition, and the characteristic function for the grand coalition is v(N). The players form coalitions in any form and the solution concept will predict the coalitions that form and the final allocation (payoffs) to all coalitions and ultimately to the players.

The basic idea behind coalition game theory is that the players will be benefit by forming coalitions, and each member's payoff will be better or equal to the payoff when the player is acting alone. In a cooperative game model, the formation of the grand coalition, N, will lead to the highest benefit of the coalition since by super additivity the amount received, v(N), is always better, or equal to the total amount earned by any number of disjoint set of coalitions they could form. We will prove that it is reasonable to suppose that rational players will always agree to form the grand coalition and receive maximum payoff v(N). A grand coalition always guarantees the best payoffs, and follows rules to split the amount reasonably among the players. We will discuss one of the possible properties of an agreement on a fair division, that it be stable in the sense that no coalition should have the desire and capability to upset the agreement of forming the coalition. This understanding is known as 'core' in coalition game theory, and is used widely in all forms coalition game theory. To understand core, we need to introduce another term called the imputation.

Imputations are distributions of payoff vectors at the individual marginal level which are efficient and individually rational. Imputation can be expressed with the help of payoff vectors. For a coalition game, an imputation or payoff vector $\boldsymbol{x} = (x1, x2, \ldots x_n)$ for a coalition S is a proposed amount distributed among the players, such that player i is to receive x_i. The total amount received by the players in the coalition is v(S), where S is a subset of N. The set of imputations may be written as: $\{\mathbf{x} = (x1, \ldots, xn) : i \sum_{i \in N} xi = v(N)$, and $xi \geq v(\{i\}) \quad \forall \quad i \in N\}$. To satisfy the imputation conditions, a payoff vector has to be group rational. If the payoff vector is expressed as x = (x1, x2, . . . , xn), the x will be group rational or efficient if and only if $\sum_{i=1}^{n} xi = v(N)$. A player participating in a coalition will always expect to receive a better payoff than could be earned acting alone. This essential condition for imputation can be expressed as follows: **x** = (x1, x2, . . . , xn), is that $xi \geq v(\{i\})$ for all players i in the coalition [2].

The Shapley value is one of the popular solution concepts for dividing the worth of the coalition. The Shapley value is characterized by a collection of desirable properties known as Shapley Axioms. The Shapley Value imputation for the i^{th} player is given by [5]:

$$\emptyset i(v) = \sum_{S \in N\{i\}} \frac{(|S|-1)!\,(n-|S|)!}{n!}(v(S \cup \{i\}) - v(S))$$

The Nucleolus solution concept is defined as an n-tuple imputation x = (x1, x2,…xn) such that the excess (unhappiness) of any possible coalition S cannot be lowered without increasing any other greater excess until all coalition reaches to a satisfaction level. The nucleolus of a coalition game is the imputation with lexicographically minimal excess, based on ordering of the imputations [9].

Some additional solution concepts will be described briefly. In a Core Concept solution the core of the coalition game is the set of actions A of the Grand Coalition N such that no coalition has an action that all its members prefer to action A[3]. In coalition game, the core is defined as the set of all feasible allocations that cannot be improved upon by a coalition. An imputation is said to be in the core if the imputation is equal or better than the individual pay-offs. A coalition is said to improve upon or block a feasible allocation if the members of that coalition are better off under another feasible allocation. In a Kernel solution [8] concept payoff, all players are in a sort of "bilateral equilibrium", in the sense that the threats to each other are equalized [10]. The definition seems to involve interpersonal utility comparisons. The Stable Set solution concept was suggested by Von Neumann and Morgenstern in 1944, in their book, Theory of games and economic behavior. The stable set solution concept [8], also known as the von Neumann-Morgenstern solution dealt with the games with more than 2 players. A stable set is a set of imputations that satisfies two properties: (a) Internal stability (b) No payoff vector in the stable set is dominated by another vector in the set, means no other imputations can block the coalition [14]. External stability: All payoff vectors outside the set are dominated by at least one vector in the set. Von Neumann and Morgenstern saw the stable set as the collection of acceptable behaviors in the society. The Banzhaf power index is a power index defined by the probability of changing an outcome of a vote where voting rights are not necessarily equally divided among the voters or shareholders. This solution concept was invented by Lionel Penrose in 1946, was named after John F. Banzhaf III and is sometimes called the Penrose–Banzhaf index [14].

SHAPLEY VALUE SOLUTION CONCEPT

This solution concept method calculates a single payoff for each player in the coalition, the average of all marginal contributions of a player in the coalition. The basic idea is that those who contribute more to the coalitions that include them should earn more.

A value function, φ assigns to each possible characteristic function of an n-person game, v, a vector of real numbers $\emptyset$i(v) = ($\emptyset$1(v), $\emptyset$2(v), ... $\emptyset$n(v)). Here $\emptyset$i(v) represents the worth or value of the ith player in the game with characteristic function v(S).

The Shapley Axioms for $\boldsymbol{\varphi}(v)$[2] **:**

1. **Efficiency:** This is also known as Group Rational, or Collectively Rational; **t**he total worth distributed among the players: $\sum_{i \in N} \emptyset i(v) = v(N)$.
2. **Symmetry.** If i and j are such that $v(S \cup \{i\}) = v(S \cup \{j\})$ for every sub-coalition S in N, and S not containing i and j, then $\emptyset i(v) = \emptyset j(v)$. Two participants, i, j are said to be symmetric with respect to coalition game (N, v) if they make the same marginal contribution to the coalition.
3. **Dummy Axiom.** If i is such that $v(S) = v(S \cup \{i\})$ for every coalition S not containing i, then $\emptyset i(v) = 0$
4. **Additivity.** If u and v are characteristic functions, then $\boldsymbol{\varphi}(u + v) = \boldsymbol{\varphi}(u) + \boldsymbol{\varphi}(v)$.

The first axiom syas that the total value earned the players is the total value of the grand coalition. For a coalition to act together, this is the basic rule, as each participant will do better in the coalition than individually. The second axiom says that if the characteristic function is symmetric for two players i and j, then the values assigned to i and j should be equal, i.e. v({i}) = v({j}). The third axiom states that the

contribution by a dummy participant is null and his payoff vector is null. The forth states that when two games are played at the same time the sum of the values of the games are as if they are played separately.

The Shapley value is used to distribute the total gains to the players, provided that the players were the part of the coalition. For a game (N, v) the distribution is said to be fair in the sense that it satisfies the following condition, $\varphi_i(v) \geq v(\{i\})$, that the players' payoff will be a fair portion of the payoffs of the Grand Coalition.

If the total number of participants in the game is n, then a coalitional is expressed by the pair (N, v), where N = {1, 2,, . . , n} is the set of players and v is called the characteristic function of the game, which determines the worth, defined on the set, 2^N, of all possible combinations of coalitions, i.e. the subsets of N. The formula is used to calculate the average marginal contribution by individual player, i to each possible coalition, (S1, S2, …Sn) those can be formed from the players. To form the coalition, one player enters at a time; so, there exists N! ways to do this. Now, during the formation of coalition S, we can do it in S! ways. The characteristic function will be v(S). As player i-th enters the coalition S, the new value of the characteristic function will become v(S U {i}).

Player i is a member of the coalition S; so the quantity, v(S) − v(S − {i}), is the amount by which the value of coalition (S − {i}) increases when player i joins the coalition. Now, to find value φi(v), we need to list all coalitions containing i, sum up all the value of player i's contribution to that coalition, then multiply by value ((|S| − 1)!(n − |S|)!/n!), and ultimately take the sum. We have to choose a random order of the players with all n! permutation orders of the players equally likely. Next, we have to determine positional worth of the player as follows: if, when player i enters the coalition, he forms coalition S and he finds coalition (S − {i}) is already there, he receives the amount [v(S) − v(S − {i})]. Now, we have to compute the probability of finding the coalition S − {i} in front of him; and it should be (|S| − 1)!(n − |S|)!/n!. The denominator of the expression is the total number of possible permutations of the n participants. The numerator is number of these permutations in which the (|S| −1) members of (S −{i}) coalition come first in ((|S| − 1)!) ways; then player I; and then the remaining (n − |S|) players in ((n − |S|)!) ways. So, this formula shows that the amount φi(v) is just the average amount player i contributes to the grand coalition if the players sequentially form this coalition in a random order [2]. The Shapley Value for player i-th player is given by:

$$\emptyset i(v) = \sum_{S \in N\{i\}} \frac{(|S|-1)!\,(n-|S|)!}{n!}(v(S \cup \{i\}) - v(S))$$

NUCLEOLUS SOLUTION CONCEPT

The nucleolus of a cooperative game is a solution concept that makes the largest unhappiness of the coalitions as small as possible, or, equivalently, minimizes the worst inequity. In 1969, Schmeidler came up with a new solution concept known as the nucleolus; he proposed an allocation scheme that minimizes the "unhappiness" of the most-unhappy coalition during distribution of payoffs. Schmeidler defines "unhappiness" or excess of a coalition as the difference between what the members of the coalition could get by themselves and what they are actually getting if they accept the allocations suggested by a solution. It was shown by Schmeidler that if the core for a cooperative game is non-empty, then the nucleolus is always located inside the core and thus assures stability of the grand coalition [7]. For calculating Nucleolus, there does not exist any established formula; in most of the cases, it is computed analytically, or numerically in an iterative manner by solving linear programming (LP) problems.

In cooperative games, the players jointly coordinate their actions by forming multi-level coalitions. The most important steps in the process is the fair distribution of the worth among all coalition members generated from such a joint effort. The Shapley Value and Nucleolus are widely recognized and used as a fair way of distributing the gain in a coalition. There exist efficient algorithms for computing the nucleolus

using linear programming based techniques; the implementation of those methodologies are infeasible in multi-player coalitions as the burden of decision making is distributed among all players in the coalition, and there is no single decision market that can aggregate all data and compute for all.

As a solution concept, the nucleolus is very important and well accepted solution in cooperative game theory despite calculation difficulties. The nucleolus satisfies some important desirable properties, e.g. if core is not empty, it exists uniquely in the core; and is considered as an important fair division scheme [7]. Many researchers have used this concept to analyze computational, business and management problems, though the complexity of calculations made the nucleolus a tough choice in many resource allocation applications.

For fairly distribution of cost or payoffs among multiple players, one should choose an allocation scheme that satisfies a natural monotonicity property of the coalition. In the context of cost sharing, the monotonicity of an allocation scheme means that, if the cost or worth incurred by each possible coalition rises, then the cost or worth allocation to each coalition under the scheme should be increased. The nucleolus is not always monotonic which is considered as a drawback of this concept [7].

In many cost allocation problems, when the cost for using the common resource increases, then the nucleolus solution may suggest a lower cost allocated to some entities, which means that the nucleolus is not monotonic always. Other solution concepts those satisfy the monotonicity property can be used instead of the nucleolus, or they can be used in combination. Grotte introduced a new method of calculating the Nucleolus; he normalized the nucleolus by dividing the excess of each coalition by the number of players in the coalition; this new concept, he name per capita normalized nucleolus. Grotte proved that the per capita nucleolus is monotonic and also always exists in the core [7].

When nucleolus is calculated, it can be readjusted to be in the core, if the core is not empty. The nucleolus satisfies the symmetry axiom and the dummy axiom; it is group rational and individually rational. The only difficult part to prove is the uniqueness of the nucleolus. Since the nucleolus always exists and is unique, we may speak of the nucleolus of a game. Like the Shapley value, the nucleolus will satisfy individual rationality if the characteristic function is super-additive or, more generally, if it is monotone in the sense that for all players i and for all coalitions S not containing i, we have $v(S)+v(\{i\}) \leq v(S \cup \{i\})$. In contrast to the Shapley value, the nucleolus will be in the core provided the core is not empty. The nucleolus satisfies the first three axioms of the Shapley value [2].

Excess, an inequity measure of an imputation $\boldsymbol{x}$ for a coalition S, is defined as: $e(\boldsymbol{x}, S) = v(S) - \sum_{J \in \boldsymbol{S}} \boldsymbol{x_j}$. Excess measures the amount or the size of the inequity by which coalition S falls short of its potential v(S) in the allocation x. Since the core is defined as the set of imputations such that for all coalitions S, we immediately have that an imputation x is in the core if and only if all its excesses are negative or zero. During the distribution of worth, the coalition which complains that it is not getting its proper share, efforts will be made to give it a fair share.

For calculating Nucleolus, there does not exist any established formula; in most of the cases, it is computed analytically, or numerically in an iterative manner by solving linear programming problems. The steps of finding the nucleolus is to find a vector $\boldsymbol{x} = (x1, x2, \ldots, xn)$ that minimizes the maximum of the excesses $e(\boldsymbol{x}, S)$ over all S subject to $xj = v(N)$. This problem of minimizing the maximum of a collection of linear functions subject to a linear constraint is easily converted to a linear programming problem. After this is done, one may have to solve a second linear programming problem to minimize the next largest excess, and so on [7]. We will follow the analytical method.

From the definition of Nucleolus, it is clear that the nucleolus of a cooperative game is a solution concept that makes the largest unhappiness of the coalitions as small as possible, or, equivalently, minimizes the worst inequity. Using analytical method, which is based on lexicographic ordering we reduce the largest excess of the imputations, for all coalitions as much as possible, then decrease the second largest excess as much as possible, and continue this process until the n-tuple imputation x is determined [7].

The nucleolus is computed by applying linear programming in multiple steps:

Step 1: In this step, possible coalitions are formed, empty coalition is omitted.
Step 2: Using the characteristic functions, pro-rata imputations are calculated.
Step 2: In this step, individual coalition's joint worth is assigned to the coalitions.
Step 3: At this stage, the excess e(x,S) is calculated.
Step 4: Now using the table, one needs to find next vector $\boldsymbol{x} = (x1, \ldots, xn)$ that minimizes the maximum of the excesses $e(\boldsymbol{x}, S)$ over all coalitions S subject to $v(N)$.
Step 5: Step 4 is repeated until all imputations are processed; and the excess are minimized.

MEASURING FAIRNESS

We will now focus on a game with three players and look into the imputations generated by Shapley Values and Nucleolus.

Assumptions and representations:
(1). We will represent the coalition as: {1}, {2}, {3}, {1, 2}, {1, 3}, {2, 3}, {1, 2, 3}
(2). Characteristic functions: v(1), v(2), v(3), v(1, 2), v(1,3), v(2, 3), v(1,2,3) : this characteristic functions expresses a 3 player coalition game.
(3). Each player's marginal share in the coalition is called the imputation; players imputations will be represented by: x1, x2, x3 satisfying: x1>= v(1), x2 >= v(2) and x3 >= v(3). Also, x1 + x2 + x3 = v(1, 2, 3) [2].
(4). When all imputations are in the core, they are considered as 'fair' and none of the coalition will try to block the imputations in the core. The imputations will be in the core, iff

(1) x1 + x2 >= v(1,2)
(2) x1 + x3 >= v(1,3)
(3) x2 + x3 >= (v(2,3)

(5). Symmetrical players: Two players i & j are symmetrical when characteristic function v(ik) = v(jk) with assumption that k's marginal imputation is the same on the both coalition.

There are various methods of measuring fairness. Shapley value and Nucleolus are popular Solution Concepts for coalition game based solutions, applications and models. Coalition games based applications and predictions models needs effective models with fair Solution Concepts. Our algorithm will help to understand the effectiveness and fairness of the imputations used deducted using Shapley Value and Nucleolus.

1. Comparing Deviations: We will use deviations of imputations from pro-rata, Shapley value, and Nucleolus; imputations having larger deviations are less fair.
2. Lexographic ordering : We will use lexographic order for comparing Shapley Values with Nucleolus values.
3. Smaller Core: We will use Core capabilities of the imputations, i.e. which values create a compact smaller Core.

For comparing deviations we have the steps:
(1). Take the given coalition game for 3 players (|N| =3), write it in terms of characteristic functions, v(1), v(2), v(3), v(12), v(1,3), v(2,3), v(1,2,3); and imputations: x1, x2, x3.

(2) Calculate pro-rata imputations for individual players and coalitions.

$x_1^{PR}, \quad x_2^{PR}, \quad x_3^{PR}$

(3) Calculate imputations using Shapley Value Solution concepts:

$x_1^{S}, \quad x_2^{S}, \quad x_3^{S}$

(4) Calculate imputations using Nucleolus Solution concepts:

$x_1^{N}, \; x_2^{N}, \; x_3^{N}$

(5) Next, calculate the deviations of imputations between the pro-rata imputations and Shapley Value imputations; and then, between the pro-rata imputations and Nucleolus imputations. Now, compare the deviations, if are positive, and do not exceed Grand coalitions payoffs, then the bigger imputations are more fair than the other.

$x_1^{DS} = x_1^{PR} - x_1^{S}$
$x_2^{DS} = x_2^{PR} - x_2^{S}$
$x_3^{DS} = x_3^{PR} - x_3^{S}$
$x_1^{DN} = x_1^{PR} - x_1^{N}$
$x_2^{DN} = x_2^{PR} - x_2^{N}$
$x_3^{DN} = x_3^{PR} - x_3^{N}$

For the lexicographical ordering method we use the lexographical order. We say, for any vector y =(y_1,..., y_k) is lexographically less than a vector z = (z_1,...,z_k), and write y <L z, if $y_1 < z_1$, or if $y_1 = z_1$, or and $y_2 < z_2$, or if $y_1 = z_1$, $y_2 = z_2$ and $y_3 < z_3$, or..., or if $y_1 = z_1$, ... , $y_{k-1} = z_{k-1}$ and $y_k < z_k$ [2]. That is, y <L z if in the first component in which y and z differ, that component of y is less than the corresponding component of z. Similarly, we write y ≤L z if either y <L z or y = z.

For the smaller core method we use the core concept together with barycentric coordinates to compare the imputations: if core imputations create triangles with smaller area, the distribution will be more accurate and less prone to fluctuate; a bigger area of the triangle indicates less fairness, which is the cause of dissatisfactions.

EXAMPLE: COALITION OF THREE NEIGHBORING FARMS

This is a three-player coalition game involving three neighboring farms connected to each other and to the main highway by a series of trails. The farms are planning to build paved roads connecting them to the highway. They can build them individually, or by forming coalitions as shown in Figure 1.

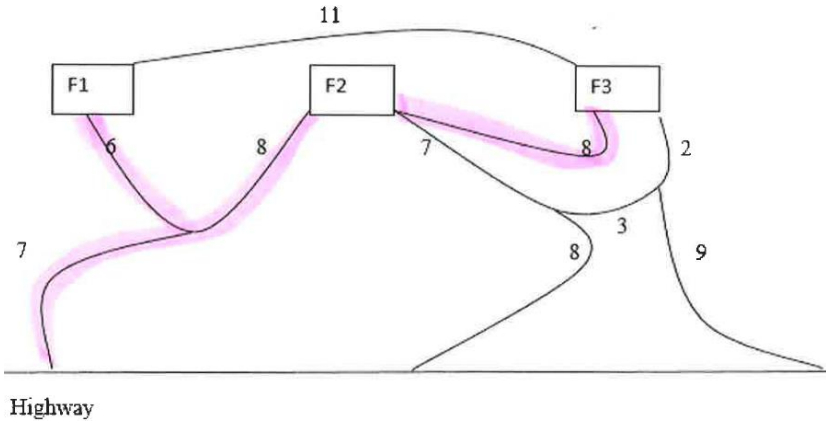

Figure 1. Logical connections and estimated paving costs in millions of dollars for calculating coalition benefits for farms F1, F2, and F3. The optimal road paving solution is highlighted in red.

Possible Coalitions:

{∅}, {F1}, {F2}, {F3}, {F1, F2}, {F1, F3}, {F2, F3}, {F1, F2, F3}

Opportunity Cost:
We define the opportunity cost for each player and all possible coalitions. An opportunity cost is defined as the minimum cost of a player or coalition. The opportunity cost in this example are: oc(F1) = 13, oc(F2) = 15, oc(F3) = 11, oc(F1,F2) = 21, oc(F1,F3) = 22, oc(F2,F3) = 20, oc(F1,F2,F3) = 29.

Possible coalitions:
(1) Players F1 and F2 can build the desired road for v(F1, F2) = 21 million dollars. If built separately, the farms have to spend 28 million. Jointly the farms save = 7 million.
(2) Players F1 and F3 can build it together for v(F1, F3) = 22. If built separately, the farms have to spend 24 million. Jointly the farms save 2 million.
(3) Players F2 and F3 can build it for v({F2, F3}) = 20. If built separately, the farms have to spend 26 million. Jointly the farms save 6 million.
(4) All 3 players: F1, F2, F3 i.e. the grand coalition can build for v({F1,F2, F3}) = 29. If build separately, the farms have to spend 39 million. Jointly the farms save 10 million.

Characteristic functions:
V(F1) = 0, V(F2) = 0, V(F3) = 0, v({F1, F2}) = 7, v({F1, F3}) = 2, v({F2, F3}) = 6, v({F1,F2, F3}) = 10

We now find the pro-rata profits for the players, where the players share the savings proportional to their opportunity costs. The pro-rata distribution is a simple distribution and not considered a solution concept but rather assumes that the farms form a hypothetical Grand Coalition which gives proportional incentives to all players. The pro-rata distribution to the farms is:

(1) F1 distribution: [29 * 13/ (13 + 15 + 11)] = 9.67 and savings = 13 – 9.67 = 3.33
(2) F2 distribution: [29 * 15/ (13 + 15 + 11)] = 11.15 and savings = 15 – 11.15 = 3.85
(3) F3 distribution: [29 * 11/ (13+ 15 + 11)] = 8.17 and savings = 11 – 8.18 = 2.82

Pro rata imputations: (3.3, 3.9, 2.8)

Computing Shapley Value

The coalitions and characteristic function are as above.

We find inductively:

c{F1} = v({F1}) = 0, c{F2} = v({F2}) = 0, c{F3} = v({F3}) = 0, c{F1,F2} = v({F1,F2})−c{F1}−c{F2} = 7 – 0 − 0 = 7
c{F1,F3} = v({F1,F3}) − c{F1} − c{F3} = 2-0-0 = 2 and c{F2,F3} = v({ F2,F3})-c{F2}-c{F3} = 6-0-0 =6
Finally,
C{N} = v({N}) - c{F1,F2} - c{F1,F3} - c{F2,F3} - c{F1} - c{F2} - c{F3} = 10 - 7 - 2 - 6 - 0 - 0 - 0 = -5
Hence, we know we can write v as
v = w{1} + w{2} + w{3} +7w{1,2} + 2w{1,3} + 6 w{2,3} -5w{1,2,3} or
v = 7w{1,2 } + 2w{1,3}) + 6w{2,3} -5w{1,2,3} (omitting 0 values)
Now, we find φ1(v), φ2(v), φ3(v):

$\varphi 1(v) = \frac{7}{2} + \frac{2}{2} - \frac{5}{3} = \frac{17}{6}$

$\varphi 2(v) = \frac{7}{2} + \frac{6}{2} - \frac{5}{3} = \frac{29}{6}$

$\varphi 3(v) = \frac{2}{2} + \frac{6}{2} - \frac{5}{3} = \frac{14}{6}$

Shapley Value imputations: (17/6, 29/6, 14/6) = (2.8, 4.8, 2.3)

Computing Nucleolus

The coalitions and characteristic function are as above.

Table 1. Tabular system for calculating Nucleolus

Coalition	v(S)	e(x,S)	(3.3, 3.9, 2.8)	(3.5, 3.9, 2.6)	(3.5, 3.9, 2.6)
{F1}	0	-x1	-3.3	- 3.5	-3.5
{F2}	0	-x2	-3.9	-3.9	-3.9
{F3}	0	-x3	-2.8	-2.6	- 2.6
{F1,F2}	7	7 –x1- x2	- 0.2	- 0.45	-1.4
{F1,F3}	2	2 –x1 –x3	-4.1	-4.1	-4.1
{F2, F3}	6	6 –x2 –x3	- 0.7	- 0.45	-0.5

Step 1: To find imputations, we create a matrix with the pro-rata imputations; here, the imputations will be (3.3, 3.9, 2.8).
Steps 2: We determine the vector of excesses of imputations denoted by e = (−3.3, −3.9, −2.8, 0.2, −4.1, 0.7).
Step 3: We look for the first dissatisfied coalition by identifying largest of these values of the vector, and it is -0.2, for the coalition (F1, F2). This coalition will be dissatisfied as the other coalitions are doing better than it is. So, we have to improve the excess of this coalition by making it smaller. Also here, we will look for nearest large value, which will be used to normalize the imputations; that value is -0.7.
Step 4: The next large imputation is -0.7 for coalition (F2, F3); and it is the closer value. We will try to normalize the values of these two coalition such that excesses e(**x**, F2, F3) = e(**x**, F1,F2); to do that we will increase x1 and decrease x3; and they will meet at -0.45 By solving the excesses for the two coalitions, we find that x1 = 3.5 and x3 = 2.6.
Step 5: Next vector of excess is (−3.5, −3.9, −2.6, 0.45, −4.1, 0.45). At this stage, we have two stable values calculated from the last steps: x1 = 3.5 and x3 = 2.6. The third value x2 = 10 – x1 –x3 gives us 3.9, which is the current value
Step 6: Once, x1 and x3 have been calculated, we recalculate the new values for the coalition by using values of x1 & x3 . New imputation vector is (−3.5, −3.9, −2.6, −1.4, −4.1, −0.5).
Step 7: Now, we will recalculate the value of x2; we will try first equation (6 –x2 –x3 = -0.45). Here, if we use the current value of x3 = 2.6, we have x2 = 3.9.
Step 8: By solving another equation (7 – x1 –x2 = - 0.45), we try to see whether there will be better value for x2; it gives x2 = 4.0; which actually may upset other two values: x1, x3.
Step 9: So, we will go with the imputations (3.5, 3.9, 2.6)

Nucleolus imputations: (3.5, 3.9, 2.6)

Comparing Fairness

1. **Deviations of imputations:**
   Pro-rata imputations of the coalitions: {(1,2), (1,3), (2,3)}: (43, 37, 40)
   Shapley value imputations of the coalitions: { (1,2), (1,3), (2,3) }: (46, 31, 43)
   Deviation for Shapley Values: **(-3, 5, -3)**
   Pro-rata imputations of the coalitions: { (1,2), (1,3), (2,3) }: (43, 37, 40)
   Nucleolus imputations of the coalitions: { (1,2), (1,3), (2,3) }: (43, 37, 40)
   Deviation for Nucleolus Values: **(0, 0, 0)**

2. **Lexicographical Ordering of imputations as coalitions:**

Imputations of coalitions according to Shapley Values: {(1,2), (1,3), (2,3) } (46, 31, 43)
Imputations of coalitions according to Nucleolus values: {(1,2), (1,3), (2,3) } (43, 37, 40)
Lixicographical order, S <>l N, for
Set S{46, 31, 43} and set N{43, 37, 40} in mixed state.

3. Smaller Core:

(a) Finding the Core using Shapley Value imputations:
We have the imputations: (17/6, 29/6, 14/6)
The core created by Shapley Value imputations:
The triangle at the middle of the barycentric triangle, vertices: (0, 0, 60), (60, 0, 0), (0, 60, 0) created by coalition imputations represent the core.
The coalition imputations are represented by the barycentric equilateral triangle ABC and the triangle xyz at the middle of the barycentric triangle ABC (vertices: (0, 0, 60), (60, 0, 0), (0, 60, 0)) represents the core (Figure 2). The area of triangle xyz (the core) = area of triangle ABC – (area of trapezoid Amyq + area of trapezoid Bozm + area of trapezoid Coxq). Herons' formula will be used to find the area of the triangle. Heron's formula: area of triangle = sqrt(s(s -a) (s -b) (s -c)) ; semi-perimeter, s = (a +b +c) /2.

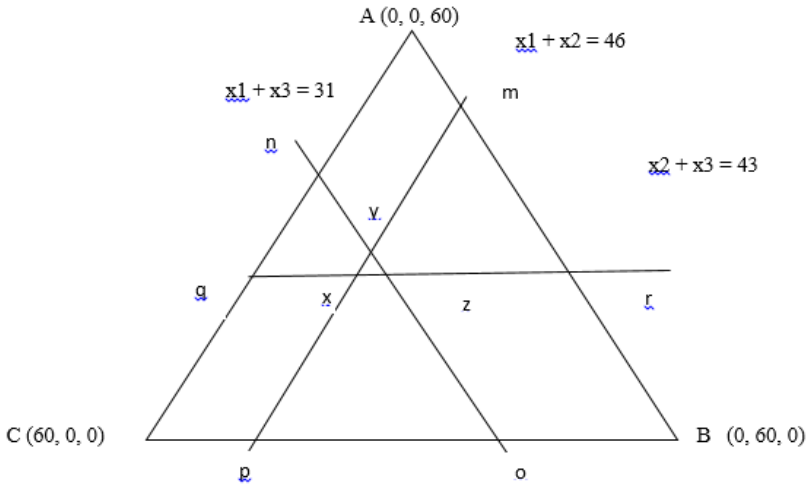

Figure 2. The Shapley Value barycentric triangle ABC and the core triangle xyz.

Line mp intersects sides AB at m and BC at p respectively; line mp also intersects line qr at the point y, and line on at the point z respectively. Line qr intersects sides AB at the point r and AC at q respectively; line qr also intersects line mp at the point y, and line on at the point x respectively. Line on intersects sides AC at the point n and BC at o respectively; line on also intersects line qr at the point x, and line mp at the point y respectively. Area triangle ABC = sqrt(s(s -a)(s -b)(s -c)), Herons' formula =sqrt(90 * 30 * 30 * 30) = 1558.845 sq units. Area of triangle xyz(the core) = area of triangle ABC – (area of trapezoid Amxq + area of trapezoid Boym + area of trapezoid Cqzo). Height of ABC triangle = 51.96 units.

Area of trapezoid Amxq = (((29 + 43)/2) * h) = 36 * 12.123 = 436.464 sq units
Area of trapezoid Boym = (((17 +46)/2) * h) = 31.5 * 25.114 = 791.091 sq units
Area of trapezoid Cqzo = (((14 +31)/2) * h) = 22.5 * 14.721 = 331.222 sq units
Area of core = 1558.845 – (436.428 + 791.091 + 331.222) sq units = 1558.845 - 1558.741 = 0.104 sq units

(b) Finding Core using Nucleolus imputations:
Nucleolus Values: (3.5, 3.9, 2.6)
The core created by Nucleolus Value imputations:

The triangle at the middle of the barycentric triangle with vertices: (0, 0, 60), (60, 0, 0), (0, 60, 0) created by the coalition imputations represents the core (Figure 3). Triangle ABC is equilateral with sides: a = 60, b = 60, c = 60.

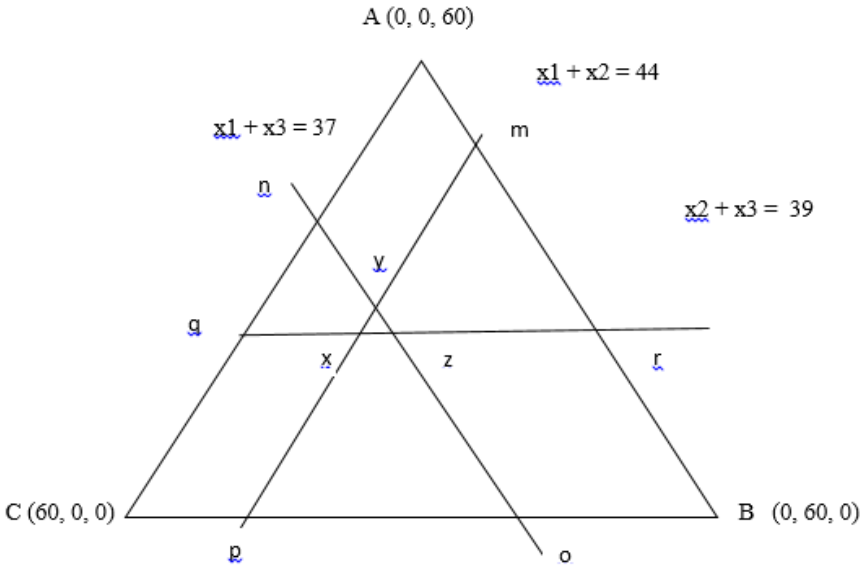

Figure 3. The Nucleolus Value barycentric triangle ABC and the core triangle xyz.

Line mp intersects sides AB at m and BC at p respectively; line mp also intersects line qr at the point y, and line on at the point z respectively. Line qr intersects sides AB at the point r and AC at q respectively; line qr also intersects line mp at the point y, and line on at the point x respectively. Line on intersects sides AC at the point n and BC at o respectively; line on also intersects line qr at the point x, and line mp at the point y respectively. Area triangle ABC = sqrt(s(s -a) (s -b) (s -c)) Herons' formula =sqrt(90 * 30 * 30 * 30) = 1558.845 sq units. Area of triangle xyz(the core) = area of triangle ABC –(area of trapezoid Amxq + area of trapezoid Boym + area of trapezoid Cqzo). Height of ABC triangle = 51.96 units, perimeter p = (a +b +c) /2. Area triangle ABC = sqrt(p(p-a) (p-b) (p-c)) Herons' formula = sqrt(90 * 30 * 30 * 30) = 1558.845 sq units.

Area of trapezoid Amxq = (((23+ 39)/2) * h) = 31 * 13.856 = 429.536 sq units
Area of trapezoid Boym = (((21 +44)/2) * h) = 32.5 * 19.919 = 647.367 sq units
Area of trapezoid Cqzo = (((16 +37)/2) * h) = 26.5 * 18.167 = 481.425 sq units
Area of core = 1558.845–(429.536+481.425+647.367) = 1558.845-1558.326 = 0.517 sq units

Comparing the areas of the cores:
Area of the Core for Shapley Values = 0.104 sq units
Area of the Core for Nucleolus = 0.517 sq units

Comparing fairness:
For this example, a summary of the imputations (payoffs) for the three methods is shown in Table 2.

Table 2. Summary of the payoffs to the farms in millions of dollars for the three methods.

	Farm 1	Farm 2	Farm 3
Pro Rata	3.3	3.9	2.8
Shapley Value	2.8	4.8	2.3
Nucleolus	3.5	3.9	2.6

The simple pro-rata payoff method, although not considered a solution concept, can serve as a baseline for comparison with the two solution concept methods. The Shapley Value solution concept method gives higher payoffs to the players contributing more to the coalition, so in this case Farm 2 was given a substantially higher payoff relative to the Pro Rata payoffs because it was the main contributor as can be seen in the optimal road paving solution in Figure 1. The Nucleolus solution concept method provides payoffs similar to the Pro Rata method, merely shifting a small amount of payoff from Farm 3 to Farm 1. Comparing the two solution concept methods, the core created by the Shapley Value payoffs was significantly smaller in size than that of the Nucleolus payoffs, indicating that the excess between the payoffs was less and therefore the Shapley Value solution concept method had a fairer distribution of the payoffs.

CONCLUSIONS

Coalition games are being applied to many fields, including economics, financial, computing, politics etc. In this study, efforts have been made to study and understand the level of fairness of 'Solutions Concepts' based on coalition imputations between the two most popular 'Solutions Concepts': Shapley value and Nucleolus used in coalition games. To do that, the computational methods for solution concepts have been presented. In Coalition game, which is a special case of cooperation games derives imputations by implementing few well known solution concepts like Shapley Value, Nucleolus, Core, Kernel etc.

The main contributions of the study:

- A computational method has been proposed to compare and find the level of fairness between Shapley Value and Nucleolus.
- Calculations of imputations using solution concept Nucleolus base on pro-rata based imputations and Shapley Value imputations.
- Generalization of the model for more than three players.
- An example of cost sharing and joint ventures has been presented with coalition model of three players.
- Solution concept Shapley Value has been applied to calculate the worth of coalition.
- Another solution concept namely Core, has been applied to compare the coalition's fairness.

In the illustrative example, with barycentric coordinate triangle, Shapley value formed smaller core, Nucleolus values formed a bigger core; so, Shapley value is more fair solution concept, as it formed smaller core. Shapely values have more deviations, i.e. they are fairer compared to Nucleolus based imputations, as they have better distribution than pro-rata distribution. From the Lixicographical orderings, it is difficult to make clear conclusions, as the results were mixed.

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A Plasma Collection Center Task Assignment and Tour Scheduling Problem with an Emphasis on a Cross-Trained Workforce

ABSTRACT

This research focuses on the development of a mathematical model to address the daily personnel scheduling of plasma collection centers with varying levels of cross-trained employees. Given the public service aspect of donating plasma and saving lives, the forecasted and growing demand of plasma must be met to ensure there is enough supply to manufacture the life-saving therapies for the patients. Typically, plasma center managers require 8+ hours to complete the formulation of a weekly personnel schedule which is not easily adjusted due to the complexity of hard copy calculations and personnel job qualifications (District Operations Manager, 2017). Centers' strict federally regulated constraints along with a fluctuating supply of donors motivate new scheduling challenges. Scheduling a sufficient amount of employees for each shift for each day along with the time-on-task assignment over a 6-day operation while ensuring all employees scheduled are qualified to perform that task creates a distinct and innovative model in personnel scheduling. We introduce an integer linear programming model that incorporates staffing cost, industry-specific federal regulations, donor supply, employee availability, and a cross-trained workforce to reduce staffing cost in an efficient manner.

INTRODUCTION

This paper considers the unique challenges of personnel scheduling within blood plasma donation centers with varying levels of cross-trained employees. Plasma center managers tend to look at personnel scheduling differently than a resource management decision due to the public service aspect of saving lives. Typically, plasma center managers require 8+ hours to complete the formulation of a weekly personnel schedule which is not easily adjusted due to the complexity of hard copy calculations and personnel job qualifications (District Operations Manager, 2017). This paper proposes an integer linear programming model for weekly personnel scheduling that incorporates industry-specific federal regulations, donor supply, employee availability, and a cross-trained workforce to reduce staffing cost in an efficient manner.

The plasma donation process is very similar to the blood donation process with two exceptions: donors are paid for donation and plasma is universal, in other words, not blood-type sensitive (American Red Cross, 2013). Because donors are paid, changes in the U.S. economy result in a fluctuating donor supply (Beliën & Forcé, 2012). For example, when gas prices increase or the unemployment rate increases, donor supply increases. A donor can make approximately 300 dollars a month by donating plasma eight times a month (District Operations Manager, 2017). In addition, new usage approvals in plasma protein therapy create an environment of increasing demand for the raw material, plasma, complicating the scheduling process (Rytilä & Spens, 2006). A computerized, model-based scheduling tool provides managers with the ability to respond efficiently and effectively to the fluctuating supply of donors weekly and even daily.

Alleviating frustration with such a complex personnel scheduling problem enhances the potential that the demand for plasma will be satisfied and helps to ensure the development and distribution of life-saving therapies to patients. In addition, better scheduling helps reduce the cost of producing plasma, the price of plasma protein therapy and the financial burden on patients. Plasma therapies are used to treat life-threatening, chronic diseases listed in Table 1. A total of 1,200 plasma donations are required to manufacture therapies for one patient with hemophilia; a total of 900 plasma donations for one patient with genetic emphysema; a total of 130 plasma donations for one patient with a primary immune deficiency demonstrating the influence of the industry (DonatingPlasma.org, 2016b; PPTA, 2013)

Table 1: Life-Threatening, Chronic Diseases Helped with Plasma Therapies (DonatingPlasma.org, 2016b)

- Bleeding Disorders & Blood Clotting Disorders
- Immune System Deficiencies
- Genetic Emphysema
- Burns
- Shock
- Trauma
- Major Surgery
- Cardiopulmonary Issues
- Organ Transplants
- Pediatric HIV
- Hepatitis
- Liver Conditions
- Animal Bites, specifically rabies
- Rh Incompatibility

The plasma donation industry continues to grow nationally and internationally due to changes in the U.S. economy and newly approved pharmaceutical use of plasma protein therapy. See Figure 1 for plasma donation growth in the U.S. from 2003 to 2015 and Figure 2 for plasma center growth from 2006 to 2016. The U.S. experienced a 182% increase from 2003 to 2015 in plasma donations. Consequently, the U.S. and Europe experienced an 85% increase in the number of plasma donation centers from 2006 to 2016.

Figure 1: Donations in Millions for Government-Licensed Plasma Donation Centers from 2003-2015 in the U.S. (PPTA, 2015, 2016)

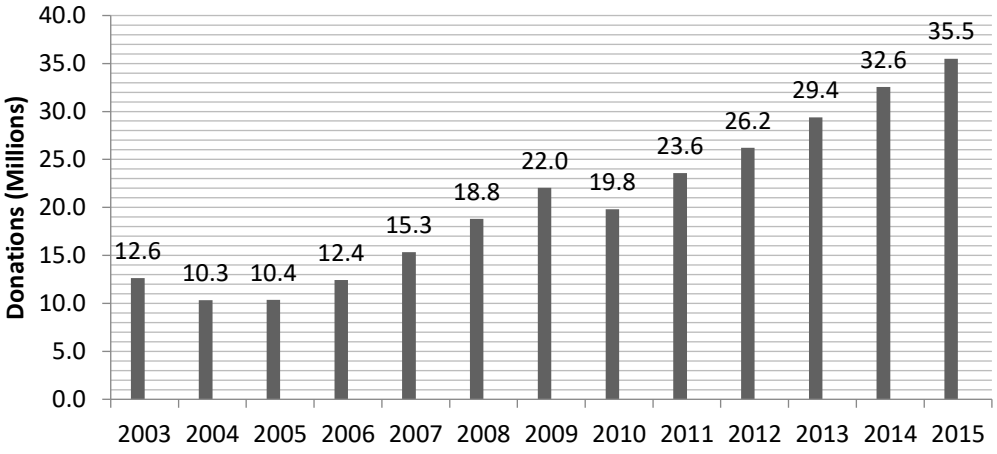
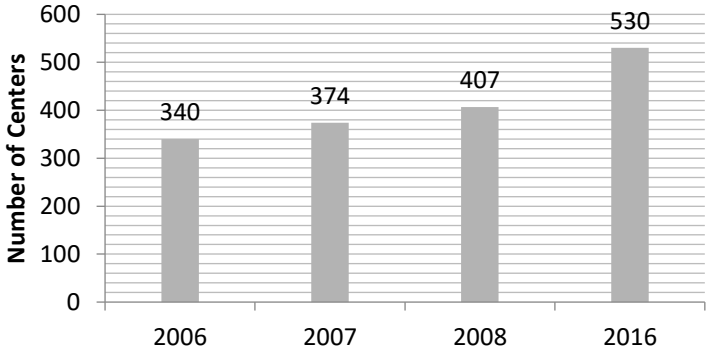


Figure 2: Number of Government-Licensed and IQPP-Certified Plasma Collection Centers in 2006, 2007, 2008 and 2016 in the U.S. and Europe (DonatingPlasma.org, 2016a; Plasma Protein Therapeutics Association, 2009)



Plasma is a unique commodity that can be imported to or exported from the U.S. as the raw material for life-saving therapies. Currently, the U.S. has approximately 4.5 times the amount of raw material than Europe because European plasma operations do not meet the U.S. federal regulations set by the Food and Drug Administration (FDA) and the International Quality Plasma Program (IQPP). A plasma collection center must be licensed by the FDA and certified by the IQPP in order to sell plasma to pharmaceutical companies where the life-saving therapies are manufactured (PPTA, 2009). A district operations manager of one of the largest global plasma

collection corporations breaks down plasma center manufacturing cost into three primary components: soft goods (manufacturing materials), staffing, and overhead, where staffing is 30 percent of the total cost (District Operations Manager, 2017). If plasma donation centers can reduce staffing costs by cross-training employees, the U.S. can potentially maintain its position in the global supply chain of plasma; in other words, plasma independency.

LITERATURE REVIEW

The problem addressed in this paper is an integer personnel scheduling model that optimizes staffing cost by identifying the ideal cross-training levels while incorporating employee availability, industry-specific federal regulations, and fluctuating donor supply levels over a 6-day operation. Thus, we review key contributions to the literature in task assignment and tour scheduling, cross-trained workforces, and blood bank collection centers to provide background and context for the methodology and techniques used in our model.

Task Assignment and Tour Scheduling

Personnel scheduling can become a complex task assignment problem based on the size of the problem and integrality requirements. Two early articles used probability theory and linear programming to address the issue (Dantzig, 1954; Edie, 1954). Later, Kuhn proposed the well-known Hungarian polynomial algorithm to solve the general assignment problem (Kuhn, 1955, 1956). The general assignment problem evolved into the generalized assignment problem by introducing a cost matrix, allowing multiple tasks to one person, and providing the best set of personnel-to-task assignments based on the minimum total cost (Fisher, Jaikumar, & Van Wassenhove, 1986; Ross & Soland, 1975). Similarly, our objective is to minimize staffing cost by using individual payrate.

The generalized assignment problem is an NP-hard combinatorial optimization problem. Dakin suggested a tree-search algorithm inspired by Land and Doig to address such a problem (Dakin, 1965; Fisher et al., 1986; Land & Doig, 1960). Later, Ross and Soland expand on the tree-search method and present the branch and bound method to improve computational efficiency for the generalized assignment problem (Ross & Soland, 1975). Similarly, Henderson and Berry applied a branch and bound algorithm using an integer linear programming model to develop a workforce schedule for telephone operators for 15-minute shifts in a 24-hour timeframe (Henderson & Berry, 1977). The employees were assumed to be available for all shifts and we make the same assumption with 2-hour intervals in a 14-hour day in a 6-day work week.

In 1990, Thompson compared two linear programming models in regard to shift scheduling where the workforce is only available for particular shifts and where employees are qualified to perform all job tasks (Thompson, 1990). Thompson concentrated specifically on the management of services versus the management of production. We assume all employees are available for all shifts but qualified to perform one, some or all job tasks.

More recently, Rahimian, Akartunali and Levine implement a hybrid approach using integer programming and variable neighborhood search algorithms to address the nurse rostering problem (Rahimian, Akartunali, & Levine). The nurse rostering problem has similar features as the plasma personnel scheduling problem including a restricted number of shifts scheduled in a day, employee availability constraints, no split shifts, and a limited total number of workdays in the planning period. We incorporate different job tasks and allow the employee to change tasks multiple times with the scheduled work day. In addition, we will address our plasma personnel

problem using an integer programming model to address the level of complexity in the structure of the problem.

Cross-Trained Workforce

Mahhotra and Ritzman utilized a simulation model to assist in the development of a workforce scheduling model concentrating exclusively on part time, cross-trained employees (Malhotra & Ritzman, 1994). They concluded that the benefit of part time, cross-trained employees is dependent on different operational factors; although, the overall impact of utilizing part time, cross-trained employees reduced staffing cost. We expand the scope of our model to part time and full time cross-trained employees.

Later, Brusco and Johns developed a workforce scheduling model using integer linear programming to minimize staffing costs and incorporate cross-trained employees within a single work shift (Brusco & Johns, 1998). They concluded that having a cross-trained workforce allows for better scheduling flexibility; although, they did not look at an extended time-frame. We will expand the problem to a 6-day planning period using multiple shifts in a 14-hour workday with employee availability parameters.

In 2002, Gomar, Haas and Morton evaluated the effect of using a cross-trained workforce in the construction industry where multiple projects with a variety of skills need to be completed (Gomar, Haas, & Morton, 2002). The objective minimized the employee turnover costs (hiring and firing) and found that cross-trained employees were always preferred. Our objective minimizes total cost related to the payrate of the employee and the hours worked by that employee.

Later, Say and Karabat apply a two stage optimization model to evaluate the trade-off between the output of the company and the skill improvement of the employee when using cross-trained employees (Say et al., 2007). They concentrate primarily on employee skill improvement where we require an employee to work in every skilled job task within the 6-day work week to maintain skill level.

Blood and Plasma Collection Centers

The blood bank literature focuses on either inventory and supply chain management (Beliën & Forcé, 2012; Kuker, Kuker, Badjie, Johnson, & Stubbs; Ma, Lei, & Okudan, 2013; Pierskalla, 2004; Rytilä & Spens, 2006) or donor recruitment and retention (Bagot, Murray, & Masser, 2016; Bednall & Bove, 2011; Farrugia, Farrugia, Penrod, & Bult; Masser, White, Hyde, & Terry, 2008; Ringwald, Zimmermann, & Eckstein, 2010; Vavić et al., 2012). This paper addresses the personnel resource scheduling aspect specifically related to plasma operations which has not been researched to date.

MATHEMATICAL MODEL

The resulting unique combination of personnel scheduling features creates complexity in daily plasma operations presented in this model. Given the public service aspect of donating plasma and saving lives, the forecasted and growing demand of plasma must be met to ensure there is enough supply to manufacture the life-saving therapies for the patients. Centers' strict federally regulated constraints along with a fluctuating supply of donors motivate new scheduling challenges. Scheduling a sufficient amount of employees for each shift for each day along with the time-on-task assignment for that shift over a 6-day operation while ensuring all employees scheduled are qualified to perform that task creates a distinct and innovative model in

personnel scheduling. We introduce an integer optimization model that incorporates industry-specific federal regulations, donor supply, employee availability, and a cross-trained workforce to reduce staffing cost in an efficient manner.

A Model for a Plasma Collection Center

The features of this personnel scheduling model represents shift scheduling (or hours of the day) and days off scheduling (or days of the week) (Alfares, 2004; Baker, 1976; Bechtold, Brusco, & Showalter, 1991; Brucker, Qu, & Burke, 2011; Van den Bergh, Beliën, De Bruecker, Demeulemeester, & De Boeck, 2013). Plasma collection centers operate *d* days a week with *p* 2-hour periods a day. Employee shifts must be scheduled in 4, 6 or 8-hour blocks of time. Plasma employees can work 2 to 4 consecutive periods a day and split periods (shifts) are not allowed. Work days do not need to be consecutive; however, the number of work days cannot exceed 5 over the *d*-day operation. Donor supply levels are calculated based on the previous production by period and estimated using a Poisson distribution. The calculated donor supply level is converted to integer values that identify the number of employees needed for job task *j* during period *k* on day *l*, denoted by r_{jkl}.

A key contribution of this model is the utilization of cross-trained employees and the impact on staffing costs. We use a mixed, heterogeneous workforce where full time and part time employees are qualified to perform multiple job tasks within a facility but not necessarily all job tasks (Alfares, 2004). Employee availability is based on full time or part time status. The minimum number of available hours is denoted by w_i and the maximum number of available hours is denoted by v_i. We do not allow overtime in our model.

There are *m* number of job tasks and plasma employees can be qualified to perform one or more of these job tasks. The total number of employees in each job area when cross-training is equal to 0 percent where each employee is trained in only one area is denoted by P_j. Employees must be scheduled in all their qualified job tasks within the *d*-day operation to maintain job task competency. Job task assignments for an employee can only change when the period assignment changes. In addition, federal regulations require a nurse to be on site at all times during plasma collection operations along with a 1:6 phlebotomist-to-donor ratio when a donor is connected to a donation machine.

Let binary variable s_{ij} = 1 if employee *i* is qualified to perform task *j*; 0 otherwise. Let the binary variable x_{ijkl} = 1 if employee *i* is scheduled to work task *j* in period *k* on day *l*; and 0 otherwise. Let the binary variable y_{il} = 1 if employee *i* is scheduled to work on day *l*; and 0 otherwise. An integer linear programming model for this problem is given below in equations (1) – (18).

$$MIN \ \sum_{j=1}^{m}\sum_{k=1}^{p}\sum_{l=1}^{d} 2c_i x_{ijkl}, \forall i \quad (1)$$

Subject To:

$$\sum_{j=1}^{m} x_{ijkl} \leq 1, \forall i,k,l \quad (2)$$

$$\sum_{j=1}^{m}\sum_{k=1}^{p} x_{ijkl} \leq 4(y_{il}), \forall i,l \quad (3)$$

$$\sum_{j=1}^{m}\sum_{k=1}^{p} x_{ijkl} \geq 2(y_{il}), \forall i,l \quad (4)$$

$$\sum_{l=1}^{d} y_{il} \leq 5, \forall i \quad (5)$$

$$\sum_{i=1}^{n} x_{ijkl} \geq r_{jkl}, \forall j,k,l \quad (6)$$

$$\sum_{i=1}^{n} x_{i(j=nurse)kl} \geq 1, \forall k, l \quad (7)$$

$$\sum_{j=1}^{m}(x_{ijkl} + x_{ij(k+v)l}) \leq 1, \forall i, l \; where \; v \in \{4,5,6\}, (k+v) \leq 7 \quad (8A)$$

$$\sum_{j=1}^{m}(x_{ijkl} - x_{ij(k+1)l} + x_{ij(k+2)l}) \leq 1, \forall i, l \; where \; k \leq 5 \quad (8B)$$

$$\sum_{j=1}^{m}(x_{ijkl} - \frac{1}{2}x_{ij(k+1)l} - \frac{1}{2}x_{ij(k+2)l} + x_{ij(k+3)l}) \leq 1, \forall i, l \; where \; k \leq 4 \quad (8C)$$

$$\left\lceil \left(\frac{\left(\sum_{i=1}^{n}\sum_{j=1}^{3} s_{ij}\right)}{n-\left(\sum_{i=1}^{n} s_{i4}\right)} \right) - 1 \right\rceil * 100 = T \quad (9)$$

$$\sum_{j=1}^{\mathrm{m}}\sum_{k=1}^{\mathrm{p}}\sum_{l=1}^{d} 2(x_{ijkl}) \leq v_i \,, \forall i \quad (10A)$$

$$\sum_{j=1}^{\mathrm{m}}\sum_{k=1}^{\mathrm{p}}\sum_{l=1}^{d} 2(x_{ijkl}) \geq w_i \,, \forall i \quad (10B)$$

$$\sum_{k=1}^{p}\sum_{l=1}^{d} x_{ijkl} \geq s_{ij}, \forall i, j \quad (11)$$

$$\sum_{k=1}^{p}\sum_{l=1}^{d} x_{ijkl} \leq 100(s_{ij}), \forall i, j \quad (12)$$

$$\sum_{i=1}^{P_1} s_{i1} = P_1 \quad (13)$$

$$\sum_{i=P_1+1}^{P_1+P_2} s_{i2} = P_2 \quad (14)$$

$$\sum_{i=P_1+P_2+1}^{P_1+P_2+P_3} s_{i3} = P_3 \quad (15)$$

$$\sum_{i=P_1+P_2+P_3+1}^{n} s_{i4} = P_4 \quad (16)$$

$$\sum_{i=1}^{P_1+P_2+P_3} s_{i4} = 0 \quad (17)$$

$$\sum_{i=P_1+P_2+P_3+1}^{n}\sum_{j=1}^{3} s_{ij} = 0 \quad (18)$$

$$x_{ijkl}, y_{il}, s_{ij} \in \{0,1\}, \forall i, j, k, l \quad (19)$$

The primary objective is to minimize staffing cost while meeting donor supply levels, industry-specific federal regulations, employee availability, operational constraints, and employee job task qualifications. Equation (1) is the objective to minimize staffing cost using the payrate of each employee (c_i) and the total number of scheduled hours.

Equation (2) ensures every employee is assigned only one job task per period if the employee is assigned to work that day. Equations (3) and (4) require the employee to work 2 to 4 periods a day if the employee is assigned to work that day. Equation (5) allows employees to only be scheduled for a max of 5 days in a *d*-day operation.

Equation (6) requires a minimum number of employees be scheduled to meet the staffing requirements for each task for each period for each day based on production levels. Equation (7) ensures a nurse is scheduled during all hours of operation meeting federal regulations. Equations (8A) – (8C) restricts split shifts in a 7-period day. In other words, if an employee is scheduled for multiple periods in a day they must be continuous. Employee *i* may, however, be working on different tasks in any of the consecutive time periods.

Equation (9) ensures the percentage of cross-training in the employee pool meets the plasma center expectations, denoted by *T*. Equations (10A) and (10B) require each employee be scheduled the total number of hours available based on full time or part time status. Equation (11) and (12) ensure each employee is qualified to work job task *j* and works each job task qualified at least once in the *d*-day operation. In addition, Equations (11) and (12) link the two decision variables, $x_{ijkl}\ and\ s_{ij}$.

Equation (13) – (16) identifies the total number of employees in each job task (P_j) when cross-training (T) is equal to 0. In other words, each employee is trained in only one job task and

is the baseline for the employee's primary job. An employee can cross-train to all job tasks apart from nursing (j=4). Nursing requires an external certification that cannot be completed in the plasma collection center; therefore, equation (17) restricts an employee from cross-training to nursing. Equation (18) restricts a nurse from cross-training to other job tasks. Equation (19) requires the assignment decision variables x_{ijkl} and y_{il} to be binary.

APPLICATION

We assume plasma collection centers operate a 6-day work week with seven 2-hour periods a day totaling a 14-hour work day. Employees must be scheduled between 6am and 8pm. A full time employee must work a minimum of 32 hours and a maximum of 40 hours in a 6-day work week; a part time employee works 16 to 20 hours. There are 4 primary job tasks: donor processing (j=1), phlebotomy (j=2), product processing (j=3), and nursing (j=4). See Figure 3 for the service flow of a donor in a plasma collection center and Table 3 for the job assignments at each station in the donor service flow.

Figure 3: Service Flow of a Donor in a Plasma Collection Center

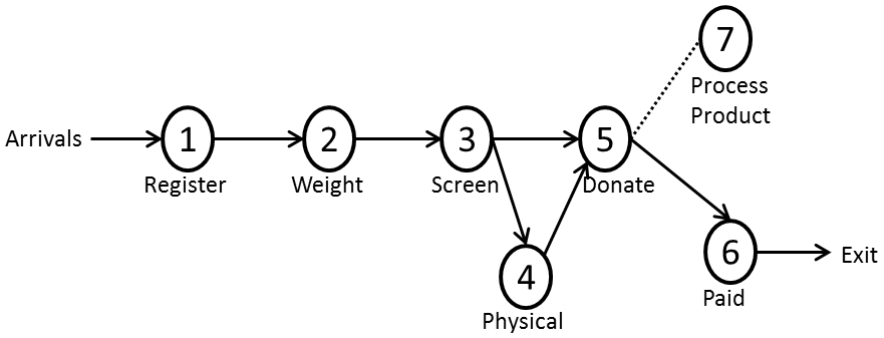


Table 3: Plasma Collection Center Job Assignment at Each Station in the Service Flow

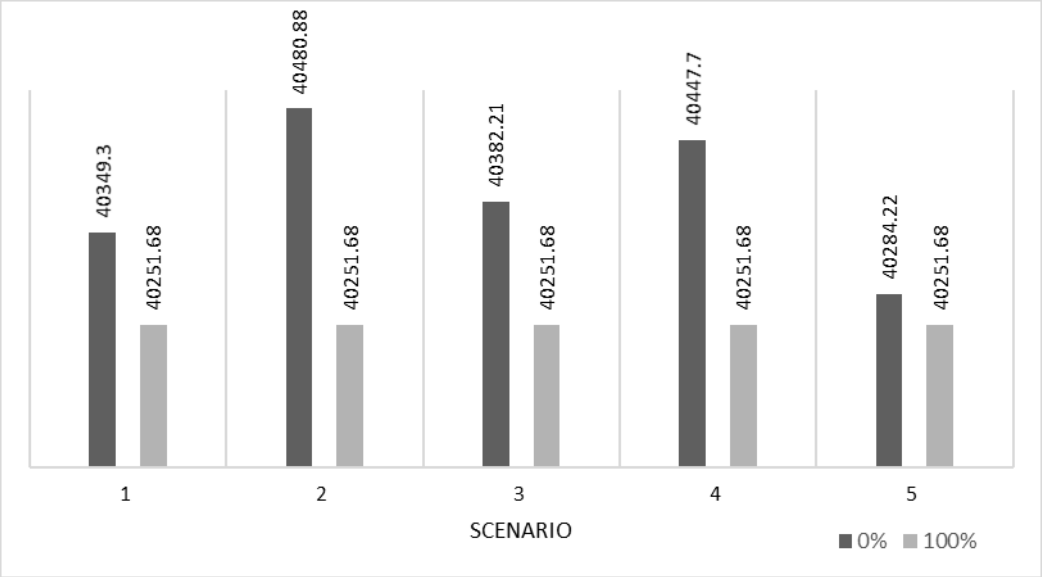
Station	Description	Qualified Job
1	Register Donor	Donor Processor
2	Donor Weigh In	Donor Processor
3	Donor Screening	Donor Processor
4	Physical Exam	Nurse
5	Donor Donates	Phlebotomist
6	Donor Paid	ATM/Donor
7	Process Product	Product Processor

We assume the payrate per employee where the primary job task is donor processing or plasma processing varies between 14 and 20 dollars per hour; phlebotomists are paid between 15.50 and 20 dollars per hour; and nurses vary between 17 and 35 dollars per hour. In our computational testing, the payrate per employee will be calculated randomly within this range. Payrate is not adjusted based on cross-training; it is considered an expectation in the industry.

We use medium-sized plasma donation centers that reach approximately 1,600 donations a week with 65 full time employees and 5 part time employees: 25 donor processors, 25 phlebotomists, 10 plasma processors and 10 nurses. We run five model scenarios with the same employee pool and vary the level of donations using a Poisson distribution. We look at each scenario with two extreme levels of cross-training: 0 and 100 percent. Each medium-sized plasma center model requires 12,460 binary variables with an additional 11,067 constraints. The integer linear programming model for this problem is optimized using IBM ILOG CPLEX Optimizer 12.7. Each scenario calculated within 0.5% of optimality or 15 minutes (900 seconds) of CPU time.

Figure 4 displays the results for each scenario at 0 and 100 percent cross-training. The plasma center manager can visually evaluate the impact of cross-training to the staffing cost and make informed staff training decisions. Surprisingly, we found a staffing cost lower bound of $40,251.68 for every scenario at 100 percent cross-training. The lower bound implies no additional improvements in staffing cost occur once cross-training reaches a certain level. In addition, we reduce the hours required by a manager to complete the formulation of a weekly staffing schedule from 8+ hours to 15 minutes.

Figure 4: Optimal Objective Value Results at 0 and 100 Percent Cross-Training



CONCLUSION

This research addresses the daily personnel scheduling of plasma collection centers. We provide a mathematical optimization model that incorporates industry-specific federal regulations, donor supply, employee availability and a cross-trained workforce that minimizes staffing cost using an integer linear programming model. The decision maker can visualize the trade-off between staffing cost and cross-training to make an informed personnel scheduling

decision. This research is also applicable to various production-driven service operations where employees are trained to complete different job tasks and need to be scheduled with consideration of employee availability and employee job task qualification while meeting levels of production.

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Context-aware Privacy Score: Measurement Issues and Implications

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Privacy has become a primary concern among social network providers and data analysts. Online social networks, in fact, are human-generated logs that constantly expose their users to privacy leakage risks. Some studies define some policy-based privacy scores that quantify the intrinsic users' profile privacy according to their privacy settings or attitude, so as to provide them with a measure of their risk. However, user privacy is also influenced by contextual properties (e.g., the relative risk of the network, the position of the user within the social network) and these scores do not consider the such properties adequately. Privacy paradox refers to the discrepancy between privacy attitudes and actual behavior in which users are willing to share their private information for retail values and personalized services, despite that they are fully aware of the privacy risks on Internet.

In this paper, we intend to enhance public awareness of privacy, and to reduce the complexity of privacy paradox in social networks. We first review Item Response Theory and Information Propagation Theory. Then we define a context-aware privacy score to measure the objective user privacy risk according to the online social network properties. In designing privacy score, we assume that users that lie in an unsafe portion of the network are more at risk than users that are mostly surrounded by privacy-aware friends. Thus, users that share the same intrinsic privacy risk may have a different score depending on their subnetwork.

In this study, a privacy-aware feature selection method is proposed based on the personalization–privacy paradox, and this paradox is explored in the context of online social network services with consideration of the personal characteristics of customers using these services. We also exam the effectiveness and the reliability of our measures with experiments on simulated networks and a large social network of real users. Additionally, we discuss managerial implications and lay out future research directions.

Hospitality, Recreation, & Sports

Innovative Education & Teaching Pedagogy

CLASS NOTES

The Next Innovation in Note-Taking for Student Note-Takers

ABSTRACT

The Class Notes Mobile App has been designed to be simple and easy to use for all levels of note-taking students using a no-fail 3-step process. The App includes a patented decoding system that allows the note-taking students to use abbreviations, initials, symbols, acronyms and texting and have them decoded immediately. Class Notes was designed to be used as a note-taking tool in the background so the students will value the importance of actually recording consistent organized lecture and reading notes. Class notes explains the relevance of note-taking by showing students how taking lecture and reading notes helps them to increase their grades. Students will realize that note-taking is not just a skill they will use while in school, but that will be used throughout their lifetimes. To help students better understand the functionality of Class Notes, You Tube videos incorporating infographics and eLearning are being developed.

> *Students frequently wonder and sometimes ask, "Why are we doing this? Why do I need to know this? Why are we spending so much time on this? Why do we have to do this busywork?"*
>
> *When students don't see the connection between the content and activities of the course and their future lives, they question what's happening and what we ask them to do. Research confirms that perceived relevance is a critical factor in maintaining student interest and motivation. It also contributes to higher student ratings on course evaluations.* (Fox, 2011)

Introduction

Class Notes is the first note-taking app designed specifically to help Generation Z (born between 1995 and 2014) student note-takers to become competent note takers. Class Notes' design and patented technology may be the most significant contribution to educational note-taking since Cornell Notes was introduced in 1950 by Dr. Walter Pauk.

It has taken several years of research and development to create a complete Master Note-Taking System for Students in a note-taking app designed to meet the educational needs of Generation Z students. Generation Z students are different from previous generations. Gen Z students are tech savvy and want technology that is easy to use and will solve their problems. Class Notes is so simple and easy to use that the student note-taker can begin taking notes in less than 1-minute.

Relevance is critical to a student's success! Relevant, meaningful activities that both engage students emotionally and connect with what they already know are what help build neural connections and long-term memory storage. Students need a personal connection to the material

being introduced – how is this note-taking process going to affect me? How am I going to benefit personally from learning how to take lecture and reading notes?

Without the relevance of the purpose of note-taking to the student personally, students may not only disengage and quickly forget, but they may also lose the motivation to try. Because of the need of relevance to successfully engage students in the note-taking process Class Notes incorporates a complete screen explaining how the note-taking process will help the note-taking student increase both their retention levels and their grades. What student, professor, K-12 school system or institution of higher learning is not interested in students demonstrating an increased level of knowledge with increased grades?

What is the most important use of a note-taking app? The recording of lecture and reading notes in a consistent organized format. This is what Class Notes' design and technology allows the note-taking student to concentrate on. No longer is a note-taking student required to spend countless hours and possibly days learning how to operate a note-taking app before they can actually begin to record and save class notes in a consistent organized format. Without a consistent organized format, the student is learning how to record and save class notes each time they begin the note-taking process. Definitely not a productive use of the note-taking students' time and effort.

Class Notes' main focus is on students using a consistent organized system throughout their note-taking process. We call the Class Notes' consistent organized system the Master Note-Taking System for Students. For recording notes, they are using nationally and internationally recognized organizers/templates that have a time tested and recognized built-in consistent organized system. Specifically, these are Cornell Notes, Charting, Mind Mapping, Outline, Sentence and SQ3R. All of these organizers/templates have, for the first time, been preformatted for quick and easy student use and structure incorporating mobile technology functionalities. This allows students to open an organizer/template immediately. The mobile technology functionalities allow the note-taking student to easily customize each of the organizers/templates to meet their individual needs. Other consistent organized systems have been incorporated for the saving of recorded lecture and reading notes using a fail-safe 3-step system.

Time is of the essence when taking classroom notes. Because of the importance of classroom time it is critical that the student have the ability to take notes as quickly as possible. Abbreviations, initials, symbols and acronyms, are mentioned and recommended, in major "How to Study" textbooks, "How to Take Notes" self-study books and on Junior/Community/Technical college and major national and international 4-year college and university websites, as a simple and quick note-taking shorthand method, to help students' increase their note-taking speed. In more recent times, since 1984 when the first SMS (text message) was sent, texting has played an increasingly important role in the recording of notes. However, a significant critical missing link in using abbreviations (we will use this term to refer to abbreviations, initials, symbols, acronyms and texting) has been the ability to quickly and efficiently use mobile technology to decode abbreviations. Up until now all abbreviations were decoded manually, by the student, at the end of their note-taking process. Manual decoding is a very time consuming process. In order

to decode the student has to memorize the abbreviation and its meanings, used in the note recording process, to successfully decode their notes.

The authors have invented a mobile technology decoding system that totally eliminates the significant critical missing link needed when using abbreviations to take class notes. The U.S. Patent office has recognized the authors' decoding system by granting a patent for this decoding system. This patent also includes the ability to display the meanings of decoded abbreviations in the Authors' Predictive Text Meaning Bar located just above the normal mobile keyboard. Unlike the algorithm Predictive Text Bar presently being used on mobile devices the Predictive Text Meaning Bar does NOT use algorithms to determine possible choices. The Predictive Text Meaning Bar uses a direct relationship functionality that is totally controlled by the user. The Predictive Text Meaning system uses a "personal dictionary system" in which the student enters the abbreviations they wish to use and the appropriate matching abbreviation meanings. This means that only the matching meanings of an abbreviation recorded by the student are displayed in the Predictive Text Meaning Bar – no guessing as to the probability of certain meanings by the algorithm and displaying a totally inappropriate meaning based on the probability generated by the algorithm. The decoding system allows for faster class note recording speed and reduced spelling errors. Thus saving the student recording time when recording important class note information, eliminating the need to check spelling and saving huge amounts of time by no longer requiring abbreviations to be manually decoded. The Predictive Text system and Meaning Bar is presented for the first time in Class Notes. There are many, many additional standalone systems that when integrated into Class Notes become subsystems of the Class Notes' Master Note-Taking System for Students.

Relevance

The relevance of note-taking helps note-taking students develop into engaged, motivated and self-regulated competent note-taking learners. It is critical for note-taking students to know how this personal critical educational tool (app) is designed specifically to help them personally increase their retention levels and increase their grades.

Class Notes recognizes the critical need and importance for note-taking in the students' educational lives and later in their careers. To help note-taking students better understand and appreciate the personal relevance of note-taking Class Notes includes a Why icon. Simply tap the Why icon and a screen displays (1) the main purpose of taking notes, (2) what good note-taking involves and (3) 10 important reasons for taking notes.

Record Notes using Texting (Note-Taking Shorthand)

> *On average, Millennials spend 6.5 hours each day saturated in print, electronic, digital, broadcast and news media. They listen to and record music; view, create and publish Internet content; play video games; watch television; talk on mobile phones and instant message every day.*

The Millennial generation are practiced users of digital technology and the first to be surrounded by digital media. Information and Communication Technologies have always been part of their lives, and because of this access, Millennials naturally gravitate to it. They expect it to support their learning and do what they need it to do. Indeed, Millennials can perform more functions with mobile phones, handheld devices and other wireless equipment than they can with traditional computers. In addition to using the calendaring functions of these devices to prioritize and schedule their lives, they often prefer computer-mediated communication and have developed their own language, which consists of acronyms like "LOL" ("Laughing out loud"), "ATM" ("At the moment"), "BTW" ("By the way") and other Internet slang.

> "Today's digital kids think of ICT as something akin to oxygen; they expect it, it's what they breathe and it's how they live."
> —*Learning in a Digital Age,*
> *John Seely Brown*
> (International Education Advisory Board, n.d.)

How do you think a student will react when you say "We are going to learn to use texting today to record lecture and reading notes." That is about as relevant as it gets with today's Generation Z students. What the students do not realize is that texting is the new name for note-taking shorthand. When note-taking shorthand (using abbreviations, initials, acronyms and symbols to take lecture and reading notes) was introduced by the creator of Cornell Notes back in the early 1950's texting was not known, thus the term note-taking shorthand was used since it resembled other shorthand systems that had been around for centuries. Back in the 50's and up until Class Notes only standard universally accepted abbreviations, initials and symbols were recommended to be used for taking lecture and reading notes. Now with Class Notes a student can create their own personal note-taking shorthand using abbreviations, initials, symbols, acronyms and their own personal texting to create their personal Class Notes note-taking shorthand. This is because only Class Notes is going to read the students' personal abbreviations, initials, symbols, acronyms and texting to display their meanings in the student's Predictive Text Meaning Bar.

The major advantage of using note-taking shorthand is that information can be recorded much quicker than using long hand. How efficient is note-taking shorthand? Court reporters use a special form of note-taking shorthand to record court testimony.

CarMax, a popular national used vehicle retailer, advertises their car slogan and other text on national television:

Text	Meaning
WBYCEIYDBO	We'll buy your car, even if you don't buy ours.
LOL	Laugh out loud
BTW	By the way

These are used to let the millennials, Generation Z and other texters, know that they are their generation car dealership.

Using the Text and Meaning illustration, which can be entered, using a keyboard, the fastest – the acronym or the meaning? The acronym consists of 10 alphabetic letters and the meaning consists of 46 characters. The answer is the acronym which can be entered in less than ¼ the amount of time. Obviously not all acronyms, abbreviations, initials, symbols or texting represent the same time savings but all represent some time savings because fewer alphabetic letters, symbols and numbers entered means less time is required to obtain the same end result.

However, the major down side of using texting is that after the lecture and reading notes are taken all the abbreviations, initials, symbols, acronyms and texting must be decoded into actual words, sentences and paragraphs. PROBLEM SOLVED! Class Notes' patented system solves this major issue of decoding by automatically decoding each abbreviation, initial, symbol, acronym or text as it is entered displaying the meaning in a Predictive Text Meaning Bar located just above the standard keyboard. No more manually decoding each and every abbreviation, initial, symbol, acronym and text. The student simply taps a meaning displayed in the Predictive Text Meaning Bar and continues recording their notes. This saves the student huge amounts of time in the decoding process totally eliminating manual decoding and writing the long words, sentences and paragraphs recorded by the student and increases the recording entry speed by reducing the number of letters, characters and numbers entered while reducing spelling errors 100%.

Class Notes also has the other traditional major methods of using the keyboard for standard text and voice-to-text for recording lecture and reading notes.

Class Notes allows the student to "make-up" their own texting abbreviations and meanings. This is accomplished in the Dictionary system using what are called Personal Dictionaries. Simply tap Create Personal Dictionary and add the text and the meaning and from that point on whenever that text is entered the meaning will appear in the Predictive Text Meaning Bar. There are additional features such as:

- Import personal dictionaries that have been mailed to you.
- Email personal dictionaries to teachers and other students.
- Merge personal dictionaries to merge two personal dictionaries into one.
- Edit personal dictionaries to make corrections.
- Turn personal dictionaries on or off.

Class Notes comes with eight (8) dictionaries. These are English, French, German, Italian, Medical Acronyms, Periodic Table, Spanish and Texting. These eight (8) dictionaries represent some of the various areas in which dictionaries can be built. There are a total number of abbreviations, initials, symbols, acronyms and text for all dictionaries of 3,398 abbreviations. Class Notes uses the term abbreviations to represent abbreviations, initials, symbols, acronyms and text on the dictionary screen. The dictionaries that come with Class Notes may be turned ON or OFF as well as the individual abbreviations in any of the dictionaries along with their meanings. The individual abbreviations and their meanings do not have the functionality to be

edited, merged, emailed, renamed, deleted or saved like in Personal Dictionaries. This is to maintain the integrity of these dictionaries. The ability to purchase additional dictionaries representing special interest areas will be available in the future.

Begin Taking Consistent Organized Notes in Less Than a Minute

Students, to be successful, need to (1) know what important or pertinent information to record and (2) how best to structure their lecture and reading notes in a consistent organized format. Structuring lecture and reading notes falls into two categories. How to develop a systematic approach to using a consistent organized structure for the recording of lecture and reading notes and second how to structure, in a consistent organized format, saved notes for easy retrieval to study later.

When introducing note-taking it is important to get the note-taking students actively involved in recording consistent organized notes immediately. Today's note-taking students are the "want it NOW" generation. They do not want to be lectured about how an app works in order to start recording notes. They want to start recording consistent organized notes and recording them NOW. They do not want to spend a lot of time being lectured on how to operate a note-taking app prior to learning to record good consistent organized notes. Class Notes is all about recording consistent organized lecture and reading notes NOW! In less than a minute and as simple and easy as 1, 2, 3, from the time the note-taking student opens Class Notes, they can be recording a lecture or reading note using a consistent organized format they have setup.

Class Notes allows note-taking students to record consistent organized lecture and reading notes faster than on any other note-taking app using nationally and internationally recognized organizers/templates. Class Notes is able to achieve this incredible fast consistent organized note recording format by the use of organizers/templates and its patented Predictive Text Meaning System for recording lecture and reading notes and its simple and easy no-fail 3-step system to format the consistent organization needed to save notes.

Step 1 has the student enter the Course Title, Step 2 has the student enter the Topic Title and Step 3 has the student Select One. When the student gets to step 3 a drop down displays two selections with these being Lecture and Reading. This completes the no fail 3-step process. The note when completed and saved will be saved in the Library using the information placed in Steps 1, 2 and 3 automatically.

Student Driven

Class Notes is so simple and easy to use that in less than 1-minute a beginning note-taking student can begin taking consistent organized educational lecture and reading notes. This is one of the unique features of the Master Note-Taking System for Students developed for Class Notes.

Class Notes is much easier than taking educational lecture and reading notes the old fashioned pencil and paper method due to the many Class Notes' mobile technology functionalities and its patented process.

Class Notes was designed, to be used as a note-taking tool in the background, to take consistent organized educational lecture and reading notes. One of the major purposes of Class Notes is to not require students to learn how to use another app, while at the same time increasing the importance of the actual recording of consistent organized lecture and reading notes. This is accomplished by creating Class Notes as intuitive, simple and easy to use. Who doesn't prefer educational tools that are simple and easy to use?

Class Notes is the next innovation for note-taking students. Class Notes utilizes mobile technologies to the fullest benefit of note-taking students so the student is not forced to spend a lot of time on learning a consistent organized system to record notes and another consistent organized system to save and store notes and additional app system functions. Class Notes leaves the most important part of student lecture and reading note recording up to the student. This is the major function that the note-taking student has to master leaving the consistent organizing formatting, both in the recording of notes and in the saving and storing of notes, to the systems built into Class Notes. The note-taking student controls the recording of consistent organized lecture and reading notes by selecting nationally and internationally recognized organizers/templates and the saving of recorded notes using a no-fail 3-step system. The note-taking purpose for the note-taker is learning how to take good consistent organized lecture and reading notes -- not increasing the note-taking students' learning load of how to operate an app!

Nationally and Internationally Recognized Organizers/Templates

Class Notes incorporates all of the top nationally and internationally recognized note-taking organizers/templates recommended by the leading note-taking experts and by the top universities in the world:

Cornell Notes	Charting	Mind Mapping
Outline	Sentence	SQ3R

The reason for incorporating the top note-taking organizers/templates into the overall Master Note-Taking System for Students is to provide students with note-taking recording systems that have consistent organizational formats that have tested and proven records over the years of helping students increase their retention levels and increase their grades.

All Organizers/Templates

To help students better understand organizers there is a specific button, ALL ORGANIZERS, that when tapped displays the ALL ORGANIZERS screen. This screen displays the major advantages and disadvantages of each of the seven (7) nationally and internationally recognized organizers along with an infographic of each organizer.

To help students better visualize what each of the seven (7) nationally and internationally recognized organizers looks like, and what and where recorded notes look like and are placed, each organizer is illustrated with an infographic. Tap on the organizer example and that infographic explodes to display an easy to view infographic of that organizer.

Infographics (Visual Shorthand) and eLearning

To better help the note-taking student learn the note-taking process Class Notes incorporates eLearning into each of the organizers/templates. Infographics are included in the Tip screens to help note-taking students better understand the functionalities of each screen. When a note-taking student opens an organizer such as Cornell Notes – Complete eLearning provides the student with complete information to guide them as to what and where notes are to be recorded. As the student records note information the eLearning information, displayed on the screen, automatically disappears from the screen. With Class Notes note-taking students are always provided with the guidance they need to be competent note-takers. Because students and classes use different headings, Class Notes has the functionality to allow students to edit the headings/subheadings to whatever names they prefer. Tap the heading/subheading to be edited, the original name disappears, enter your new heading/subheading name. The note-taking student will be prompted to save the new name. When saved the new heading name becomes the default so the next time the organizer/template is called up it will have the new heading.

Should the note-taking student want additional information about the page they are on, they simply tap the Tips icon located on the icon bar at the bottom of the page and the screen will display all the unique functionalities of that screen. The screen explains, in a Bonus Tip, ***You can attach handwritten notes, drawings, PDFs, photos and videos to each of your notes.*** The PDF's have full annotation. As an important separate group the course syllabus can also be attached to a course. A note-taking student can tap the Tips icon for any screen they are on to obtain detailed information about that screen. As well, You Tube videos incorporating infographics and eLearning are being developed for student use.

Dictionaries

The dictionaries system is designed to store the three types of dictionaries available in Class Notes. The function of all three types of dictionaries is to store abbreviations and their meanings used in the recording of lecture and reading notes. These dictionaries are:

Free Note-Taking Dictionaries – dictionaries that come with Class Notes. These dictionaries have limited features. They can be turned ON or OFF and an abbreviation can also be turned ON or OFF.

Personal Dictionaries – dictionaries built by the user. These dictionaries may be edited, merged, emailed, deleted or abbreviations and their meanings can be added.

Purchased dictionaries -- dictionaries that are commercially produced to go with specific textbooks, reference books, special interest books, etc. This is a future option and not available in version 1.0. There is generally a cost for this type of dictionary.

Library

The library system is where all saved recorded lecture and reading notes are saved. The notes are saved under all of the following headings: Library, Courses, Topics, Organizers and Colors. Within each of the headings a notes' course, date, time, whether a lecture or reading note and the name of the organizer the note was recorded under are displayed for each saved note. Also on this screen are the most recent notes listed by date and lecture or reading name. The last display on this screen is deleted notes. Deleted notes is a forgiveness option that allows the student to view and recover a note that was deleted.

Search

The search system allows the student to search the entire system by keyword. This is a fast and easy method for a student to locate a note that they made but may not recall the exact title, date, etc. under which the lecture or reading note was saved.

Settings

The settings system allows the student four options. The student can turn the Quick Start guide ON or OFF. The student may also view the privacy policy, terms of service and about the app.

Additional Features

In addition to the features described above, Class Notes has the following features:

- Use text to voice to have notes read to students using voice recognition.
- Annotate PDF's.
- Translate notes from one language to another language.
- Add memo to students' calendar.
- Print and Others.

Conclusion

Class Notes is a world class note-taking app that solves several major note-taking students' problems not directly addressed in other note-taking apps.

Research confirms that perceived relevance is a critical factor in maintaining student interest and motivation. Class Notes explains the relevance of note-taking by showing how taking lecture and reading notes helps them increase their grades. Class Notes also makes the note taking process fun, simple and easy in a consistent organized format. And ENCOURAGES note-taking

students to take lecture and reading notes on THEIR TERMS using what EVERY student likes to do most – TEXT.

To solve the note-taking students' culture of impatience Class Notes allows the note-taking students to setup and begin taking a lecture or reading note in less than 1-minute. Note-taking students are very visually oriented, also the way in which the brain processes information best, so Class Notes incorporates infographics throughout the app to help note-taking students better understand the importance of proper note-taking techniques.

Class Notes goes another major mobile technology innovative step further in helping note-taking students solve one of the note-taking students' differentiators – The crave for constant and immediate feedback. Class Notes eliminates the labor intensive and time-consuming problem of decoding note-taking abbreviations. Class Notes provides the note-taking student with a patented decoding system that automatically decodes their abbreviations, in any language, not at the end of their note-taking but rather **instantly** as they are recording their lecture and reading notes.

Class Notes is a student-centered note-taking app. Class Notes solves the major issues of how to help the note-taking students by incorporating patented mobile and digital technology making note-taking simple and easy. And incorporating in the recording of lecture and reading notes what note-taking students like to do most – Text.

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Addendum

Comparative Study of U.S. and Chinese Student's Computer Anxiety in First Computer Programming Course

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A computer-programming course has been a foundation course in undergraduate computer science, computer information systems, and other majors that require knowledge of computer programming. Basic computer programming skills are important for students' success in many fields of studies and important for their careers. It has been well documented in the literature; however, student's negative attitudes and anxiety hinder their learning of computer in general and computer-programming course specific.

There has been extensive research on teaching a computer – program course at undergraduate level (Attig, Wessel, and Franke 2017), (Compeau and Higgins 1995), (Heinssen, Glass, and Knight 1987), and (Powell 2013). Some researchers studied the use of computer from users prospective (Attig, Wessel, and Franke 2017) and (Compeau and Higgins 1995). (Heinssen, Glass, and Knight 1987) developed and tested a survey instrument for computer anxiety. As one of the most extensive studies on the topic, (Powell 2013) reviewed 276 papers on computer anxiety, discussed relationships among computer anxiety and self – efficacy, attitude, perceived ease of use, perceived usefulness, and satisfaction. Powell also linked computer

anxiety to personal characteristics, such as, gender, age, education, personality, and profession/organization aspects; interactions with computer, such as, experience / actual use, training on computers, and ownership; and related computer anxiety to self – efficacy, attitudes, perceived ease of use, perceived usefulness, and satisfaction. (Adkins and Linville 2017) studied how the test frequency affected student's performance in computer programming class. (Cetin and Ozden 2015) indicated the lack of studies on students attitudes toward computer programming and developed their computer programming attitude scale for college students taking computer programming classes. Their scale has 18 items associated with three measures of attitudes, e.g., behavior, cognition, and affect. Explorative factor analysis is used to extract the three factors. (Cigdem 2015) reported a blended programming class with regression analysis. (Leso and Peck 1992) studied computer anxiety pre and post computer programming class and software application class, found computer anxiety is not reduced in both classes.

This study is to adapt Schau's attitudes toward statistics scale (Schau 1995) to computer programing attitudes for students taking their first computer programming class. The purpose is to better understanding of issues related to teaching and learning of first computer programming course, and compare the differences of U.S. and Chinese students on their learning of computer programing course. Thus the theoretical model is composed of six factors, e.g., affect, cognitive competence, value, difficulty, interest, and effort. to be developed and to be tested among students in the first computer programing classes in U.S. and China. Affect component has with six items and is to measure students' feelings about computer programming. Items in Affect component include "I will like computer programming"

and “I am scared by computer programming.” Cognitive competence component has six items and is to measure students attitudes about their intellectual knowledge and skills when applied to computer programming. Items in Cognitive competence component include “I can learn computer programming” and “I will have trouble understanding computer programming because of how I think.” The Value component has nine items to measure students attitudes about their perceptions of usefulness, relevance, and worth of computer programming in personal and professional life. Items in the value component include “Computer programming skills will make me more employable” and “Computer programming is irrelevant in my life.” The Difficulty component has seven items to measure students perceived difficulty of computer programming as a subject of study. Items in the Difficulty component include “Computer programming is a subject quickly learned by most people” and “Most people have to learn a new way of thinking to do computer programming.” The Interest component has four items to measure students individual interest in computer programming with items, such as, “I am interested in using computer programming.” The Effort component has four items to measure students willingness to devote their effort to learn computer programming with items, such as, “I plan to work hard in my computer programming course.”

The survey instrument is tested in the fall of 2017 in an Introduction to Programming class in a major state university. It is the first programming course that students need to take before they can get into Computer Science major. A letter grade of B minus is required for any student to continue their program of study. The course is prepared and offered for students without any prior computing experience, and mainly focuses on Java programming. A total of 38 responses were collected, and 35 of them deemed useful. Multiple regression will be used

to see the relationship between students attitudes and their course performance. Logistic regression will be conducted to differentiate students with or without B minus for the course.

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Addendum

Academics and the Law of Unintended Consequences
(Blame it on My Uncle Francis)

Abstract

The academic world has changed enormously since the end of World War II, and some of it can be traced to a decision (exempting college students from military service) that made sense at the time, but has created some unintended consequences, not all of which are good. This paper will outline the process that led from that decision to the current situation, including the problems it has caused for academic research.

Introduction

Whether modern universities began with the Islamic madrasas (from the Hebrew "midrash") of the 10th century or with the corporate/guild model of the University (Latin, *universitas magistorum et scholarium* – roughly "association of teachers and scholars") of Bologna, founded in 1088, there can be little question that they currently bear little resemblance to those original schools. In northern Europe, many schools, such as the University of Paris, began as training schools for the clergy and then evolved into what is called a "liberal arts" school, where the students studied the four branches of the *quadrivium*: arithmetic, geometry, music, and astronomy. These students graduated with bachelor's degrees and took on teaching positions. Southern European universities, such as in Italy, focused on law and medicine, conferring doctorates leading to professional positions. Later schools, such as Oxford (from 1096 teaching the liberal arts) and Cambridge (breaking away from Oxford in 1209 to study the sciences) continued this division.

Initially, students were drawn from the lesser gentry, as a convenient place for a second son, and from the growing middle class. It wasn't until the mid-1400's that it became fashionable for sons (no daughters, of course) of the upper nobility to be sent off for a few years of study. Over time, the perquisites of the Universities grew, and "town versus gown" problems (illicit drinking, gambling, whoring, poaching, brawls, and sometimes full-scale riots) became notorious, if not common. Students had bad reputations among townspeople, who deeply resented the clerical status which allowed them to escape censure from city and state (Cobban, 1999).

Originally, professors were simply teachers. The professors were sometimes hired by the corporation that ran the University, but a common method was that the students paid the teachers directly. Therefore, the greater your reputation as a teacher, the greater your income and poor teachers simply didn't survive. Professors were expected to take part in all aspects of the University, including administrative tasks, though with the much smaller size that was common for schools at that time, service was not much of a burden (I am sure, however, that everyone still complained about meetings). As for research, it was strictly up to the professor. Certainly attaining renown would enhance your value to students, but there was no concept such as "tenure" and no detailed accounting of publications. Early publications were less a matter of communicating ideas and more about establishing precedence for ideas, such as Newton's famous puzzle message to Henry Oldenburg establishing the work he was doing on calculus at the same time as Leibniz (Newton, 1676). Still, there was "pressure to publish," even leading to falsification

of research results, which was common enough that novelist Dorothy L. Sayers could use it as the focal point of her mystery novel "Gaudy Night," (Sayers, 1935).

The US was obviously far behind Europe in terms of establishing schools, but once they got started, schools flourished (Trow, 1988). By 1779, 15 permanent colleges and universities had been founded (compared to only two, Oxford and Cambridge, in England), which grew to 381 by 1860, most of which were affiliated with one or another religious sect. Thomas Jefferson was an early driving force for a secular education, with the philosophical ideal of building a meritocracy based on education rather than an aristocracy based on lineage. This was the ideal upon which his University of Virginia was founded. The Morrill Land Act, encouraging the creation of agricultural colleges, led to a rapid creation of 69 colleges in the post-Civil War era. The "Enlightenment" grabbed Jefferson's ideas and, under the guidance of Charles W. Elliott, president of Harvard from 1869 to 1909, the concept of entrance exams was established, and competitive excellence as a result of earning a college degree became expected. This was the beginning of the concept that a university education should be a prerequisite for many jobs.

The early part of the 20th century, through World War I, was a period of economic disruptions that led to many smaller colleges failing. That period's movement toward protection of industrial workers through the creation of unions was reflected in John Dewey's founding of the American Association of University Professors (AAUP), and the advocacy of "tenure" for professors. This was presented not as security of employment, but rather as protection of professors from any backlash for teaching unpopular doctrines. It is not a coincidence that socialism and communism, as well as the corruption of large businesses, were common subjects of debate among intellectuals, and that such topics were highly unpopular among those supporting the schools, such as the wealthy and state governments.

It took a long time to establish tenure as a common aspect of university life. An informal survey of more than 70 colleges and universities by Edgar Lovett (first president of Rice University) in 1935 found that most schools that offered tenure did so not to protect professors but as an inducement when trying to hire (Rosenthal, 2011). Following the 1940's, and the rapid growth in the number of university students that followed WWII, tenure became a common aspect of university life, though approximately only 21% of college instructors currently have tenure (https://www.aaup.org/issues/tenure).

The period following WWII changed American universities. The previous twenty years had seen an increase in the number of students (as a college degree became a prerequisite for many jobs), and the GI Bill offered tuition assistance to veterans returning from the war. One effect of these changes was an increase in the number of faculty needed, which led to an increase in specialization among the faculty. Some of this specialization can be attributed to the increased depth of knowledge that was building up around many topics, making a broad understanding of every aspect of a field nearly impossible, but some push for specialization was also due to the increased number of professors, each of whom needed to carve out a research niche in which to publish. These effects, fueled by another factor that had a more delayed effect, as will be discussed next.

Consequences of War

To a certain extent, the first half of the Twentieth century was defined by the two World Wars. The United States came late to both; in terms of years, the US saw less than half of the involvement experienced by European nations. Once involved, however, the US devoted soldiers and materials until the wars were brought to an end. Whatever the economic consequences of this policy, a separate consequence was the deaths of so many young men. Sadly, wars kill soldiers and soldiers are drawn primarily from young men in their late teens and early twenties. This has always been true, but in the 1800's, the number of university-educated men (and women, obviously, but since women were equally excluded from universities and military service, this paper has rather a sexist overtone to it) was low, and the issue, while present, was not viewed as significant.

This brings me to my Uncle Francis. According to family legend, Uncle Francis was one of the top rising freshman in 1942 when he volunteered for military service. Like so many servicemen, he was killed in action. By the end of WWII, given the recent growth in the number of students attending college and the belief in the intellectual excellence of those that attended college, there was a recognition that soldiers are drawn primarily from college-aged young men, and thus the conclusion was drawn that wars were destroying our intellectual elite. This led the newspapers to warning of the "brain-drain" that was occurring, and eventually led to the exemption of the college-bound from military service. The law was certainly well-meant, but in the following conflict, the Korean War, people realized that those men enrolled in universities were not subject to the risks of military service. Given the brevity of the Korean conflict (even less than the length of US involvement in the World Wars), this deferral amounted to immunity from being drafted. With the advent of the Vietnam conflict a generation later, the well-meant law created a flood of applicants to colleges and universities.

The Law of Unintended Consequences

All of the seeds that had been in sown in the first half of the twentieth century suddenly sprang to full growth, affecting every part of the university system. Slow, steady growth switched to a mushrooming demand, which the universities struggled to accommodate. This was a basic change in the motivation to attended university. Students attending college to learn, which had already decreased from the primary group of students to a subset, now fell to a mere fraction of the student body. Even those from the true leisure class, for whom a university education was a status symbol, became a minority. Many university students were now attending with the simple goal of avoiding military service. The financial sacrifice involved (scholarships could not begin to cover the new demand) also created an interesting side-effect in that the new students considered their education to be an investment rather than an end in itself. Besides keeping the students safe from harm, the time and money spent at a university was expected to lead to a better life afterwards.

These new students, who previously would not have been attending college, needed professors, classrooms and course material they could handle. There was also an aspect of desperation, for failing out of college meant induction into the one branch or another of the armed services, and a potentially one-way trip to Southeast Asia. Universities, at the same time, really enjoyed the increased revenue created by all these new minds, eager to be educated. Rather than lose that

stream of revenue, universities did everything they could to accommodate and retain these students.

The list of effects on universities from this increase in demand is long: new campuses were created, existing campuses were expanded, salaries grew (first for faculty already there, then for the new faculty hired to deal with the new students), new majors were created with increasing levels of specialization, new levels of administration were added to handle the increased workflow, new problems were created by students that didn't fit the old molds, and a host of others. The affect on society was also profound – the trend toward making a university education a prerequisite for jobs exploded.

Graduating with a university degree originally meant a place of prestige in society. This mindset stayed the same, but prestige doesn't pay many bills. The new flood of graduates (many of whom ended up in the military despite their best efforts, since the Vietnam War saw many more years of involvement for the US than the previous three) were looking for jobs and took whatever jobs they could find, even if a university degree made them overqualified. Over time, assuming the university degree actually conferred some benefit to the graduates, their success in those jobs led to seeking university graduates for those positions, ultimately resulting in a university degree becoming a minimum requirement for those jobs. This, of course, only increased the demand for a university education, but the universities certainly didn't object to that.

There is one particular affect of this growth in university education that this paper will explore in further detail – the effect on academic research. Just as the proliferation of college students meant that students who previously were not considered college material (along with their more-gifted colleagues) were entering college, the demand for classes created by that flood of students meant more professors were needed. This is not to say that the professors were unqualified, just that the elite were already professors, so the new ones had to be drawn from a larger, less select, pool, just as was true with the students.

The interesting part is that these new professors were intended to return to the original purpose of university professors – they were intended to be primarily teachers; hired to fill demand created by the new students. Since tenure was now a fact of life for universities, the new professors sought to gain this most prestigious state, valuing the employment security as much, if not more, than the freedom to express unpopular ideas. The AAUP had published guidelines for tenure, but for many schools, tenure was equally about checking off boxes and collegiality (was the tenure candidate seen as an acceptable member of the family). As schools continued to grow, the tenure process became increasingly about proving your worth and meeting preset criteria. Research was one of the easiest areas to set criteria for, while teaching was one of the hardest.

For a university, research publication has many benefits besides the obvious recognition gained from widely-recognized work. Universities are classified as Research I or Research II in part based on the number of research publications produced. This directly affects funding and grants, which in an era of decreased public funding, is seen as an important alternate source of revenue by University administrators. In addition, accreditation bodies for the various regions and disciplines make it a point to count the number of papers published when a school seeks accreditation (the stamp of approval that says a school is doing a good job). Accreditation is also based on teaching,

but, as noted, teaching has no simple, clear-cut measure (such as published papers for research), so it is much more difficult to evaluate whether professors are doing the teaching portion of their job.

While many factors have affected the growth of universities of the past fifty years, there can be no doubt that military exemption (possibly a good idea in itself) had the unintended effect of fueling that growth in both students and professors. From 1960 to 1990, the number of bachelor's degrees awarded increased from just over 390,000 to more than 1,000,000. In the same thirty years, instructional staff in colleges and universities grew from roughly 280,000 to over 980,000 (National Center for Education Statistics, 1993). With increased numbers of professors seeking tenure, and the ease of counting publications as a gateway to tenure, there has come an explosion in the number of research papers published.

Consequences for Research

The goal of research publication is not to communicate, but simply to increase the number of papers published, since that is what the schools (and accreditation bodies) count. Professors do not read research papers to see what their colleagues are doing; they read them to make sure what they are doing is different from their colleagues. Papers rarely communicate any significant results, because waiting until results are truly significant carries too many risks: decreased number of publications, time lost when publications might have been made, and most significantly, the possibility that another professor might publish ahead of you. All of this has led to the prevalence of "epsilon" research publications.

In mathematics, the value "epsilon" represents the smallest possible change. In mathematics, such a small change is valuable, since you can establish the effects of such a limited change much more easily than you can the effects of a major change that might have multiple, and conflicting, effects. This is also true in other branches of study. By itself, this is not a problem, but couple that with the push to publish, and you end up with papers that represent minimal increases in knowledge being published constantly. All research papers are supposed to be evaluated for a contribution, but no one measures whether the contribution is great or small, so any small change can be argued to be a contribution, and therefore worthy of publication. It would be difficult to find many papers, even in top-ranked scholarly journals, which present a result that anyone cares about.

This increase in the need to publish has had other effects. What used to be a simple concept (research) has been renamed basic research to allow subdivision into research of engagement, research of application, research of pedagogy, etc. (AACSB, 2012), elevating mundane work to the level of research. The fact that this is not research can be seen in how it is viewed by the reader. If a professor completes a consulting project and publishes it as research, the professor who reads about it does not try to copy what was done, but must do something different, otherwise the second professor will not be able to publish his/her results. These "research papers," rather than communicating to seek an extension of what was done, communicate to force others to do something different.

The growth of epsilon research and the elevation of consulting and surveys to the level of research are direct results of the increase in the number of professors frantically trying to publish so as to

achieve job security (tenure) and increased pay. The universities support this because the accreditation bodies insist on evaluating current universities using a model that assumes conditions haven't changed in the past 100 years. If you ask a professor what their most significant piece of research is, they can all answer you, but if you ask why it is significant, the answers get rather vague. In addition, most papers are not published in top journals, making the likelihood of any paper being significant even less.

Adapting to the New Reality

In the 1980's, Total Quality Management (TQM) was the latest idea that was going to change the world. Many of its concepts went directly against generally accepted rules, but they proved themselves to be right. One concept that is relevant to this paper is how workers are paid. The study of TQM makes it clear that simple pay schemes, such as paying workers by the hour, will lead to poor results. The fascinating (to me) sidelight to this is that rather than the unintelligent, easily replaceable automatons that workers had come to be considered, the workers were bright enough to figure out how to maximize their incomes while doing the least work possible.

Applying that TQM concept to the academic world helps to explain the growth of epsilon research. A simple measure (number of publications) is used to identify the best professors, so it leads to publishing papers that have little if any true value, just to publish something. If this is true, and it is, then changes as drastic as those that occurred in 1980's will need to be forced on the academic community. Research papers do not equate to quality research, so professors should no longer be evaluated on that basis.

An argument toward the reality that University professors should put more emphasis on teaching than on research can also be made by considering the number of college students and their abilities. In 1960, 9.7% of males and 5.8% of females 25 years or older had completed four or more years of college. By 1990, those numbers had increased to 24.4% of males and 18.4% of females (Center for Education Statistics, 1993). Unless someone would like to argue that the average intelligence of the population increases as population increases (which runs counter to most observations), necessarily the average quality of college students has decreased. If you consider the number of students that take remedial courses, a constant complaint of professors, it becomes even more clear that professors need to be teachers much more than they need to be publishing papers of dubious quality.

Evaluation of Teaching

Of the three areas on which professors are evaluated, teaching, research and service, teaching is the hardest to evaluate. Research is easy – count the number of peer-reviewed articles published in A, B or even C level journals. Service is somewhat easy – count the number of committees or reviews or editorships that a professor serves on. Teaching, though, has nothing to count. More than that, teaching involves not only the efforts of the professor, but also the abilities of the students and their efforts, which clouds the issue even further. Student evaluations are used, but that assumes that students know what good teaching is, and won't reward professors for easy grading (both are doubtful). Some concrete measures have been proposed, such as D/W/F rates (counting the number of students that receive drop a course, withdraw from school, or fail the course), but

such simplistic measures do not evaluate why the failure occurred or do anything to fix the problems.

There is an old story about a man who wanted to find a horse to ride in a steeplechase (where the horse and rider must clear a series of obstacles). This man bought a horse, tried it on a steeplechase course, and when it failed to clear one of the hurdles, he shot the horse and went out and bought another horse. Eventually, the man would find a horse that can make a clean jump (or run out of horses). Using a simplistic measures, such as evaluating a teacher by counting D/W/F rates is equivalent to shooting a horse for failing to clear a hurdle. TQM tells us that if we want professors to become teachers (instead of pseudo-researchers), we will have to develop a process for rewarding good teaching.

This type of discussion usually falls apart right away, because someone will claim they are doing a good job of teaching with simple lectures and multiple choice tests. It is very hard to say this is not true, because the value of teaching may not be apparent for many years, and the result is, at least in part, affected by the student, not the teacher. All of this is may be correct, but it does not prevent the establishment of stronger criteria.

Allow me to present one way in which research is evaluated using the simple statistic of counting publications. If a five-point scale is used, a score of "1" indicates little or no activity, while a "2" shows minimal acceptable work, such as work-in-progress or conference proceedings. A "3" is awarded for a journal publication or a chapter in a book, while a "4" represents two journal articles in better journals or a whole book. Finally, a "5" is for truly exceptional work, widely recognized as excellent or multiple (3 or more) articles or something similar. The professor knows what is expected and can work to achieve whatever level s/he wants. As noted above, this will lead to publication for the sake of publication, but point is that harder work results in a higher evaluation.

Now, for teaching, there is nothing simple to count, so the same five-point scale fails to create any distinctions. Using student evaluations and simplistic measures, any professors, whether doing a excellent job or not, could be given a "5" for teaching. The same scale, however, could be used to distinguish between different levels of effort for teaching. Suppose a "1" again represents a problem and a "5" presents outstanding work. On such a scale, a professor that uses presentations and tests prepared by the textbook company and graded by a machine would earn a three. You could argue a lower value, since the professor could easily be replaced by recorded lectures and a graduate student, but a three is the maximum such teaching should earn. It is entirely possible that such teaching is giving the students everything they need for the class, even if it requires minimal effort on the behalf of the professor. Defining such minimal effort as a "3"overcomes the problem that occurs with current methods of evaluating teaching, such as student evaluations or D/W/F rates, where such minimalistic teaching could earn a "5", removing any reason or reward for doing a better job teaching.

A rating of "5" for teaching should, however, show some level of teaching beyond that bare minimum. There are other aspects to teaching that increase the value provided to the student. Requiring students to apply the course material to problems (cases), requiring they write reports and make presentations, or requiring outside research are just a few examples of things professors can do (and there are many other ideas – this list is not intended to be complete). Simply requiring

these additional teaching methods from the students could earn a professor a better evaluation (maybe a "4"). Only if the professor goes further, working with the students to help them improve their ability to perform outside investigations, apply what they learn, and write or present write or present more effectively, would the professor earn a "5". This would certainly be more involved that simply counting D/W/F rates, but it would reward professors that put time into teaching and encourage other professors to do more for their students' educations.

This is just one idea, which parallels how evaluations are currently done at some schools, for changing the evaluation of teaching to identify and reward excellent teaching. The changes have to go further, though, and overall evaluation procedures need to change.

Overall Evaluations of Professors

The outline above indicates one way that teaching could be evaluated more effectively, to distinguish between minimal effort toward teaching and a superior effort. Simply implementing a more effective evaluation of teaching will not be enough, however. College and university administrations, accreditation boards, and government bodies have to stop considering research to be an effective use of a professor's time. We have argued, above, that most current research is not, in fact, research at all. Still, professors want to be tenured and schools want to be accredited, so until administrators and accreditors recognize this and deemphasize research output as a measure, the current situation will not change. Just as industrial workers would maximize output, even of low quality, when the only measure was number of units produced, so professors will continue to publish papers with minimal impact as long as "number of publications" is the primary evaluation.

In the same way, if tenure and promotion and all annual evaluations were based on teaching performance, with research a distant second, if given even that much attention, then professors, being reasonably intelligent, would begin to put their time into the activities that lead to more excellent teaching. This would mean a decrease in research output, because even professors have to choose where to put their time, but given that the current research output is flawed, that would not be a major loss to society.

There is clearly excellent research being done, and it should be rewarded. The flaw is believing that every professor should be producing large volumes of research. There is also, clearly, excellent teaching occurring. The flaw here is that the extra effort needed to produce excellent teaching is not recognized or rewarded at the same level as research. It will take a massive change in the evaluation procedures to get professors to move away from the current standard of publication for the sake of publication to an effort to improve teaching. Ultimately, as they were originally intended, universities must be a place where teaching is the thing that professors give the most effort to.

Conclusion

The growth in university graduates can be traced, in part, to a decision to exempt university students from military service. Certainly the blame does not entirely lie with my Uncle Francis, but he was part of a generation that sacrificed themselves, and that sacrifice led to changes that

had consequences that were not anticipated. That growth, of universities, of college students, and of college professors, has become self-sustaining, so there is no point in trying to reverse it. Instead, the consequences of that growth need to be dealt with. One consequence is that an old measure of professorial competence, the publication of research papers, is no longer accurate. Universities, and the organizations responsible for accrediting them, must change their expectations of professors away from the emphasis on research and toward the function that professors should now serve – teaching. The evaluation of teaching need not be complicated, but separation in evaluation between those putting in minimal effort and those working hard to add value to their classes must occur if professors are to change their behavior. Both these changes, emphasizing teaching over research and rewarding teaching over research, are needed to allow professors and universities to return to their original purpose – educating students.

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A Pilot Study of Memorandum Writing in the Productivity Module of an Operations Management Course

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ABSTRACT

This paper presents a class exercise to introduce memo writing and feedback in the context of productivity improvement in the core business course, operations management. The exercise includes an initial memo, class discussion questions, in-class student memo writing, peer review using a Memo Strengths and Weaknesses Form, memo revising, and instructor assessment and feedback. Instructor assessment of the last memo revision demonstrated that the majority of participants exceeded expectations for spelling, professionalism, punctuation, and problem statement while the majority of participants failed to meet expectations for grammar, writing a clear request, and identifying a correct memo recipient for the audience.

INTRODUCTION

Because there is strong demand for employees with writing skills (Knoch, May, Macqueen, Pill & Storch, 2016; Lim, Lee, Yap, & Ling, 2016), many business schools seek to integrate writing across the curriculum. Furthermore, written communication is part of the curriculum content required by the Association to Advance Collegiate Schools of Business standards (AACSB, 2017). Integrating writing in quantitative subjects has been labeled a high-impact educational practice (Kuh, 2008).

For business faculty teaching large sections of core quantitative business courses, adding a writing assignment and assessment of both conceptual understanding and writing mechanics is challenging (Knoch et al., 2016; Plutsky & Wilson, 2001). Thus, faculty may seek support from university writing centers that offer paper readings, grammar reviews, and writing discussion groups facilitated by student peers who have demonstrated exceptional writing skills (Ashbaugh, 1994; Plutsky & Wilson, 2001; Kovach, Miley, and Ramos, 2012).

The author of this paper added memo writing to the core quantitative undergraduate business course, Operations Management. An earlier version of a memo exercise for a productivity problem was presented (Williams and Gallamore, 2016). This paper extends this earlier pedagogical work and adds repeated review, feedback, and assessment results. Since initial experiences with the memo exercise demonstrated multiple types of student weaknesses, the author developed and added a Memo Strengths and Weaknesses Form for students to use for the purpose of soliciting peer feedback regarding multiple elements of their memo writing. This paper describes the extended teaching instrument and assessment results for the Spring 2017 implementation.

METHOD

In the productivity memo exercise, students assume the role of an operations manager in a corporate office of a fictitious coffee shop chain, Calm Coffee, and must respond to the COO's request to continue reporting improved productivity. The exercise requires each student to read and discuss a memo, write a memo, seek peer feedback twice, and revise his or her memo twice. Figure 1 illustrates the process flow for the active learning exercise and assessment.

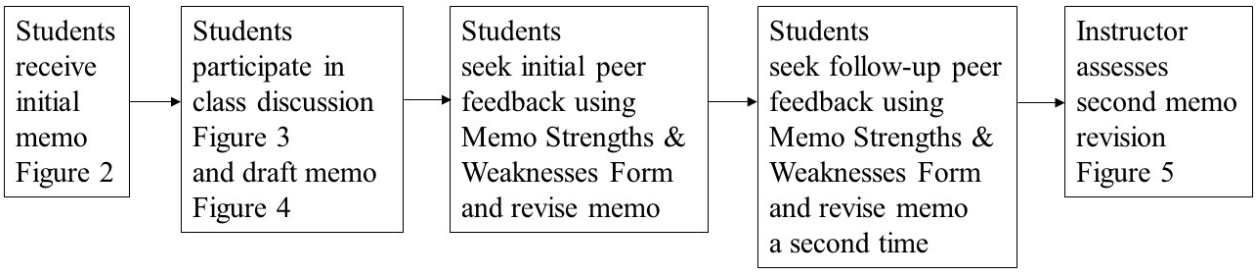

Figure 1. Process flow for productivity memo active learning exercise and assessment

Figure 2 shows the initial memo that is given to students from the fictitious COO requesting a productivity improvement report using a new data management system. The exercise has been conducted face-to-face and online.

TO: Kaitlyn Sum, Operations Manager, Calm Coffee
FROM: Sofia Martin, COO, Calm Coffee
DATE: January 9, 2017
RE: Annual productivity improvement report

We are excited that Calm Coffee's productivity is up 5% from last year. To make this productivity increase a trend, I am requesting an annual productivity improvement report (APIR).

To make it easier to compare productivity over time, IT has developed an APIR template for the data and information entry for the productivity improvement report. The data entry sections of the template will include cost inputs from accounting. The information entry sections will include descriptions such as changes in equipment, process design, or recipes.

Starting June 15, submit an annual productivity improvement report in the new APIR template. If you have any questions, please feel free to contact me.

Figure 2. Initial Memo

Figure 3 shows a face-to-face class discussion about the Figure 2 memo. The instructor introduced the three memo conceptual elements: recipient, problem statement, and request alongside the formula for productivity. The instructor guided the students to think about the

productivity formula inputs while identifying personnel in the organization who may track data related to organization inputs.

Who is the **recipient** of the COO's initial memo in Figure 2? Kaitlyn Sum, OM

What **problem** does the COO indirectly reference in the memo in Figure 2? Productivity

What clear **request** does the COO make in the memo in Figure 2? APIR (annual productivity improvement report)

Recall that productivity = $\frac{\text{outputs}}{\text{inputs}}$. What are some examples of inputs?

labor, raw materials (coffee beans, disposable cups, cream), equipment (coffee makers, chairs)

Who in an organization tracks its performance (measures the inputs)?

accounting, store managers, equipment vendors, warehousing

Figure 3. Class discussion questions and examples of student responses

Next the instructor reviewed the College of Business writing rubric elements: audience, content, conclusion, grammar, punctuation, spelling, and professionalism. The instructor adapted the first three conceptual elements for the context of an operations management memo. The audience element is described as the memo recipient. The content element is described as the operations problem while the conclusion element is described as the follow-up request. The instructor asked students to review the team members listed at the end of Figure 3 and to identify a team member within the organization that might have information and insights about an organizational input that could be reduced to improve productivity. When students were given the memo template in Figure 4, they took approximately 10 to 15 minutes to write the memo in class.

MEMO

TO: _____

FROM: _____

DATE: _____

RE: _____

_____

_____

_____

_____

_____

_____

Figure 4. Memo Template

The instructor gave students the Memo Strengths and Weaknesses Form and asked the students to seek feedback from a peer from one of the following organizations: the College of Business Writing Center, the University Writing Center, a class mate, or a colleague from an organization of their choice. Students had to specify from which organization their peer had been chosen. The Memo Strengths and Weaknesses Form was composed of three columns. The first was labeled "Rubric Element" and contained the seven College of Business writing rubric elements: audience, content, conclusion, grammar, punctuation, spelling, and professionalism. The second and third columns were labeled "Strengths" and "Weaknesses" respectively and contained blank spaces for peer evaluator comments. Students had two weeks to seek the peer feedback and then use it to type their revised memo. Students were awarded two midterm points extra credit for the completed first Strengths and Weaknesses Form and two midterm points extra credit for the first revised memo.

After students turned in their first revision, they were asked to seek feedback a second time with the Memo Strengths and Weaknesses Form by a designated due date two weeks later and to use the subsequent feedback to type their second revision. Students were awarded two final exam points extra credit for the second completed Strengths and Weaknesses Form and two final exam points extra credit for the second revised memo. The instructor marked detailed feedback on the second revision and returned it to the students. The following is a summary of the instructor assessment.

INSTRUCTOR ASSESSMENT

The assessment was conducted at a state university with an undergraduate enrollment of over 10,000. The operations management course sections were offered within an AACSB accredited college of business with more than 1300 enrolled undergraduate students. The author's university Institutional Review Board approved the study. Participants in the study enrolled in operations management with the author Spring 2017, signed an informed consent, completed the memo on the template shown in Figure 4, turned in both completed Memo Strengths and Weaknesses Forms, and turned in both memo revisions. The gender and year classification demographics of the participant group were 54% female/46% male and 54% senior/46% junior.

The instructor assessed the student writing for both conceptual understanding and writing mechanics following the second revision using the seven College of Business writing rubric elements. The assessment results for the 13 participants are summarized in Figure 5. The author used three performance levels to score the memos: Does Not Meet Expectations, Meets Expectations, and Exceeds Expectations.

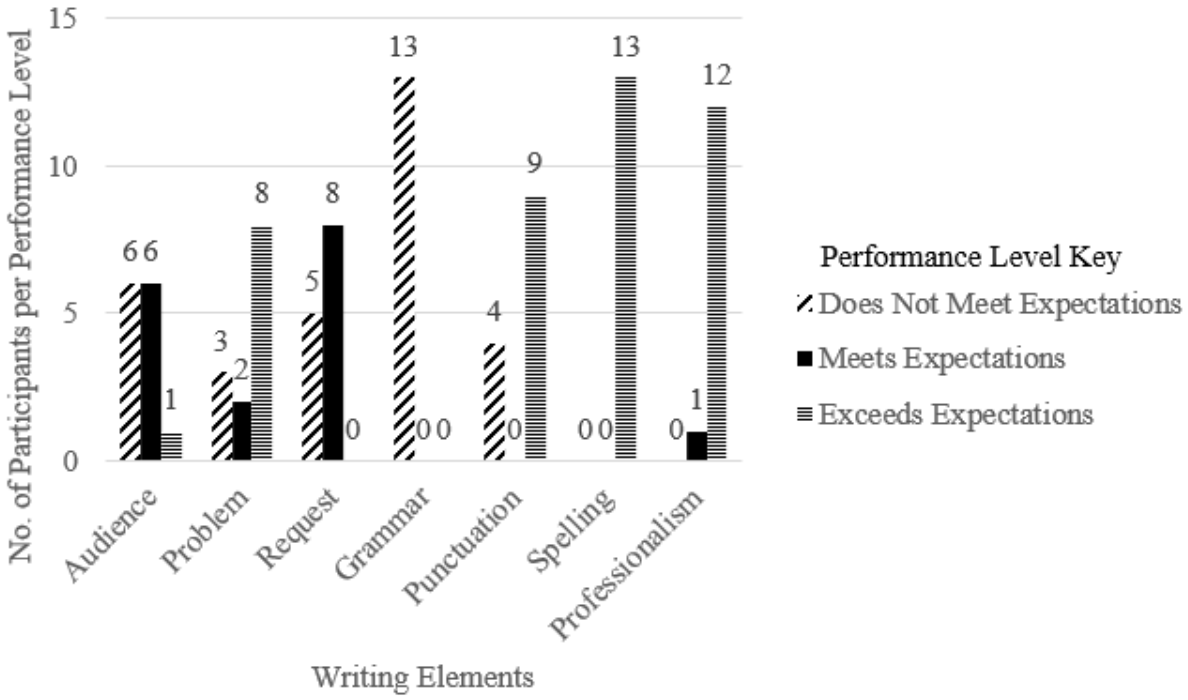

Figure 5. Instructor assessment of participant memo writing following peer review.

DISCUSSION AND CONCLUSION

Before discussing the interesting insights this pilot study suggests, limitations are noted. The sample size is small. Only 13 students completed both peer feedback forms and the revised memos following the initial memo in-class or online. Perhaps the extra credit was an inadequate incentive. In addition, students may not have realized the extent to which their business memo writing skill was lacking.

Figure 5 illustrates that participant memo writing, following the second revision, showed several clear strengths and weaknesses. Writing elements in which the majority of participants exceeded expectations included spelling, professionalism, punctuation, and problem statement. The instructor assessment of the final revision indicated that grammar was undoubtedly the weakest element of the participants' writing as every participant failed to meet expectations in that area. At least a third of participants failed to identify a correct recipient for their memo or make an appropriate request.

Interestingly, some Memo Strengths and Weaknesses Forms did not contain detailed feedback. In the strengths column of each form, over 70% contained detailed comments. In the weaknesses column of each form, nearly half of the forms contained a check or were blank. Many peers seemed reluctant to point out any weaknesses with detailed suggestions. Future research is needed to develop a system that encourages more useful feedback from student peers.

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IS, IT, e-Business, & Social Media

A Recommendation System for Choosing an IT-related Major

Abstract

An important decision for a freshman student is a choice of major. If a student changes majors due to a poor initial decision, the student could end up spending more time in college and will likely spend more money for tuition, fees, room, and board. In addition, it is also likely that students in the wrong major initially may have lower grades which may negatively impact scholarships. The reasons for students picking the wrong initial major are varied and in this paper, the authors will look at the various reasons. The authors then propose a novel solution to part of the problem.

Introduction

By many accounts, a young person's choice of college major is an important one. As Gallup (2017, p4) puts it: "Students' chosen fields of study have important implications for their livelihoods." The choice of major may also underwrite a student's academic success. Steinhauer (2017) highlights that some colleges, like Georgia State, have found the most predictive indicator of success is a student's first grade in the first class of their major program. Steinhauer (2016) reviews a report by the Education Advisory Board that suggests "students who change their major as late as senior year are more likely to graduate from college than students who settle on one the second they set foot on campus." In addition, the very act of declaring a major is seen as important: "Most advising professionals consider undeclared students, especially those in their second year or later, to be at elevated risk of leaving school before they graduate." (Education Advisory Board, 2016).

Students' choice of academic major

Many students experience difficulties in choosing their academic major at college. There are many potential reasons for these difficulties and deferring the decision to choose a major, including: being unclear or poorly informed about which majors are available; having poorly formed personal preferences; not being accepted into a program or college offering one's preferred major; having inadequate advice and counselling (Gallup, 2017); being given advice to choose and stick with a major; poor performance in a chosen major creating barriers to changing majors; the choice of major may be less important than the choice of college (Selingo, 2017); a college intentionally encourages students to explore different areas of study prior to declaring a major (Steinhauer, 2016); or simply procrastination when it comes to making a challenging life commitment.

Many students change majors when they get to college. While the actual statistics of the number of students who change their major is not centrally tabulated, Selingo (2017) recently remarked: "*Many colleges ask you to choose a major as early as your senior year of high school, on your admissions application. Yet there's a good chance you'll change your mind. The*

Education Department says that about 30 percent of students switch majors at least once." The Education Advisory Board (2016) states that most students -- as many as 80 percents in some surveys -- will switch majors at one point during their time in college.

The total number of credit hours required to fulfill degree requirements, and credit hours designated "free electives," varies across different majors. Liberal Arts programs tend to have a greater number free elective credit hours compared with, for example, engineering courses. In addition, some programs may have different requirements in foundation subject areas, such as math and science. A student wishing to change majors may, therefore, have completed courses that are not part of the new program and cannot be accommodated for credit through "free electives." Moreover, the risk of losing credit for completed studies when changing majors rises the later into a program a student is when he or she decides to change their major. The inability to transfer credit for program credit means that students changing majors may be required to complete additional courses and possibly delay their graduation. As Selingo (2017) puts it: "*Changing majors can cost you a semester or two, especially if you switch to one unrelated to your first choice.*" In summary, for some students, changing major may add substantial costs to their education.

Students use a wide variety of sources when choosing their initial major. Gallup posits that students use four categories for their sources - formal sources, informal social network, informal school-based and informal work-based in the article Major Influence: Where Students Get Valued Advice on What to Study in College (2017):

1. Formal sources include high school and college counselors and internet and print media.
2. Informal social network sources include family, friends, and community leaders.
3. Informal school-based sources include high school teachers, high school coaches, college faculty and miscellaneous staff.
4. Informal work-based sources include employers, coworkers, and people with experience in the field and military.

Each of these sources may help students pick an appropriate major if the source is knowledgeable of the student's abilities and major requirements. If not, then the source may direct the student to a major that will later be changed. This may be especially problematic in engineering and IT disciplines where there are fewer sources that are knowledgeable about the requirements and expectations of programs.

There have been several interesting attempts at providing a solution to the major-selection problem:

- Designing a program to delay the choice of major: Steinhauer (2016) discusses a promising initiative to allow students to initially enroll in "meta-majors," which are clusters of courses in the same general field -- business, humanities or STEM, for example. The author mentions that Georgia State University is one institution that offers this option.

- Automated advice and informational web sites: A number of websites offer advice on which college to attend, as well as which majors may suit a specific student. Examples of these websites include *mypath101.com*, *BigFuture* (by the CollegeBoard) *and naviance.com.* For example, *Mypath101.com* describes itself as: "*A New Way to Navigate College"* The website is designed to be a resource to *"help students figure out who they are and where they want to go—then shows them how to get there.*" Another example is gafutures.org which has information on careers in Georgia. The website has a lot of useful program information for students but it is difficult to find the information.

The challenge of choosing an IT-related major

While choosing a college major is difficult, choosing an IT-related major can be sometimes especially challenging. Examples of IT-related majors include: Computer Science, Informatics, Data Science, Computer Engineering, Information Technology, and Information Systems.

IT is a very broad and fluid field undergoing rapid change. Moreover, there are many different types of job across the IT-related fields, with new job titles and roles appearing often. It is therefore not surprising that people who are not within the IT field have trouble staying abreast of IT-related career opportunities. It is even difficult for IT professionals to do this. The inherent challenges in understanding the complexity within the IT field extends to the challenge of students choosing between a number of IT-related majors. Moreover, the distinction between IT-related majors is not crisp and may bleed into each other (for example, a program in Data Science may include a number of computer science courses). Selecting IT-related majors, which are are easy to confuse and with many HS counselors not aware of the finer points of distinction or perhaps not have not heard of them at all, is especially difficult for students.

Motivated by this clear need to improve the IT-related major selection process, the authors propose that a mobile application that leads students through a simple intuitive major search recommendation system could be part of the solution to choosing the right major.

Design and building a recommendation system for choosing an IT-related major

The recommendation system for choosing an IT-related major (hereafter referred to as the *CEIT Major Selection Tool*) was designed by two faculty members (one in Information Systems, and the other in Information Technology) and developed by a team of senior computer science majors as part of their capstone project within a course on software engineering. Screenshots from the application are presented in Appendix A: Example Application Screenshots.

While previous solutions to assist students to select a college major, such as the previously mentioned websites, attempt to cater for a wide range of colleges and majors, the *CEIT Major Selection Tool* focus is constrained to IT-related majors. Moreover, the initial version of the application does not attempt to cover all IT-related majors, but rather focuses only on the following college majors:

- Bachelor of Science - Computer Engineering
- Bachelor of Science - Computer Science
- Bachelor of Science - Information Technology
- Bachelor of Business Administration - Information Systems

High school and new college students are more likely to use an app that is easy to use, has an intuitive interface, and is informative. Also, since the vast majority of high school students either have a smartphone or access to one suggest that a mobile app would be a good platform for the recommendation system. In addition, the app will need to enable students to interrupt using the app and then return to where they left off.

The app is designed to engage high school students will also be useful for college freshmen. College freshmen who change their major are less likely to have taken a lot of courses that will not count towards their degree is some fashion even if the courses become free electives.

Design

To elicit users' preferences, users are initially presented with mini-vignette questions pairs and asked to choose which question reflected their preference based on which task they felt interests them more. Questions were designed to present a task a professional with that qualification could possibly be asked to do as part of their everyday job. The intention was to express these tasks in simple ways that most high school students could relate to, even without a business or technical background. Examples of questions included:

IT Major	**Question Text**
IS	Designing the next version of a marketing and sales computer system
IS	Analyzing a computer system to ensure it is user-friendly and accurate
IS	Designing the next version of a computer system to be used by office workers for hiring employees
IS	Working with top-level business executives on a plan to safeguard important files
CS	Writing the computer code needed to implement a new iPhone app
CS	Using a programming language to create new video games
CS	Programming the software for a point-of-sale system to be used in a retail store
CS	Creating the next version of a computer operating system, like Windows

	(Microsoft) or iOS (Apple)
CS	Creating a program that identifies security breaches within the business network
IT	Ensuring the computer network an application runs on is secure and always available
IT	Installing servers to meet the needs of a growing business
IT	Setting up and configuring a web server to enable people to share photos
IT	Installing and configuring networking equipment to allow wireless communication
IT	Ensuring the computer operating system is properly working on employees' computers and has the latest security updates
CE	Programming the software that connects a photography sensor to a camera
CE	Designing the circuitry of the next smartphone camera to capture even better quality photos
CE	Designing a new type of video card to run complex games faster
CE	Design software for a heart rate monitor to be used in a hospital
CE	Developing a motion sensor for a home security system
CE	Designing the hardware components for a new virtual reality system

The question pairs were initially randomly selected (but each question pair had to reflect two different majors). Based on the initial choice, a specific major was discounted. For example, if a user was presented with two tasks - one reflecting CS and the other reflecting IS, and they chose IS as their preferred task, then that user was not presented with any further CS-related questions. After all the majors had been reflected in the question pairs, and choices elicited from the users, the user is presented with a primary and a secondary recommendation about what IT-major they could be interested in based on their previous question choices. In addition to the primary and secondary majors presented, the app also provides buttons that take enable the user to learn more about the suggested majors.

The design of the app interaction attempted to accommodate the many users who were expected to use the app on the condition they will receive a recommendation but with limited interaction (i.e., their attention span with respect to using the app would be quite limited). It was

therefore expected that if a user was required to answer too many questions, or had to pass through too many screens, they would be more likely to abandon their app session. The tolerance for interaction points is an empirical question and deserves further investigation, as the confidence in the recommendation would likely increase through the use of question redundancy, and by ensuring the user would have to choose between questions addressing all combinations of majors (reflecting a complete pairwise comparison matrix).

Future extensions

In the future, the authors intend to extend the concept for engineering majors. In addition, the app will need to be promoted to high school students and counselors. It could also be extended to allow students to forward their results to their high school counselors. It would also be possible to provide a way for app users to contact appropriate virtual mentors to answer questions and provide more information on majors.

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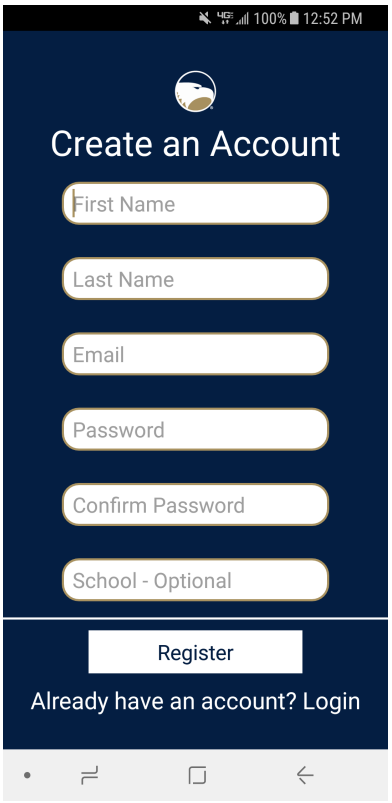
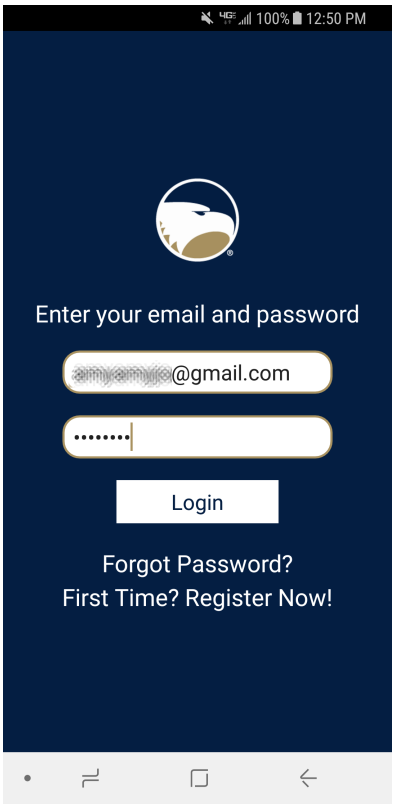
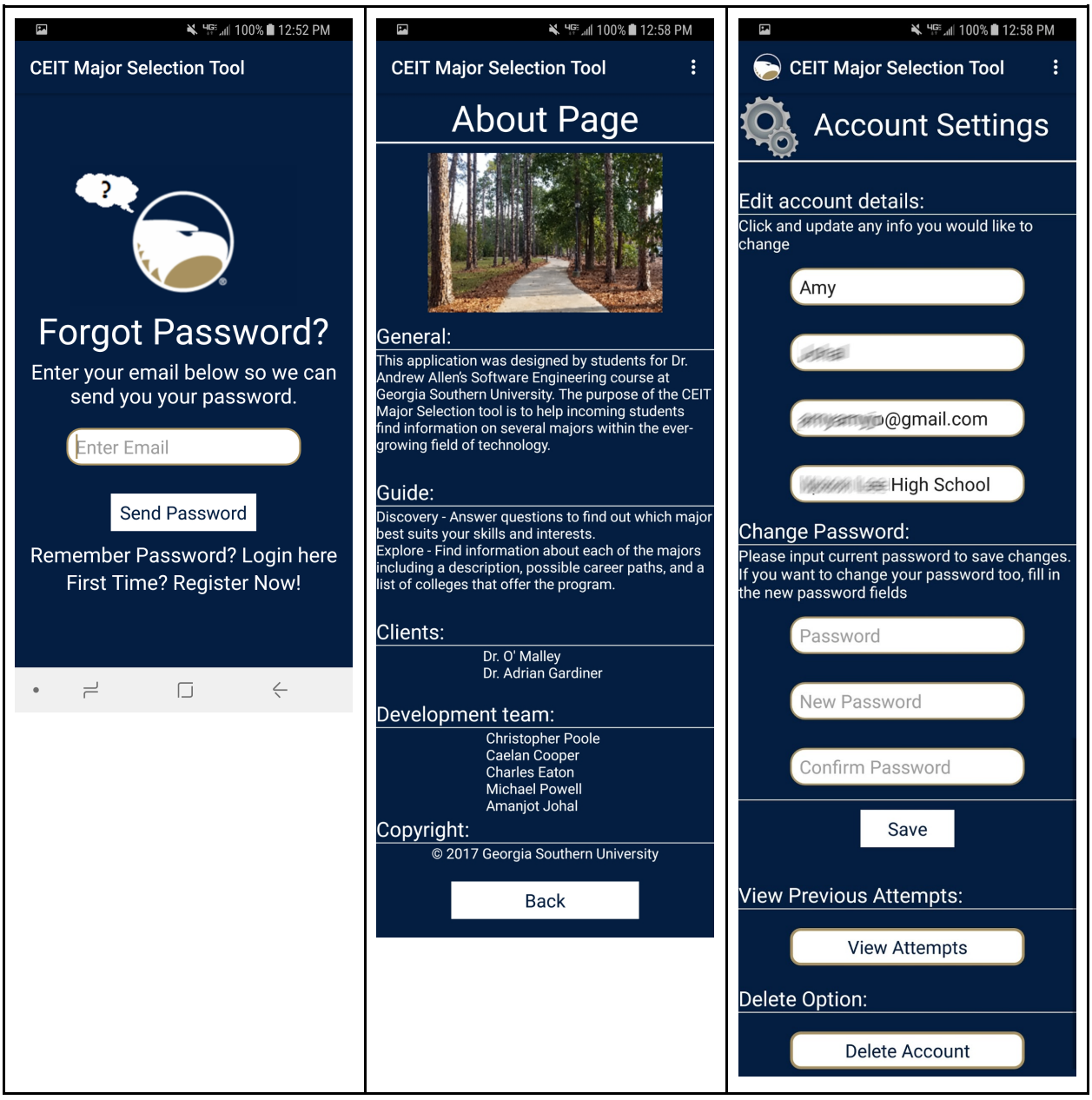
Appendix A: Example Application Screenshots

App branding and settings

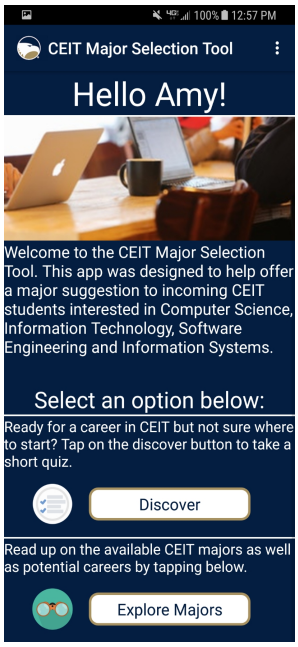




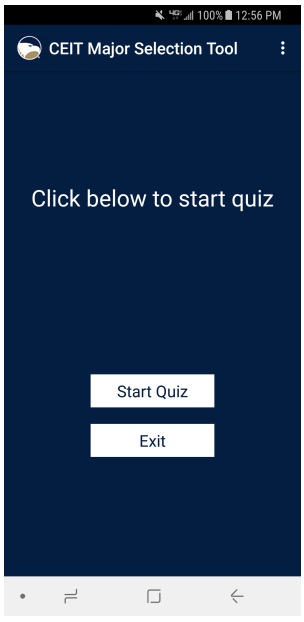

100% 12:52 PM
CEIT Major Selection Tool
Forgot Password?
Enter your email below so we can send you your password.
Enter Email
Send Password
Remember Password? Login here
First Time? Register Now!
100% 12:58 PM
CEIT Major Selection Tool
About Page
General:
This application was designed by students for Dr. Andrew Allen's Software Engineering course at Georgia Southern University. The purpose of the CEIT Major Selection tool is to help incoming students find information on several majors within the ever-growing field of technology.
Guide:
Discovery - Answer questions to find out which major best suits your skills and interests.
Explore - Find information about each of the majors including a description, possible career paths, and a list of colleges that offer the program.
Clients:
Dr. O' Malley
Dr. Adrian Gardiner
Development team:
Christopher Poole
Caelan Cooper
Charles Eaton
Michael Powell
Amanjot Johal
Copyright:
© 2017 Georgia Southern University
Back
100% 12:58 PM
CEIT Major Selection Tool
Account Settings
Edit account details:
Click and update any info you would like to change
Amy
@gmail.com
High School
Change Password:
Please input current password to save changes. If you want to change your password too, fill in the new password fields
Password
New Password
Confirm Password
Save
View Previous Attempts:
View Attempts
Delete Option:
Delete Account

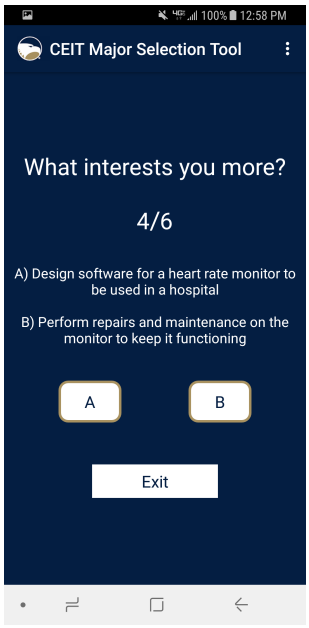
8

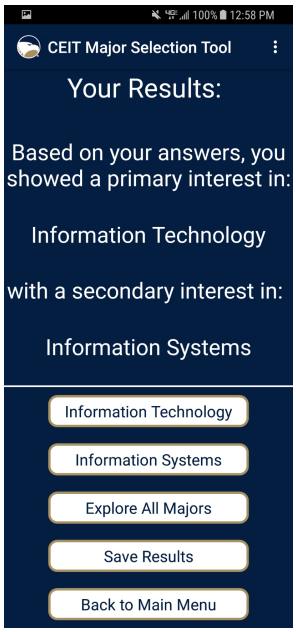
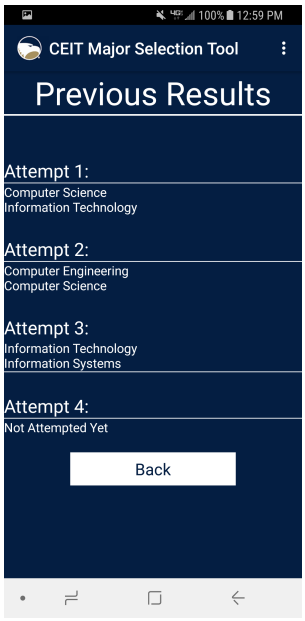
Main navigation

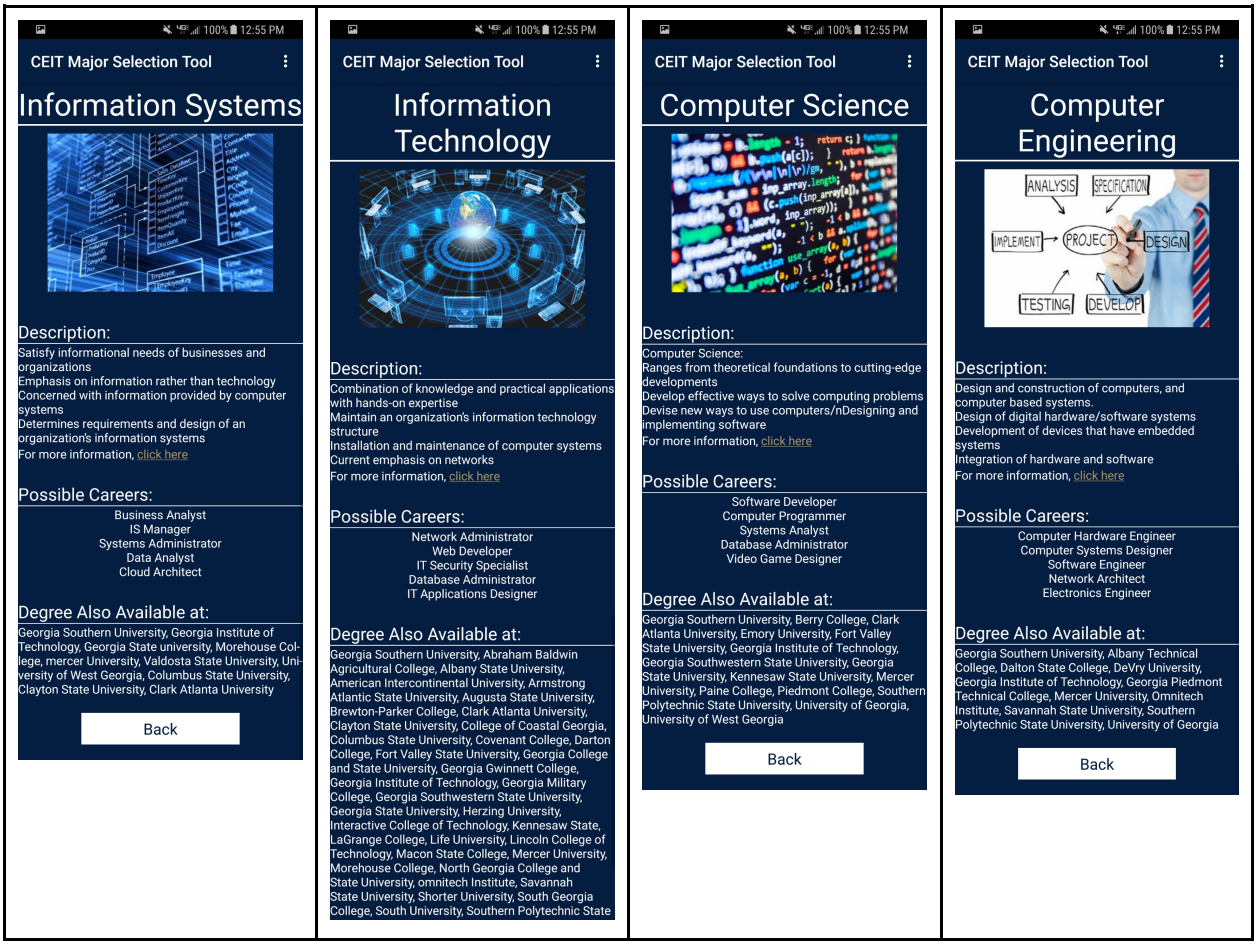


Data collection - Discover





Presentation of recommendation	
	


CEIT Major Selection Tool
Information Systems
Description:
Satisfy informational needs of businesses and organizations
Emphasis on information rather than technology
Concerned with information provided by computer systems
Determines requirements and design of an organization's information systems
For more information, click here
Possible Careers:
Business Analyst
IS Manager
Systems Administrator
Data Analyst
Cloud Architect
Degree Also Available at:
Georgia Southern University, Georgia Institute of Technology, Georgia State university, Morehouse College, mercer University, Valdosta State University, University of West Georgia, Columbus State University, Clayton State University, Clark Atlanta University
Back
CEIT Major Selection Tool
Information Technology
Description:
Combination of knowledge and practical applications with hands-on expertise
Maintain an organization's information technology structure
Installation and maintenance of computer systems
Current emphasis on networks
For more information, click here
Possible Careers:
Network Administrator
Web Developer
IT Security Specialist
Database Administrator
IT Applications Designer
Degree Also Available at:
Georgia Southern University, Abraham Baldwin Agricultural College, Albany State University, American Intercontinental University, Armstrong Atlantic State University, Augusta State University, Brewton-Parker College, Clark Atlanta University, Clayton State University, College of Coastal Georgia, Columbus State University, Covenant College, Darton College, Fort Valley State University, Georgia College and State University, Georgia Gwinnett College, Georgia Institute of Technology, Georgia Military College, Georgia Southwestern State University, Georgia State University, Herzing University, Interactive College of Technology, Kennesaw State, LaGrange College, Life University, Lincoln College of Technology, Macon State College, Mercer University, Morehouse College, North Georgia College and State University, omnitech Institute, Savannah State University, Shorter University, South Georgia College, South University, Southern Polytechnic State
CEIT Major Selection Tool
Computer Science
Description:
Computer Science:
Ranges from theoretical foundations to cutting-edge developments
Develop effective ways to solve computing problems
Devise new ways to use computers/nDesigning and implementing software
For more information, click here
Possible Careers:
Software Developer
Computer Programmer
Systems Analyst
Database Administrator
Video Game Designer
Degree Also Available at:
Georgia Southern University, Berry College, Clark Atlanta University, Emory University, Fort Valley State University, Georgia Institute of Technology, Georgia Southwestern State University, Georgia State University, Kennesaw State University, Mercer University, Paine College, Piedmont College, Southern Polytechnic State University, University of Georgia, University of West Georgia
Back
CEIT Major Selection Tool
Computer Engineering
ANALYSIS
SPECIFICATION
IMPLEMENT
PROJECT
DESIGN
TESTING
DEVELOP
Description:
Design and construction of computers, and computer based systems.
Design of digital hardware/software systems
Development of devices that have embedded systems
Integration of hardware and software
For more information, click here
Possible Careers:
Computer Hardware Engineer
Computer Systems Designer
Software Engineer
Network Architect
Electronics Engineer
Degree Also Available at:
Georgia Southern University, Albany Technical College, Dalton State College, DeVry University, Georgia Institute of Technology, Georgia Piedmont Technical College, Mercer University, Omnitech Institute, Savannah State University, Southern Polytechnic State University, University of Georgia
Back

COMPARING THE FIT BETWEEN THE CHIEF MARKETING TECHNOLOGIST JOB FUNCTION AND FIRM INDUSTRY COMPETITIVE ENVIRONMENT: A PRELIMINARY INVESTIGATION

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INTRODUCTION AND BACKGROUND

The modern day business landscape is characterized by rapidly changing digital technologies. Digital technologies such as social media, cloud, mobile applications, and real time analytics enable unprecedented levels of connectivity for individual customers and businesses worldwide that invest heavily in consumer-centricity. Amidst the increasingly customer focused orientation of firms, a new C-level position, that of the chief marketing technologist (CMT), is on the rise in digital information technology reliant firms. Amongst the numerous responsibilities that have been suggested in published literature, CMT's are responsible for aligning marketing technology with business goals, serving as a liaison to IT, and evaluating and choosing technology providers (Brinker and McLellan 2014), bringing an "organization's digital footprint under one roof", and interfacing with the customer (Dumuresque 2014); for using digital technology to generate new sources of revenue, create new capabilities, and customer experiences (McDonald 2013); and to enable digital transformation (Fitzgerald et al. 2013). Continuing the academic research on the topic of CMT's, and particularly as it relates to the roles of CMT's, the primary objective of our research is to determine which of the two roles, marketer or technologist, is of primary importance for CMT appointments. More importantly, we compare the fit of the CMT role with the competitive environment of the SMBs.

RESEARCH OBJECTIVES AND PROPOSITIONS

Existing research posits that the CMT position falls under both job descriptions as a CMT is often credited with providing both technological and market-driven expertise in creating digital products and services. Furthermore, the ever increasing demand for better interfacing between the information systems and marketing functions in firms has placed the CMT role firmly at the intersection of marketing and technology (Lord and Velez 2013). Recent research, drawn from empirical evidence, on CMTs also clearly highlights the two prominent roles of CMTs. For instance, a recent report by the consulting firm SapientNitro [1] describes six distinct CMT archetype clusters - three of which are predominantly involved in marketing activities, with the other three driven predominantly by information technology management motivations. The six CMT archetypes and their areas of focus are described in table 1.

[1] Today's marketing technologists cluster into 6 distinct archetypes. Of the 6 archetypes – 3 are focused on technology, 3 on marketing. Analyzing the Chief Marketing Technologist (2015). http://www.sapientnitro.com/content/dam/sapientnitro/assets/white-papers/Analyzing_the_CMTO_final.pdf

Table 1: Description of CMT Role Archetypes	
Marketer/Marketing Focus CMT Archetypes (Higher marketing skills)	**Technologist/Technology Focus CMT Archetypes (Higher technology skills)**
Content Curators ***Focus:*** Use content marketing and related technologies to direct communications-oriented marketing. ***Professional Skills and Experience:*** Content creation, copywriting, and content optimization.	**Infrastructure Architects** ***Focus:*** Development of enterprise marketing platforms, technology architecture, and digital asset management platforms. ***Professional Skills and Experience:*** Enterprise architecture, technology selection, lifecycle management, software design, programming, coding, software development operations and IT operations. Experience with front-end technologies (e.g. HTML5, JavaScript, and CSS), data visualization technologies, and content management and digital asset management systems.
Media & Marketing Analyzers ***Focus:*** To conduct market research, generate consumer insights and oversee strategic planning of marketing activities. ***Professional Skills and Experience:*** Marketing research, consumer insights, competitive intelligence, advertising, marketing communication development, market segmentation, and psychographics.	**Experience Engineers** ***Focus:*** Enhancing digital technology user experience by creating rich, responsive, and multi-platform accessible digital interfaces. ***Professional Skills and Experience:*** eCommerce technologies and platforms, front-end technologies (e.g. HTML5, JavaScript, and CSS), software design, programming, coding, website design, design and development of mobile apps and platforms, GIS, geomapping, and geotargeting.
Marketing Mavens ***Focus:*** Building marketing programs using expertise in marketing strategy, strategic positioning and promotion. ***Professional Skills and Experience:*** Marketing strategy and positioning, and marketing operations management.	**Data Divas** ***Focus:*** Acquire, integrate and utilize customer and market data to generate key marketing insights. ***Professional Skills and Experience:*** Data science, analytics, statistics, modeling, data management software and systems, CRM systems and platforms, marketing operations management.

We contend that the specific CMT archetype (marketer or technologist) depends on the prevailing industry environment of the CMT's firm. To test our contention we delve into research in industrial economics, strategic management, and information systems which argue that the industry competitive environment has a significant impact on a firm's strategic actions (Dess and Beard, 1984). We use prior research and highlight two specific industry environmental factors - munificence (Randolph and Dess 1984) and hypercompetitiveness (Castrogiovanni 2002; Randolph and Dess, 1984). Environmental munificence refers to the extent to which critical resources exist in the environment (Randolph and Dess 1984). On the other hand, an

environment characterized by intense and rapid competitive moves, in which competitors must move quickly to build new advantages and simultaneously erode the advantages of their rivals is known as a hypercompetitive environment (Thomas and D'Aveni 2009).

Our central thesis is that the nature of a firm's competitive environment forces them to create market-based (pull) or technology-based (push) products and services. Market-based products and services are designed for new and niche market segments with features specifically tailored and customized for the customers in the new segment (Christensen and Bower 1996). On the other hand, tech-based products and services are marketed to existing customers and markets and provide technologically superior benefits to customers than existing products (Chandy and Tellis 1998). Thus, the specific flavor of CMT - marketer or technologist, depends on the industry competitive environment. In other words, the distribution of CMT's with either marketing, technological, or both skill attributes will be determined by the competitive environment of the industry in which they operate. We make the case, for example, that for firms that compete in hypercompetitive markets, the returns on products and services is often eroded due to the high level of price competition among competitors. Firms operating in such markets must seek newer sources of revenue by introducing products and services in niche market segments, often by designing market-based products and creating new market segments. We argue that the challenges faced by the CMT in such environments (market segmentation, marketing, research, and consumer insight) can be better addressed by the skills possessed by marketer CMTs and hence firms in hypercompetitive environments are more likely to appoint marketer CMTs.

> ***Proposition 1:*** Firms in industries characterized by high hypercompetitiveness are more likely to appoint marketer CMTs.

Munificent environments are characterized by greater availability of resources. Thus, it is relatively easy for firms in munificent environments to survive. Consequently, firms are able to pursue higher goals that go above and beyond mere survival (Castrogiovanni 1991). As a result, research has indicated that environmental munificence is positively associated with a number of strategies that are pursued by firms (Dwyer and Oh 1987). It has been observed that the growth and prosperity potential in a munificent environment allows firms to invest in new business initiatives (Koka, Madhavan, and Prescott 2006) and become more diversified. Furthermore, abundant resources enable firms to invest in infrastructure development and generate slack resources (Keats and Hitt 1988). The skills required to oversee IT infrastructure development, and concerted experimentations with data and interfaces are more likely to be present in technologist CMTs. Thus,

> ***Proposition 2:*** Firms in industries characterized by high munificence are more likely to appoint technologist CMTs.

We intend to make additions to the above set of propositions by making the case for other competitive environment considerations by drawing relevant theory from industrial economics, strategic management, and information systems on industry competitive environment (Dess and Beard 1984).

METHODOLOGY

The propositions in this paper will be tested empirically by coding qualitative data from CMT appointment announcements and job postings. A coding scheme utilizing the descriptions of the position's focus, skills, and experience elucidated in table 1 above is being developed. Raters with teaching and research experience in marketing or information systems will be recruited to rate each CMT appointment announcement and job posting into two (possibly more) role archetypes. The resultant quantitative data will be tested using the appropriate statistical method. Our study will utilize data from a number of secondary data sources such as: (1) Appointment announcements of newly appointed CMTs to assess their roles and strategic/functional objectives in the hiring organization, (2) CMT job postings from online job sites, and (3) Secondary data from Compustat for industry competitive environment.

CONCLUSION

In this paper we investigate two types of CMTs - technologist and marketer, and map the prevalence of each type to specific industry environments. In doing so we also answer the question, "what type of CMT does a firm need?" by providing empirical evidence of a link between a focal firm's industry competitive environment and CMT type. Future research using the findings of our study could shed more light on the competitive environmental conditions under which CMT appointments leads to firm value creation.

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Management, Org Behavior, Org Theory, & HRM

Abstract

The wealth of information and data available on the subject of labor turnover is an indication of the importance of this topic to business owners who are striving for sustainability, especially after the last economic downturn. This topic is also critical for the cities, small towns that depend on the tax revenue generated by these businesses, which, as tax payers, serve as the life's blood for many municipalities. Turnovers appear to be an increasing problem. According to the Job Openings and Labor Turnover Survey (JOLTS), September 2014 report, the number of quit rates increased 12%, from 2.5 million in August 2014, to 2.8 million in September, noting that this was the highest level of quits since April 2008. The Bureau of Labor Statistics (BLS) collects and compiles JOLTS data monthly from a sample of non-farm establishments. The JOLTS report looks at hires and separation rates, seasonally adjusted by industry classification and region.

The research looks at a third-party logistics provider (3PL) located in Northwest, Alabama. The firm has provided logistics solutions for automotive original equipment manufacturers (OEM) and large tier 1 suppliers since the 1990s. The firm is one of four companies that comprise a holding company headquartered in northeastern United States. The other four companies are:
1) a fuel tank manufacturing company; 2) an assembly company, providing modular systems primarily to an OEM; 3) also a third-party logistics company that has global capability; and 4) a QC Inspection company that specializes in quality inspection. Each company in the holding organization is incorporated as a limited liability company (LLC) and run as a separate entity.

Automotive manufacturing companies value suppliers that can provide end-to-end solutions, which are made possible by combining upfront logistics capability with manufacturing know-how. Fortunately, the logistics firm, by its connection and affiliation with the holding company, is viewed by its customers as a hybrid between a pure

logistics company and a manufacturing company. This designation offers the logistics firm an advantage when competing for new business against other 3PL's that are more limited in scope. This combination, along with a business philosophy that values rapid response to requests, has resulted in double-digit growth over the past six years.

The company has created a niche in logistics by working effectively for clients on assigned projects, and offering robust end-to-end solutions in operations, assembly, engineering, kitting, transportation, inventory management, point of use (POU) replenishment and IT systems. The logistics firm supports clients in three industry verticals: automotive, government sector, and consumer industrial. The logistics firm's client list includes major OEMs, Tier One Suppliers, Retail and Food and Beverage Suppliers and an Aerospace Manufacturer, among others.

The company employs more than 800 people. The logistics firm is positioned well in the community and has been warmly received by the market place as evidenced by its financial reports and marketing materials that demonstrate the company achieving and maintaining a double-digit growth rate for the past six years.

The logistics firm has won numerous performance awards from clients and community leaders alike, including a 2015 Impact Awards nominee for Tier III business of the year; a 2013 Performance Award from a Tier I client; and the 2011 Supplier of the Year Award from a Community Advocacy Organization.

Research Question

The primary research question is: "Why do 70% of firm's new hires NOT make it to their one-year anniversary?" More specifically, to what

extent does dissatisfaction with working conditions, personal factors, new-hire on-boarding processes, and compensation have on voluntary separations or quits?

This research was conducted to examine and analyze the primary factors that are driving the high employee turnover at the firm and to determine actions that can be taken by the management team to improve employee retention.

Methods of analysis

The research was conducted by administrating electronic surveys to individuals at the work site, using iPads or in computer labs. This research surveyed current employees to gauge and rank the work, interpersonal, and personal factors that would lead employees to consider quitting. Of 709 current company employees and 10 former employees, 486 received surveys; 281 surveys were completed and analyzed for this study.

Conclusions

Analysis of the data revealed two major categories of concern regarding high employee turnover at the firm:

Monetary Issues - Salary, annual raises and performance incentives.

Non-monetary Issues - Fair treatment, opportunity to improve when a mistake is made, recognition and relationships with team members and with management.

Recommendations

The company should begin to direct management’s focus toward Mitigating problems and improving retention rates through the following five-step process.

4

1) Re-align wage structure:

Conduct survey to compare existing wages against local competitors.
   a. If a wage gap exists, the company should close that gap.
      i.The gap should be closed by 50%
      ii.Wage increases should be in place by February 1, 2016.

2) Eliminate the current, contentious reward practice:

   Stop the current, annual pro-rated wage increase practice that is thought to be unfair by employee responders.

3) Reactivate cross-training performance:

   Incentivize employees to take advantage of training that will increase their pay and prepare them to be more valuable to the company.

4) Institute “Reduced Expense Sharing” program:

   Cut plant expenses and share these monies 50/50 with the hourly workers and salaried managers. This approach will promote team work as these two groups work towards a common mutually beneficial outcome.

5) Re-align culture, returning to the 5 C’s:

   To build a people-centered organization, the company founders espoused values of Caring, Committing, Connecting, Communicating and Celebrating. The results of this study suggest that there is now a need to refocus both managers and employees on these 5C’s.

5

Limitations of the Study

This study is based exclusively on surveys from current hourly employees. Surveying employees who left the company would be another source of data. However, only a few former employees were available to complete the surveys, which could have disproportionate effect on findings. As a result, that demographic was deleted from consideration and the five (5) responses received were not included in the analysis. It may well be that those who have actually left the company voluntarily would express different concerns or rank concerns differently.

Public Sector, Not for Profit, & Health Care Management

A PRELININARY EXAMINATION OF PUBLIC DIALYSIS TRANSPORT EFFICIENCY USING AVAILABLE TECHNOLOGIES

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ABSTRACT

The provision of para-transit services for patients needing dialysis is vital to patient maintenance. The availability of para-transit services varies in North Carolina counties depending on federal, state and local funding. Because these resources are limited, it is important to use available technologies to maximize resource usage. A survey was developed and administered to para-transit county administrators. Results of the preliminary data analysis showed that the use of technologies increased as the number of available dialysis centers increased. Counties also invested in more technologies as their feelings about funding adequacy for investments in general and from federal sources increased. Finally, those counties that felt they would be able to keep up with demand for dialysis services in the future tended to invest in more technologies.

INTRODUCTION

Patients with kidney disease face many difficulties in getting to and from life-saving dialysis treatments. Typical patients require multi-hour dialysis three times per week. Federal law mandates that these patients are covered under Medicare even if they are under 65 years of age. Medicare, however, does not provide needed transportation to the treatments. Even if they have transportation, many of the patients are too weak to drive after treatment or may find it difficult to find family members to take time to transport them to the treatments.

Para-transit services are offered to provide needed transport to life-saving dialysis centers. Governmental para-transit services are available in some but not all North Carolina's 100 countries. North Carolina is a state where the counties with the most resources are in the central, Piedmont area of the state. The Appalachian area and the Eastern part of the state are largely agricultural areas with lower tax bases. The poverty in these areas does not allow for much funding from county government sources, and a larger proportion of residents have limited means of transport. Limited funding is available through the Elderly/ Disabled Transportation Assistance Program and Medicare. Consequently, public transit mangers need inexpensive yet effective means of scheduling transportation for these patients where dialysis is a life or death matter. Medical transportation needs in rural areas of North Carolina has been a focus of the NCA&T Transportation Institute for over 40 years (Saltzman, 1976; Sulek & Lind, 2000; Sulek & Lind 2005). Advances in digital communication media present opportunities to improve the efficiency of delivering these transit services. Findings regarding technologies used to assist with the scheduling are discussed in this paper. Results of discussions with North Carolina para-

transit directors and dialysis clinics on how to provide such technologies to insure the patient is ready when the paratransit vehicle arrives will be presented.

BACKGROUND

Dialysis transit needs arose with the availability of the artificial kidney machine to cleanse the blood of patients with failing kidneys. Dr. Willem Kolff invented dialysis machines during World War II (Eggers, 2000). They became available on a larger scale with the invention of the shunt by Dr. Belding Scribner (Eggers, 2000). The lifesaving devices became part of the fabric of health care starting in the 70's. The passage of the Social Security Amendments of 1972 (P.L. 92-603); in which Section 299I enabled patients needing dialysis to receive treatment that would be covered by Medicare even if under the age of 65 (Swarminathan et al., 2012). There are about 300,000 people in the United States receiving dialysis treatment for end stage renal disease - ESRD (Kidney Disease Statistics for the United Stated, 2016).

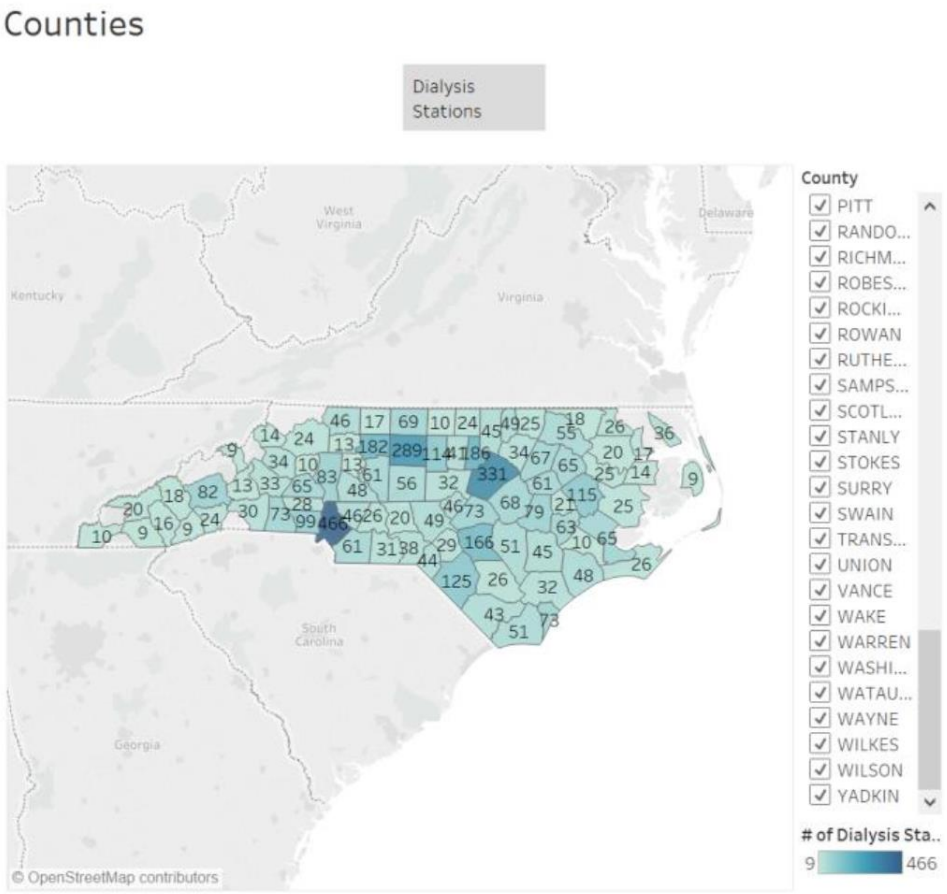
For-profit dialysis chains dominate the market providing the majority of the dialysis centers in the country (Johnson, 2014). Results of this study show that this is also true in North Carolina. Also, Wake Forest Hospitals (Bowman Grey) operates some centers, and while others are owned by individual doctors. Medicare payments and the efficiency of the for-profit chains have resulted in the dominance of the for-profits in providing dialysis centers even in remote, rural counties in North Carolina. Dialysis annual costs are around $20 billion, and the number of patients rises from six to seven percent annually with one-third of the patients in a minority category. Medicare pays about $60,000 per year per Medicare patient (Swaminathan et al., 2012). Figure 1 shows the number of dialysis stations in each county of North Carolina.

THE TRANSIT PROBLEM

Not all dialysis patients need assistance in traveling to and from dialysis clinics; however, as the patient's health deteriorates it becomes more difficult for family members to meet patient needs after hours of dialysis treatment resulting in a very tired patient. The paratransit vehicles used for patient transport in the counties include hydraulic lift devices to help with patients who may be in wheelchairs or otherwise immobile.

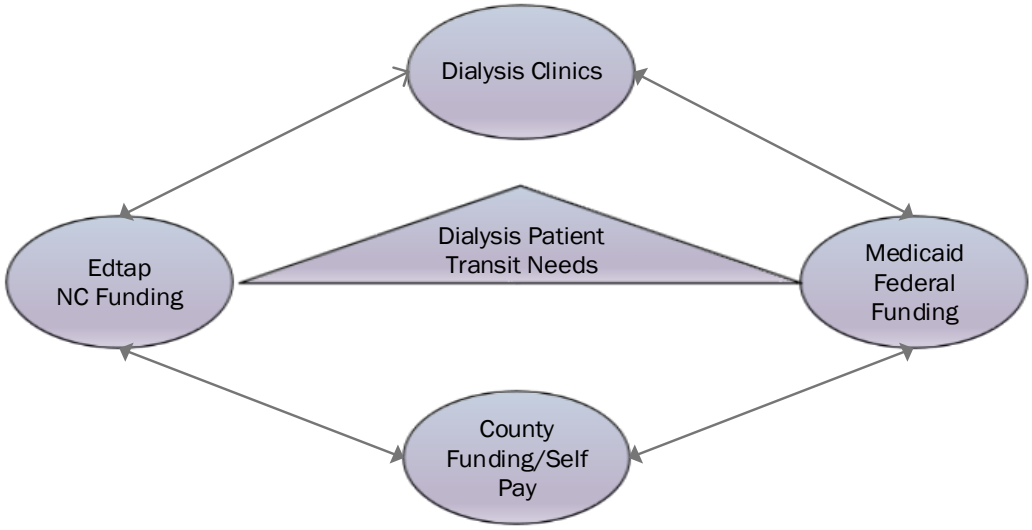
The provision of these transit services for dialysis patients to dialysis centers presents an agency problem (Eisenhardt, 1989) where the local counties provide the paratransit, non-emergency paratransit vehicles yet the funding sources include federal, state, and local resources. Thus, the county paratransit operator is the agent that provides the principal, the dialysis center, with the work of transporting dialysis patients to their centers under conditions of incomplete and asymmetric information. In agency theory (Figure 2) the work carried out in this arrangement is the transport of needy patients from their homes to the dialysis center and then back to their homes. Thus, the work of transport has been delegated from the dialysis clinics to the paratransit authorities in each county.

FIGURE 1
DIALYSIS STATION BY COUNTY



The goals of the principal and the agent may not be in alignment. The agent (paratransit) collects riders in need of paratransit services for doctor appointments, dialysis appointments, and other transit needs. Scheduling these pickups with a limited number of vehicles in counties creates scheduling and routing problems for the paratransit agencies. Further, the principal in this study has a set schedule where patients come to the dialysis clinic in a three to four hour windows on a Monday, Wednesday, Friday or a Tuesday, Thursday, Saturday schedule. Asymmetric information for scheduling often exists between the dialysis centers (principal) in a county, the para-transit authority (agent), and the patient's knowledge of his/her schedule. If a patient is not ready for a paratransit pickup or a paratransit vehicle misses or is late for a dialysis patient pickup this can have a cascading effect on these inter-related actors from the para-transit schedule, to other patients, to the dialysis clinics, on to receiving reimbursement for this transport.

FIGURE 2
AGENCY MODEL



Most dialysis clinics (principals) have a social worker who works with the dialysis patients (agents) to obtain transportation. All patients who receive dialysis are deemed disabled, and qualify for Medicaid within the Medicare income guidelines, thus Medicaid will pay their travel costs within their guidelines. Other funding sources, if available, are used to supplement the cost of transportation to and from dialysis. Also, there is some federal funding from the Home and Community Block Grant federal program for those over the age of 60. There is a North Carolina program entitled the Elderly and Disabled Transportation Assistance Program (EDTAP) that provides transportation for those over the age of 60 and deemed disabled. There is a budget set for EDTAP based on the county population, and the funds are prone to be depleted before year end. Most dialysis patients are on a fixed income so that the part of the transportation cost the disabled patient pays often is more than he/she can afford. All these sources and grants from the Federal Transportation Agency are used to buy the para-transit vehicles.

A coordination problem between these agencies (dialysis units, patients, and para-transit operators) exists. The principal (dialysis clinic) cannot verify that the agent (para-transit authority) has behaved appropriately due to asymmetric information sharing. Another issue is that of risk sharing that arises when the principal and agent have different attitudes towards risk. Dialysis clinics and patients know that the dialysis treatment is necessary for patient survival. Paratransit operators are aware of this risk yet they must transport many such patients under the scheduling and information difficulties noted above. The problem here is that the principal and the agent may prefer different actions because of these different risk preferences.

METHODOLOGY

This study is part of a project for the Center for Advanced Transportation Mobility (CATM) located at North Carolina A&T State University. The study setting consists of all one hundred North Carolina counties where an attempt was made to contact those responsible for paratransit services in each county. The North Carolina Public Transit website was used to compile a list of preliminary contacts. County websites were checked to determine whether there was a para-transit contact. When a contact was unavailable, the county's public transit office or county administration was contacted by phone to identify the best contact.

A preliminary survey containing Likert scaled, short answer and open-ended questions was developed and pre-tested in two counties. Based on comments and suggestions, adjustments were made to the survey. County transportation agencies were then contacted and interviewed by phone to complete the survey. A total of 91 counties provided information for this study.

PRELIMINARY DATA ANALYSIS

Data were collected for 91 out of 100 counties. These counties were geographically dispersed throughout the state and populations were compared to those counties that participated in the study. As Table 1 shows, the non-responsive counties seemed to be in line with those counties that did participate. No factors were identified to indicate bias with regards to participation.

TABLE 1
COMPARISON OF RESPONDENTS TO NON-RESPONDENTS BASED ON POPULATION

	Non-Respondents	Respondents
Average Population	111,824.09	96,584.53
Max	495,279.00	967,971.00
Min	13,487.00	4,141.00

In this preliminary data analysis, where the use of technologies in support of para-transit was a focus of the paper, an interim correlation matrix was produced in Table 2.

Table 2
Pearson Correlations[1]

	technew	dialmeet	povlevel	CoPopn	Pat/Pop	q6	q7	q8	q9	q11	q12	q13	q14	q15
technew	1	-.152	.037	.099	-.031	.074	-.131	.337**	.218*	.357**	.511**	-.058	.299**	.217*
dialmeet		1	-.044	.169	.011	-.040	-.142	-.332**	-.109	-.422**	-.338**	-.290**	-.007	.138
povlevel			1	-.251*	.181	-.015	-.051	-.071	.089	-.069	.035	.078	-.030	.030
CoPopn				1	-.475**	.004	.068	.012	.031	-.034	.090	.033	.033	.109
Pat/Pop					1	-.064	-.118	.065	-.077	-.039	-.038	-.020	.022	.053
q6						1	.229*	.103	.141	.188	.344**	.036	.045	.013
q7							1	-.262*	.166	.036	.144	.068	-.046	-.032
q8								1	.413**	.317**	.370**	.114	.201	.185
q9									1	.223*	.363**	-.088	.080	.340**
q11										1	.398**	.139	.126	.162
q12											1	.085	.209*	.228*
q13												1	.038	.001
q14													1	.279**
q15														1

[1]**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

Based on these inter-item correlations, the variable TechScore combined the score for questions 25 to 29 from the questionnaire (Table 3). These questions related to the use of technologies to control the transit provision and technologies related to the interface between the transit provider and the rider. The questions used a five-point Likert scale, and the questions were framed as "To what extent do you agree" (where 1 = Strongly Disagree to 5 = Strongly Agree).

Table 3
Technology Score Variable

	Patients use a Website to schedule trips (Q29)	Patients use the phone to schedule trips (Q28)	On-board cameras are used to monitor the vehicles (Q26)	GPS is used to locate vehicles (Q25)	Patients use a smartphone app to schedule trips (Q27)	TechScore
Mean	4.944	4.933	4.933	4.878	2.844	22.533
Minimum	1	3	3	1	1	11
Maximum	5	5	5	5	5	25
Variance	0.188	0.108	0.085	0.266	2.245	4.679
Std. Dev.	0.433	0.328	0.292	0.516	1.498	2.163
Count	90	90	90	90	90	90

Differences Due to Location

Disparities between the lower income areas of the state and the higher income levels of the state were expected, and the data analysis supports it. For instance, the poverty levels and county populations have a significant negative correlation ($p < 0.05$). This finding suggests that the counties with larger populations have lower poverty levels (and vice versa). The state has a few larger population areas (for instance, the Raleigh, Durham, Chapel Hill metropolitan area) where more industry and jobs are located compared to lower populations in rural areas with little industry and few jobs. Another interesting finding was county population has a negative correlation with the percentage of dialysis patients in the population suggesting that smaller counties have a larger proportion of dialysis patients.

Use of Technologies

The data also show some interesting findings related to the use of technologies and feelings about the adequacy of funding for paratransit services (see Table 4). There is a significant positive correlation between the perception that overall funding is adequate and the adoption of

technologies ($p < 0.001$). These results suggest that as the funding adequacy increases, counties tend to invest more money in paratransit. When the funding sources are broken down, however, it turns out that counties are relying on federal funding ($p < 0.001$) but not significantly on state ($p = 0.490$) or county ($p = 0.218$). This finding supports the importance of federal funding from the American with Disability Act via Medicaid for supporting paratransit. The state funding is primarily for the elderly through EDTAP but the county and city funding is inconsistent due to different tax bases in these areas.

Table 4
Correlations of Questions Related to Technology Score

Question	Correlation	Sign
On average, how many dialysis patients do you serve? (Q3)	0.018	ns
How many dialysis centers does your county have? (Q5)	.193	p<.10
To what extent is(are) funding adequate? 1 = Very inadequate to 5 = Very adequate		
Paratransit funding from state sources. (Q6)	.074	ns
Paratransit funding from county sources. (Q7)	-.131	ns
Paratransit funding from federal sources. (Q8)	.34	p<.001
Overall funding for paratransit services. (Q9)	0.218	p<.05
To what extent do you agree? 1 = Strongly Disagree to 5 = Strongly Agree.		
We feel that we will be able to keep up with demand for dialysis services. (Q11)	0.357	p<.001
We have adequate funding to invest in new transit technologies. (Q12)	0.511	p<.001
The number of dialysis centers will increase in the next 5 years. (Q15)	0.217	p<.05
#of Meetings with each dialysis center per year	-.152	ns
Patients need additional service for transport (Q14)	.299	p<.004
All of our buses are ADA compliant. (Q23)	-.028	ns

In general, the correlation between technology use and the adequacy of funding for technologies has a significant relationship ($p < 0.001$). As feelings of the adequacy of funding for investment in new transit technologies increases, so too do the perceptions about the transit company's ability to keep up with demand ($p < 0.000$).

Keeping Up with Growing Demand

Finally, there is a positive correlation between feelings that the county will be able to keep up with demand for dialysis services and the technology score ($p < 0.001$). Those counties investing in technologies (and finding the funding for those investments) tend to be more positive about future funding and their ability to keep up with growing demand.

There is a positive correlation between state and county funding sources ($p = 0.030$) and a negative correlation between federal and county funding ($p = 0.013$). This finding suggests that in the minds of the transit directors, state and county funding are viewed in the same way. The negative correlation suggests that as their confidence in federal funding increases, their confidence in county funding decreases. This finding is also supported by the positive correlation between overall funding for paratransit services and funding from federal sources ($p < 0.001$).

Also examined were feelings about the ability to keep up with an increasing demand for dialysis transportation. First, there was a positive correlation between keeping up with increasing demand and feelings about the adequacy of federal funding ($p = 0.002$). This finding suggests that as confidence in the transit company's ability to keep up increases so too does the confidence placed in the availability of getting federal funding.

Customer Satisfaction

The negative correlation between the number of times the paratransit operator calls the dialysis clinic during the year with the feelings that patients are satisfied with paratransit services offered indicates that where there is higher satisfaction on paratransit services, then fewer phone calls are needed ($p = 0.006$). This relationship implies that when the paratransit is running smoothly less communication with the dialysis centers is needed. More calls indicate troubleshooting to handle scheduling and reduce the missed appointments. There is a positive relationship between what transit directors see as patient needs for additional service for dialysis support and their feelings about the adequacy of funding for new technologies ($p = 0.048$).

Forecasting for the Future

Transit directors who see the need for an increasing number of dialysis centers in the next five years tend to invest in more technologies ($p = 0.040$). The relationship between dialysis centers and investment in technologes also goes hand in hand with the view that as growth increases adequate funding will be available to invest in new paratransit technologies ($p = 0.031$). Finally, there is a positive correlation between expected growth in dialysis centers and the need for additional service for dialysis support ($p = 0.008$).

DISCUSSION

This preliminary data analysis from an ongoing project provides an interesting look at the current state of paratransit services for dialysis treatment in North Carolina. Overall, it appears that counties with larger populations are more confident in their ability to keep up with growing demand for dialysis transport.

An application of agency theory suggests that one important component in improving transit service to dialysis patients is to use available technologies to connect the three constituencies affected by the need for transport (Figure 2). First, the transit agencies need to utilize their resources in a cost-efficient manner. Avoiding waste due to lack of contact with patients (who may have decided on another means of transportation, rescheduled their appointment or be unable to get ready in a timely fashion) is important. From the perspective of the dialysis centers, they would like to run their schedules in an efficient manner (schedule those patients who take longer or have more variability in time later in the day and make sure they are fully utilizing their facilities). From the patient's perspective, they would like to have transport provided at times that do not keep them waiting for an appointment at the dialysis center or leave them at the dialysis center after treatment.

The patient needs are the center of this agency model with the patients needing to obtain their dialysis treatments on a set schedule at a set dialysis unit located as near as possible to where they live. Transportation to the dialysis centers can be done by the patient's family or via paratransit. When paratransit services are used, the payment for these services is complicated and varies based on the finances of the county. A reliable payment partner is the United States Americans with Disability Act where the transit costs can be covered. In North Carolina, there are EDTAP funds for riders over the age of 65; however, the funds are often depleted before the year's end. Some counties use the United Way and other non-profits to raise funding for paratransit equipment and services. Also, riders are charged to make up the difference where there is not enough funding. These transit agencies, dialysis principals, and dialysis patients create communication and coordination issues across these entities due to communication and differing goals. Further complicating this is the fact that each of these is implemented in different counties where each county has to establish its own processes of coordination. The county interviews indicated a need for improved communication technologies but a recognition that the weakest link is the dialysis patient who may not even have a cell phone.

Future research is needed to identify low cost digital technologies that can reduce the lost communication in this agency model where dialysis clinics, patients, and paratransit systems must work closely together. Of particular interest is to identify technology that will work in remote, rural areas of the state that can be an extension of the paratransit system in serving the dialysis patients. A comparative prototype study of a system using traditional communication

technologies to one that can be digitally based would help to identify the usability of such technology for the ADA patients who are in most cases not digitally savvy as most are part of the Baby Boomer age group.

Further research is needed on the unique demands of establishing a paratransit model across county governments in North Carolina that vary from urban to rural. Neither funding nor infrastructure permits a statewide solution for providing dialysis transport for needy patients to and from their homes to dialysis centers. This life-saving treatment must be received two times a week for three to four hours per session per patient. Funding for this transportation is a combination of federal, state, and some local United Way funding and as the agency model shows, this necessitates the need for close coordination to prevent informaton loss and assymetry and to overcome conflicting goals to satisfy the transportation needs of the dialysis patients often living at the poverty level.

Investment in digital scheduling and notification systems for paratransit is limited at best. Needed are digital, wearable technologies for these patients to enable communication with the paratransit agencies. Patients need to know the time of their pickup, and they need to know if the paratransit vehicle is running late both for pickup from the home and pickup at the dialysis center. Many of these patients are not technology savvy, and many may be elderly with limited vision. Needed are devices with a high degree of usability. Funding for these devices for the patients and in the paratransit operations is an issue as well. Dialysis clinics are a key part of this agency model. Currently, the dialysis clinics provide social workers to coordinate with the patients. These social workers could become for the patients the means of receiving training in using the devices. The social workers are strong advocates for their dialysis patients. Given the constraints of lack of funding and lack of user knowledge of handheld devices, presents an interesting but important problem. Resolution of this problem will cut costs from inefficient paratransit systems and help save lives. Further research will identify alternative solutions that may help in this paratransit context.

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An Optimization Model for Multi-Source Fund Allocation at a Food Bank

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Non-profit hunger relief organizations receive both monetary and non-monetary donations from government and private donors. While there is limited control and visibility in terms of the type of in-kind donations received, monetary donations allow for more flexible decision to be made with respect to inventory allocations. However, the manner in which these donations can be used may have restrictions that impact purchase and distribution decisions. This paper presents a multi-period, multi-product deterministic optimization model to determine how limited donor funds can be allocated to food purchases. The model captures the restrictions placed on donor funds that influence inventory management practices. Additionally, the model incorporates constraints on storage space, nutritional value of products and food distribution targets. A computational study is performed to analyze potential purchasing and distribution practices under various conditions. The results have implications on how hunger relief organizations can maximize the diversity of nutritious food distributed to food insecure populations. The results show evidence of a budget-equity relationship in some cases that lead to high amounts of waste.

WHAT DO PROFESSORS NEED TO DO FOR EFFECTIVE RETIREMENT PREPARATION?

A SYMPOSIUM

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ABSTRACT

The symposium will draw upon successful symposia at SEDSI 2016 and 2017 which dealt with various issues involving professors in retirement. This proposed symposium will focus on the issues that professors need to consider at some years out from retirement. The issues to be discussed include financial as well academic and psychological. The symposium will be of importance to mid- and late-career faculty. However, the perspectives of those already retired or at the retirement stage will be valuable. The emphasis of the symposium will be on audience participation and a guided discussion of the various issues and opportunities to be faced in planning for retirement.

THE SYMPOSIUM

A number of members of the SE Decision Sciences Institute (SEDSI) are in mid- or late-career stage, and others are in the retirement stage and others have recently retired. Therefore the topic of the symposium is pertinent to many.

The panel will consist of the four SEDSI members listed above, as well as a financial/retirement planner, possibly from TIAA. Panel members would give brief opening statements of approximately seven minutes, with the emphasis of the session being on participation and idea-sharing by the audience, facilitated by the panelists. “Take away” handouts will be provided which summarize issues to be considered in retirement planning, including a checklist.

Additionally, following the conference, participants may wish to build a community of support among themselves.

The general objectives of the panel would be a sharing of personal questions, concerns, ideas, and plans regarding approaching retirement. Among the issues to be discussed are healthcare, insurance, retirement compensation, social security, whether to take a phased retirement plan, etc., and the importance of *starting early* in planning for such. There are various guides for such steps, such as the *Getting ready to retire* guide published by the Virginia Retirement System [ ].

There are also *academic concerns* such as thinking about what kinds of activities one might want to be engaged in after retirement such as part-time teaching, professional involvement (e.g., continuing involvement in SEDSI), and research and publishing. And preparing oneself *psychologically* for a major change in life such as retirement is important as well *One example* is that many of us have considered SEDSI a very important part of our academic careers in a number of ways. This has been more than strictly professional; the networking and friendship support system is very important as well. Members may wish to be considering meaningful ways to remain involved in SEDSI after retirement.

A somewhat analogous workshop entitled Mid-Career and Senior Consortium is conducted annually at the Management and Organizational Behavior Teaching Conference (MOBTC) [4]. The sessions explore the issues and challenges mid-career and senior faculty face in juggling multiple demands in the midst of a changing educational and academic environment. Sessions are oriented toward a conversation among the facilitators and audience. Among other topics frequently discussed are retirement decisions among the participants. Notable also is an emphasis in building a community of support.

Fishman [2] conducted an in-depth study of 14 emeritus faculty members in 2009. They were engaged in a wide variety of academic and professional pursuits, including work in the areas of teaching, research, and service, as well as consulting.

Remaining active in some meaningful activity in retirement has been found by many to be important to the well-being of retired persons in general. For example, Buford [1] interviewed 100 high-profile persons (not just academics) who were engaged in a wide variety of pursuits in retirements. Many of these individuals related that their friends and colleagues who did not remain active often developed health problems, and even died prematurely!

Another question a faculty member needs to decide is *when* it's time to retire. In a roundtable discussion at a management teaching conference [5] facilitated by recently retired members of the organization the question was asked “How do I know when it’s time to retire?” The response was “You’ll know!” The implication being that a professor may develop an intuitive sense of when it’s time to move on to other pursuits.

In conclusion, given the tight-knit nature of SEDSI, the discussion should be valuable, relevant, and enlightening for the participants. Closer relationships may be formed among members who are facing similar decisions and questions.

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Supply Chain Management, Logistics, POM, & TQM

This paper is a systematic literature review of supply chain management research seeking to understand the use of qualitative techniques to research supply chain collaboration (SCC). This study expands our understanding of how qualitative research has been utilized in SCC and suggests ways that qualitative research can be used to enrich our understanding of this important supply chain phenomena. Management, operations and supply chain literature published between 2007 and 2016 was systematically reviewed for papers that present qualitative studies of SCC. We found that qualitative research, as a single methodology, has been used sparingly to study SCC. Accordingly, this research found only a sparse population of papers that fit the criteria (39). This literature review suggests that qualitative research in SCC is lacking and there are many opportunities to utilize underused qualitative research methods to provide new knowledge and insight in this area. This research fills a gap in the literature because, to date, there are no literature review papers that explore qualitative research in SCC. This paper provides researchers with support for qualitative research in SCC and data to support ideas for future research using qualitative methodologies.

Bi-Objective Hazardous Materials Routing and Scheduling to Reduce Social and Economic Impacts: A Game Theory Approach

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Abstract

Hazardous materials (hazmats) logistics and distribution is inherently a multi-criteria decision problem with conflicting objectives. Since the safest path can be long and costly, this research develops a new bi-objective multi-period optimization model to find optimal links and routes keeping balance between safe and fast distribution of hazmats between origin(s) and destination(s) through the transport network. The transport network includes multiple origins and destinations along with multiple hazmat classes to better mimic the challenges faced by practitioners. Due to lack of sufficient historical data or unreliability of the past data (due to possible changes in regulations, network structures, developments, etc.), we consider unknown probabilities for hazmat incidents. In addition to consider the bi-objective model, a game theory demon approach is considered in a link-based model. The objective functions of the mathematical model are defined to minimize both the probability of population exposure affected by hazmat transport risks (social objective) and the total transportation time (economic objective) in the distribution network. Since the formulated problem is bi-objective, this paper also proposes a solution method based on an integrated Monte-Carlo simulation and fuzzy goal programming to obtain Pareto-optimal (non-dominated) solutions. A numerical example is provided to illustrate the effectiveness of the developed mathematical model and the solution method in obtaining Pareto-optimal solutions.

Keywords: Transportation; Vehicle Routing; Game Theory; Hazardous Materials, Multi-Objective Optimization; Fuzzy Goal Programming

1. Introduction

With the rapid development of global economy, the demand for hazardous materials is continuously increasing in recent years. Institute of Hazardous Materials Management (IHHM) defines hazardous material (hazmat) as "any item or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors" (IHHM, 2017). Hazardous materials have been classified into nine different classes based on their physical, chemical, and nuclear properties as explosives, gases, flammable liquids (and combustible liquids), flammable solids, oxidizers and organic peroxides, toxic materials and infectious substances, radioactive materials, corrosive materials, and miscellaneous dangerous goods (Keller and Associates, 2001). In most developed countries, a significant amount of hazardous materials shipments are transported by commercial carries through highway and interstate networks of which 90% are long distance travels. Commercial carriers in the United States transport over 3 billion tons of hazardous materials each year. Such hazmat shipments can be highly risky and highly sensitive and if improperly handled, labeled, or packaged could result in the loss of life, property damage, and harm to national security interests (U.S. GAO, 2014). The most common hazardous materials for transportation include cooking gas, fuel oil, and chemicals such as ethyl alcohol, and gasoline. Because of highly flammable, corrosive, explosive, poisonous or radioactive nature of dangerous goods, the carriers of hazmats, when involved in a road accident, may lead to disastrous consequences such as fire, explosion, spillage, and leakage, resulting in a large number of fatalities and injuries besides property loss and environmental pollution (Yang *et al.*, 2010).

Compared to the number of shipments and the amount of hazmat transported through the transport networks, the number of hazmat incidents, fatalities, injuries and economic loss compared to the flow of hazmats is diminutive. In the United States, total number of hazmat fatalities and injuries in air, highway, rail, and water transportation modes were 9 and 177 in 2016. Total number of incidents was 18255 and the resulted cost was over 75 million dollars (BTS, 2017). As such, hazmat incidents are categorized among low-probability-high-consequence events. While the number of hazmat incidents is a small fraction of the total number of shipments, it is obvious that the number of affected people is more than a non-hazmat accident due to nature of hazmats where there is tremendous societal costs as well as environmental impacts. This makes

hazardous materials transportation, routing, and scheduling operations are very important and sensitive logistical decisions.

In order to avoid or reduce the consequences of hazmat incidents in transportation networks, a dispatcher can adopt any of the following two strategies. Routing strategy tries to split the flow of hazmat shipments among several routes between origin-destination (OD) points to avoid severe consequences in the single route in the event of an incident. Alternatively, scheduling attempts to distribute hazmat transportation flows over multiple time periods to avoid them accumulated in a route concurrently. In this research, both of these strategies (i.e., routing-scheduling) are considered simultaneously. The absolute majority of the hazmat routing or routing-scheduling encounters a computational difficulty because the proposed solution techniques are mainly based on exhaustive route enumeration techniques that make it practically ineffective for large-scale practical problems. In order to resolve this issue, (Szeto *et al.*, 2017) suggest a link-based approach which is more effective than traditional route-based algorithms in reducing computational efforts. In this research, we model the problem using the link-based approach but differently.

Hazmat incidents are low probability events. On the other hand, there is always development and expansion of existing roads, which makes the historical data unreliable due to changes in condition of the roads. Besides, usually some new roads are constructed over time and added to the transportation network where there is no sufficient historical data on them. As such, we encounter a transportation network in which incidents probabilities are unknown or uncertain. Therefore, unlike the majority of the traditional literature this research focuses on unknown incidents probabilities.

In order to cope with the routing-scheduling problem with unknown incident probabilities, (Szeto *et al.*, 2017) assume that the dispatcher is risk averse. Therefore, instead of focusing on probability of accidents we consider the worst-case scenario, which converts a probabilistic problem to a deterministic version. This worst-case scenario may be criticized by practitioners because (1) it searches the safest routes and does not consider travel distance; therefore, sometimes a dispatcher may travel a long distance from origin to destination that can be costly, and (2) not all dispatchers are fully risk-averse; how a risk-seeking or risk-neutral company can use such a model. In order to address these issues, this research aims at focusing on (i) unknown probabilities while (ii) providing a decision-making platform for a wider range of companies in terms of their risk attitude. In other words, in addition to risk-averse companies, we also consider risk seeking and

risk neutral companies. We define two objectives for the model: (1) minimization of total number of affected people and (2) minimization of total transport time. If we have a model with just a single objective (i.e., the risk objective function), then we are dealing with a risk-averse decision maker. On the other hand, when we solve the model with the other objective function (distance) then the decision maker is risk seeking. Any linear combination of these two objective functions will give us a Pareto solution, which is neither risk averse, nor risk seeking.

The original single-objective dispatcher problem assumes that the dispatcher is risk-averse. In other word, he seeks strategies based on worst-case scenario. In multi-objective context, it is equivalent that he is looking for solutions far away from the worst possible solution (Nadir solution). We chose fuzzy goal programming to mimic the risk-averse behavior of the dispatcher in finding non-dominated solutions. Other goal programming methods try to minimize the gap between candidate solutions and the best possible solution (ideal solution) whereas fuzzy goal programming tries to maximize the gap between candidate solutions and the worst possible solution.

Using link-based approach and game theoretic concepts, the problem is formulated a mixed-integer linear programming model. If the model was single objective (either with loss or transport time objectives), it could be solved using exact solution techniques such as branch-and-bound on commercial software products for large-scale problems. Since we are dealing with a bi-objective model, the Monte-Carlo simulation is used to solve the model for different randomly generated set of weights. In other words, Monte-Carlo simulation helps us generate random weights for membership functions to find non-dominated solutions (that should be uniformly extended over the objective function space) of the bi-objective model. If we do not use Monte-Carlo model we have to assign user-specified weights to the membership functions and we will not be able to capture the entire Pareto-optimal spectrum.

The remainder of this paper is organized as follows: Literature review is presented in Section 2. The detailed problem description is provided in Section 3 and it is mathematically formulated in Section 4. In Section 5, the solution approach is presented and discussed. Computational results including presentation of a sample case study and practicality of the optimal solutions, and validation of the model and solution algorithm are presented in Section 6. Section 7 concludes the paper by highlighting the contributions and provides direction for future research.

2. Literature Review

An early study of (Batta and Chiu, 1988) addressed the problem of finding an optimal path that minimizes the weighted sum of lengths over which hazardous material shipment is within a threshold distance of population centers. (Gopalan *et al.*, 1990) developed and analyzed an integer programming model to generate an equitable set of routes for hazardous material shipments. The objective was to determine a set of routes to minimize the total risk of travel and spread the risk equitably among the zones of the geographical region covered by the transportation network. (Erkut and Verter, 1998) performed an empirical analysis on the U.S. road network and showed that different risk models usually select different "optimal" paths for a hazmat shipment between a given origin-destination pair. Their study examined that the optimal path for one model could perform very poorly under another model. Other significant early studies in the area of routing and scheduling of hazmat shipments can be found (List *et al.*, 1991), (Klein, 1991), (Jin *et al.*, 1996), and (Nozick *et al.*, 1997).

One of the groundbreaking studies in the area of hazmat logistics was found in (Bell, 2000) in which a two-player non-cooperative game is envisaged between on the one hand the network user seeking a path to minimize the expected trip cost and on the other hand an "evil entity" choosing link performance scenarios to maximize the expected trip cost. The applications of the classis two-player non-cooperative game are also found in (Bell and Cassir, 2002), (Bell, 2003), (Bell, 2004), (Bell, 2006), (Bell, 2007), (Szeto, 2013) and (Szeto *et al.*, 2017). However, all of these studies used single-objective optimization models to formulate the two-player non-cooperative games.

(Huang *et al.*, 2004) considered safety, costs and, security criteria and used GIS to quantify the factors on each link in the network that contribute to the evaluation criteria for a possible route. (Chang *et al.*, 2005) developed a method for finding non-dominated routes for multiple routing objectives in networks in which the routing attributes are uncertain and the probability distributions that describe those attributes vary by time of day.

(Zografos and Androutsopoulos, 2004) and (Androutsopoulos and Zografos, 2010) developed bi-criterion routing and scheduling problem to minimize the total cost and risk as time-dependent attributes. The authors formulated a routing and scheduling model to determine the non-dominated time-dependent paths for servicing a given and fixed sequence of customers (intermediate stops) within specified time windows. They also constructed a special-purpose dynamic programming algorithm to determine the k-shortest time-dependent paths on different numerical examples. In

another study, (Androutsopoulos and Zografos, 2012) expanded their previous work by applying weighted-sum method to decompose the bi-objective vehicle routing and scheduling problem to a series of single-objective instances of the problem where a route-building heuristic algorithm is presented for addressing each of the constituent single-objective problems.

(Akgün *et al.*, 2007) examined the effects of weather systems on hazmat routing by analyzing the effects of a weather system on a vehicle traversing to characterize the time-dependent attributes of a link due to movement of the weather systems. In addition, it was demonstrated that the heuristic algorithms can provide near-optimal solutions for large-scale practical problems. (Carotenuto *et al.*, 2007) dealt with the generation of minimal risk paths for the road transportation of hazardous materials between an origin-destination pair of a given regional area by formulating the problem mathematically and proposing two heuristic algorithms. (Erkut and Alp, 2007) considered an integrated routing and scheduling problem in hazardous materials transportation where accident rates, population exposure, and link durations on the network vary with time of day and tried to minimize risk in form of accident probability multiplied by exposure subject to a constraint on the total duration of the trip. The authors also proposed pseudo-polynomial dynamic programming algorithms for different versions of their model and examined the computational effectiveness of the algorithms on a realistic example network.

(Verter and Kara, 2008) provided a path-based formulation for this network design problem by which alternative solutions can be generated by varying the routing options included in the model for each shipment. Each solution corresponds to a certain compromise between the two parties in terms of transport risk and economic viability. (Dadkar *et al.*, 2010) developed a game-theoretic model of the interactions among government agencies, shippers/carriers and terrorists as a framework for the analysis. (Reilly *et al.*, 2012) developed a three-player game of the interactions among a government agency, a carrier, and a terrorist along with an effective solution procedure for the game.

The conditional value-at-risk (CVaR) models are known to be flexible and suitable for hazmat transportation that can be solved efficiently. For instance, (Toumazis and Kwon, 2013) proposed a new method for mitigating risk in routing hazardous materials based on CVaR measure on time-dependent networks. Their research extended the previous studies by considering CVaR for hazmat transportation in the case where accident probabilities and accident consequences are time-dependent. (Kang *et al.*, 2014) extended the Value-at-Risk (VaR) framework to apply the VaR

concept to a more realistic multi-trip multi-hazmat type framework, which determines routes that minimize the global VaR value while satisfying equity constraints.

In the recent study of (Asgari *et al.*, 2017), a model for obnoxious waste location-routing problem considering various types of wastes and several treatment technologies is proposed. They formulated a multi-objective location-routing model with three objective functions minimizing the treatment and disposal facility undesirability, different costs related to the problem, and eventually the risk associated with transportation of untreated materials. The researchers also developed an effective memetic algorithm in which a tabu search algorithm performs the local search tested on a real-life case study. (Hu *et al.*, 2017) considered a time-dependent hazardous materials vehicle routing problem in a two-echelon supply chain system to determine the departure time and the optimal route with a minimum risk value for hazardous materials transportation. The most recent study in the area hazmat logistics is found in (Kumar *et al.*, 2018) in which an integrated fleet mix and routing decision for hazmat transportation is developed to minimize the overall costs for long-haul shipments. The formulated non-linear model with integer variables for the number and type of trucks, and the route choices is solved via a genetic algorithm.

Contribution of the research

After reviewing and analyzing the relevant literature in order to determine the exciting gaps in the body of knowledge, the contribution of this research can be summarized as follows:

1. A new bi-objective network optimization model is formulated to minimize the total expected loss (based on risk of population exposure) and the total transport time for hazmat logistics and distribution problem with multiple hazmat classes and multiple departure times.
2. The worst-case scenario to deal with inherent uncertainties of link failures as unknown probabilities is considered.
3. The expected loss and transport time are treated as multi-period attributes for the problem.
4. A new hybrid algorithm to solve the bi-objective model and obtain the Pareto-optimal solutions based on Monte Carlo simulation and fuzzy goal programming is developed and tested.

3. Problem Description

We consider a network $G = [N, A]$ which consists of a set of nodes N with $|N| = n$ and a set of undirected links A with $|A| = m$. The links correspond to highway segments and the nodes to highway intersections. The network G has multiple origin and destination points identified by the sets O and D. In addition to the nodes and links in the base network, we define different departure times and different hazmat classes for the flow of the hazmat throughout the network links. Based on this network, a space-time expanded network (STEN) (or an expanded network) $G' = [N', A']$ can be constructed to capture T departure time choices of the dispatch problem, where N' and A' are the set of nodes and directed links of the space-time expanded network respectively.

The proposed integrated routing and scheduling problem involves three definitions: loss, expected loss, and total expected loss. Loss (expected loss) is defined as the number (expected number) of people affected in the event of accidents. Expected loss can be defined on the link, route, and network levels. The expected loss on a link (route) is the expected number of people affected in the events of accidents on that link (or route). The sum of the expected loss on all links or routes gives the total expected loss in the network. For each link ij, $loss_{ijt}$ is measured by the population inside a circle of given impact radius, centered at any point on link ij, in the event of an accident from node i to node j at departure time t. The impact radius would depend on the hazardous material under consideration, and can vary from several feet to several miles. This is the most popular measure of hazardous materials transport risk in the literature (Erkut and Verter, 1998) and corresponds to the definition of transport risk for hazardous material proposed by the (U.S. Department of Transportation, 1994).

It is obvious that for Low Probability High Consequence (LPHC) events such as link failures, there is little historical and reliable data available. As such, the decision maker cannot base his estimates to measure the likelihood of an incident. In addition, any historical data that may exist is likely to be out of date, in the sense that probabilities based on them may not reflect the current situation in making decisions. Over the time it would take for sufficient data to accumulate, there may have been significant technological progress with regard to vehicle or infrastructure safety. As a result, a risk-averse dispatcher may prefer to base choices on pessimistic assumptions about link incident probabilities. Link failure is basically rare, so as previously mentioned there is likely to be insufficient data from which to estimate failure probabilities. Hence q_{ijt}, the conditional probability of an incident on link ij during departure time t given that an incident occurs, are

unknown. However, the dispatcher is risk-averse so we assume he plans on the basis of one link failure ($\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T} q_{ijt} = 1$). Multiple link failures are excluded from consideration in this study as they are being too unlikely. However, they can be considered in a case of an extensive natural disaster such as earthquake, flood, or hurricane. We are now interested in determining the worst case scenarios for q_{ijt}, where $ij \in A,\ t \in T$. It is proven in the literature that the risk-averse dispatcher will in general not wish to use one route but rather a mix of routes. Apart from equity of exposure considerations addressed in other work, which are of course important too, exposure of hazmat to the population can be reduced by using a mix of routes. In addition to the total expected loss, the dispatcher is interested to find the shortest paths in the distribution network that can start from any of the origins and end to any of the destinations. So the dispatcher's problem involves in finding the safest links and routes with regard to risk of population exposure and simultaneously determining the shortest paths within the distribution network.

We define the problem as an extension of classic network optimization problems. In this case, each link in the network depending on its type (interstate highway or state roads) and time of day (morning peak hours, off-peak hours, and evening peak hours) is associated with a transport time and unknown probability of a incident (e.g., traffic accidents, inclement weather, etc.). Here the transport time and risk are considered as multi-period parameters so they may vary for the links during different time of day. The outcome of this model would be an interesting decision-making trade-off for the hazmat company's dispatcher when he is planning to choose routes, departure times, and intermediate stopping locations for the outgoing hazmat-carrying trucks (containers and tankers). According to the preceding discussion, it is concluded that the following assumptions are necessary to develop the time-space expanded network.

Assumption 1: The network has multiple origins and destinations.

Assumption 2: Unlike previous hazmat research papers that consider shipment distribution between each OD pair (which is similar trip distribution in conventional transportation systems), we consider supply (in origins) and demand (in destinations) are known and deterministic for different hazmat classes at OD pairs. In fact, these data resembles trip attraction and trip generation in classic transportation systems. The total supply and total demand are not necessarily equal for different hazmat classes which may result to the surplus of supply in the supply points because of their capacity.

Assumption 3: The departure time of the dispatcher is deterministic and the departure time choice set is known.

Assumption 4: Travel time is known and deterministic but it depends on the choice of departure time. Therefore, we face a multi-period model in which travel time on a link in each period may change.

Assumption 5: The number of people affected in the event of an incident on each link is known but it also depends on the choice of departure time.

Assumption 6: Probability of using a link at specific departure time is unknown.

Assumption 7: Probability of incident in a link at specific departure time is unknown.

Assumption 8: The dispatcher is both risk-averse with regard to hazmat transport risks and optimal-oriented with regard to travel time when selecting links and departure times.

Assumption 9: Simultaneous hazmat incidents will not happen. The reason is that hazmat incident is a low-probability event. Naturally, multiple link failures can be unlikely (Bell, 2007).

4. Problem Formulation

4.1. List of notations

In this section, we introduce the notation used in the paper and based on the description of the problem and its assumptions. Then, we formulate the problem mathematically.

Sets

N	set of nodes in the network G
A	set of links in the network G
O	set of origin nodes in the network G
D	set of destination nodes in the network G
T	set of departure times
H	set of hazmat classes
K	set of objective functions

Indices

i	Index for node i in the network G, $i = 1, \ldots, N$

j	Index for node j in the network G, $j = 1, \ldots, N$
t	Index for departure times, $t = 1, \ldots, T$
h	Index for hazmat classes, $h = 1, \ldots, H$
k	Index for objective functions, $k = 1, \ldots, K$

Decision variables

x_{ijth}	Flow of hazmat class h from node i to node j at departure time t, $i \in N$, $j \in N$, $h \in H$, $t \in T$
p_{ijt}	Probability of link ij selected for shipment at departure time t, $i \in N$, $j \in N$, $t \in T$
q_{ijt}	Conditional probability of an incident on link ij during departure time t given that an incident occurs, $i \in N$, $j \in N$, $t \in T$

Parameters

$loss_{ijt}$	Loss, or population exposure, is defined as the number of people impacted in the event of an accident from node i to node j at departure time t, $i \in N$, $j \in N$, $t \in T$
$transport_{ijt}$	Transport time from node i to node j at departure time t, $i \in N$, $j \in N$, $t \in T$
$supply_{ih}$	Supply for hazmat class h at origin node i, $i \in O$
$demand_{jh}$	Demand for hazmat class h at destination node j, $j \in D$
μ_k	Membership function of the objective function k, $k \in K$
f_k^{min}	The lowest possible value of the objective function k, $k \in K$
f_k^{max}	The largest possible value of the objective function k, $k \in K$

4.2. Mathematical models

Bi-objective minimax optimization model for risk-averse dispatcher

Based on the network representation, assumptions, and definitions, the bi-objective routing and scheduling problem for hazmat shipment is modeled as a two-person non-cooperative zero-sum game and formulated as a link-based *minimax* problem over the transport network as follows:

$$Min_p \left(Max_q \left(\sum_{i=1}^{N} \sum_{j=1}^{N} \sum_{t=1}^{T} p_{ijt}.q_{ijt}.loss_{ijt} \right) \right) \quad (1)$$

$$Min\ f_2 = \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T}\sum_{h=1}^{H} transport_{ijt}.x_{ijth} \quad (2)$$

Subject to:

$$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T} q_{ijt} = 1 \quad (3)$$

$$\sum_{j=1,j\notin O}^{N}\sum_{t=1}^{T} p_{ijt} = 1 \quad \forall\, i \in O \quad (4)$$

$$\sum_{i=1,i\notin D}^{N}\sum_{t=1}^{T} p_{ijt} = 1 \quad \forall\, j \in D \quad (5)$$

$$\sum_{i=1,i\neq k}^{N}\sum_{t=1}^{T} p_{ikt} - \sum_{j=1,j\neq k}^{N}\sum_{t=1}^{T} p_{kjt} = 0 \quad \forall\, k \notin O, k \notin D \quad (6)$$

$$\sum_{j=1,j\notin O}^{N}\sum_{t=1}^{T} x_{ijth} \leq supply_{ih} \quad \forall\, i \in O, h \in H \quad (7)$$

$$\sum_{i=1,i\notin D}^{N}\sum_{t=1}^{T} x_{ijth} \geq demand_{jh} \quad \forall\, j \in D, h \in H \quad (8)$$

$$\sum_{i=1,i\neq k}^{N}\sum_{t=1}^{T} x_{ikth} - \sum_{j=1,j\neq k}^{N}\sum_{t=1}^{T} x_{kjth} = 0 \quad \forall\, k \notin O, k \notin D, h \in H \quad (9)$$

$$\sum_{h=1}^{H} x_{ijth} \leq M.p_{ijt} \quad \forall\, i \in N, j \in N, t \in T \quad (10)$$

$$0 \leq p_{ijt} \leq 1 \quad \forall\, i \in N, j \in N, t \in T \quad (11)$$

$$0 \leq q_{ijt} \leq 1 \quad \forall\, i \in N, j \in N, t \in T \quad (12)$$

$$x_{ijth} \geq 0 \text{ and integers} \quad \forall\, i \in N, j \in N, t \in T, h \in H \quad (13)$$

M is a very large number

The above optimization model is a bi-objective model with minimization of transport risk associated with unknown probability incidents and links selection and the minimization of transport time as formulated in equations (1) and (2). Constraint (3) indicates that there is only one link failure ($\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T} q_{ijt} = 1$). The risk-averse dispatcher in general will not wish to use

one route but rather a mix of links so generally ($\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T} p_{ijt} \geq 1$). Constraints (4) and (5) impose the requirement of using a mixed strategy for link selection probabilities at origin and destination points. Constraint (6) makes sure the inbound and outbound probabilities of link selection at intermediate nodes are equal to each other. Constraint (7) restricts the total amount of transported hazmat from each origin point for each hazmat class to be less than the supply amount of hazmat classes available at each origin point. Constraint (8) requires the total amount of delivered hazmat to each destination point for each hazmat class is greater than the demand of hazmat class at the destination points. The group of constraint (9) makes sure that the inbound and outbound flow transported hazmat for intermediate nodes are equal. To make sure that a link is available to transport hazmat at specific departure times whenever the link is included in a mixed strategy (its probability of selection is greater than zero), constraint (10) uses a very large number, *M*, to ensure the equivalent if-then-constraint is met. In the above optimization model, constraints (11) and (12) impose the requirement of probability of link selection, p_{ijt}, and the conditional probability of link failure, q_{ijt}, to be in the range of [0,1]. Because our modeling approach is based on routing and scheduling of trucks (containers and tankers), we restricted the decision variables to be general integer using constraints (13).

Equivalent Bi-objective optimization model for risk-averse dispatcher

Minimax problems in the literature have been found to be difficult to solve as their models are bi-level optimization problems and are in general non-convex and non-linear. Although the proposed problem in this research is bi-level in nature, it has the following useful properties:

1. The proposed problem has a bi-linear objective function with respect to total expected risk.
2. The constraints are linear and can be separated into two groups according to decision variables because link selection, p_{ijt}, and conditional link selection, q_{ijt}, probabilities do not simultaneously appear in the constraints.
3. Each element of a solution vector of the link selection probabilities can take any value between zero and one inclusively, and the sum of all the elements equals to one, because the dispatcher chooses a mixed strategy of his/her own game.

The above bi-objective *minimax* problem can be converted to the following bi-objective mixed-integer optimization model by defining a new free variable *V* to be minimized in the objective function (14). In addition, a new set of constraints (16) is now included in the original set of

constraints to ensure that the free variable V is greater than the maximum possible expected loss of population exposure in each link at specified departure times. For more details of the conversion game theory mixed strategy problems with two-person zero-sum game assumptions to equivalent linear programming models, see Section 15.5 of (Hillier and Lieberman, 2014).

$$Min\ f_1 = V \tag{14}$$

$$Min\ f_2 = \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T}\sum_{h=1}^{H} transport_{ijt}.x_{ijth} \tag{15}$$

Subject to:

$$p_{ijt}.loss_{ijt} - V \leq 0 \quad \forall\, i \in N, j \in N, t \in T \tag{16}$$

$$\sum_{j=1, j\notin O}^{N}\sum_{t=1}^{T} p_{ijt} = 1 \quad \forall\, i \in O \tag{17}$$

$$\sum_{i=1, i\notin D}^{N}\sum_{t=1}^{T} p_{ijt} = 1 \quad \forall\, j \in D \tag{18}$$

$$\sum_{i=1, i\neq k}^{N}\sum_{t=1}^{T} p_{ikt} - \sum_{j=1, j\neq k}^{N}\sum_{t=1}^{T} p_{kjt} = 0 \quad \forall\, k \notin O, k \notin D \tag{19}$$

$$\sum_{j=1, j\notin O}^{N}\sum_{t=1}^{T} x_{ijth} \leq supply_{ih} \quad \forall\, i \in O, h \in H \tag{20}$$

$$\sum_{i=1, i\notin D}^{N}\sum_{t=1}^{T} x_{ijth} \geq demand_{jh} \quad \forall\, j \in D, h \in H \tag{21}$$

$$\sum_{i=1, i\neq k}^{N}\sum_{t=1}^{T} x_{ikth} - \sum_{j=1, j\neq k}^{N}\sum_{t=1}^{T} x_{kjth} = 0 \quad \forall\, k \notin O, k \notin D, h \in H \tag{22}$$

$$\sum_{h=1}^{H} x_{ijth} \leq M.p_{ijt} \quad \forall\, i \in N, j \in N, t \in T \tag{23}$$

$$0 \leq p_{ijt} \leq 1 \quad \forall\, i \in N, j \in N, t \in T \tag{24}$$

$$x_{ijth} \geq 0 \text{ and integer} \quad \forall\, i \in N, j \in N, t \in T, h \in H \tag{25}$$

V is a free unbounded variable
M is a very large number (26)

Complexity of the optimization model can be expressed as a function of problem size affected by the model parameters and network setting. The above proposed model contains $I \times J \times T \times (1+H)+1$ decision variables from which $I \times J \times T \times H$ are general integer and one variable is a free unbounded variable. The model has $3 \times I \times J \times T + I \times (1+H)$ linear constraints and two linear objective functions.

5. Solution Approach

Because the developed model in this research has two objectives, Fuzzy Goal Programming (FGP) is considered as the solution approach. The main difference between regular goal programming method and fuzzy goal programming is that regular goal programming tries to minimize the sum of the deviations from the optimal (i.e., best) solutions with regard to the objective functions. Whereas fuzzy goal programming tries to maximize the sum of the membership functions (i.e., distance) from the nadir (i.e., worst) solutions of the objective functions. This solution method is chosen because of risk averse attitude of the dispatcher as he is making decisions to avoid the worst-case outcomes (nadir solutions).

The major drawback of the standard fuzzy goal programming model is that it can obtain only one non-dominated solution which is highly dependent to the decision maker's choice of the weights of the membership functions. Integrating the standard point-by-point approach with a randomly generated preferences/weights independent from the decision maker can provide the entire Pareto optimal front in a simulation run. To rectify this dependability and in order to obtain the true Pareto-optimal front the following hybrid Monte Carlo simulation model is also developed in which randomly generated and normalized weights for membership functions are used in fuzzy goal programming sub-model during each simulation replication.

6. Numerical Example

6.1. Network and data setting

In order to demonstrate an application of the developed model and the solution method, a transportation network consisting of 15 nodes and 33 transport links was created as illustrated in the Figure 1. It is assumed that the network has two origins (nodes 1 and 2) and two destinations (nodes 14 and 15); these nodes are highlighted in gray. In addition, two different departure times

and three classes of hazardous materials are considered to fully capture the complex aspects of the dispatcher's problem.

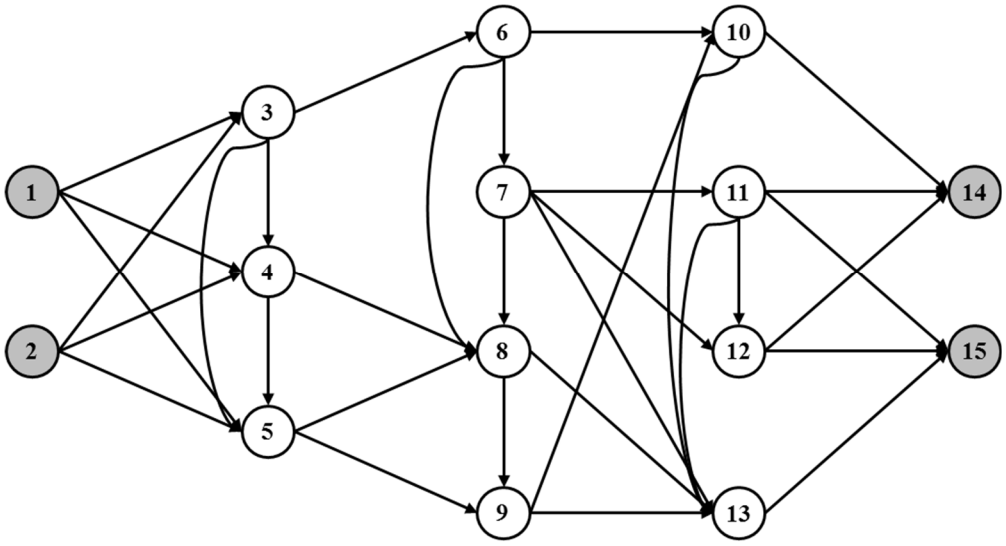

Figure 1. An illustration of the network for the numerical study.

To illustrate the time-varying nature of the population and transport time, we consider two periods with different impacted populations around the roads as shown in Table 1. We assumed that during the first period, the majority of population stay at home generating fewer work-related trips. As such, the estimated transport time for each link is shorter. For the second period, since the majority of populations are at work or taking work-related trips, the impacted population is assumed to be less but on the other side, transport time is longer compared to the first period. We also estimated supply and demand for three classes of hazmat as the number of standard tankers and containers (to make the transport time measureable) at origin and destination nodes respectively as provided in Table 2. Visual Basic.Net programming environment is used to develop the simulation model in which LINGO optimization software (LINGO 17.00, unlimited version) is utilized to solve the fuzzy goal programming sub-model in the algorithm all to be run on a laptop computer equipped with Intel® Core™ i7-6600U CPU @ 2.60 GHz and 16.00 GB RAM.

Table 1. Impacted population and transport time for the network links during two periods of a day.

Link	Impacted Population		Transport Time (hours)	
	$t = 1$	$t = 2$	$t = 1$	$t = 2$
1,3	38479	26185	2.12	2.59
1,4	28713	20248	5.88	7.33
1,5	32046	23483	5.56	8.04
2,3	34407	25633	3.92	4.90
2,4	11489	7132	3.06	4.12
2,5	24967	18992	5.30	6.39
3,4	47883	34026	4.78	6.40
3,5	5876	3607	5.70	7.55
3,6	21045	14239	2.06	2.55
4,5	38774	26533	3.14	4.16
4,8	47681	36962	8.94	11.34
5,8	37536	27116	4.62	5.54
5,9	9977	7304	4.96	6.46
6,7	43759	27796	5.08	6.72
6,8	34716	23201	9.96	12.71
6,10	42358	29850	4.18	5.50
7,8	10004	6596	9.92	13.48
7,11	35874	22027	2.14	3.06
7,12	39939	31947	5.64	7.21
7,13	31132	23455	2.58	3.77
8,9	22019	16690	6.54	9.20
8,13	30142	22721	6.56	8.84
9,10	20964	15264	9.88	13.26
9,13	10845	6570	3.48	5.21
10,13	49483	38948	8.06	10.92
10,14	40228	31458	7.22	10.72
11,12	40144	28554	5.06	6.96
11,13	7023	5247	3.66	4.98
11,14	45362	28918	4.68	5.62
11,15	45126	27315	6.26	7.96
12,14	22925	16054	9.32	12.53
12,15	16628	11483	2.74	3.85
13,15	28652	20420	9.12	11.59

Table 2. Supply and demand for three classes of hazmat.

Node	Supply			Demand		
	$h = 1$	$h = 2$	$h = 3$	$h = 1$	$h = 2$	$h = 3$
1	8	12	5			
2	9	7	3			
14				7	11	4
15				8	5	3

6.2. Computational results

Optimal solutions of the objective functions

Table 3 and Table 4 show the optimal (i.e., ideal) solutions with respect to each objective function independently while ignoring the other objective function subject to the functional and operational constraints (16)-(26). It can be observed that through the optimal solution for objective function (1) the lowest possible value for the total expected loss, number of people affected, is 10033 while the total transport time is 947 hours. In this case, it can be stated that the dispatcher tends to diversify the link selection probabilities as much as possible in order to reduce the negative effect of hazmat spillage due to possible link failures especially during the first departure time. During this period 22 links of the distribution network has non-zero selection probability indicating the possibility of large selection poll. In addition, if a link has zero selection probability during a departure time, it will not be possible to use that link to transport any classes of hazmat (e.g., link (3,4) for $t = 1$). During the second departure time, since less population can be impacted overall, the dispatcher's optimal link selection is less diversified as only 12 links with non-zero selection probability are be considered for selection. However, these candidate links have generally higher chance of being selected compared to the first departure time in which there are more candidate links with lower probability of selection. According to this optimal scenario during the first departure time, 14 candidate links are selected to transport different classes of hazmat while 7 links are used for the shipments during the second departure time.

The modeling approach enables the dispatcher to choose different departure times in the supply nodes as well as in the intermediate nodes. For example, the total supply for hazmat class 1 is 8+9=17 and the total demand is 7+8=15. We observe in intermediate node 3 that the total inbound shipment is 6+7=13 units from which 11 units are shipped to node 6 during the first departure time and 2 units are shipped to node 6 during the second departure time. (Shipping to the same node during two departure times). Intermediate node 6 receives 13 units of shipment from which 6 units are shipped to node 7 during the first departure time and 7 units are shipped to node 10 during the second departure time. (Shipping to different nodes during two departure times).

Table 3. The optimal solution with regard to expected loss ($f_{1,\min}$ = 10033 and f_2 = 947 hours)

Link	Link Selection Probability		Transported Hazmat					
	$t = 1$	$t = 2$	$t = 1$			$t = 2$		
			$h = 1$	$h = 2$	$h = 3$	$h = 1$	$h = 2$	$h = 3$
1,3	0.261	0.383	6	0	5	0	0	0
1,4	0.043	0.000	2	0	0	0	0	0
1,5	0.313	0.000	0	11	0	0	0	0
2,3	0.292	0.058	7	0	2	0	0	0
2,4	0.167	0.000	0	5	0	0	0	0
2,5	0.402	0.081	0	0	0	0	0	0
3,4	0.000	0.000	0	0	0	0	0	0
3,5	0.000	0.000	0	0	0	0	0	0
3,6	0.300	0.694	11	0	7	2	0	0
4,5	0.000	0.000	0	0	0	0	0	0
4,8	0.210	0.000	2	5	0	0	0	0
5,8	0.267	0.000	0	0	0	0	0	0
5,9	0.529	0.000	0	11	0	0	0	0
6,7	0.229	0.361	6	0	3	0	0	0
6,8	0.000	0.000	0	0	0	0	0	0
6,10	0.237	0.167	0	0	1	7	0	3
7,8	0.000	0.000	0	0	0	0	0	0
7,11	0.000	0.380	0	0	0	6	0	3
7,12	0.211	0.000	0	0	0	0	0	0
7,13	0.000	0.000	0	0	0	0	0	0
8,9	0.112	0.000	0	0	0	0	0	0
8,13	0.333	0.033	0	5	0	2	0	0
9,10	0.239	0.183	0	0	0	0	11	0
9,13	0.218	0.000	0	0	0	0	0	0
10,13	0.000	0.258	0	0	0	0	0	0
10,14	0.249	0.319	0	11	3	7	0	1
11,12	0.000	0.000	0	0	0	0	0	0
11,13	0.000	0.000	0	0	0	0	0	0
11,14	0.221	0.000	0	0	0	0	0	0
11,15	0.159	0.000	6	0	3	0	0	0
12,14	0.211	0.000	0	0	0	0	0	0
12,15	0.000	0.000	0	0	0	0	0	0
13,15	0.350	0.491	0	5	0	2	0	0

The optimal solution with respect to the total transport time results to minimum 648 hours of transport but it affects as twice as the population, 20154 as shown in Table 4. In this optimal scenario, the transport time can be mostly improved only by 32% while the total expected loss is more than doubled. The link selection probabilities in this situation reveals a different pattern as the optimal solution enforces the dispatcher against diversification. During the first departure time,

only 14 candidate links have non-zero selection probabilities making the selection pool more restricted while for the second departure time the dispatcher is even more confined with only 8 available links with non-zero selection probability. This pattern of optimal solution indicates that if the dispatcher goal is to minimize the total transport time only, the optimal solution narrows down the dispatcher's choice to few candidate links from the distribution network but these links will have much higher likelihood for selection resulting to a significant increase of impacted population. Note that this optimal scenario uses only 8 links during the first departure time and no links during the second departure time to transport all the hazmat classes through the distribution network to meet the demand specified at nodes 14 and 15.

Table 4. The optimal solution with regard to total transport time (f_1 = 20154 and $f_{2,\min}$ = 648 hours)

Link	Link Selection Probability		Transported Hazmat					
	$t = 1$	$t = 2$	$t = 1$			$t = 2$		
			$h = 1$	$h = 2$	$h = 3$	$h = 1$	$h = 2$	$h = 3$
1,3	0.520	0.166	8	12	5	0	0	0
1,4	0.000	0.000	0	0	0	0	0	0
1,5	0.000	0.315	0	0	0	0	0	0
2,3	0.581	0.000	7	4	2	0	0	0
2,4	0.000	0.419	0	0	0	0	0	0
2,5	0.000	0.000	0	0	0	0	0	0
3,4	0.000	0.000	0	0	0	0	0	0
3,5	0.000	0.000	0	0	0	0	0	0
3,6	0.633	0.633	15	16	7	0	0	0
4,5	0.000	0.000	0	0	0	0	0	0
4,8	0.419	0.000	0	0	0	0	0	0
5,8	0.245	0.000	0	0	0	0	0	0
5,9	0.000	0.070	0	0	0	0	0	0
6,7	0.457	0.443	8	5	3	0	0	0
6,8	0.000	0.000	0	0	0	0	0	0
6,10	0.367	0.000	7	11	4	0	0	0
7,8	0.000	0.000	0	0	0	0	0	0
7,11	0.399	0.000	0	0	0	0	0	0
7,12	0.501	0.000	8	5	3	0	0	0
7,13	0.000	0.000	0	0	0	0	0	0
8,9	0.000	0.000	0	0	0	0	0	0
8,13	0.664	0.000	0	0	0	0	0	0
9,10	0.000	0.000	0	0	0	0	0	0
9,13	0.070	0.000	0	0	0	0	0	0
10,13	0.000	0.000	0	0	0	0	0	0
10,14	0.367	0.000	7	11	4	0	0	0
11,12	0.399	0.000	0	0	0	0	0	0

Link	Link Selection Probability		Transported Hazmat					
	$t = 1$	$t = 2$	$t = 1$			$t = 2$		
			$h = 1$	$h = 2$	$h = 3$	$h = 1$	$h = 2$	$h = 3$
11,13	0.000	0.000	0	0	0	0	0	0
11,14	0.000	0.000	0	0	0	0	0	0
11,15	0.000	0.000	0	0	0	0	0	0
12,14	0.000	0.633	0	0	0	0	0	0
12,15	0.267	0.000	8	5	3	0	0	0
13,15	0.000	0.733	0	0	0	0	0	0

Practicality of the trade-offs among the objective functions

Figure 2 illustrates the Pareto-optimal (non-dominated) solutions obtained by the hybrid Monte Carlo simulation and fuzzy goal programming. As can be seen, Pareto frontier is convex in the objective functions space. It means a risk-averse decision maker who considers a single objective of risk sacrifices travel time significantly less than a risk-seeking decision maker who considers a single objective of economic objective. It is observed that the algorithm performs well in finding the Pareto-optimal solutions close enough to the ideal solutions and far enough from nadir solutions make them more likely to be close enough to the true Pareto front (task 1). The ideal solutions are depicted at the two corners of the trade-off curve as ($f_{1,\min} = 10033$ and $f_2 = 947$ hours) and ($f_1 = 20154$ and $f_{2,\min} = 648$ hours). The algorithm is also capable in capturing Pareto-optimal solutions at the extreme ends of the objective functions space (task 3). On the other hand and with respect to the second task of solving multi-objective optimization, it can be verified that the algorithm is able to find almost uniformly distributed Pareto-optimal solutions over of the Pareto region. Another conclusion is that the Pareto-optimal solutions are more clustered within the range of 11000-13000 for population loss and 660-730 hours of transport time giving more choices of optimal dispatching strategies to the decision maker.

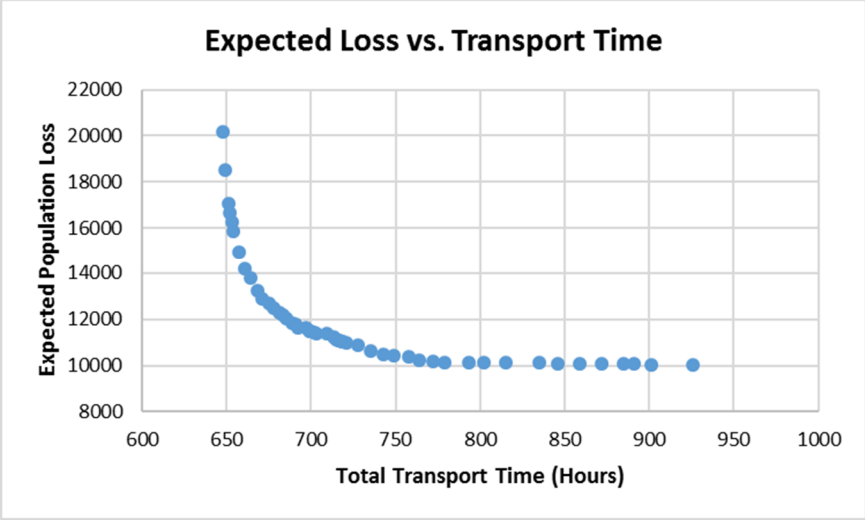

Figure 2. Pareto-optimal solutions depicting the trade-off between total expected loss and transport time.

7. Conclusions and Future Research

This paper studies an integrated routing and scheduling hazmat transportation problem with multiple supply and demand locations and unknown link incident probabilities. A new multi-objective network optimization model is formulated to minimize the total expected loss (based on risk of population exposure) and the total transport time for hazmat logistics and distribution problem with multiple hazmat classes and multiple departure times. Since the formulated problem has multiple objectives, a new hybrid algorithm to solve the bi-objective model and obtain the Pareto-optimal solutions based on Monte Carlo simulation and fuzzy goal programming is also developed and tested. In order to illustrate the effectiveness of the developed mathematical model and the solution method in obtaining Pareto-optimal solutions, a realistic numerical example consisting multiple supply and demand points, three hazmat classes with two departure times is provided. The most interesting insight for practitioners extracted from the model and its solution technique is that the Pareto frontier is convex in the objective functions space. It means a risk-averse decision maker who considers a single objective of risk sacrifices travel time significantly less than a risk-seeking decision maker who considers a single objective of economic objective. Therefore, we recommend even risk neutral decision makers consider the higher weight for risk. This way, while they well observe societal impacts of hazmat incidents, they ensure adverse economic impacts are not drastically increased.

Similar to all research activities, there are limitations and assumptions in this research that can lead an interested reader toward future research directions. First, the transport network in the problem is formed by unidirectional (one-way) links but in reality, the transport networks are formed by a combination of both one-way and two-way links. Of course, it is very likely that the optimal solutions will be eventually based on one-way links but the input can also be in a two-way format. Although probabilistic concepts are employed in this research, the main parameters of the developed model are deterministic. The second area for future research is to capture uncertainty to the input parameters of the model mainly for population exposure that is defined as the number of people impacted in the event of an accident and the transport time through the links of the distribution network. Capturing the uncertainty with regard to the above parameters makes the problem more interesting but more complicated to model and solve. It is expected that the use of robust optimization techniques such as fuzzy set theory and algorithms or stochastic programming will be of necessity in such future research.

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AN EFFICIENCY-DRIVEN APPROACH TO FACILITY LOCATION-ALLOCATION DECISION UNDER THE RISK OF DISRUPTIONS

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ABSTRACT

Contrary to the traditional models for the strategic facility location-allocation (FLA) design focusing primarily on cost-efficiency, we introduce an efficiency-driven approach to FLA decision under the risk of disruptions. We consider bi-objectives of minimizing the total relevant costs and of maximizing the total amount of covered demand. Using a multi-objective programming model and a concept of production efficiency, we propose an innovative procedure of finding the most efficient FLA decision. We conduct a case study to evaluate the proposed procedure and demonstrate that our proposed procedure performs very well and can help the practitioners and decision-makers to evaluate FLA decisions fairly.

Keywords: Facility Location-Allocation, Risk of disruptions, Total Relevant Costs, Total Amount of Covered Demand, Multi-Objective Programming Model

INTRODUCTION

Due to the frequent and unexpected natural and man-made disruptions over the last decades, facility location-allocation (FLA) decisions under disruption risks have received increasing attention and have become one of the main issues in the area of logistics and supply management. A significant stream of research on supply chain network structure related to disruption management focuses on FLA decisions (Hopp, Iravani, and Liu [9]). As a result, the need for a resilient and agile supply chain network has been underscored.

Facility location-allocation (FLA) decisions inherently consist of two kinds of decision plans. One is a strategic decision plan on the facility location, while the other one is an operational decision plan on the allocation of the facility to the customers. The traditional models for the strategic FLA design focused primarily on cost-efficiency, assuming that the facilities are supposed to work and ignoring the fact that the facilities are under the risk of disruptions. Thus, these traditional FLA models consider an objective of minimizing the total logistics cost (TLC), such as the fixed cost of opening/using the facility plus the transportation or shipping cost. Some authors (Askin, Baffo, and Xia [1] and Manatkar, Kathick, Kumar and Tiwari [13]) consider also maintaining desired service level in addition to reducing the TLC. Contrary to the most single-period FLA problem, Manzini and Gebennini [14] and Mantkar et al. [13] apply mixed integer programming optimization models to design and manage multi-period, multi-stage, and multi-commodity FLA problem. As many references in Current et al. [2], Daskin [3,4], Farahani et al. [6,7], and Fang and Li [5] indicate, many researchers have worked on multi-objective/criteria facility location-allocation (MOFLA) problems whose objectives sometimes conflict with each other in nature (See Lee et al. [12]).

However, many of those references ignored the disruption risks, which implies that facilities are always available (see Peng et al. [15]). Some examples of supply chain disruptions have been very well known, such as the 1999 earthquake in Taiwan, the 1999 Hurricane Floyd, and the 9/11 terrorist attack. Especially combining the effects of both 2005 Hurricanes Katrina and Rita, 1.3 million barrels/day of refining was shut down. Garcia-Herreros et al. [8] cite that a fire accident caused by a random lightning bolt at the Philips microchip plant in Albuquerque, New Mexico, is one of the emblematic cases of supply chain network resilience. When the fire cut off the supply of a key component for cell phone manufacturers Nokia and Ericsson, Nokia's production lines were able to adapt quickly by using alternative suppliers, whereas Ericsson lost in revenue of $400 million (See Latour [11]).

When the facilities are under the risk of disruptions, the expected amount of covered/satisfied demand (EACD) would be one of the most important performance measures. Thus, contrary to the conventional total cost minimization approaches, we will formulate FLA problem as the multi-objective programming (MOP) model with the objective of simultaneously maximizing EACD and minimizing the total relevant cost (TRC). The production efficiency (PE) is generally defined to be the ratio of output to input. In this paper, we will define PE to be the ratio of EACD, which can be considered as an output, to TRC, as an input. We use the efficiency-driven approach by generating the input, TRC, and the output, EASD, directly through formulating and solving the FLA problem as the MOP model. This approach is contrary to the approach of Klimberg and Ratick [10] and Fang and Li [5], assuming all inputs and outputs are already known and fixed. Using a multi-objective programming model and a concept of PE, we propose an innovative procedure of finding efficient FLA decision regarding PE. Conducting a case study using the actual data of disruptions in South Carolina, we evaluate the proposed procedure and demonstrate that our proposed procedure performs very well and can help the practitioners and decision-makers to evaluate FLA decisions fairly.

In the next section, we provide a brief introduce to general FLA models with MOP with the minimax objective approach. Next, we apply our proposed FLA model to a case study to demonstrate the applicability of our approach.

BACKGROUND

Combined FLA model with MOP with minimax objective approach

The following nomenclature is used:

Sets:

M: index set of potential facility sites *(j =1, 2, …, M and m = 1, 2…M*)

Parameters:

b_j: minimum number of sites that facility j can cover

B_j: maximum number of sites that facility j can cover

c_{jm}: cost of shipping one unit of demand per mile from facility j to site/demand point m

CAP_j^{max}: capacity of facility j

d_{jm}: distance between facility j and site m

D_m: demand of site m
f_j: fixed cost for constructing and operating facility j
F^{max}: maximum number of facilities can be buil
h_j: holding cost per item per unit time at facility j
ℓ: unit penalty cost per unsatisfied demand
L_j: replenishment lead time at facility j
S_j: ordering cost for facility j to place an order
σ_m: standard deviation of demand per unit time at site m

Decision Variables:
F_j: binary variable deciding whether a facility is located at site j
y_{jm}: binary variable deciding whether site m is covered by facility j

In above nomenclature, facility *j* denotes the facility located at site j. We assume that a_{jm} and d_{jm} equal to zero if *j* = *m* and that each facility follows an (r, Q) policy to maintain its inventory and carries a safety stock to maintain a desired service level of β.

The total logistics cost, *TLC*, which has been the traditional objective of most FLA models, consists of the fixed cost of locating facilities, the transportation/shipping cost from DFs to the DPs, cycle stock cost, and safe stock cost to maintain the desired service level of β, as shown in (1).

$$TLC = \sum_{j\in M} f_j F_j + \sum_{j\in M}\sum_{m\in M} D_m d_{jm} y_{jm} c_{jm} + \sum_{j\in M} F_j \left[\sqrt{2S_j h_j \sum_{m\in M} D_m y_{jm}} + h_j z_\beta \sqrt{\sum_{m\in M} L_j \sigma_m^2 y_{jm}}\right]. \quad (1)$$

To enhance facility's resilience, it would be important to locate facilities to the locations with the lowest probabilities of disruption if possible, so that the chances of facilities' being disrupted are minimized. We assume that if a facility is disrupted, it is shut down or unavailable, so it can't handle the supplies being delivered to the demand points. Letting p_j denotes the risk probability of facility's being disrupted, which is located at site j, we express the expected amount of covered demands (*EACD*) from distribution facilities as

$$EACD = \sum_{j\in M} F_j\, q_j \sum_{m\in M} \left(y_{jm} D_m\right), \quad (2)$$

where $q_j = 1 - p_j$ and Note that since both F_j and y_{jm} in (2) are decision variable, Equation (2) is no more a linear combination. To linearize it, we define $Z_{jm} = F_j * y_{jm}$ and rewrite (2) as

$$EACD = \sum_{j \in M} q_j \sum_{m \in M} D_m Z_{jm}, \tag{3}$$

where

$$\max\{0, F_j + y_{jm} - 1\} \leq Z_{jm} \leq \frac{F_j + y_{jm}}{2}.$$

Now, the expected amount of uncovered/unsatisfied demands (*EAUD*) is obtained by subtracting *EACD* in (3) from the total demand. That is,

$$EAUD = \sum_{m \in M} D_m - \sum_{j \in M} q_j \sum_{m \in M} D_m Z_{jm}, \tag{4}$$

Then, the total penalty cost for uncovered demand, TPC, is obtained from multiplying a unit penalty cost, ℓ, by $EAUD$, which is expressed as

$$TPC = \ell[\textstyle\sum_{m \in M} D_m - \sum_{j \in M} q_j \sum_{m \in M} D_m Z_{jm}] \tag{5}$$

Now, the total relevant cost, TRC is the sum of the total logistics cost given (1) and the total penalty cost in (5).

$$TRC = (1) + (5). \tag{6}$$

Let the nonnegative deviation variables, δ^+_{TRC} and δ^-_{EACD}, denote the amounts by which each value of TRC and *EACD* deviates from the minimum value of TRC, TRC_{min}, and maximum values of *EACD*, $EACD_{max}$, respectively. Then, the deviation variables are given by

$$\delta^+_{TRC} = TRC \text{ in } (6) - TRC_{min}, \tag{7}$$

$$\delta^-_{EACD} = EACD_{max} - EACD \text{ in } (3). \tag{8}$$

Now, the minimax objective can be expressed as

$$\textit{Minimize the maximum of } \left\{\alpha_1^+ \frac{\delta^+_{TRC}}{TRC_{min}},\ \alpha_2^- \frac{\delta^-_{EACD}}{EACD_{max}}\right\},$$

where α_1^+ and α_2^- are relative importance weights attached to the overachievement and underachievement deviation variables and the sum of all weights equals one for the purpose of analysis. Now, set *Q* equal to the maximum variable, such as

$$Q = Max\left\{\alpha_1^+ \frac{\delta^+_{TRC}}{TRC_{min}},\ \alpha_2^- \frac{\delta^-_{EACD}}{EACD_{max}}\right\}. \tag{9}$$

The formulation for multi-objective FLA model with the minimax objective is given as follows:

$$Minimize \;\; Q = Max \left\{ \alpha_1^+ \frac{\delta_{TRC}^+}{TRC_{min}}, \; \alpha_2^- \frac{\delta_{EACD}^-}{EACD_{max}} \right\}, \tag{10}$$

subject to

$$\alpha_1^+ \frac{\delta_{TRC}^+}{TRC_{min}} \leq Q, \tag{11}$$

$$\alpha_2^- \frac{\delta_{EACD}^-}{EACD_{max}} \leq Q, \tag{12}$$

$$TRC - \delta_{TRC}^+ = TRC_{min}, \tag{13}$$

$$EACD + \delta_{EACD}^- = EACD_{max}, \tag{14}$$

$$\sum_{j \in M} y_{jm} = 1, \qquad \forall m \in M \tag{15}$$

$$\sum_{j \in M} F_j \leq F^{max}, \tag{16}$$

$$y_{jm} \leq F_j, \qquad \forall j \; and \; \forall m \in M \tag{17}$$

$$F_j \cdot b_j \leq \sum_{m \in M} y_{jm} \leq F_j \cdot B_j, \qquad \forall j \in M \tag{18}$$

$$\sum_{m \in M} D_m y_{jm} \leq CAP_j^{max} \cdot F_j, \qquad \forall j \in M \tag{19}$$

Solving the above MOP models with a set of $\boldsymbol{\alpha} = (\alpha_1^+, \alpha_2^-)$, $\alpha_1^+ + \alpha_2^- = 1$, will generate an FLA option and the number of options depends upon the value of each element of $\boldsymbol{\alpha}$. Let E_P^k denote the production efficiency score (PES) for the k^{th} option generated by solving the MOPs, where $k = 1, 2, \ldots, K$. Then, by definition, E_P^k is given by

$$E_P^k = \frac{EACD^k}{TRC^k}. \tag{20}$$

For the maximum efficiency score to be equal to one (1.000), we use normalized efficiency score as follows:

$$E_P^{kN} = \frac{E_P^k}{Max_{\omega \in \{1, \ldots \Omega\}} E_P^\omega}. \tag{21}$$

Another important performance measure is the percentage of covered/satisfied demand to total demand (PCDT). The PCDT for the k^{th} option is given by

$$PCDT^k = \frac{EACD^k}{\sum_{m \in M} D_m}. \quad (22)$$

CASE STUDY AND OBSERVATIONS

To demonstrate the applicability of the mathematical models and the framework presented, we conduct a case study using major disaster declaration records in South Carolina (SC) did. The catastrophic floods striking South Carolina will go down in the history books, not only because of the lives they've taken or the destruction they've wrought, but also because of the sheer amount of rainfall. By the time the last raindrop is counted, the October 2015 storm will go down as one of the most prolific rainfall events in the modern history of the United States. This historic flooding tore through SC when numerous rivers burst their banks, washing away roads, bridges, vehicles, and homes. Hundreds of people required rescue and the state's emergency management department urged everyone in the state not to travel. The Federal Emergency Management Agency (FEMA) opened disaster recovery centers (DRCs) in several SC counties to help SC flood survivors. We use the problem of locating DRCs in SC as our case study. Forty-six (46) counties are clustered based on proximity and populations into twenty counties. Then, one city from each clustered county based on a centroid approach was chosen. We assume that all population within the clustered county exists in that city. The distance between these cities is considered to be the distance between counties. We assume that when a major disaster is declared, the DRC in that county can't function due to the damaged facility and supply items and closed or unsafe roads and highways. Based on the historical record and the assumption, the risk probability for each site (a county or a clustered County) is calculated. For the case study, we hypothetically pre-determine t the input parameters (see Hong [16]).

Using Excel Analytical Risk Solver Platform with 'Gurobi' Solver Engine, we solve the MOP model given in (10) and (19) for various values of $\boldsymbol{\alpha}$, where each weight changes between 0 and 1 with an increment of 0.01. To see the effects of the unit penalty cost, we consider four cases with four different values of it, ℓ = \$0.00, \$5.00, \$10.00, and \$15.00. There are 101 configurations arising out of the combinations of the setting of $\boldsymbol{\alpha}$. After 101 runs, we reduce 101 configurations into thirty-six (36) for Case I of ℓ = \$0.00, twenty (20) for Case II of ℓ = \$5.00, eighteen (18) for Case III of ℓ = \$10.00, and thirteen (13) for Case IV of ℓ = \$15.00, consolidated configurations, based on the values of the performance measures. In Table 1, we report these schemes, along with the set of weights, $\boldsymbol{\alpha} = (\alpha_1^+, \alpha_2^-)$ and the values of several performance values explained in the previous section, *TRC, EACD*, E_P^k, E_P^{kN}, and $PCDT^k$. For example, the scheme #34 in Case I with the highest PES of 0.137 is generated by solving the MOP model with weight values ranging from $\boldsymbol{\alpha}$ = (0.89, 0.11) to $\boldsymbol{\alpha}$ = (0.94, 0.04). This scheme generates \$24,596.25, 3370.30, and 0.750 as the optimal values of TRC^{34}, $EACD^{34}$, and $PCDT^{34}$, respectively.

As shown in Table 1, we observe that the scheme with the minimum TRC, TRC_{min}, is not the most efficient scheme. For each case, the last scheme with $\boldsymbol{\alpha}$ = (1.00, 0.00) generate the TRC_{min}. Similarly, the scheme with the maximum EACD, $EACD_{max}$, is not the most efficient one either.

Note that, for each case, the first scheme for each case with $\boldsymbol{\alpha}$ = (0.00, 1.00) generate $EACD_{max}$, which would generate the highest $PCDT$. As the scheme #34 in Case I turns out to be the most efficient one, #16 in Case II, #15 in Case III, and #2 in Case IV, are the most efficient one for each case. We can observe that PCDT for the most efficient scheme increases, as the unit penalty cost, ℓ, increases. The reason is that as ℓ increases, TRC increases due to the increase in TPC. As TRC increases, the scheme with higher EACD is expected to more efficient.

We depict the location-allocation for DRCs for the most efficient scheme of each case in Figure 1. The only difference between the two schemes of Case I and Case II is the location of DRCs {Charleston} and {Beauford}, where {Charelston} is selected by the scheme #34 of Case I and {Beaufort} by the scheme #16 of Case II. The possible reason is that the risk probability of {Beaufort} is much less than of that of {Charleston}. Consequently, the scheme #16 of Case II generates a higher EACD. Note that all other location-allocation schemes are exactly same. In terms of DRC locations, the two schemes of Case II and Case III are identical. We see that the only difference regarding allocation of DRC comes from who covers the site {Orangeburg}, where a DRC {Lexington} in Case II covers {Orangeburg} while, in Case III, a DRC{Beauford} covers it. Since the risk probability of {Beauford} is less than that of {Lexington}, the scheme #15 of Case III generates a higher EACD. In the scheme #2 in Case IV, we note that DRCs {Rock Hill, Lexington} selected by Case I through III are replaced by {Greenwood, Sumter}. A DRC {Greenwood} has a much lower risk probability and feeds six sites including itself. Since {Florence} has a higher risk probability than {Sumter} and the risk probability of {Bennetsville} is the same as {Sumter}, {Sumter} is selected as a DRC in Case IV.

SUMMARY AND CONCLUSIONS

In this paper, we study a facility location-allocation (FLA) design problem under the risk of disruptions. We consider two major performance metrics: the total relevant cost (TRC) and the expected number of covered/satisfied demand (EACD). The TRC consists of the fixed cost of locating facilities, the transportation cost, cycle stock cost, safe stock cost, and the penalty cost for unsatisfied demand. The efficiency score is defined to be the ratio of EACD to TRC. We develop a multi-objective programming (MOP) model for the FLA problem, taking these two performance metrics into consideration simultaneously.

Using a case study, we observe that the facility with a lower risk probability should be ready to cover a site which is covered by the other facility with a higher risk probability. Another observation is that any site should be ready to perform as a facility, if the primal facility is unavailable or shut down due to disruptions That is how to enhance the flexibility of facility in FLA design problem.

ACKNOWLEDGEMENTS

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Evans-Allen project number SCX-313-03-15.

REFERENCES

References are available upon request from Hong.

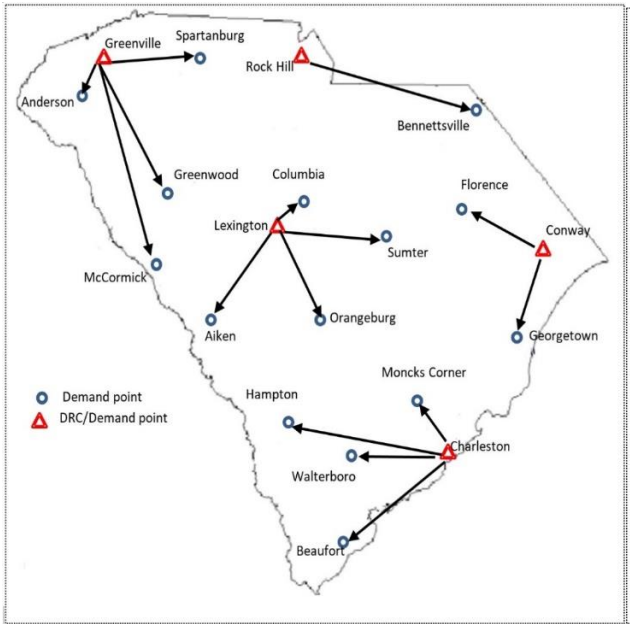
Table 1. Numerical Results

Scheme	α_1^+	α_2^-	TRC^k	$EACD^k$	E_P^k	E_P^{kN}	$PCDT^k$
Case I (ℓ = \$0.00)							
1	0	1	\$35,459.37	3791.87	0.107	0.780	0.843
2	0.01	0.99	\$32,223.49	3791.87	0.118	0.859	0.843
3	0.02	0.98	\$32,182.61	3769.19	0.117	0.855	0.838
4	0.03	0.97	\$31,863.63	3763.14	0.118	0.862	0.837
5	0.04	0.96	\$31,456.37	3747.21	0.119	0.869	0.833
6	0.05	0.95	\$31,215.35	3741.26	0.120	0.875	0.832
7	0.08	0.92	\$31,191.84	3711.07	0.119	0.868	0.825
8	0.09	0.91	\$30,665.58	3704.76	0.121	0.882	0.824
9	0.1	0.9	\$30,419.23	3693.14	0.121	0.886	0.821
10	0.12	0.88	\$30,114.26	3676.62	0.122	0.891	0.818
11	0.14	0.86	\$29,718.99	3667.74	0.123	0.901	0.816
12	0.15	0.85	\$29,419.90	3655.15	0.124	0.907	0.813
13	0.16	0.84	\$29,030.01	3655.15	0.126	0.919	0.813
14	0.2	0.8	\$28,784.25	3633.15	0.126	0.921	0.808
15	0.21	0.79	\$28,703.45	3624.40	0.126	0.922	0.806
16	0.22	0.78	\$28,544.29	3624.40	0.127	0.927	0.806
17	0.23	0.77	\$28,113.40	3620.56	0.129	0.940	0.805
18	0.28	0.72	\$27,615.90	3589.81	0.130	0.949	0.798
19	0.33	0.67	\$26,835.71	3566.17	0.133	0.970	0.793
20	0.4	0.6	\$26,808.56	3559.59	0.133	0.969	0.792
21	0.43	0.57	\$26,338.21	3535.42	0.134	0.980	0.786
22	0.49	0.51	\$26,308.80	3528.84	0.134	0.979	0.785
23	0.53	0.47	\$26,323.31	3479.88	0.132	0.965	0.774
24	0.54	0.46	\$25,760.06	3473.10	0.135	0.984	0.772
25	0.62	0.38	\$25,728.21	3466.52	0.135	0.983	0.771
26	0.63	0.37	\$25,528.60	3461.48	0.136	0.990	0.770
27	0.67	0.33	\$25,496.74	3454.90	0.136	0.989	0.768
28	0.69	0.31	\$25,397.66	3438.48	0.135	0.988	0.765
29	0.7	0.3	\$25,365.81	3431.90	0.135	0.987	0.763
30	0.73	0.27	\$25,176.79	3389.67	0.135	0.983	0.754
31	0.78	0.22	\$25,125.58	3386.94	0.135	0.984	0.753
32	0.79	0.21	\$24,783.65	3381.92	0.136	0.996	0.752
33	0.88	0.12	\$24,754.25	3375.34	0.136	0.995	0.751
34	0.89	0.11	\$24,596.25	3370.30	0.137	1.000*	0.750
35	0.95	0.05	\$24,566.84	3363.72	0.137	0.999	0.748
36	0.97	0.03	\$24,442.36	3293.23	0.135	0.983	0.732
Case II (ℓ = \$5.00)							
1	0	1	\$38,980.01	3791.87	0.097	0.857	0.843
2	0.01	0.99	\$35,744.13	3791.87	0.106	0.934	0.843
3	0.05	0.95	\$35,527.91	3763.14	0.106	0.933	0.837
4	0.07	0.93	\$35,200.32	3747.21	0.106	0.938	0.833
5	0.08	0.92	\$34,989.06	3741.26	0.107	0.942	0.832
6	0.14	0.86	\$34,621.78	3704.76	0.107	0.943	0.824
7	0.16	0.84	\$34,433.55	3693.14	0.107	0.945	0.821
8	0.19	0.81	\$34,211.15	3676.62	0.107	0.947	0.818

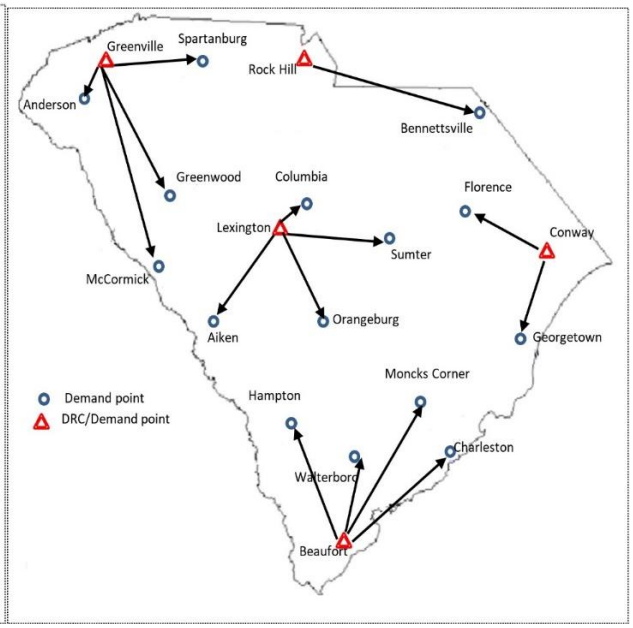
9	0.21	0.79	$33,860.29	3667.74	0.108	0.954	0.816
10	0.24	0.76	$33,786.00	3655.15	0.108	0.953	0.813
11	0.25	0.75	$33,234.24	3655.15	0.110	0.969	0.813
12	0.33	0.67	$32,902.27	3624.40	0.110	0.970	0.806
13	0.36	0.64	$32,490.59	3620.56	0.111	0.982	0.805
14	0.44	0.56	$32,146.84	3589.81	0.112	0.984	0.798
15	0.51	0.49	$31,484.88	3566.17	0.113	0.998	0.793
16	0.63	0.37	$31,141.13	3535.42	0.114	1.000*	0.786
17	0.75	0.25	$30,874.55	3473.10	0.112	0.991	0.772
18	0.8	0.2	$30,701.21	3461.48	0.113	0.993	0.770
19	0.87	0.13	$30,354.05	3381.92	0.111	0.981	0.752
20	0.96	0.04	$30,224.77	3370.30	0.112	0.982	0.750
Case III (ℓ = $10.00)							
1	0	1	$42,500.65	3791.87	0.089	0.904	0.843
2	0.01	0.99	$39,264.77	3791.87	0.097	0.979	0.843
3	0.08	0.92	$39,192.19	3763.14	0.096	0.973	0.837
4	0.12	0.88	$38,944.27	3747.21	0.096	0.975	0.833
5	0.15	0.85	$38,762.77	3741.26	0.097	0.978	0.832
6	0.24	0.76	$38,577.97	3704.76	0.096	0.973	0.824
7	0.27	0.73	$38,447.87	3693.14	0.096	0.973	0.821
8	0.31	0.69	$38,308.04	3676.62	0.096	0.972	0.818
9	0.35	0.65	$38,001.59	3667.74	0.097	0.978	0.816
10	0.4	0.6	$37,828.36	3655.15	0.097	0.979	0.813
11	0.41	0.59	$37,438.47	3655.15	0.098	0.989	0.813
12	0.54	0.46	$37,260.25	3624.40	0.097	0.986	0.806
13	0.58	0.42	$36,867.78	3620.56	0.098	0.995	0.805
14	0.69	0.31	$36,677.78	3589.81	0.098	0.992	0.798
15	0.76	0.24	$36,134.05	3566.17	0.099	1.000*	0.793
16	0.91	0.09	$35,944.05	3535.42	0.098	0.997	0.786
17	0.98	0.02	$35,873.82	3461.48	0.096	0.978	0.770
18	0.99	0.01	$35,853.30	3370.30	0.094	0.952	0.750
Case IV (ℓ = $15.00)							
1	0	1	$46,021.29	3791.87	0.082	0.930	0.843
2	0.01	0.99	$42,785.41	3791.87	0.089	1.000	0.843
3	0.19	0.81	$42,688.22	3747.21	0.088	0.990	0.833
4	0.24	0.76	$42,536.48	3741.26	0.088	0.992	0.832
5	0.43	0.57	$42,404.93	3676.62	0.087	0.978	0.818
6	0.48	0.52	$42,142.89	3667.74	0.087	0.982	0.816
7	0.54	0.46	$42,032.59	3655.15	0.087	0.981	0.813
8	0.55	0.45	$41,642.70	3655.15	0.088	0.990	0.813
9	0.72	0.28	$41,618.23	3624.40	0.087	0.983	0.806
10	0.73	0.27	$41,244.97	3620.56	0.088	0.990	0.805
11	0.86	0.14	$41,208.72	3589.81	0.087	0.983	0.798
12	0.88	0.12	$40,783.22	3566.17	0.087	0.987	0.793
13	1	0	$40,746.97	3535.42	0.087	0.979	0.786

Figure 1: Efficient Facility Location-Allocation Network Schemes

(Scheme #34 in Case I)



(Scheme #16 in Case II)



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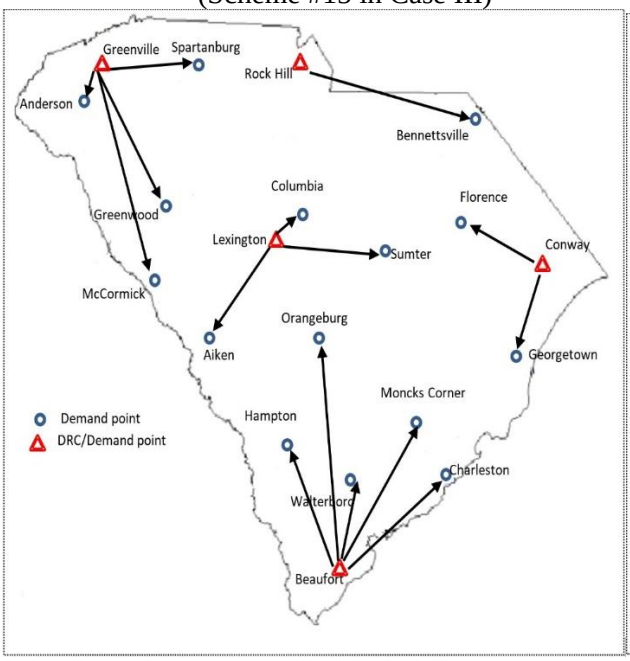

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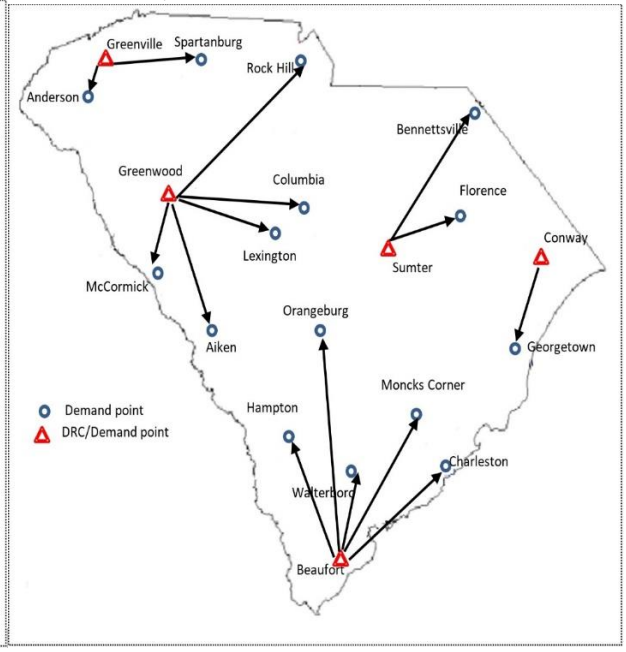

MBA/Masters Student Papers

Abstract

Undergraduate Student Papers

Corporate Social Responsibility Within Fast Fashion Corporations

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Anderson University: SEDSI Research Paper 2017

Introduction

Today the average American throws away 82 pounds of textile waste a year (Morgan, 2015). Today more than 7 percent of landfill mass within the United States comes from wasted textiles (Mercola, 2017). Today only 10 percent of donated clothing is salvageable and sellable at resell shops (Mercola, 2017). Today fashion is the second most polluting industry in the world, behind the oil industry (Morgan, 2015). Today Americans buy 22 billion items of clothing a year with only 2 to 3% being made within United States borders (Mercola, 2017). Today there are 52 fashion micro-seasons a year, with new clothing lines created every week, while 20 years ago fashion experienced four definable seasons (Morgan, 2015). Today Americans buy 500% more clothing than they did in 1980 (Mercola, 2017). Today we live in a world of consumerism. Today the way we consume extends into our personal wardrobes: our dresses, shirts, pants, etc. are to be used up, not used out. Today a purchase is a fad, not an investment. And today fast fashion effects each one of us, knowingly or not, because *today* fashion is a 3 trillion-dollar industry, and a piece of that pie is hanging in your closet at home right now.

Research Purpose

So, today in 2017, what does “fast fashion” mean? How should such a seemingly vast industry be defined? By what criteria? While crafting a working definition of fast fashion, this research paper will explore two major fashion companies in order to compare and contrast the varying corporate social responsibility practices within their supply chains. By analyzing different companies’ corporate social responsibility statements and/or statements on sustainability along with outside literature pertaining to said companies, this research will explore the reliability and truthfulness of said statements. This research will firstly look at, *if* these companies actively strive for a perceived sense of social consciousness and *if so*, whether the perception is tangibly practiced. In later paragraphs, there is also an interview with a current business owner in the fashion industry. He shares his professional opinion on fast fashion and how his corporation fits

into the game. Lastly, the paper will conclude with questions of further research pertaining to reverse supply chain in fashion, the life cycle of garments, and an update on H&M pertaining to recent news in 2018.

The Process of Defining Fast Fashion

"Fast fashion is… clothes that move quickly?" "It's all about those numerous fashion companies now, right?" "It has to do with what we wear and how much stuff we have?" If one Googles the words "fast fashion definition" roughly 14 million results appear in less than 1 second. 14 million results (and growing) that pertain to definitions, articles, research papers, interviews etc., yet when I ask college peers or family members, responses like the above are given. Are they wrong? Is fast fashion not about moving clothes quickly or what we wear or that today we seemingly have more "fashion" brands than ever? Without any previous research, consumers can deduce some sort of definition or meaning about this term: fast fashion. While there appears to be an overwhelming amount of information available, when searching specifically for scholarly sources from 2012 to 2017 with the words "fast fashion definition" less than 25,000 results appear. I chose to mainly focus on relevant articles from the fast 5 years because of the dynamic nature of this industry. Therefore, research conducted 10 years ago may no longer be relevant to current fast fashion businesses and models. So, from these results I skimmed and sorted further by requiring the exact phrase "defining fast fashion" to be within the works, to which I found 5 scholarly sources and from these sources I defined fast fashion for this research paper.

Fast Fashion Definition

The definition of fast fashion this research created and utilize is: fast fashion is a term that describes rapid production and mass consumption of trendy clothing: shirts, pants, accessories, shoes, etc. from design to creation to the final consumer (Moeng, 2012) (Huoviala, 2015). One author defines fast fashion by, "…three elements: quick response, frequent assortment changes

and fashionable design at affordable prices." (Huoviala, 2015). This definition highlights the production element, the designer aspect, and the consumer contribution of fast fashion. Like most efficient supply chains, fast fashion strives for short lead times, responsive product development, and the lowest costs possible. These supply chains are highly reactive and require a stealthy design aspect that focuses upon consumer trends (Huoviala, 2015). Fast fashion magnifies efficient productivity resulting in short lead times, low inventory, and quick response systems (Twine, 2014). Fast fashion is an industry that has created its dominance by studying its consumer and attempting to both predict and produce to the dynamic level of its client (Twine, 2014). A company that qualifies to be fast fashion must model the above definition and literally "churn out" cheap new styles and looks every week. Examples of such companies are Zara, H&M, Urban Outfitters, Forever 21, and more recently companies like JcPenny's and Kohl's have attempted to add aspects of fast fashion to their department stores (Loeb, 2015). This paper takes a closer look at Zara and H&M.

Zara: A Fashion Force

One of the foremost leading brands of the fast fashion model of business is the international mega-company, Zara. Zara was founded in 1975 off the coast of Spain in A Coruña (Inditex, 2017). Zara is one of 8 fashion brands the global powerhouse Inditex owns. Inditex was formed as a woman's clothing store in 1963 in A Coruña, Spain (Inditex, 2017). According to Inditex's website, the fashion retailer owns 7,405 stores globally with 2,236 "Zara stores" and of those, 312 retail locations are based in the United States (Inditex, 2017). Inditex's core belief is that, "the customer is at the center of everything" (Inditex, 2017). A quote from Inditex's website defines Zara's values, "Over the years, Zara has remained faithful to its core values, expressed simply in the same four key words that define all our stores: beauty, clarity, functionality and sustainability" (Inditex, 2017).

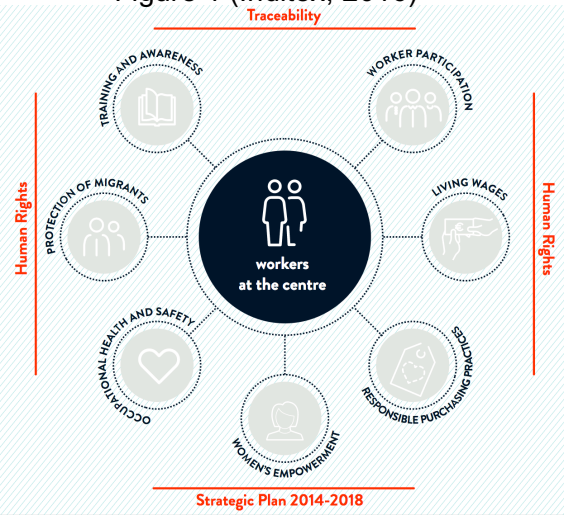
Right there amid their four company key words is "sustainability". Just by the sheer

numbers alone, 2,236 stores, this idea of sustainability would seem like a light in the distance, too far to reach and too dim to shine realistically, but Zara stands confident in their companies' efforts (Inditex, 2016). In fact, Inditex, who sets the standards and policies for all its 8 companies, has a 356-page Annual Report from 2016 pertaining to their year review, their sustainable strategy, and their priorities (Inditex, 2016). "This year, it should be noted that the Annual Report has taken the new Global Reporting Initiative standards as benchmark. These standards were launched on 19 October 2016 and replace the previous GRI-G4 reporting guide. Inditex has not only followed the principles and guidelines of the new standards, but also actively participates in the GRI Standards Pioneers Programme, sharing the process of learning to use the new standards with companies from other sectors," this quote from the report explains how, as of 2016, Inditex is using new methods for reporting and is also actively reporting on their progress with, "the 17 United Nations Sustainable Development Goals (SGDs) for tackling climate, change, poverty and inequality and evidence our commitment to the United Nations Global Compact and its Guiding Principles on Business and Human Rights" (Inditex, 2016, pp. 8-9).

Review of Inditex Annual Report

With a company of this scale and magnitude, it is not surprising that their annual review encompasses well over 300 pages, but it is *still* incredibly overwhelming as an average consumer. Each page is detailed with line after line of wordy ambitions and actions taken by the company to showcase their commitment to ethical fashion, centered towards their rigorous commitment to people, planet, profit, as is custom with CSR. The true heart of their CSR is

Figure 1 (Inditex, 2016)



people. Inditex's companies thrive because of its near 163,000 employees (Inditex, 2016, p. 43). Figure 1 shows a simplified version of their mission for their fashion empire, with "workers at the centre" (Inditex, 2016, p. 63)

While each topic covered in this annual report is certainly noteworthy, this paper mainly focuses on the current actions and theories being taken towards sustainability. Figure 1 highlights how the company promotes sustainable areas like women empowerment, living wages, etc. The report later breaks down these subcategories of "sustainable management of supply chain" into further depth. Things like increasing training and awareness of women and children in their rights across factories in India and Turkey, improving their management systems, requiring A and B level suppliers according to their Code of Conduct, increasing factory inspections and training sessions for partners and internal employees, etc. are just a limited few examples from the 20 plus pages explaining steps and stories from the 7 bubbles in Figure 1 (Inditex, 2016, pp. 67,71,80).

Another section in the report broke down how Inditex is dealing with the 17 SGDs in accordance with the United Nations Global Compact. The first 6 global goals are: no poverty, no hunger, good health, quality education, gender equality, and clean water and sanitation (Inditex, 2016, p. 224). Under every goal is a "priorities section" which says things like "people, improving: welfare and communities, recycling, corporate governance, etc.". After this section is the "highlighted indicator of 2016" which explains a standard or step taken, then lastly there is the "results 2016" that explains numerically how these standards measured up. The 17 goals are broken down into roughly 50 subsections (Inditex, 2016, pp. 224-226).

Zara's Sustainable Impact…#joinlife

Zara reached net sales of 15,394 millions of euros, opened 51 new stores worldwide, and entered 12 new online markets in 2016 (Inditex, 2016, p. 15). Out of all Inditex's 8 brands, Zara has the largest financial and global impact. Zara's most tangible, rather noticeable, sustainability

effort in 2016 was increasing clothing recycling hubs in stores globally and introducing its newest line: “Join Life” (Inditex, 2016, p. 15). The Join Life clothing line can be found in stores and on Zara’s website. What does “Join Life” mean? Well the specific online tab/link simply says, “a selection of the best sustainable raw materials and processes that helps us to take care of the environment” and from this page there are subcategories that lead to Womens, Mens, Kids, and TRF sections (“TRF” stands for Trafaluc, and according to various websites, this word is made-up slang to mean “I have to have this”) (Morris, 2017).

Under the “Kids” section of Join Life, there is a “Baby Girl Sustainable Editorial 2017” that shows short clips and images of a young girl wearing Zara’s organic cotton, which is certified by the Organic Cotton Standard (Zara, 2017). There are various other editorials, well-made videos of models wearing the ethical fashion, marketing this line. When you click on different items of clothes to find further details, short quotes like “Ecologically grown cotton is produced through practices that help us to protect biodiversity, such as crop rotation and the use of natural fertilizers” and “recycled polyester made from recovered post-consumer polyester garments. Recycled polyester uses less water and energy, fewer natural resources and it reduces polyester waste products” appear (Zara, 2017). The line utilizes up-cycled garments and textiles, organic cotton, and fabrics created from recycled plastic bottles and wood (Zara, 2017).

This is Zara’s most public and visible way of addressing sustainability. The Join Life clothing line is one of Zara’s initiatives to show tangible change towards their more ethical and socially responsible practices. This line is meant to be as hip, trendy, and popular as all their lines, just with a conscious twist thrown in. Their supply chain is incredibly vast and effects thousands and thousands of employees and hundreds of thousands of consumers. They have a responsibility *to be* responsible for their whole system, and perhaps this clothing line is the best way to show their conscious social actions to consumers or perhaps there is still more ground to cover, and greater leaps to be taken.

Hennes and Maurtiz (H&M): Leading the Way

Another major power house in the fast fashion industry is H&M. Hennes & Mauritz was founded in Sweden in 1947. Today, 70 years later, they own and operate 5 successful fashion brands which includes both COS and Cheap Monday (H&M, 2016). The H&M Group releases an official, extensive sustainability report every year, just like their competitor Zara. The 2016 report was 123 pages long, lined full of vision and strategy claims for the next few years, standards and policies, future goals, current steps towards equality and sustainability, and information pertaining to their reporting methods (H&M, 2016). Like Zara, the company covers a vast amount of "sustainable goals and practices" in order to account for quality and care in their fast fashion methods. Trendy, cheap, fast, and now perhaps ethical, H&M has begun actively exploring ways to positively increase their public image… enter yearly sustainability reports.

Review of H&M Sustainability Report

At one glance of the extensive report, one might deduce that the intensive work put into informing me, the consumer, about H&M's sustainable practices, insinuates and concludes that their methods are very ethical and very sustainable *therefore* making them one of the most forward moving companies in the industry. And maybe they are. In fact, H&M's newest and most promising slogan for responsibility is: "100% Leading the Change" (H&M, 2016). This claim means that, within the fashion world, they are working to be the most innovative and active leader of positive industry change.

In their "About" section, H&M writes, "Through our brands, we want to inspire fashion fans around the world to dress in their own personal style. We are driven by a desire to always create the best offering for our customers – and to do so in a sustainable way" (H&M, 2017). They want to create the best looks for their customers with the best practices. Figure 2 on the following page illustrates the company's sustainability strategy from the report.

Figure 2 (H&M, 2016, p. 13)

The vision is to be "renewable" and "fair" and "equal". To achieve these ideals, they utilize a change-making program that includes: goals, roadmaps, standards and policies, and methods and follow-ups (H&M, 2016, p. 17). While H&M has been operating for the past 70 years, their first sustainability report was only released in 2009. Before 2016, every issue included their "7 Conscious Commitments". Now after 2016, the future reports are intended to be "future focused", orientating company goals towards tomorrow's steps to be taken (H&M, 2017).

H&M Key Performance Measures and Responsibility Influences

Demands for improvement have been overwhelmingly inspired by poor publicity and the nudges of various company stakeholders (which are customers, communities, colleagues, suppliers, industry peers, investors, and a handful of others) (H&M, 2016, p. 150). These demands have been met with various policy changes coupled with tangible actions. Some of the key performance indicators they use to measure these changes are: % of sustainably sourced material of total material use which increased from 13% to 26% in 3 years with a goal of 100% by 2030, % of cotton from more sustainable sources which increased from 22% to 43% in three years with a goal of 100% by 2020, number of supplier factories using Fair Wage method (% of production volume) which increased from 3 factories to 140 with a goal of a 50% increase with total overall number of factories by 2018, along with various other KPIs (H&M, 2016, p. 123).

Overall, H&M has been moving towards both a perceived and functioning sustainable supply chain over the past decade. These changes have come about slowly, considering the life

span of the company and brand presence, but despite the pace thus far, H&M now wants to be "100% leading the change." While their claims may seem grand, perhaps they must be even grander to achieve true suitability and company-wide social responsibility. Are they doing enough? Does this report show the whole, honest picture and are stakeholders impressed? In the paragraphs to come, this paper will compare H&M's and Zara's impressive claims with third-party research. And under the section, "Do These Efforts Matter" the research will explore if these reports and reviews are effectively communicated to consumers.

What the Other Guys Say

Like previously mentioned, "bad press" often haunts both Zara and H&M. Though, these companies indicate positive steps towards upcoming sustainable development, they still have a long way to go to achieve both authentic ethical fashion and a sustainable image in the eyes of the educated consumer. "Fast fashion is creating an environmental crisis" "H&M's sustainability report hides the unsustainable reality of fast fashion" "The Hidden Cost of Fast Fashion- Worker Safety" are just a few of literally millions of article titles relating to "bad fast fashion". The internet is overflowing with articles, journal entries, and magazine excerpts relating to fast fashion companies' unethical actions and the "harsh realities" of the industry, even with their lengthy company reports and interactive websites.

Rhana Plaza: A Harsh Reality

Perhaps one of the *harshest* of these realities came to light in 2013. From time to time, news of factory workers in developing countries going on strike or random deaths or injuries of these workers manufacturing clothes would headline news, but these stories never seemed to truly shock consumers into demanding change. But, on April 14, 2013, Rana Plaza located in Dhaka, Bangladesh collapsed on more than 3000 garment factory workers (Morgan, The True Cost, 2015). In total, 1129 workers lost their lives and over 2000 were left injured. Bangladesh is the second largest producing textile country in the world, and this market employees

approximately 4 million workers, with most of these workers being female (Morgan, The True Cost, 2015). Over 1000 human beings lost their lives making clothing. One thousand one hundred and twenty-nine people died making cheap shirts, trendy skirts, and inexpensive pants. This is the cost of unethical, unchecked fast fashion.

So how was this possible? Written just a few paragraphs up are Zara's commitment to people, to their employees and H&M's commitment to female empowerment and fair wages. Yet, a factory collapsing on thousands of garments workers does not appear to line up with these "sustainable values". While the current annual reports and sustainability reviews from these companies promise great changes, and show CSR commitment, these values have not actually been incorporated within the industry for very long. Many of these changes came because of the Rhana Plaza catastrophe. Chaos caused change.

Dirtier Truths

Shannon Whitehead, founder of the fashion company Factory45- an online accelerator program for sustainable fashion companies, wrote for Huffington Post that, "The industry giants have dedicated millions of dollars to massive PR campaigns, going so far as to launch "conscious collections" and donate proceeds to worthy causes. Yet despite these efforts, the truth remains — fashion is one of the dirtiest industries in the world" (Whitehead, 2014). Again, this begs the question, are these efforts really making a difference? These companies produce hundreds of pages on stats and models promoting a good image, yet article after article claims that fast fashion is still a threat to an ethical and sustainable society. Whitehead's article, one of many, concluded that some of the dirtier truths are that: the industry is designed to make you feel out of trend within a week, "discounts" are not truly discounts because of crazy high markups, hazardous chemicals are still hiding within mass amounts of clothing, clothing is designed to fall apart, and child labor is often still used for more tedious clothing processes like bead work and sequins (Whitehead, 2014).

These issues are directly related to both the consumers and the creators. Both Zara and H&M promise to use child-free labor and a system of checks and balances with the factories they supply from (H&M, 2016) (Inditex, 2016). Yet, some of these commitments are still in the works and are not changing the realities currently felt in the exploited developing countries. For instance, the key performance indicators that were mentioned with H&M are not 100% "truthful". At the bottom of the page, below the KPI's it says, "This KPI currently shows factories that received the H&M group's workplace dialogue training" (H&M, 2016, p. 125) What does this mean? While the stats may be accurate on the suppliers they have "audited", there are still a substantial number of suppliers that have not received full training thus still using unethical practices. Therefore, the numbers only show a slice or a glimmer of the true sourcing reality.

The True Cost Documentary

The 2015 documentary, "The True Cost" was received with great national publicity by The New York Times, CNN, Huffington Post, the LA Times, and numerous other sources for being "staggering" and "gut-wrenching and alarming" (Morgan, 2015). The film is, "…an unprecedented project that invites us on an eye-opening journey around the world and into the lives of the many people and places behind our clothes" (Morgan, 2015). The hour and half film explores issues varying by global region and industry, from cotton farming in Texas to dress sewing in India. Viewers hear testimonies from people across the fashion spectrum: from farmers to factory workers to factory owners to actual fashion company reps and designers. The documentary powerfully shows fashion's dirtier realities and the effects of unchecked industry practices on people and planet. Many of the opening paragraph's stats came from the documentary, and as a consumer, it begs the question, are these companies doing enough, and if so, then why does the industry still seem so bad, so dirty?

Fast Fashion Successful Supply Chains

Sustainability and issues of CSR are the heart of this research, but it is still important to

note that when it comes to the fast fashion model of business and its effects upon gross profit and economic growth, there is much research that admires and commends these supply chains. These companies can turn over incredible amounts of inventory with just-in-time methods and the ability to convince consumers that they should come back often, weekly, for more (Ḿartınez de Albeinz, 2014). Less holding costs and faster supply chains- from a business perspective, this is exactly what every product based company would hope for. Fast fashion has tapped into the ability to use quick response supply chains to get the most "bang for their buck" (Loeb, 2015). How responsibly they do this, is this research's main concern. However, when it comes to an economic perspective, these supply chains are incredibly admirable and have greatly influenced companies within their industries and beyond to inspire more effective and leaner, though perhaps not always ethical, practices to cut cost and increase revenue (Loeb, 2015).

A Personal Perspective: A Fashion Brand Owner's Opinion

Sustainably is not the antithesis of profit, and as the above paragraph evidences, fast fashion supply chains are incredibly successful. Numerous articles actually argue that rather than these companies defining buyer trends, it is us, consumers that have been driving up the demand and intensity of fast fashion thus creating the success (Moeng, 2012). I interviewed the owner of a jewelry and accessories company, based in Brooklyn, New York to get in an insider's perspective. New York is *the* place for all things trendy and fashionable. Amongst the Burberrys, Guccis, and high end fashion companies of 5th avenue are the trendier, cheaper Zara and H&M (Visit5thAvenue, 2017). This NY jewelry company took around 2 years to plan, design, source, test, and bring to market- its first appearance online was July of 2017. The owner shared his struggles with sourcing, his opinion on fast fashion, how he feels his company fits in with the big brands, and his personal role in educating his customers.

In his perspective, fast fashion is consumption. He called companies like Zara and H&M places where customers "consume and move on". The items purchased there are not timeless

and most likely will be noticeably out of season within a few months, and certainly by the next year. He also spoke on quality, that these companies are far more concerned with mass quantity than genuine quality.

When it came to sourcing for his company, he found many hurdles to jump over. The jewelry company aims to be transparent and ethical, and these ideals took many months and multiple trips overseas to China to effectively work through. While fast fashion giants focus on cheap and trendy and companies like MadeWell and JCrew focus more on fine or higher end fashion, his company is a bridge. The jewels are ethically sourced from factories that use good environmental measures and fair labor practices, but are still not the highest grade of stones. The designs are fashionable and modern, trendy even, thus not expected to have a life span longer than 3 to 5 years but classic enough to last longer than one season. The mid-way price reflects this ideal- not 3 dollars cheap and not 300 dollars high, simply a middle ground for consumers who want to look trendy but expect higher quality.

So, do consumers *really* look for ethical companies? In his experience, yes and no. While corporate social responsibility is very important in his smaller scale business, he does not see that the industry demands such practices, yet. Consumers want “cool” items, but/and if the item is made well, by people that are treated fairly or for a good cause, then it is that much more incentivized. The aspect of doing good is literally a tangible leverage point that can push consumers to buy one item with a good story, priced a few dollars more, over another item inexpensively, mindlessly made. The consumer becomes conscious, and it can affect sales.

Do These Efforts Matter

After reading and skimming hundreds of pages from: sustainability reports, clothing stores’ “our story” sites, journal and research papers pertaining to fast fashion, viewing a fashion focused documentary, and speaking with someone who has skin in the game, I have concluded that consumers, slowly as it may feel, are beginning to watch… to care today about where their

clothes came from and how ethically they were made. Huge companies like H&M and Zara are taking some action to showcase their push towards sustainability and fair fashion. Their efforts effect consumers which effects consumption. The research has shown that some of these efforts are for show, that word verbiage like “sustainability” and “ethical” are defined in many ways and might be becoming as mainstream and trendy as the companies themselves. There are still, today, hundreds upon hundreds of articles condemning the evils behind fast fashion. Yet, today, there are still also hundreds of articles praising the new green efforts being taken and the incredibly efficient supply chain system that fast fashion companies incorporate into their business models. Feelings are split upon the rights and wrongs of the industry and the extent to which it is consumers’ verses corporations’ responsibility.

Then, do these efforts matter? Are these companies using CSR for short-term agendas or long-term changes? Is it all an act? Both Zara and H&M have plans expanding from 2016 all the way to 2030 with milestones built in along the way to track their progress. Both companies write about empowering woman, helping children, increasing commitment to less waste and more things renewable and reusable, and ultimately implementing positive change. The fashion industry has been left unchecked for too many years, and it has taken disasters like Rhana Plaza to wakeup stakeholders, consumers, and companies to see that ethical fashion is fashionable. Changes like the Join Life clothing line and sourcing from suppliers who do not use child labor or who pay their employees fair wages are just a couple positive implementations beginning to catch fire.

Conclusion

Some conscious shoppers are not 100% convinced by these efforts. Director of *the True Cost* documentary, Andrew Morgan, wants consumers to simply start asking questions, not just blindly accept what’s in front of them. In an interview, he said, "I don't want people to think, 'I should feel guilty if I love the things that I wear.' We just need to take a step back from our

incessant consumption of mediocre stuff. Let's go back to a place where we invest in pieces that we love, that we're going to wear and hold on to" (Morgan, Is Your $40 Skirt Hurting the Envrionment?, 2015).

So again, the question, do these efforts matter, in simplest terms *is* yes. How much they matter and why, is a question that consumers must figure out on a very personal level. Seeing the importance of corporate social responsibility within fast fashion can help consumers implement changes in their consumption which ultimately implements changes within the fashion industry which then ultimately leads towards a more sustainable system. So, today in a world of 40 million garment workers with 34 million being female and 97% of them making less than a dollar a day, where each person in the US throws away an average of 70 pounds of non-biodegradable clothing waste a year and purchases close to 500% more clothing than we did two decades ago, even with these stats, today can change… today fashion can be reformed, reshaped (Mercola, 2017). Today we can consume less, think more, and ask bigger questions-meaningful questions. Today ethical fashion can be fashionable and sustainable can be stylish because today's consumers have power over fashion corporations' tomorrows.

Limitations to Research and Opportunities for Further Research

While conducting research, I discovered various limitations to this paper. Firstly, nearly all the sources are secondary or tertiary, with the acceptation of the personal interview therefore my research trusts the sources presented to be accurate. These sources were found solely through online websites, journals, documentaries, and annual reviews/reports. While this did not create trouble while searching for information, it is a limitation to the report. I also faced the limitation of entering a less than familiar topic of study. I personally have never previously conducted research on this topic, and found limited sources relevant to the prompt of this paper.

Some interesting topics for further research relating to corporate social responsibility and ethical supply chains in the fast fashion industry may relate to reverse supply chain and leaner

supply methods. As noted in the research, the fashion industry seemingly pollutes far more than it protects the environment. Some greener companies like Patagonia and Coyuchi already promote recycling their worn out, worn down garments back through their companies while also promoting keeping items longer by offering free repair at retail locations (Patagonia , 2017). Case studies on reverse supply chains, like that utilized in Patagonia, could help "lean-up" the industry and reduce textile waste and garment pollution. Research on current and potential green processes in the fashion industry could also be conducted to see how such practices might increase or positively impact fast fashion sustainability efforts in the future.

Updates on H&M in 2018

On January 7th 2018, a sweatshirt posted on H&M's online shopping site went viral for being insensitive and racist (Press, 2018). Like previously mentioned in the paragraph "What the Other Guys Say", this instance is just one of numerous examples where fast fashion companies have been "called out" for being culturally inconsiderate. Something unique to this instance has been the responses by varying celebrities, such as The Weekend, LeBron James, and Sean Combs (Press, 2018). These celebrities were so outraged by the sweatshirt that they have publicly declared that they no longer wish to work with H&M or wear their clothing. While H&M apologized the following morning and numerous times since, many people are still on the fence about letting the company off the hook. Angry activist groups in South Africa, less than a week after the viral image, stormed various H&M stores, rampaging and forcing the company to close them due to safety issues as a public display of their disapproval (Miller, 2018).

H&M's slogan, "100% leading the change" entails leadership across all the various markets they sell to. While the company noted the offense as an accident, they too noted that it was inexcusable and that they must be intentionally more sensitive to all their customers (Press, 2018). This issue may feel like an overreaction from a snowflake culture, considering catastrophes like Rhana Plaza where garment workers literally lost their lives making cheap

clothing, like the controversial sweatshirt, that we as society are so angry about… an anger towards a garment's message, not the process by which it was made. It is still an important issue to note and watch as fashion continues to evolve. Though it is highly debatable to which one aspect of fast fashion should get more importance over another, this sort of bad press will no doubt spur on new marketing campaigns, contingency plans for PR, and/or letters of reconciliation and apologies from H&M as they try to mend their public image in 2018.

Fully socially responsible fast fashion companies attempt to encompass sustainability and responsibility within all aspects of their supply chains, including sensitive, "hot button topics" within society. 2018 has evidenced, thus far, the importance of a good public image when it comes to social responsibility within these corporations. Yet, fast fashion corporations are just that, corporations- not moral entities. But as this instance shows, amongst the many instances in the past, we the consumer are not happy with these efforts nor with offensive clothing. While the issue of how the clothing was made and by whom may not be today's topic, negative press can be the driving force behind overall corporation developments, developments that can create improvements throughout the whole value chain. Fast fashion can be made more ethical, and consumers *are* asking for changes today.

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The Impact of Social Influences on the Perceived Likelihood of Academic Dishonesty Among Undergraduate Business Students

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Abstract

This study explores the impacts of social influences on the perceived likelihood of undergraduate students participating in academic dishonesty. The influential factors used in this study come from Latané's (1981) social impact theory, or SIT. The theory uses a mathematical equation to explain that the social impact experienced by an individual is a function of the strength of the information sources, immediacy (proximity of the information sources to the target), and number of information sources. This study investigates these factors as they pertain to the instructor in a classroom setting. Specifically, I examine how instructor attributes impact students' propensity to cheat. In the study, the instructor's strength is measured as the reputation of the instructor in the classroom, immediacy is measured as the proximity of the instructor to students, and number is measured as the number of proctors monitoring the instructor's test setting. The objective of the study is to determine whether knowledge of these factors can assist universities in reducing the incidence of academic irregularities on campus.

Introduction

The completion of this study is part of the author's academic curriculum as a student of the Honors College at East Carolina University. All Honors College students must design and implement a Senior Honors Project (SHP) related to their field of study, under the supervision of a faculty mentor. This concentrated scholarly study offers students the opportunity to deliver an original contribution to the department they are affiliated with. The SHP is broken down into two highly structured semesters where the student must coordinate directly with their chosen mentor to fulfill the requirements outlined in the curriculum. The first semester consists of meticulous research and theoretical application in order construct the framework of the project. During this semester, students are tasked with identifying the topic of their project and using literary analysis to determine the significance of the potential results. This requires the students to construct a literary review, develop a hypothesis, pinpoint an appropriate target population, and create an investigative tool for gathering data. By the end of the first semester, the project design is solidified and reviewed to ensure all methods of data collected are ethical. The second semester includes the implementation of the project created during the first semester. The students collect data from the target population using the investigative tool called out in the project design. The information collected is then scrutinized and interpreted to determine the results of the study. Students are required to build a presentation that conveys the results of the study in a clear and concise fashion. Faculty members within the Honors College coordinate with each student's mentor to assess the overall performance of each SHP. The students receive a grade for their project which determines whether or not they qualify for graduation from the Honors College.

Problem Statement and Purpose

Research regarding the antecedents and likelihood of academic dishonesty is of high interest across all levels of education. Numerous studies have been conducted to research the moral character of students as it relates to cheating. Examination of these studies suggest that there may be a large gap between the perceived likelihood of cheating and the actions of students when moral judgement is involved. The vast majority of college students agree that cheating is morally wrong, however, their actions often contradict this belief (McCabe and Trevino, 1996). The majority of research related to cheating focuses on student characteristics and how they impact the likelihood that students will cheat (Sierra and Hyman, 2006). These studies consistently ignore the effect that external (i.e., social, environmental, situational) influences have on student decisions and very little research exists where the impacts of these factors are tested. The purpose of this study is to investigate the gap between perceived likelihood of cheating and actions of students by examining the impact of social influences. The originality of this experiment comes from the investigation of instructor attributes, as opposed to student attributes.

Literature Review

Social Impact Theory

Social impact theory, or SIT, was created by Latané (1981) to explain the impact of social influence on an individual's behavior. The theory explains the effects on individuals that come from the presence and actions of other people, whether those people are real or implied (Latané, 1981). These effects, called the "social impact" by Latané, are described as "changes in physiological states and subjective feelings, motives and emotions, cognitions and beliefs, [and] values and behavior" (Latané 1981, p. 343). The first principle of social impact theory, or SIT, states that the amount of social impact (î) experienced by an individual (the target or recipient) is a multiplicative function of the strength, S, the immediacy, I, and the number, N, of social sources present. It can be stated in mathematical notation as:

$$(1) \qquad \hat{\imath} = f(\mathrm{SIN})$$

Strength refers to "the salience, power, importance, or intensity of a given source" to the receiving individual; immediacy implies "closeness in space or time and absence of intervening barriers or filters"; and, number means "how many other people [sources]" are influencing the receiver (Latané 1981, p. 344).

The social impact described in the theory is comparable to the physical presence of light and sound. Latané uses a light bulb analogy to illustrate the first principle of the social impact theory. "As the amount of light falling on a surface is a multiplicative function of the wattage or intensity of the light bulbs shining on the surface, their closeness to the surface, and the number of bulbs, so the impact experienced by an individual is a multiplicative function of the strength, immediacy, and number of people affecting him or her" (Latané 1981, p. 344). This simple and highly applicable theory has been used in several studies to explore the effect of social influence on individual behavior.

Daunt and Greer (2015) used SIT to investigate inappropriate behaviors among consumers. Most research regarding this topic focuses on consumer traits and dispositions to explain why consumers misbehave (Daunt and Harris, 2012a; Egan and Taylor, 2010; McColl-Kennedy et al., 2011). This research has proven to be valuable, however, it consistently ignores one of the most important explanations of inappropriate behavior: opportunity (Daunt and Greer, 2015). Daunt and Greer propose that "consumers do not typically misbehave because they are inherently 'bad'" (Daunt and Greer, 2015). Instead, consumers choose their behavior based on the opportunity presented to them, combined with environmental stimuli (Daunt and Greer, 2015). Daunt and Greer use SIT to further explore how opportunities can be affected by the strength, immediacy, and number of the real or implied presence of other individuals (Daunt and Greer, 2015).

The study used a random group of college students to test the likelihood of theft, given a specific opportunity. They were instructed to read a short scenario and answer a series of questions quickly and honestly. In the scenario, the students were presented with a hypothetical situation where they had the chance to steal an iPhone. The variables used in Daunt and Greer's study were social strength (i.e., whether or not the surrounding individuals were known to the potential offender) and the social density (i.e., the number of other individuals present) (Daunt and Greer, 2015). Daunt and Greer hypothesized that "the likelihood opportunistic theft is greater when unknown others are present and social density is high" (Daunt and Greer, 2015). In

other words, the potential offender is more likely to behave inappropriately if they are surrounded by strangers in a crowded environment. The results of this study showed that while moral judgement and self-control were related to inappropriate behavior, social strength and social density had a significant effect on the potential offender's decision to commit theft (Daunt and Greer, 2015).

A study conducted in 2005 used SIT to investigate the effects of non-interactive social strength (size of social presence) and social immediacy (how close the subject is to the social presence) on the self-presentation behaviors of consumers (Argo et al., 2005). The self-presentation behaviors witnessed in this study were behaviors that managed the social impression of the subject (Argo et al., 2005). The researchers hypothesized that as the level of social strength increased, the consumers would be more likely to manage self-presentation behavior (Argo et al., 2005). Furthermore, they hypothesized that as the social presence moved further away from the subject, the social strength would no longer matter (Argo et al., 2005). The results of the study supported both hypotheses and the researchers concluded that the mere presence of others had a profound impact on an individual's behavior (Argo et al., 2005).

Although these studies specifically examined consumer behavior, the principle of each study can potentially be applied to other areas of research. Daunt and Greer (2015) used SIT to determine the effect of social influences on the likelihood of participating in an unethical behavior. Argo et al. (2005) used SIT to explore the effects of social influences on self-presentation behaviors. Both of these studies support the claim that social influence can shrink the gap between perceived likelihood of cheating and the actions of students when considering moral development.

Academic Dishonesty

A plethora of literature exists on the propensity of students to cheat with studies yielding different results as to what types of students cheat (i.e., gender, GPA level, major, nationality, etc.), how students cheat (i.e., copying during exam, plagiarism, programming formulas in calculators, using cellphones, etc.), and why they cheat (i.e., internal pressure such as an intrinsic need to stay ahead of peers; external pressures such as need to maintain scholarships or appease others, especially parents; and taking advantage of an opportunity that enables cheating). Differences in results can be attributed to various methodologies used, including how variables

are measured and the different types of samples taken such as differences in majors, class levels, and type of institution, and when the studies were published.

The majority of cheating studies investigate student attributes that may increase the likelihood that they will cheat (Sierra and Hyman, 2006). Relatively few studies investigate situational factors that may impact the propensity to cheat. Situational factors include the likelihood of being a student being reported by a teacher and the severity of the penalty for being caught (Staats et al., 2009), and the student-proctor ratio, arrangement of seating during tests, classroom size, and the existence of institutional honor codes (Houston, 1986a, 1986b; Leming, 1980).

This study seeks to extend prior research on situational factors by examining attributes of instructors. Studying instructor traits, such as whether the presence or absence of an attribute impacts the likelihood of cheating, has practical implications for academia. This study fills a void in the literature by investigating three independent variables that capture instructor attributes, and their interactions, that may influence students' perceptions of academic misconduct.

Method

This experiment used Latané's (1981) social impact theory to determine the impact of social influences on the perceived likelihood of academic dishonesty among undergraduate business students. Specifically, these social influences were applied to the instructor in a hypothetical classroom setting to measure the instructor's impact on the likelihood of cheating. The study used a 3x2 within-subjects design whereby participating students were given each of the three variables explained in SIT (strength, immediacy, and number). Students were given one of two conditions for each variable (a high or low strength variable, a high or low immediacy variable, and a high or low number variable). The sample for the experiment included one hundred and eighty (180) students taking classes in the College of Business at East Carolina University. A Qualtrics survey was distributed to each student where they were asked to read a brief scenario and respond to a series of questions as honestly as possible. Students were not offered any incentive to complete this survey and did so completely on their own volition.

At the start of each survey, the students were prompted to read a statement that explained their rights as participants of the experiment. The purpose of this statement was to ensure that all

information gathered was free of coercion and received in an ethical and voluntary fashion. The statement read:

"Dear Participant,

I am asking you to take part in a research study that I am conducting. The survey you are asked to complete will take 5-10 minutes to complete.

If you agree to take part in this survey, you will be asked questions that relate to your demographic information and the perception of academic dishonesty.

This research is overseen by the ECU Institutional Review Board. Therefore, some of the IRB members or the IRB staff may need to review this research data. However, the information you provide will not be linked to you. Thus, your responses cannot be traced back to you by anyone, including myself.

You do not have to take part in this research, and you can stop at any time. If you decide you are willing to take part in this study, please continue on with the following survey.

Thank you for taking the time to participate in my research.

Sincerely,

Joseph Harrison
MBA Candidate | BSBA Finance"

If the students agreed to continue, they were asked to answer a series of questions regarding their demographic information. For each question, students were able to select their response from a series of preset answer choices. The responses received from these questions were used during the data analysis process to further explore the statistical significance of the results. The questions presented to the students are listed below.

1) *What is your age in years?*
    a. *Students were given a drop down menu that allowed them to choose their response. The answer choices started with "18 or younger", listed all ages from "19" to "59", and ended with "60 or older".*
2) *What is your gender?*
    a. *Students were able to respond using one of the following choices:*

i. *Male*
ii. *Female*

3) *Which answer choice best describes your undergraduate field of study?*
   a. *Students were able to choose one of the following options:*
      i. *Business -- Accounting*
      ii. *Business -- Finance*
      iii. *Business -- Hospitality Management*
      iv. *Business -- International Business*
      v. *Business -- Management*
      vi. *Business -- Management Information Systems*
      vii. *Business -- Marketing*
      viii. *Business -- Operation and Supply Chain Management*
      ix. *Business -- Risk Management*
      x. *Business -- Undecided*
      xi. *Nonbusiness -- Construction Management**
      xii. *Nonbusiness -- Fashion Merchandising**
      xiii. *Nonbusiness -- Health Services Management**
      xiv. *Nonbusiness -- Industrial Distribution**
      xv. *Nonbusiness -- Interior Design**
      xvi. *Nonbusiness -- Sports Studies**
      xvii. *Nonbusiness -- Other**
      xviii. *Nonbusiness --Undecided**

      **Denotes nonbusiness majors that are enrolled in business courses (i.e. students pursuing a business minor)*

4) *What is your current student level classification?*
   a. *Students were able to choose from one of the following options:*
      i. *Freshman*
      ii. *Sophomore*
      iii. *Junior*
      iv. *Senior*

v. *Graduate Student**

**Denotes a graduate student that completed the survey while enrolled in an undergraduate level business course*

5) *What is your self-reported GPA?*
   a. *Students were able to report their GPA on an interactive bar graph that ranged from "0.00" to "4.00". The answers on the graph were limited to two (2) decimal places.*

Control Variable. The scenario presented to the students was included in the parent survey before any survey flow logic was applied. The purpose of this was present the same control variable to each student and to ensure that all variables were tested independently. The scenario given to each student was the following:

"You are a student taking a general education class. You are sitting in an auditorium style classroom with fold up desks at each seat. There are a total of 12 seats in each row and they are split in half by a walking aisle that spans the length of the classroom. There are 12 rows of seats which allows for a total of 144 students at any time. There is a desk at the front of the classroom with a computer and a chair for the professor teaching the class. Exits located at the front and back of the classroom.

The classroom is at maximum occupancy. The professor handed out exams and walked back to the front of the classroom. There is only one version of the exam. The only items allowed on each student's desk are the test, scantron, and a pen/pencil. Due to the style of seating in the classroom, the desks are very close in proximity. This creates an unobstructed view of the contents on the desks located immediately to each student's left and/or right. Assume students in the class are not close acquaintances with others students sitting in the class."

After the students familiarized themselves with the scenario, they were directed to assume the role of the student in the classroom setting provided, but to consider all new information independently as they progressed through the survey.

Dependent Variable. This study measured the perceived likelihood that a student would cheat on an exam, given a hypothetical situation. The dependent variable was the "perceived

likelihood rating" that was provided in each participant's response. The scale was in numerical form and ranged from one (1) to ten (10). Each numerical value coincided with a "level" of perceived likeliness.

Upon completion of the demographically-focused questions, students continued on to the eight (8) independent sets of questions. The survey flow logic was constructed so that each student would randomly receive one (1) of the eight (8) sets of questions. The logic was also configured in such a way that each set of questions was distributed evenly. Each set contained three questions that addressed the three variables in SIT; one (1) question associated with strength, one (1) associated with immediacy, and one (1) associated with number. Within the eight (8) sets of questions, there were a total of four (4) high-level strength questions (S_H), four (4) low-level strength questions (S_L), four (4) high-level immediacy questions (I_H), four (4) low-level immediacy questions (I_L), four (4) high-level number questions (N_H), and four (4) low-level number questions (N_L). The combinations used in the eight (8) sets of questions are listed below. Note that the order of the three variables was dynamic to reduce the potential of order effects.

1. $(S_H)+(I_H)+(N_H)$
2. $(S_H)+(I_L)+(N_H)$
3. $(S_H)+(I_H)+(N_L)$
4. $(S_H)+(I_L)+(N_L)$
5. $(S_L)+(I_H)+(N_H)$
6. $(S_L)+(I_L)+(N_H)$
7. $(S_L)+(I_H)+(N_L)$
8. $(S_L)+(I_L)+(N_L)$

As each variable was presented, the student was prompted to answer a question regarding the perceived likelihood of academic dishonesty. For the purpose of ethical practices, the students were not asked to provide the likelihood that they would have personally participated in academic dishonesty. Instead, they were asked whether or not they perceived that a student, in the hypothetical scenario presented, would have partaken in unethical practices (i.e., cheating on the exam). The question presented to the students was as follows:

"Given this information, what is your perception on the likelihood that a classmate in the scenario provided would participate in some form of academic dishonesty?"

The students were asked to rate their perception on a scale from one (1) to ten (10). A rating of one (1) implied that the participant perceived that it was extremely unlikely that a student in the hypothetical situation would have cheated on the exam. A rating of ten (10) would have implied that the participant perceived that it was extremely likely that a student in the hypothetical situation would have cheated on the exam. An example of the scale used in the survey is shown below.

Etremely Unlikely				***Somewhat Likely***					***Extremely Likely***
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
○	○	○	○	○	○	○	○	○	○

As each student provided their rating and continued to the subsequent screen, they were not permitted to change the answer they provided on the previous question. When the students reached each new question (i.e. each independent variable), the following statement appeared at the top of the screen:

"Please disregard the information provided on the previous page and continue with the information below (assuming just the original classroom setting)."

Directly underneath that statement was the information related to the next independent variable being investigated. The students were once again asked to rate their perception on a scale from one (1) to (10). The following sections discuss the details, variables, and hypotheses for each independent variable in the study.

Strength

Independent Variable. This study used the influence of social strength, as it pertained to the professor, as an independent variable. The level of social strength was, in this case, determined by the perceived reputation of the instructor in the classroom. Social strength was

measured by providing the participants with supplemental information that contained either a high strength independent variable (S_H) or a low strength independent variable (S_L). The students were then asked to consider the supplemental information, in conjunction with the original situation (i.e., the control variable), and rate their perception on the likelihood that a student in the hypothetical situation would have cheated on the exam. Each student that participated in this study received one (1) question related to social strength (i.e., students that received a high strength variable question did not receive a low strength variable question, and vice versa). The high and low strength independent variables used in the survey were as follows:

(S_H): *"It has come to your attention that the instructor of your class has a reputation of sending students to the Academic Integrity Committee (AIC) for participating in academic dishonesty. A friend of yours was in your instructor's class last year and she witnessed the instructor send four students to the AIC during that semester alone. You have never personally witnessed a student cheating while taking exams in this class."*

(S_L): *"It has come to your attention that the instructor of your class has never reported a student to the Academic Integrity Committee (AIC). A friend of yours was in your instructor's class last year and she witnessed students cheating on every test. You have also personally seen students cheating while taking exams in this class."*

SIT proposes that as the strength of a social influence increases, it will have an increasing effect on an individual's behavior. In this case, it was expected that an increase in the perceived strength of the instructor would result in a decrease of the likelihood that a student would participate in academic dishonesty. Similarly, a decrease in the perceived strength of the instructor would result in an increase of the likelihood that a student would cheat on the exam. This information was used to develop the first hypothesis (H1) for this study:

H1: The greater the instructor's strength (i.e., the reputation of strict academic integrity enforcement), the lower the perceived likelihood that students will participate in academic dishonesty.

Immediacy

Independent Variable. This study used the influence of social immediacy, as it pertained to the professor, as an independent variable. The level of social immediacy was, in this case, determined by the perceived physical distance between the students and the professor in the classroom. Social immediacy was measured by providing the participants with supplemental information that contained either a high immediacy independent variable (I_H) or a low immediacy independent variable (I_L). The students were then asked to consider the supplemental information, in conjunction with the original situation (i.e., the control variable), and rate their perception on the likelihood that a student in the hypothetical situation would have cheated on the exam. Each student that participated in this study received one (1) question related to social immediacy (i.e., students that received a high immediacy variable question did not receive a low immediacy variable question, and vice versa). The high and low immediacy independent variables used in the survey were as follows:

(I_H): *"You notice that the instructor started walking down the aisle in the middle of the classroom once the exams have been distributed. The instructor appears to carefully monitor all of the students, on both sides of the aisle, as they complete their exams. Upon reaching either end of the aisle, the instructor turns around and walks down the aisle again."*

(I_L): "*You notice that the instructor stays seated at the front of the classroom once the exams have been distributed. The instructor does not appear to carefully monitor the students because the professor rarely looks up from the computer screen at the desk."*

SIT proposes that as the immediacy of a social influence increases, it will have an increasing effect on an individual's behavior. In this case, it was expected that an increase in the perceived immediacy of the instructor would result in a decrease of the likelihood that a student would participate in academic dishonesty. Comparably, a decrease in the perceived immediacy of the instructor would result in an increase of the likelihood that a student would cheat on the exam. The second hypothesis (H2) for this study was created based on this information:

H2: The greater the instructor's immediacy (i.e., the closer the instructor is in proximity to the students), the lower the perceived likelihood that students will participate in academic dishonesty.

Number

Independent Variable. This study used the influence of social number, as it pertained to the professor, as an independent variable. The level of social number was, in this case, determined by the perceived number of proctors in the classroom. Social number was measured by providing the participants with supplemental information that contained either a high number independent variable (N_H) or a low number independent variable (N_L). The students were then asked to consider the supplemental information, in conjunction with the original situation (i.e., the control variable), and rate their perception on the likelihood that a student in the hypothetical situation would have cheated on the exam. Each student that participated in this study received one (1) question related to social number (i.e., students that received a high number variable question did not receive a low number variable question, and vice versa). The high and low number independent variables used in the survey were as follows:

(N_H): *"As the instructor was handing out the exam, you noticed that three graduate assistants entered the room. After passing out the last exam, the instructor announced that the graduate assistants were there to serve as additional proctors for the duration of the exam. There are now four people proctoring the exam."*

(N_L): *"As the instructor was handing out the exam, you noticed that three graduate assistants entered the room. After passing out the last exam, the instructor approached the graduate assistants. The instructor and the graduate assistants spoke for a brief moment and all three graduate assistants proceeded to leave the room. The instructor is the only proctor for the exam."*

SIT proposes that as the size of a social influence increases, it will have an increasing effect on an individual's behavior. In this case, it was expected that an increase in the perceived

number of exam proctors in the room would result in a decrease of the likelihood that a student would participate in academic dishonesty. Likewise, a decrease in the perceived number of proctors in the room would result in an increase of the likelihood that a student would cheat on the exam. This information was used to construct the third hypothesis (H3) for this study:

H3: The greater the size of the social influence (i.e., the greater the number of proctors in the room), the lower the perceived likelihood that students will participate in academic dishonesty.

Method of Analysis

The perceived likelihood that a student would cheat, the dependent variable, was captured using a 10-point Likert scale with endpoints of Extremely Unlikely and Extremely Likely. The three independent variables (social strength, social immediacy, and social size) were dichotomous variables (i.e., operationalized by having a greater or weaker presence). T-tests that compared the distribution of data under each scenario were used to analyze the initial results. Because the dependent variable was on a ratio scale and the independent variables were nominal, the data was also analyzed using Analysis of Variance (ANOVA). Main effects and interactive effects (although not hypothesized) were examined to determine if the presence of multiple factors had an even greater effect on the perceived likelihood that a student would cheat.

Experimental Results

Hypothesis Testing

As hypothesized, the high level conditions for all three independent variables significantly reduced the perceived likelihood of cheating relative to the low level conditions.

H1. The first hypothesis tested pertained to the impact of social strength on the perceived likelihood that students would have participated in academic dishonesty. The results of this study supported my hypothesis that as the level of social strength increased, the perceived likelihood that students would have cheated decreased. The mean of the high strength condition was 4.29 and the mean of the low strength condition was 6.66. This created a significant difference of 2.37 ($p<.001$).

H2. The second hypothesis tested pertained to the impact of social immediacy on the perceived likelihood that a student would have cheated on the exam. The results supported my hypothesis that as the level of social immediacy increased, the perceived likelihood that students would have cheated decreased. The mean for the high immediacy condition was 3.76 and the mean for the low immediacy condition was 6.78. These means created a highly significant difference of 3.02 ($p<.001$).

H3. The third and final hypothesis tested pertained to the impact of social number on the perceived likelihood that a student would have cheated on the exam. The results supported my hypothesis that as the level of social number increased, the perceived likelihood that students would have cheated decreased. The mean for the high number condition was 3.74 and the mean for the low number condition was 5.19. The difference of these means was also significant at 1.45 ($p<.001$).

In addition, the overall mean of all the high level conditions was 4.25 and the overall mean of all low level conditions was 6.14, which is highly significant ($p<.001$). Of the three independent variables, number had the lowest mean under both conditions (3.74 and 5.19 for the high and low conditions, respectively) as noted in **Table 1** below.

The variable with the largest mean difference between conditions was immediacy, operationalized at the proximity of the proctor. When the proctor was nearby (i.e., walking through the aisle during the exam), the students reported one of the lowest perceptions of cheating, but when the proctor was stationary in the front the class (i.e., more distant proximity to students), the condition had the highest level of potential academic dishonesty. This suggests that the immediacy measure had the largest overall impact on student behavior.

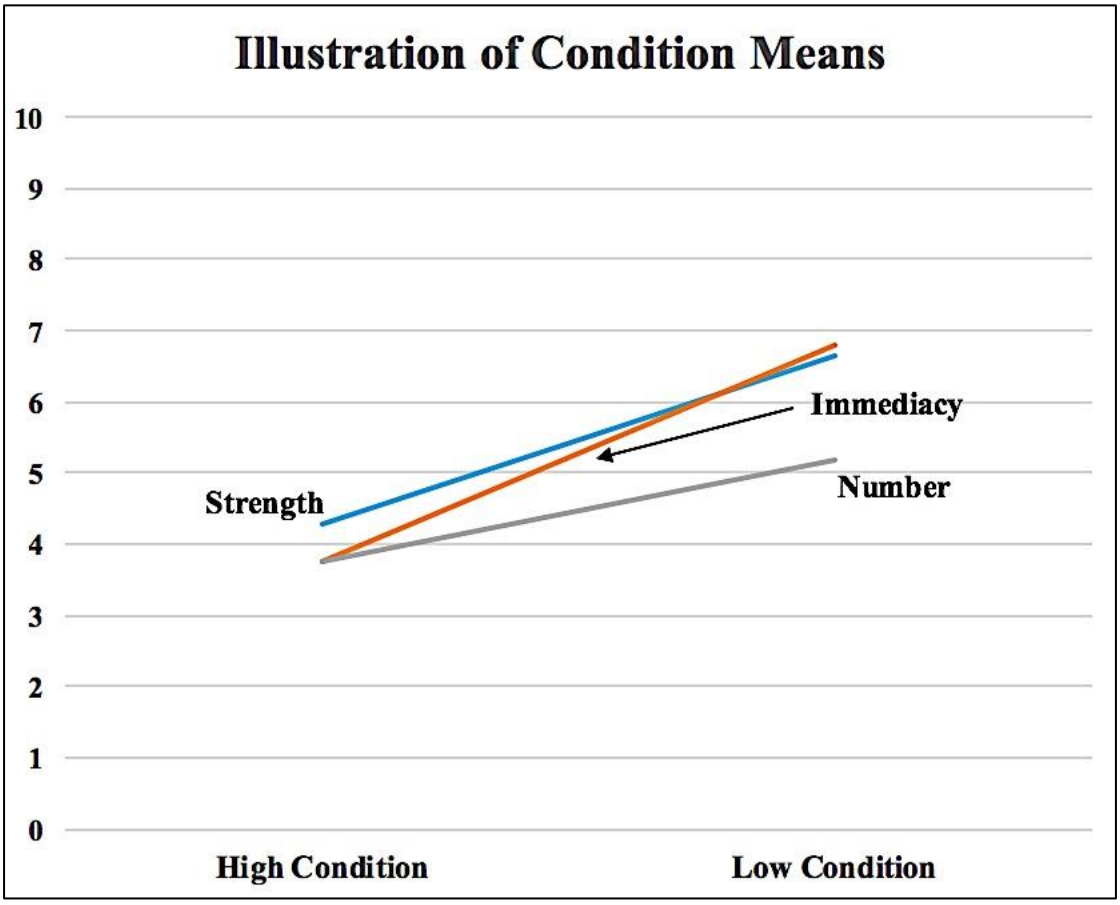
Table 1

T-tests Comparison of Independent Variables
MEANS

Independent Variables	**High Condition**	**Low Condition**	Difference
Strength	4.29	6.66	2.37 ***
Immediacy	3.76	6.78	3.02 ***
Number	3.74	5.19	1.45 ***
Condition Mean	4.25	6.14	1.89 ***

*** $p<.001$

Figure 1



Independent Variable Comparison

The variable condition means were further analyzed by studying the comparison between independent variables. In this test, each high and low condition mean was compared to the high and low condition means of the other two independent variables. The purpose of this test was to determine whether or not there was a significant difference in the effectiveness of one variable compared to the others.

There were no statistically significant differences in the perceived likelihood of cheating between the Strength and Immediacy variables in both the high and low conditions. In the low condition, there were significant differences ($p<.001$) between Number and both Strength and Immediacy. This suggests that the presence of a proctor, even if not overly observant, was a

greater deterrent to cheating than the increased levels of social strength and the increased levels of social immediacy. A summary of this information is found in **Table 2** below.

Table 2

T-tests Comparison Between Independent Variables

BETWEEN CONDITION MEANS

Strength (High)	**Immediacy (High)**	**Difference**
4.29	3.76	0.53^
Strength (High)	**Number (High)**	
4.29	3.74	0.55^
Immediacy (High)	**Number (High)**	
3.76	3.74	0.02^
Strength (Low)	**Immediacy (Low)**	
6.66	6.78	0.12^
Strength (Low)	**Number (Low)**	
6.66	5.19	1.47***
Immediacy (Low)	**Number (Low)**	
6.78	5.19	1.59***

^ not significant; ** p<.01; *** p<.001

Conclusion

The experimental results imply that increased levels of all three instructor-influenced variables (strength, immediacy, and number) had the potential to deter students from partaking in academically dishonest practices. Additionally, the difference between the high condition mean and low condition mean was highly significant for all three independent variables. The results of this study also indicate that instructor-related influences can impact the likelihood of cheating a classroom setting. The purpose of this study was to investigate the gap between the perceived likelihood of cheating and the realized actions of students. It is conceivable that a portion of that gap can be attributed to instructor-influenced variables. These findings are important because the vast majority of research on cheating focuses on student attributes, as opposed to instructor attributes.

Additional Research

In the future, different measures of each independent variable (strength, immediacy, and number) will be developed and tested. This will help discover which instructor attributes are most effective at deterring academic dishonesty. In addition, different combinations of the variables will be tested to determine the best practice for instructors to implement and reduce the likelihood of cheating. Demographic information can also be incorporated in the data analysis process to establish any possible correlations between factors such as age, gender, socioeconomics, race, and ethnic affiliation.

The variable of social number yielded the lowest mean in both the high condition and the low condition. This seems to suggest a "perception of detection," whereby an increased number of proctors present (i.e., the greater the likelihood of being detected) reduces the likelihood of cheating. To further test this, I will repeat the experiment with a varying number of proctors to see if the inverse relationship between the number of proctors and the likelihood of cheating holds.

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THE IMPACT OF WORKPLACE PRACTICES ON PATIENTS SEEKING MENTAL HEALTH TREATMENT: A DECISION TREE APPROACH

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ABSTRACT

Our goal is to mine the Mental Health in Tech Survey data set to gather information related to the impact of workplace conditions on people seeking mental health treatment. The purpose of this data mining project is to determine whether various employer environments and employee background have any impact on whether or not that employee would seek mental health treatment. We have the knowledge necessary to mine this data set through various courses including statistics, database, data mining, discrete math and public speaking. We will follow the cross-industry standard process for data mining (CRISP-DM) to effectively mine the data set. The CRISP-DM has several steps that we will follow to mine and produce results from this data set which include: business understanding, data understanding, data preparation, modeling, evaluation, and deployment. This data set will allow investigation into the mental health issues that are impacting the IT field. It is important for employers to understand the opportunities to help with mental health issues in order to create a more inclusive and productive work environment. Some key findings of this study are that work interference, family history of mental health conditions and benefits offered for mental health treatment have an impact on participants seeking mental health treatment. It was determined that employers should provide mental health benefits and reduce work condition factors that could impact mental health issues.

Keywords: Data mining, decision trees, workplace mental health

1. INTRODUCTION

Mental health is an important issue that can impact employee well-being and productivity. The non-profit corporation Open Souring Mental Illness (OSMI) originally conducted a survey in 2014 on mental health issues in technology companies. The survey is still ongoing as of 2016. OSMI was founded by Ed Finkler who speaks at tech conferences about mental health issues and conducts research about mental health issues in tech workplaces. Participants are asked mental health related questions to determine if a participant did or did not seek mental health treatment based on work related factors. The dataset includes 1260 rows or instances and has 26 columns or attributes. Appendix A contains a complete list of attributes.

The purpose of this data mining project is to determine whether or not various employer environments and employee background have any impact on whether or not that employee would seek mental health treatment. We will follow the cross-industry standard process for data mining (CRISP-DM) to effectively mine the dataset. The CRISP-DM has several steps that we will follow to mine and produce results from this dataset which include: business understanding, data understanding, data preparation, modeling, evaluation, and deployment. This dataset will allow investigation into the mental health issues that are impacting the IT field. It is important for employers to understand the opportunities to help with mental health issues in order to create a more inclusive and productive work environment.

2. BUSINESS AND DATA UNDERSTANDING

We are using Decision Tree and Naïve Bayes to create mining models for the Mental Health in Tech Survey Dataset. We will look at relevant studies of mental health issues in the workplace then we will investigate the use of Decision Trees and Naïve Bayes. We will be using the CRISP-DM process to mine the data and this process will also be discussed in the literature review.

2.1 Literature Review

A review of the literature was conducted to understand current studies related to mental health in the workplace. A study conducted by Deloitte LLP found that, "84% of employees have experienced physical, psychological, or behavioral symptoms of poor mental health where work was a contributing factor" (Hampson and Soneji, p. 6). Also, according to the Deloitte study, "35% of employees did not approach anyone for support on the most recent occasion they experienced poor mental health. 86% would think twice before offering to help a colleague whose mental health they were concerned about" (Hampson and Soneji, p. 6). This survey shows that a large number employees included in the survey have mental health issues as a result of factors related to the workplace. The 2006 National Survey on Drug Use and Health is a United States nationwide survey that uses face-to-face interviews at citizen residences to collect health information data (Dept of Health and Human Services Substance Abuse and Mental Health Services Administration., p. 89). The 2006 National Survey on Drug Use and Health found that 28.3 million adults (12.9 percent of the adult population) have cases of mental health that are treated in the United States (Dept of Health and Human Services Substance Abuse and Mental Health Services Administration, p. 89). A two-stage stratified random sampling study was conducted in Shanghai, China using the World Health Organization (WHO) (Five) Well-Being Index (WHO-5) test to assess the mental health of 2,979 employees from 35 companies showed that "977 workers (34.9%) reported poor mental health" (Gao, Weaver, Dai, Liu, Jin, and Fu, p. 2-3).

An online survey of 746 human resources professionals and business leaders was conducted to determine the training needs regarding mental health and mental health issues in the workplace. (Shann, Martin and Chester). Of the participants surveyed, "68% of leaders reporting that they had worked with, or managed, someone who was experiencing depression" (Shann et al., p. 305). This percentage shows that mental health training is needed due to the amount of mental health issues observed in the workplace. "Thirty-nine percent of leaders reported that they had actively promoted a mental health promotion initiative in their workplace" (Shann et al., p. 306).

A survey called the National Comorbidity Survey Replication (NCS-R) was conducted in which 9282 participants were interviewed. The NCS-R investigates mood disorders in the workplace. It was estimated by the survey that the annual workplace costs of major depressive disorder is $36.6 billion (Kessler, Akiskal, Ames, Birnbaum, Greenberg, Hirschfeld 1564).

Given the prevalence and high costs of mental health issues in the workplace, a number of studies have been conducted to examine the effects of intervention. These are summarized in the next section.

2.1.1 Effects of Intervention

Mental Health intervention studies were conducted to determine the effect of counseling, assistance programs and other work based intervention programs on the treatment of mental health. An intervention study conducted on chefs was conducted in an effort to prevent mental health issues from arising. Participants were issued a pre-intervention and post-intervention survey. The results of the survey showed intervention was successful in reducing mental health risks (Pidd, Roche, and Fischer).

An intervention study of nine Chinese retail enterprises over the course of a 30-month period was conducted to "examine the effectiveness of a workplace-based intervention program to improve mental health, work ability, and work productivity" (Sun, Buys and Wang, p. 305). "The program addressed job-related factors found to be related to depression, including the workplace physical and psychosocial environment, overtime work hours, conflicts with managers and coworkers, and work stressors", using regression analysis and variance to determine differences in pre-intervention and post-intervention measures of variables (Sun et al., p. 409). The intervention methods resulted in, "significant improvements in participants' work ability, particularly their overall ability to meet work demands, including job-related mental demands" (Sun et al., p. 409). A study of workforce intervention of depression by the State Government of Maine was conducted in which 1,525 participants completed the screening for the study and 153 were deemed eligible. The study found that, "Comparing the WHI [Work and Health Initiatives] and usual care groups, the adjusted mean total productivity cost savings from the WHI was $6041.70 per participant. This reflects an adjusted estimated per participant savings in at-work productivity for the WHI of $979.70 and an adjusted estimated savings per participant in absence costs of $5062.00 (Lerner, Adler, Hermann, Chang, Ludman, Greenhill, and Rogers, p. 8). This study shows that implementing a workplace intervention initiative may cost money, but the savings are substantial. A study was conducted to determine the effectiveness of intervention for psychosocial work factors and mental health issues among the 1,659 participants. The study found that, "during the 30-month follow-up, the prevalence of three psychosocial work factors significantly decreased…high PD [psychological demand] decreased from 50.1% to 45.4%, low co-worker SS [social support] dropped from 53.9% to 48.9% and low reward…decreased from 36.1% to 30.9%". (Gilbert-Ouimet, Brisson, Vezina, Trudel, Bourbonnais, Masse, Baril-Gingras, and Dionne, p. 58). This study utilized regression analysis to compare the intervention group with the baseline control group.

2.1.2 Data Mining Techniques

Figure 1 is an example of a Decision Tree. Figure 1 represents a tree to determine whether or not to give someone credit. To read the tree you would start at the top of the tree with Age>40. If the person's age is greater than 40 then we would move to the next node which is Home Owner. If they are a home owner, then we will move to the "Give a Credit" leaf node. This leaf node is the final node in the tree, so we would make the decision to give them credit. Decision trees allow us to create mutually exclusive and exhaustive rules based on the attributes in our data set to determine what decision we should make for each individual. The following is a rule: If their age is great than 40 and they are a home owner then we will give them credit. Decision trees are adept at handling categorical data. Given that all our data is categorical, this makes it a good fit for a decision tree.

The Naïve Bayes mining algorithm uses a probabilistic approach to predicting a certain outcome. The Naïve Bayes formula is: $P(C|A) = \frac{P(A|C)P(C)}{P(A)}$. A is the set of inputs which we know, and C is the variable which we are predicting. We will multiply the probability that event A will happen given event C by the probability of C then divide by the probability of event A. The Naïve Bayes algorithm will show the probability of a certain event to occur based on the predicted output. Figure 2 below is an example of the Naïve Bayes attribute characteristics. This example in Figure 2 seeks to predict if someone will purchase a bike. If there are no children at home then someone is more likely to purchase a bike.

2.1.3 CRISP-DM

The cross-industry standard process for data mining (CRISP-DM) will be used to mine and produce results from this dataset which include: business understanding, data understanding, data preparation, modeling, evaluation, and deployment. The business understanding is the goal of mining the dataset. The data understanding is understanding the independent and dependent variables contained in the dataset. Data preparation is any transformation or preprocessing that is needed before the dataset can be used in a data mining algorithm. Modeling

will involve the use of data mining techniques such as Decision Trees or Naïve Bayes. Once the dataset has been modeled then we can evaluate the results and further deploy the model on the entire dataset.

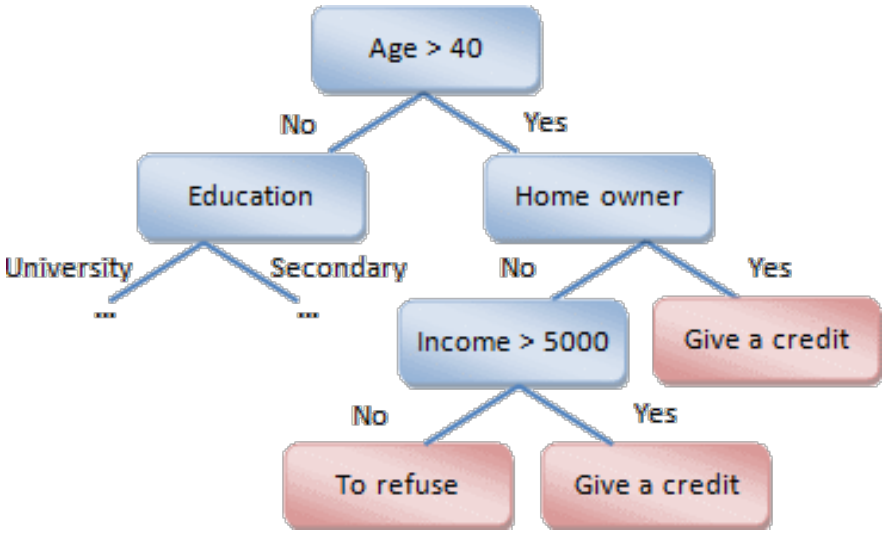

Figure 1: Decision Tree Example
Source: http://help.prognoz.com/en/mergedProjects/Lib/06_datamining/lib_decisiontree.htm

Characteristics for 1

Attributes	Values	Probability
Number Children At Home	0	
Marital Status	M	
Marital Status	S	
Region	North America	
Commute Distance	0-1 Miles	
Education	Bachelors	
Occupation	Professional	
Region	Europe	
Number Cars Owned	1	
Number Cars Owned	0	
Total Children	0	
Number Cars Owned	2	
Education	Partial College	
Age	45 - 52	
Occupation	Skilled Manual	
Total Children	1	

Figure 2: Naïve Bayes Attribute Characteristics
Source: http://www.sqlservercentral.com/articles/Data+Mining/97948/

2.2 Goal Identification

Our goal is to determine how likely someone is to seek mental health treatment based on their work conditions and employer sentiments towards mental health within their current technology company. We are seeking to determine if someone is more likely to seek treatment if the employer is open about talking about mental health or

if work conditions are favorable regarding mental health related issues (such as having mental health care options or mental health benefits). Our output is the treatment attribute shown in Table 1 which is a yes or no variable that indicates if a participant did or did not seek mental health treatment. Our input columns will focus on employer sentiments about mental health and work-related conditions that can impact someone's decision to seek mental health treatment. Demographics will be used to determine if it is a factor in seeking mental health treatment.

2.3 Target Data Set

The data set being mined is titled Mental Health in Tech Survey. The data set contains structured answers to a survey regarding employee mental health and their work conditions. The initial targets to take the survey were employees working for companies in the technology industry so that more information could be collected on mental health and its correlation to a technology company's employee environment. The non-profit corporation Open Souring Mental Illness (OSMI) originally conducted the survey in 2014 and collected the data. Their data set was published to Kaggle.com. The survey is still ongoing as of 2016. OSMI was founded by Ed Finkler who speaks at tech conferences about mental health issues. He then created OSMI to further speak on mental health and research about mental health issues in tech workplaces.

The original Mental Health in Tech Survey dataset included 1260 rows or instances and 26 attributes. Table 1 lists the dataset's attributes and their inclusion in the data mining structure. Appendix A includes a full list of attributes and a column that indicates whether an attribute is used in the mining structure.

2.4 Project Plan

The strategy we are using for mining this data relates to algorithms that can effectively handle categorical data. This will be a supervised data mining project since we are trying to specifically predict the output of the treatment variable. The attributes of the dataset are shown in Table 1. We will run mining models with Decision Trees and Naïve Bayes to determine the best algorithm to predict the output variable. These mining techniques would be most appropriate for the data given that the data set contains mostly categorical data and both algorithms are adept at handling categorical data. A Decision Tree allows you to predict the most likely response of the participant by creating rules to determine their decision until a leaf node is reached. Naïve Bayes determines the probability of a given output based on your inputs.

We will be building four Decision Tree mining models using Microsoft SQL Server Analysis Services 2016 (SSAS 2016). Parameters will be varied to attempt to improve the accuracy of the model. For the Mental Health in Tech Survey data set, a decision tree will produce a tree of rules that will determine a participant's response to receiving treatment based on what they chose for other attributes. The complexity parameter will be varied in each Decision Tree to determine the growth of the Decision Tree and limit the amount of leaf nodes on the tree.

We will then build 2 mining models in SSAS 2016 using Naïve Bayes. We will vary the Minimum Dependency Probability parameter. This parameter determines the limit of the content generated and a minimum probability between the inputs and outputs.

3. DATA PREPARATION – PREPROCESSING AND TRANSFORMATION

During data exploration, we found that some corrections needed to be made to certain columns due to inconsistent formatting of the data. For instance, the gender column had a variety of answers outside the acceptable "Female", "Male", or "Other" categories. In order to use the gender category, we had to transform all of the data to be either "Female", "Male", or "Other". For instances that were explicitly male, female, m, f, M, or F, they became "Female" or "Male" based on their response. For the instances that were not henceforth mentioned, they were labeled as "Other".

For the attribute age, there were several errant values. Several values for age were negative (-1729, -29, and -1) and age clearly cannot be negative. There were also some values for age that were clearly outside the normal and acceptable age range (329 and 99999999999). As for the treatment of these rows, because there were only five of them they were deleted. This would not have a significant impact on the accuracy of the dataset.

The data set contained survey responses from participants who noted that they were not employed by a technology company. 226 instances were deleted to ensure we were only considering participants who worked for a technology company as that was the original intent of the survey.

Attribute Name	Data Type	Meaning	Work Conditions, Employer Sentiment, or Demographic?
Age	Number	Age of survey participant	Demographic
Gender	Variable Character	Gender of participant	Demographic
Family_history	Variable Character	Does the participant have family history of mental health issues	Demographic
Treatment	Variable Character	Did the participant seek treatment or help for a mental health condition	Output Variable
Work_interfere	Variable Character	Does the participant feel work interferes with their mental health condition if they have one	Work Conditions
Tech_company	Variable Character	Is the participant working for a tech company	Demographic
Benefits	Variable Character	Are there mental health benefits offered by the employer	Work Conditions
Care_options	Variable Character	Is mental health care offered by the employer	Work Conditions
Wellness_program	Variable Character	Is mental health part of the employer's wellness program	Work Conditions
Seek_help	Variable Character	Are there resources offered by the employer to seek help with or address mental health issues	Work Conditions
Anonymity	Variable Character	Are you anonymous if you use mental health treatment	Work Conditions
Leave	Variable Character	Is it easy to take medical leave for mental health condition issues	Work Conditions
mental_health_consequence	Variable Character	Would discussing mental health with your employer have negative consequences	Employer Sentiments
phys_health_consequence	Variable Character	Would discussing physical health with your employer have negative consequences	Employer Sentiments
Coworkers	Variable Character	Can you discuss or would you be willing to discuss mental health issues with coworkers	Work Conditions
Supervisor	Variable Character	Can you discuss or would you be willing to discuss mental health issues with your supervisor	Employer Sentiments
mental_vs_physical	Variable Character	Is mental health taken as serious as physical health by your employer	Employer Sentiments
obs_consequence	Variable Character	Have you seen negative consequences occur with your coworkers in terms of mental health	Work Conditions

Table 1: Data Identification Table

4. MODELING – MINING RESULTS

We have a total of 1028 rows after eliminating outliers and participants who do not work for a tech company. A Decision Tree algorithm and Naïve Bayes algorithm was used to determine the best algorithm to analyze the data. Naïve Bayes and Decision Tree are able to handle categorical data. Given the lower accuracy of Naïve Bayes shown in Table 2 and the visual appeal of a Decision Tree, we decided to use a Decision Tree as the final mining algorithm. A Decision Tree will allow users to visually see the outcome of treatment and determine rules to best predict how participants advance to the leaf node.

There are 617 instances in the training set and 411 in the test set. The training set will be the number of instances used to develop and train the model. Once the model has been trained it will then be deployed for all instances which will include the test set. We created 4 different decision tree mining models named MH_1 through MH_4. The parameter that was varied was the Complexity Parameter. This parameter inhibits the growth of the decision tree. The other mining model complexity parameters are show in Table 2 below. Of the 4 Decision Tree models used, the MH_4 mining model shown in Figure 3 was our best tree. This was determined by evaluating the variables that had the greatest impact on the treatment variable. The MH_4 tree is a single Decision Tree that explains multiple factors that impact the outcome of treatment including work interference, gender, coworkers, family history, benefits and mental VS physical. The accuracy rate shown in Table 2 indicates how accurately the model will predict the treatment attribute in the test set. All Decision Tree mining model accuracies are the same so the Decision Tree with the most leaf nodes will be used which is MH_4. Figure 4 shows the dependency network

which represents the attributes that have the strongest link or effect on the output variable which is treatment. Work interference has the strongest link to the treatment variable. Ignoring the work interference variable still produces a strong accuracy of 72.9%.

Model	Accuracy	Complexity Parameter	Minimum Dependency Probability
MH_1	81.99%	.9	
MH_2	81.99%	.6	
MH_3	81.99%	.3	
MH_4	81.99%	.1	
Bayes_1	81.75%		.5
Bayes_2	81.75%		.9

Table 2: Parameter and Accuracy Table

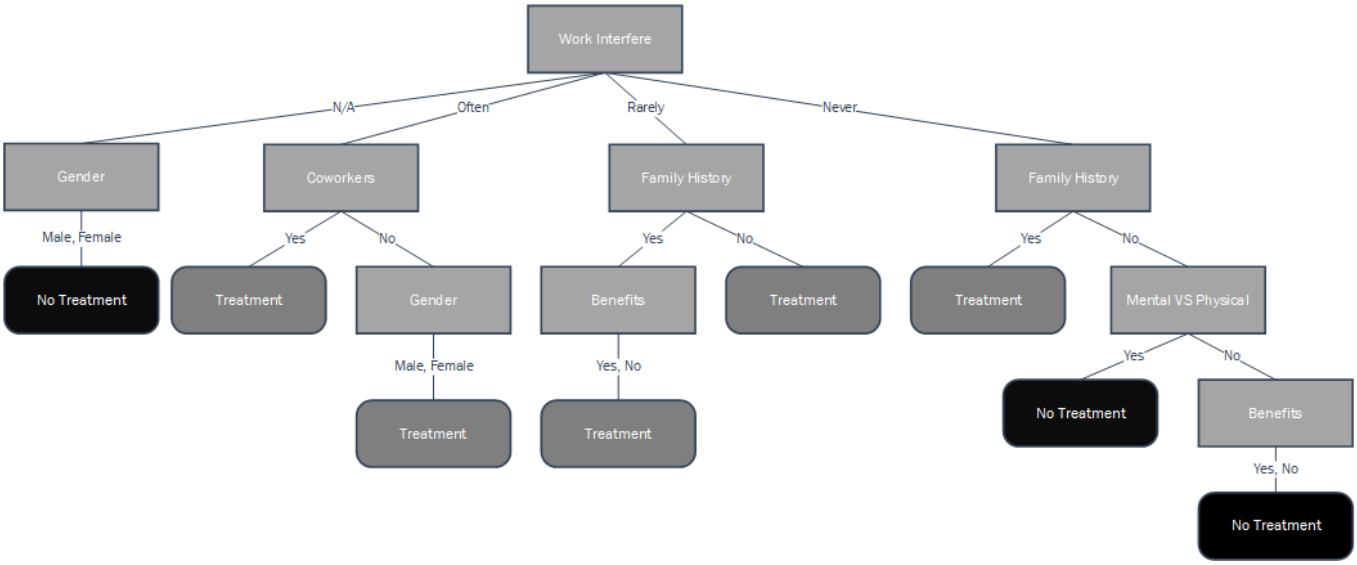

Figure 3: MH_4

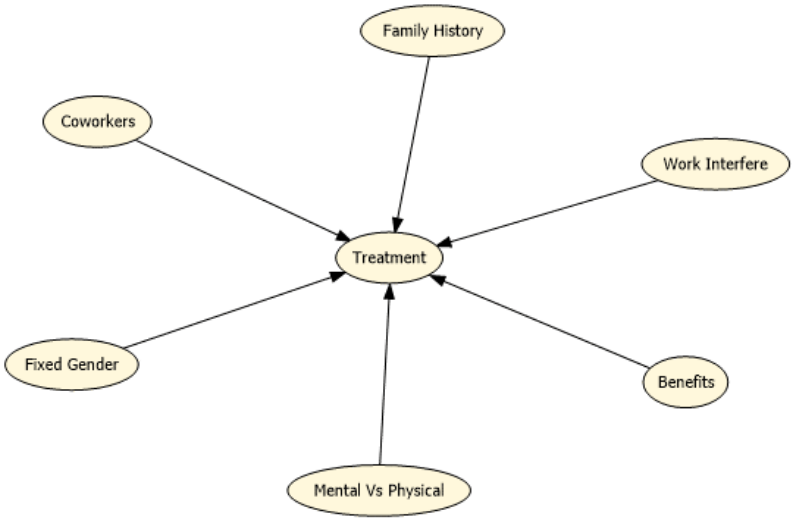

Figure 4: Mining Model Dependency Network

5. INTERPRETATION AND EVALUATION

Using the MH_4 mining model shown in Figure 3 we will evaluate the model. The Decision Tree produces rules to classify the inputs or nodes needed to reach a certain outcome of the treatment variable. The rules of the Decision Tree are shown in Appendix B. The accuracy of the rules in Appendix B is how accurately the rule predicts the outcome of treatment. The rule is displayed as IF(antecedent) THEN (Consequent). Therefore, the accuracy is the fraction of rows that satisfy the antecedent that also satisfy the consequent. We can make conclusions on whether an employee is more likely to seek mental health treatment based on the rules. Based on the rules it is more likely that if work interferes with a mental health condition, the individual has a family history of mental health issues and benefits for mental health treatment are offered then the participant will seek treatment. If work does not or never interferes with a mental health issue and they have no family history then they are not likely to seek mental health treatment.

The classification matrix associated with model MH_4 is shown in Table 3. Based on the sensitivity shown in Table 4, the sensitivity of the model is 94.28%. This indicates the model is accurate in predicting the true positives 94.28% of the time. Our positives would be the individual saying "Yes" to seeking treatment for mental health. The model will predict a true negative or "No", 69.15% of the time. The lift shown in Table 4 is 1.49 indicating that we are 1.49 times better off using the model to predict treatment than if we had no model. Overall, given the high rate of sensitivity of predicting the true positives and the lift being above 1 we can conclude that model is satisfactory at predicting if someone will get treatment for mental health issues.

The dependency network shown in Figure 4 tells us the variables that are most likely to affect treatment. From strongest link to weakest the following variables impact treatment: Work Interferes, Family History, Mental VS Physical, Gender, Coworkers and Benefits. The dependency network further illustrates that there is a strong linkage between work interference and family history of mental health issues to seeking treatment for mental health.

Classification Matrix for Predicting Treatment			
	Yes (Actual)	**No(Actual)**	**Predicted Totals**
Yes	198	62	260
No	12	139	151
Actual Totals	210	201	411

Table 3: Classification Matrix for Predicting Treatment

Lift	**Sensitivity**	**Specificity**
(198/260)/(210/411)=1.49	198/210=94.28%	139/201=69.15%

Table 4: Classification Evaluation

6. DEPLOYMENT PLAN – ACTION AND CONCLUSION

Based on the rules developed in Appendix B and the key measures identified in Table 4 it would be recommended that employers develop benefits regarding mental health and assist in diminishing the impact of workplace stresses on mental health issues. Based on the rules we are confident that it is more likely that if work interferes with a mental health condition, the individual has a family history of mental health issues and benefits for mental health treatment are offered then the participant will seek treatment. Work condition factors were more of an influence on predicting treatment than the employer sentiments. Employers should focus on identifying those work factors that interfere with mental health issues to find ways to decrease the work stress on mental health.

This dataset contains survey results from employees working for a tech company. Participants are asked mental health related questions to determine if a participant did or did not receive mental health treatment based on work condition factors. After preprocessing and data exploration, 1028 instances were kept for the mining model. According to related literature on mental health in the workplace, interventions can prove effective in helping employees and reducing company expenses due to employees being absent from work or unable to contribute. Using a decision tree, it was determined that employers should provide mental health benefits and reduce work conditions factors that could impact mental health issues. Based on the sensitivity shown in Table 4, the model is accurate in predicting the true positives 94.28% of the time and will predict a true negative 69.15% of the time. The lift shown in Table 4 indicates we are 1.49 times better off using the model to predict treatment than if we had no model. The rules show that if benefits are offered then employees are more likely to seek treatment.

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APPENDIX A: COMPLETE LIST OF ALL DATA SET ATTRIBUTES

Attribute Name	Data Type	Meaning	Including in Model	Work Conditions, Employer Sentiment, or demographic?
Timestamp	Date	Date at which survey was completed or submitted		
Age	Number	Age of survey participant	YES	Demographic
Gender	Variable Character	Gender of participant	YES	Demographic
Country	Variable Character	Country participant lives in		
State	Char(2)	State the participant lives in		
Self_employed	Variable Character	Is the participant self employed		
Family_history	Variable Character	Does the participant have family history of mental health issues	YES	Demographic
Treatment	Variable Character	Did the participant seek treatment or help for a mental health condition	YES	
Work_interfere	Variable Character	Does the participant feel work interferes with their mental health condition if they have one	YES	Work Conditions
No_employees	Number	Number of people currently employed by the company the participant works for		
Remote_work	Variable Character	Does the participant work remotely 50% or more of the time		
Tech_company	Variable Character	Is the participant working for a tech company	YES	Demographic
Benefits	Variable Character	Are there mental health benefits offered by the employer	YES	Work Conditions
Care_options	Variable Character	Is mental health care offered by the employer	YES	Work Conditions
Wellness_program	Variable Character	Is mental health part of the employer's wellness program	YES	Work Conditions
Seek_help	Variable Character	Are there resources offered by the employer to seek help with or address mental health issues	YES	Work Conditions
Anonymity	Variable Character	Are you anonymous if you use mental health treatment	YES	Work Conditions
Leave	Variable Character	Is it easy to take medical leave for mental health condition issues	YES	Work Conditions
mental_health_consequence	Variable Character	Would discussing mental health with your employer have negative consequences	YES	Employer Sentiments
phys_health_consequence	Variable Character	Would discussing physical health with your employer have negative consequences	YES	Employer Sentiments
Coworkers	Variable Character	Can you discuss or would you be willing to discuss mental health issues with coworkers	YES	Work Conditions
Supervisor	Variable Character	Can you discuss or would you be willing to discuss mental health issues with your supervisor	YES	Employer Sentiments
mental_health_interview	Variable Character	In an interview would you be willing to bring up or ask questions about mental health issues		
phys_health_interview	Variable Character	In an interview would you be willing to bring up or ask questions about physical health issues		
mental_vs_physical	Variable Character	Is mental health taken as serious as physical health by your employer	YES	Employer Sentiments
obs_consequence	Variable Character	Have you seen negative consequences occur with your coworkers in terms of mental health	YES	Work Conditions
Comments	Variable Character	Additional comments		

Table 5: Complete Data Set Attributes List

APPENDIX B: COMPLETE LIST OF ALL RULES

Rule		Accuracy	Coverage
Antecedent	**Consequent**		
If (Work Interfere = 'NA' and Fixed Gender = 'Male')	No Treatment	113/115 = 98.2%	113/617 = 18.3%
If (Work Interfere = 'NA' and Fixed Gender = 'Female')	No Treatment	20/20 = 100%	20/617 = 3.2%
If (Work Interfere = 'Rarely' and Family History = 'Yes')	Treatment	31/34 = 91.1%	34/617 = 5.5%
If (Work Interfere = 'Rarely' and Family History = 'No')	Treatment	30/50 = 60%	30/617 = 4.8%
If (Work Interfere = 'Never' and Family History = 'No')	No Treatment	83/89 = 93.2%	83/617 = 13.4%
If(Work Interfere = "Never' and Family History = 'Yes')	No Treatment	12/19 = 63.1%	12/617 = 1.9%
If(Work Interfere = 'Often' and Coworkers not = 'Yes')	Treatment	38/46 = 82.6%	38/617 = 6.2%
If(Work Interfere = 'Often' and Coworkers = 'Yes')	Treatment	14/14 = 100%	14/617 = 2.3%
If(Work Interfere = 'Rarely' and Family History = 'Yes' and Benefits not = 'Yes')	Treatment	16/19 = 84.2%	16/617 = 2.6%
If(Work Interfere = 'Rarely' and Family History = 'Yes' and Benefits = 'Yes')	Treatment	15/15 = 100%	15/617 = 2.4%
If(Work Interfere = 'Never' and Family History = 'No' and Mental Vs Physical= 'Yes')	No Treatment	30/30 = 100%	30/617 = 4.8%
If(Work Interfere = 'Never' and Family History = 'No' and Mental Vs Physical not = 'Yes')	No Treatment	53/59 = 89.8%	53/617 = 8.6%
If(Work Interfere = 'Often' and Coworkers not = 'Yes' and Fixed Gender = 'Male')	Treatment	28/36 = 77.7%	28/617 = 4.5%
If(Work Interfere = 'Often' and Coworkers not = 'Yes' and Fixed Gender = 'Female')	Treatment	10/10 =100%	10/617 = 1.6%
If(Work Interfere = 'Never' and Family History = 'No' and Mental Vs Physical not = 'Yes' and Benefits not = 'No')	No Treatment	39/45 = 86.6%	39/617 = 6.3%
If (Work Interfere = 'Never' and Family History = 'No' and Mental Vs Physical not = 'Yes' and Benefits = 'No')	No Treatment	14/14 =100%	14/617 = 2.3%

Table 6: Complete List of All Rules

Undergraduate Student Posters

Assessing the Impact of Music-related Technologies on Amateur Musicians

(Abstract)

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The music industry has long claimed that audio-compression (such as the mp3 file format), file sharing networks (such as Napster and Limewire), and more recently, online streaming services (such as Youtube and Spotify) have negatively impacted their business. While technological advancements are generally considered a benefit for society, they have largely had negative effects on the music industry. The music industry association known as the Recording Industry Association of America (RIAA), has noted that due to music-related technologies, music purchases (in number of units and in dollar values) have abruptly and significantly declined since 2000. The purpose of this research is to examine how amateur musicians have adapted (or tried to adapt) to the impact that music-related technologies have had on the music industry.

By conducting interviews of amateur musicians, this study anticipates discovering some competitive strategies used by amateur musicians to profit of their art. Such interviews were conducted with several musicians from different demographic and musical backgrounds, including Jazz, Classical, Hip-Hop, Rock, and EDM. Using the results of the information collected from the interviews, a content analysis will be done, common themes will be analyzed and differences due to demographic and music backgrounds will be delineated. Implications for amateur musicians will be discussed.

DASI

Content and Delivery of Analytics Instruction for Undergraduate and MBA Students

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Abstract: Instructional faculty will share their experiences in creating undergraduate courses and an undergraduate minor in analytics, as well as delivering an online analytics course to MBA students. Challenges addressed during the session will include software used, course content, student capabilities, faculty expertise, and limited resources. Time will be allotted for discussion and feedback from those attending the session.

Authors Index

Addendum

Additional papers stating the following page

IMPROVING PRODUCTIVITY FOR COLLEGE STUDENTS WITH DISABILITIES THROUGH MOBILE COMPUTING DEVICES

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ABSTRACT

Applications on mobile computing devices benefit students with disabilities in post-secondary institutions to be as competitively organized as students without disabilities. The challenge is determining the best-in-class applications, and the device features for productivity for this population, from different products of technology. To address the challenge, the authors evaluated application interfaces of calendar tools for a higher-functioning population of students with developmental and intellectual disabilities (IDD). The authors found that the potential students with disabilities perceived the application tools as generally helpful in school tasks as students without disabilities perceived the tools, and they found the tools as especially important in the independence of the students with disabilities to be effectively organized for productivity as those without disabilities. The findings of the paper can be constructive for administrators exploring assistive device tools for students with disabilities.

Keywords: Assistive Device Systems, Calendar Device Tools, Low-Technology, Mobile Computing, Post-Secondary Education, Special Education, Students with Developmental and Intellectual Disabilities (IDD)

BACKGROUND

Assistive digital technology can be considered crucial in learning (Brudno, 2013). Mobile computing digital technology is considered to be helpful for people with cognitive disabilities to be as independently organized as people without disabilities (Bolte, Golan, Goodwin, & Zwaigenbaum, 2010, and ARC Empower, 2017). Notably, applications (i.e. apps) on mobile

computing devices are considered to be helpful for higher-functioning (i.e. less impaired) students with developmental and intellectual disabilities (IDD), such as students with Autism Spectrum Disorders (ASD) diagnosed at mid-spectrum, to be as organized as peer students without disabilities (Nkabinde, 2008). Particularly, the apps category of instructional aid calendar organization tools (Bouck, 2017) are, even if categorized as low-technology, noted to be important in self-management and self-monitoring of students with disabilities in curricular school tasks (Obukowicz, Stindt, Rozanski, & Gierach, 2009). Such apps may include diverse features of multimedia, and even functional interfaces of sensory and sound tools, considered appealing to those with disabilities (Goodnet, 2015). The inclusion of apps customized to students with developmental and intellectual disabilities can improve the potential of the device tools for this population. Moreover, the right to this potential of technology by students with disabilities is noted in the literature (Braddock, Hoehl, Tanis, Ablowitz, & Haffer, 2013). The challenge for administrators if not educators is evaluating the appropriately best-in-class apps and devices of organization tools for students with disabilities in post-secondary institutions.

INTRODUCTION TO PAPER

The paper began in a project of evaluating apps of calendar organization tools for people with disabilities in a community engagement course of the second author-faculty member in the Seidenberg School of Computer Science and Information Systems of Pace University. The goal of the project was to identity calendar device task tools that would be helpful to candidate students with disabilities in a current pilot inclusion program (www.thinkcollege.net [Appendix]) in the school. The improvement likelihood in the independence of higher-functioning students with developmental and intellectual disabilities with the limited low-technology tools (Bouck, Savage, Meyer, Taber-Doughty, & Hunley, 2014), from their productivity with these tools, was the important mission of the project. The interfaces in self-management and self-monitoring sensitive to students with disabilities in their school tasks was important to the likelihood mission of the project. The project was conducted by the first author of this paper, a senior undergraduate student of the university already acclimated to this population of students.

The field of mobile computing device systems consists of different mobile operating systems with disparate interfaces from diverse hardware and software technologies (Arzensek, & Hericko, 2014). From the best-of-class apps in the disability education field (www.enablingdevices.com [Appendix]), and in order to avoid the app fatigue in this field (Frenkel, 2016), the authors chose the below freeware organizing / scheduling product tools for initial study:

Table 1: **Apps of Calendar Organization Tools for Study**

App Product Tool	Platform for Tool	Tool Vendor
Day Planner Assistant – Custom Schedule	iOS 8.0 *	Viet Le
Errands To-Do List	iOS 5.0+ *	Yoctoville

Productivity - Day Planner Productive Task Manager	iOS 8.0+ *	Success Wizard

*iPad, iPhone and iPod Touch

Each of these product tools is customizable for daily independent organizing and scheduling of school tasks by those with disabilities.

The evaluation of the app product tools was designed by the authors from existing factors for helpfulness for students with disabilities. The factors of *ease* in engaging with the tools, *functionality* in generating graphs and schedules of tasks*, insertion* in generating inputs of steps of tasks with the tools, *multimedia* in presenting sensory and sound to the students with the tools, *performance* in productively providing resultant summaries of the tasks, and *visualization* in providing scheduling videos for viewing were integrated from earlier School studies of those with disabilities (Lawler, Moller, & Salloum, 2015, and Greene, Hager, & Lawler, 2016). The evaluation of the tools was also designed from factors of gaming known to millennial students with or without disabilities who are keen on inherent simplicity of the tools from their mere usability (Hussain, Abbas, Abdulwaheed, Mohammed, & Abdulhussein, 2015). These factors formed a foundation for impacting improvement in independence from gaining organizational and productivity skills of the students with disabilities. Few research studies have however reviewed education technologies, such as apps of calendar organizational tools, for students with developmental and intellectual disabilities in post-secondary institutions (Robinson, 2014).

FOCUS OF PAPER

The focus of this paper is to evaluate the chosen mobile computing apps of calendar organization and scheduling tools. The interfaces of the limited selected tools are evaluated by the factors of *ease*, *functionality*, *insertion*, *multimedia, performance* and *visualization*, in sensitivity to students with disabilities in the school of a metropolitan university. Even in the fundamental simplicity of these apps with low-technology, the assistive device tools may be important in the improvement in the independence of the students with developmental and intellectual disabilities to be as equivalent in organizational productivity skills in school tasks as students without disabilities, in a future official inclusion program (www.thinkcollege.net) now in pilot in the School. Independence is indicated to be a benefit of consequence for the continuance of students with disabilities to be in post-secondary institutions (Castillo, 2015). Therefore, this paper can be helpful to administrators and educators, and special education students, in exploring app assistive device tools for students with disabilities, for whom there are often limited productivity tools.

METHODOLOGY OF PAPER

The methodology model of this paper consisted of an evaluation of the 3 aforementioned apps of calendar organization tools, Day Planner Assistant – Custom Schedule, Errands To-Do List and

Productivity – Day Planner Productive Task Manager, by the authors as best-in-class apps for people with disabilities.

The evaluation was done in a community entrepreneurship course by 4 focus groups of 21 aged 18-21 higher-functioning (i.e. less impaired or moderately impaired) student surrogates* with developmental and intellectual disabilities from a local non-profit organization and already proficient in mobile computing tools (and by a control group of 23 aged 18-21 students without disabilities) at the Seidenberg School of Computer Science and Information Systems of Pace University (McKenna, & Lawler, 2017). The evaluation was done in the periods of October – December 2016 and February – April 2017 from a pre-tested Likert-like instrument of survey on the perceptions of the aforementioned factors of *ease*, *functionality*, *insertion*, *multimedia*, *performance* and *visualization*, relative to the features of the interfaces on the app freeware iPad tools in the simulation of 9 curricular-related school tasks. The evaluations were fulfilled on a descriptive scaling of (5) very high, (4) high, (3) intermediate, (2) low and (1) very low in helpfulness satisfaction, or non-satisfaction of (0), by the populations of students (Frankfort-Nachmias, & Leon-Guerrero, 2015).

The evaluations were anonymously competed on the instrument of survey, but the focus groups were moderated by the first author, in the classroom course environment in the Seidenberg School. The findings from the focus groups of the students with (and without disabilities) were progressively reviewed with the faculty member – second author and were summarized by the first author for study. The model of the study was consistent generically with the models of other School studies of those with developmental and intellectual disabilities by the authors (Lawler, Moller, & Salloum, 2015 and Greene, Hager, & Lawler, 2016).

*Piot inclusion program population of non-surrogates students was a low 3 students with developmental and intellectual disabilities, as the program will not be operational until 2018.

PRELIMINARY FINDINGS OF STUDY

The preliminary findings from the descriptive study is disclosing acceptability of the calendar organization tools chosen by the authors in helpfulness likelihood, if such tools are offered to higher-functioning students with developmental and intellectual disabilities, in an future official inclusion program (www.thinkcollege.net) of the Seidenberg School, as indicated in the below factors:

Table 2: **Apps of Calendar iPad Organization Tools – Evaluations of Students with Disabilities - Summary**

(Means = 0.00 / 5.00)

	Day Planner Assistant	Errands To-Do List	Productivity Day Planner	Average
Ease	2.40	2.85	3.60	2.95

Functionality	1.80	3.15	3.50	2.82
Insertion	2.05	2.50	3.65	2.74
Multimedia	1.90	1.90	3.30	2.37
Performance	2.55	2.95	3.50	3.00
Visualization	2.75	3.20	3.90	3.29
Average-Cumulative	13.45	16.55	21.45	17.17

Legend: (5) very high, (4) high, (3) intermediate, (2) low and (1) very low in helpfulness satisfaction with the organization tools

The factor findings from the perceptions of the students with developmental and intellectual disabilities in the study from performing feature simulations of the curricula school tasks on the tools are discussed below:

Ease

From the beginning of the evaluations, the students with disabilities perceived generally easy to engage, easy to learn and easy to navigate features from simulations of the curricula tasks on the device tools (means = 2.95 [Table 2]).

Functionality

They perceived the features of the tools as generally meaningful in organizational planning and scheduling and subsequent searching of "everyday" pre-school, school and post-school tasks (2.82), except for Day Planner Assistant – Custom Schedule (1.80).

Insertion

The students with disabilities perceived flexible and generally meaningful interfaces in intuitive steps to submit tasks to the tools (2.74), and they were largely perceptive on their requirements for tailoring of the tools for usability.

Multimedia

They perceived the multimedia of sensory and sound with limited potential (2.37), especially with the Day Planner Assistant – Custom Schedule (1.90) and the Errands To-Do List (1.90), perceiving *functionality* (2.82) and *ease* (2.95) as more important in the helpfulness of the tools.

Performance

They perceived personal satisfaction with measurable reporting scorecards and summaries of the school curricula tasks, and even extra-curriculum recreational tasks, tailored on the tools (3.00)

Visualization

The students with disabilities in the groups perceived pleasing satisfaction with the screen simplifications of task visuals (3.29), notably with the Productivity Day Planner – Productive Task Manager (3.90), the highest of the ratings.

The findings of the preliminary study are concurrently indicating Productivity Day Planner – Productive Task Manager as the favorite organizational tool (cumulative means = 21.45), followed by Errands To-Do List (16.55) and the Day Planner Assistant – Custom Schedule (13.45), or an average cumulative favorability (17.17) indicating helpless likelihood of these device tools or generic market tool types.

Furthermore, the findings from the perceptions of the students with disabilities as to the helpfulness of the organizational tools were largely similar to the findings from the perceptions of the students without disabilities of these tools. *Ease* perceptions of the students with disabilities however is indicating helpfulness likelihood (2.95 vs. 2.89) in the below Table 3 somewhat higher than the perceptions of the students without disabilities. Profiling of students with disabilities with similar tools may disclose the likeliness of ratings higher than students without disabilities.

Table 3: Apps of Calendar iPad Organization Tools – *Ease* Evaluations of Students with and without Disabilities

(Means of Rating = 0.00 / 5.00; Overall Rating = Cumulative Rating)

	Students with Disabilities		Students without Disabilities	
	***Ease* Overall Rating**	***Ease* Rating**	***Ease* Overall Rating**	***Ease* Rating**
Day Planner Assistant	13.35	2.40	15.55	2.75
Errands To-Do List	16.55	2.85	17.05	2.85
Productivity – Day Planner Productive Task Manager	21.45	3.60	20.75	3.05
Average		2.95		2.89

In summary, the findings of the study are indicating that the apps - Day Planner Assistant – Custom Schedule, Errands To-Do List and Productivity – Day Planner Productive Task Manager – are effective and efficient, but not enough exciting, in helpfulness likelihood in potential school tasks, in the evaluations by the higher-functioning students with disabilities; and the findings are indicating that the apps are important in the independence to be gained by the students from the likelihood in productivity of the tasks, if these students with developmental and intellectual disabilities were to be included in an official inclusion program in the Seidenberg School of Pace University.

(Further findings from the paper, on both students with and without disabilities as they continue on the project with the calendar organization tools, will be finalized for conference presentation, in detailed tables on the school tasks.)

PRELIMINARY IMPLICATIONS OF STUDY

App calendar technology can definitely help higher-functioning students with disabilities in the performance of school tasks. App device tools can improve the independence likelihood of the students from planning and scheduling their tasks by themselves (Mechling, Gast, & Seid, 2009). Findings from the perceptions of the students with developmental and intellectual disabilities are indicating the ease and the functionality and the likelihood of improved performance from the tools. The app iPad tools, along with other assistive technology tools, can if chosen correctly meet the fundamental needs of the students with disabilities (Badman, 2013) to be as proficient with the tools as those students without disabilities are with these tools. The implication of independence likelihood if not performance from the tools is an incentive for administrators of post-secondary institutions to invest in such tools for those with disabilities.

Assistive calendar organization technology can be a discreet initiative for administrators of post-secondary institutions if integrated with other assistive tools, such as communication, keyboard, mobility, notation and reading tools. Engineers in the field are focusing further on having innovations in integration of assistive technologies – freeware and non-freeware tools – in addressing the needs of higher-functioning students with developmental and intellectual disabilities (Stock, Davies, Davies, & Wehmeyer, 2006); and legislators are even focusing on higher-quality innovations in the technologies as a requirement in Universal Design for Learning (UDL) in schools (Institute for Community Inclusion, 2017). Management of such integrated tools has to be an initiative of Offices of Disability Services and Offices of Special Technology Services of post-secondary institutions, in order to maximize the potential of the tools for students with mental and other disabilities. Methodology has to be particularized for those with disabilities in the schools. The implication of further costs for increased integrated non-freeware technology tools for those with disabilities is an issue that may preclude immediate investment in the technologies.

Assistive device technology can be helpful to students with disabilities only if they have the desire to be helped by the tools. Desiring to be in an inclusion program in a post-secondary institution (www.thinkcollege.net), as in the Seidenberg School of Computer Science and Information Systems at Pace University, can be a facilitator of motivation that can be helped by the tools. Findings from the perceptions of the higher-functioning students with developmental and intellectual disabilities are indicating elements of enthusiasm and of high motivation (Kinash, Brand, & Mathew, 2012) with the device tools that may be even facets in the likelihood of improved learning performance. Moreover, motivation from the parents of the students may be helpful in the process (Rodriguez, Strnadova, & Cumming, 2014). The final implication of motivation of the students with disabilities to be in an inclusion program with particularized

technology tools is a pre-requisite for post-secondary institutions pursuing such programs and providing as required the investment in the scope of the technology tools.

LIMITATIONS AND OPPORTUNITIES

This paper is constricted by preliminary findings on a limited number of app calendar organization tools in the current literature for a limited population of students with disabilities at one university. The findings are limited moreover by a population of students with mental disabilities exclusive of students with physical disabilities that may or may not benefit from such low-technology tools. Nevertheless, the field of app assistive digital technology is frequently initiating new tools for those with disabilities (Boser, Goodwin, & Wayland, 2014). Further research is needed therefore as the new tools are introduced for those higher-functioning types with disabilities joining inclusion programs of universities. This paper is a foundation for further pursuing performance results on these students.

CONCLUSION

This paper is evaluating applications of calendar organization tools for students with disabilities. Focusing on higher-functioning students with developmental and intellectual disabilities (IDD), the authors are finding from the perceptions of the students that such tools, as examples of low mobile computing technology, can be as generally helpful to them as the tools are to students without disabilities. The helpfulness of the device tools in furnishing the likelihood of organizational skills is especially important in furnishing the independence skills of higher-functioning students with disabilities to perform with productivity skills as proudly and as self-sufficiently as those students without disabilities. Improving the rights of those with moderately impaired disabilities to diverse technology tools is important for them to be fruitfully included in inclusion programs of post-secondary institutions and is important for administrators exploring innovative methods integrating the tools in their institutions. For further research, this paper will be expanded in the study of assistive mobile computing tools for those with disabilities.

ACKNOWLEDGEMENT OF FUNDING

The authors acknowledge aggregate award funding of $1,500 as competitive stipends funded by the Office of Provost – Office of Student Success of Pace University to perform this study.

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APPENDIX

www.thinkcollege.net

(College Inclusion Programs for Students with Developmental and Intellectual Disabilities)

www.enablingdevices.com

(Special Technology Tools for Students with Developmental and Intellectual Disabilities)

- iPad Accessories
- Adapted Electronics
- Adapted Therapeutic Learning
- Capability Switches
- Classroom Ready Kits
- Communicators
- Mounting Devices
- Sensory Space
- Products for the Visually Impaired
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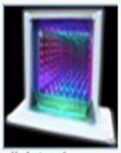
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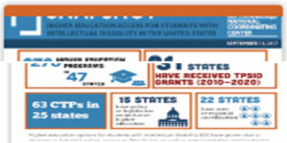

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Antecedents and Outcomes of Green Environmental Differentiation: A preliminary empirical analysis

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Abstract

As green supply chain management (SCM) practices continue to receive increasing attention from both local and global firms, there exist multiple opportunities to further investigate specific performance outcomes of green SCM practices and research how firms can position themselves to benefit from those practices. The purpose of this study is to develop and test a model that highlights the critical role of environmental differentiation. A theoretical model is proposed to explore the relationship between environmental differentiation and a series of antecedents and performance outcomes. Structural equation modeling and survey data from over 300 supply chain, logistics, purchasing, and operations executives are used to test the research hypotheses. Preliminary empirical results confirm the relationships between different enablers and performance outcomes of environmental differentiation. The findings presented in this study provides a relevant foundation for further research and practice in a current and important SCM topic.

Keywords: Empirical studies, environmental differentiation, green supply chain management, supply chain management

1. Introduction

Balancing efficiency and effectiveness to improve competitiveness and performance is the focus of supply chain management (SCM) practices (Mentzer, Min, & Zacharia, 2000). The development and implementation of green supply chain practices has been one path firms seek to balance these two strategic goals. Green practices have received significant attention from supply chain scholars and managers over the past two decades, yet multiple opportunities remain to further investigate specific performance outcomes of green practices and how firms position themselves to realize these outcomes (Wang et al., 2017). One reason these opportunities remain is related to the fact that managers continue to doubt that green initiatives can be beneficial to their firms, despite evidence to the contrary from academic research (Kirchoff, Omar, & Fugate, 2016).

An outcome of interest in the SCM performance literature is differentiation (Fugate, Mentzer, & Stank, 2010; Mentzer et al., 2001). Kirchoff, Tate, and Mollenkopf (2016) expanded the differentiation construct as an outcome in the SCM literature to include environmental differentiation. This is not a new concept; Delmas, Russo, and Montes-Sancho (2007) and Lucas and Noordewier (2016), for example, used environmental differentiation to illustrate how firms can improve performance. Differentiation has also been considered a strategic means to achieving other performance outcomes, such as increased sales and competitive advantage (Porter, 2008). Surprisingly, the literature has yet to extend this discussion to the impact of environmental differentiation on financial and operational performance outcomes.

The purpose of this research is to develop and test a model that highlights, from a SCM perspective, the critical impact of environmental differentiation on various financial and operational outcomes. To accomplish this research objective, a theoretical model is proposed to

explore the relationship between environmental differentiation and a series of antecedents and performance outcomes. Structural equation modeling and survey data from almost 350 supply chain, logistics, purchasing, and operations executives are used to test the research hypotheses.

The rest of the paper is organized as follows: The next sections describe and integrate the theories and the relevant literature into a theoretical model of environmental differentiation. The authors then present the methodology. The last sections discuss the results, and summarize a series of conclusions, limitations and directions for future research.

2. Theoretical Background

The resource based theory (RBT) is useful to investigate the enablers and outcomes that influence supply chain managers' perceptions toward the adoption of different green supply chain practices (Vachon & Klassen, 2006). The RBT explains that firms attempt to identify, develop and employ the strategic resources that are perceived to yield the best returns (Sirmon, Hitt, & Ireland, 2007). Firms that tie strategic resources to green practices in their supply chains and in their operations may be in a position to differentiate themselves from the competition, improve firm performance and create a competitive advantage (Vachon & Klassen, 2008; Zhu & Sarkis, 2004). Differentiation is considered a resource that focuses on creating value for the firm through benchmarking and adherence to best practices to differentiate their supply chains from the competition (Fugate et al., 2010). The resource of environmental differentiation has been defined as environmental management that focuses on environmental product/service characteristics and environmental product/service markets (Christmann, 2000). Environmental differentiation ultimately represents a resource that equates the ability of managers to create

environmentally friendly products/services and processes that translate positive performance results for the firm (Stead & Stead, 1995).

2.1. Antecedents of Environmental Differentiation

The concept of environmental differentiation as a resource is based on product/service and process offerings that are unique, difficult to replicate, and discernable from the competition to customers. Firms that can provide products/services that are designed, manufactured and delivered to the end customer through processes that are less impactful on the environment can differentiate themselves from the competition (Reinhardt, 1998). Two primary areas of differentiation are green design and green environmental management.

Green design or design for environment is a key consideration in green SCM as nearly 80% of the lifetime cost of a product is ensured during its design phase (Pujari, Wright, & Peattie, 2003). Product/service design is created through intra-organizational cross-functional teams and inter-organizational collaboration with members of the supply chain. Green product/service design represents one way firms differentiate themselves from the competition. The following hypothesis is therefore proposed:

H1: *Green design directly and positively impacts environmental differentiation.*

Environmental management relates to the actions, processes and procedures in place that support the overall environmental objectives of a firm (Zhu & Sarkis, 2004). The actions of top and middle management are key to supporting the goals and objectives of SCM (Mentzer et al., 2001). Processes such as ISO 14001 certification, environmental auditing of departments, and eco-labeling of products/services are part of environmental management and help create

differentiation in the firm's operations (Klassen & Johnson, 2004). Thus, we propose the following:

H2: *Environmental management directly and positively impacts environmental differentiation.*

2.2. Performance outcomes of environmental differentiation

Companies recognize that products and services designed with life cycle considerations in mind can lead to cost savings throughout the life of the product/service through less material, less waste, and lower disposal and recycling fees (Green, Morton, & New, 1996). Environmental processes create differentiation as they are geared toward reducing inefficiencies by coordinating engineering, quality, and marketing departments, and the entire supply chain as an extension of total quality management (Handfield, Walton, Seegers, & Melnyk, 1997; Shrivastava, 1995; Walton, Handfield, & Melnyk, 1998). The implementation of green design and environmental management leads to environmental differentiation, which in turn has the potential to act as a firm resource to create positive outcomes (Lucas & Noordewier, 2016). These performance outcomes include financial measures of profitability and sales growth. Performance outcomes also include service and operational measures such as timeliness, product and service availability, and better inventory management. Thus, we propose:

H3. *Environmental differentiation directly and positively contributes to firm profitability.*

H4. *Environmental differentiation directly and positively contributes to firm growth.*

H5. *Environmental differentiation directly and positively contributes to timeliness.*

H6. *Environmental differentiation directly and positively contributes to product/service availability.*

H7. *Environmental differentiation directly and positively contributes to inventory management.*

3. Theoretical Model and Research Hypotheses

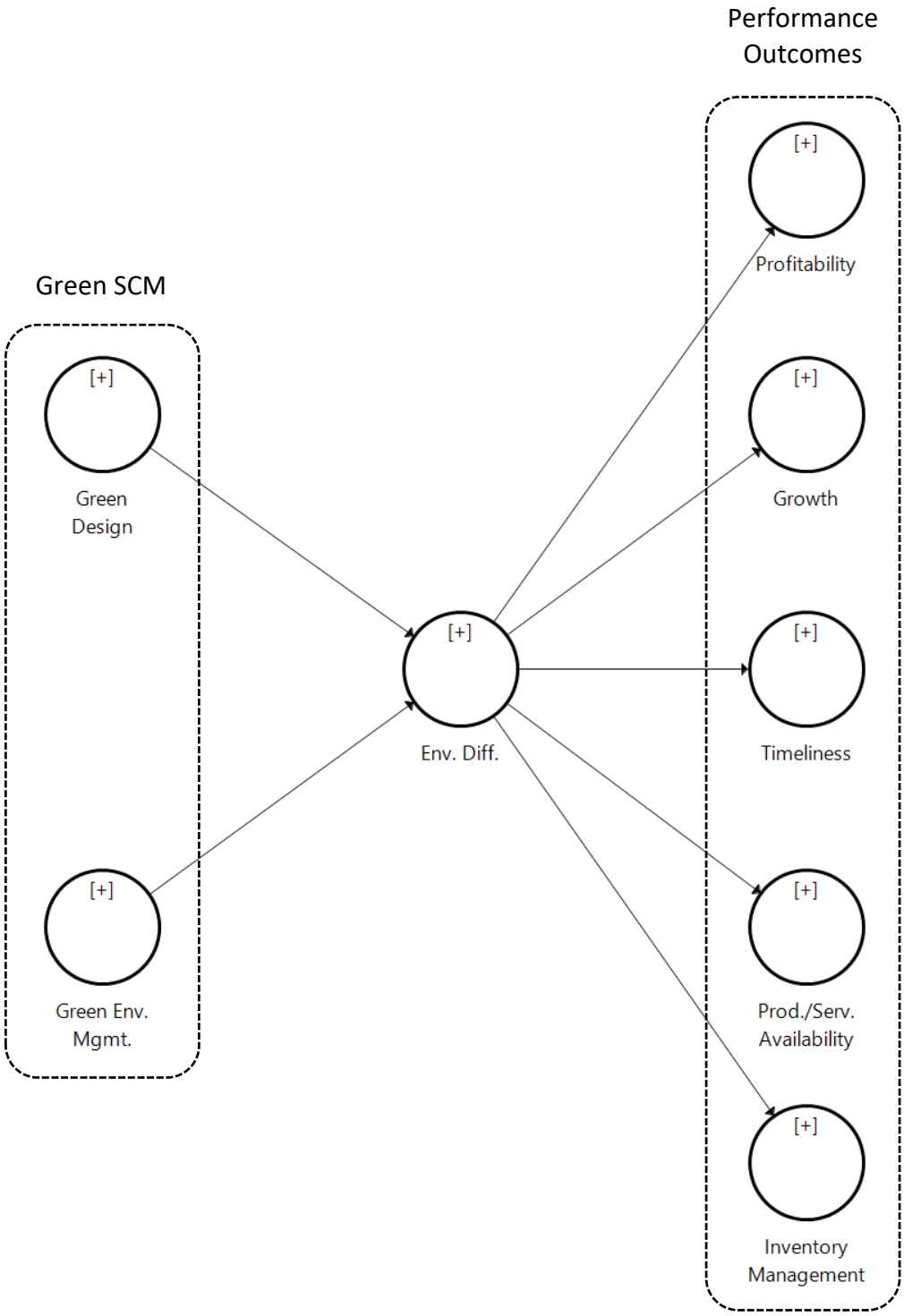
This research adapts a series of enablers and outcomes of perceived environmental differentiation from the literature. In the proposed framework, environmental differentiation represents the degree to which green supply chain management practices focus on environmental product/service characteristics, and is measured in terms of the extent to which the objectives of environmental compliance, product/service and process differentiation are met, relative to the competition. Green SCM practices represent practices aimed at the management of the upstream and downstream supply chain in order to minimize the environmental impact of the different forward and reverse supply chain flows. In this study, green SCM is measured as the extent to which environmental management and green environmental design occur within a firm SCM practices.

Performance outcomes, on the other hand, represent the extent to which a firm's resources are employed effectively and efficiently in the management of its supply chain, and the degree to which performance goals are met by a firm's SCM. The different outcomes are measured in terms of the degree to which a firm, relative to the competition, achieves operating expense reductions, working capital and fixed capital efficiencies, revenue enhancement through product/service availability, as well as market share, sales and return on sales (ROS) growth.

The resulting theoretical framework links two antecedents (*green design* and *green environmental management*) and five firm performance outcomes of environmental

differentiation (*firm profitability, firm growth, timeliness, product/service availability* and *inventory management* performance). The proposed model is presented in Figure 1.

Figure 1. Theoretical model



4. Methodology

4.1. Survey Development and Data Collection

A web-based survey was developed to test the research hypotheses presented in previous sections. The constructs were operationalized and measured using items originally developed and validated by Banerjee, Iyer, and Kashyap (2003), Bowen, Cousins, Lamming, and Farukt (2001), Christmann (2000), Fraj-Andrés, Martinez-Salinas, and Matute-Vallejo (2009), Melnyk, Sroufe, and Calantone (2003), Min (2001), Min, Mentzer, and Ladd (2007), Zhu and Sarkis (2004) and Zhu, Sarkis, and Lai (2008) (Refer to Table I). The different items included in the survey represent perceptual measures of manager's opinions. All survey items utilized a seven-point Likert type scale ranging from 1 to 7.

The target population consisted of senior supply chain executives as well as logistics, purchasing, and operations executives with knowledge of strategic SCM practices and processes, boundary-spanning aspects of SCM, corporate green attitudes and culture, as well as the behavior of main competitors.

A database containing contact information of potential participants was purchased from a leading commercial data, analytics and insights company. The potential participants included in the database came from diverse industry backgrounds, helping establish a higher level of external validity from a survey research standpoint (Cook & Campbell, 1979).

The database contained information for 3,437 potential respondents. Four rounds of e-mails were sent to the potential survey participants. A total of 367 survey responses were obtained during the data collection stage for a total response rate of 10.7% of the potential participants. Out of that total, 346 responses were deemed usable.

Non-response bias was assessed by comparing early versus late respondents (Armstrong & Overton, 1977). Since the *p*-values for all the comparisons across all survey items were not significant at the 0.05 level, non-response bias was deemed to not be a threat to the integrity of the data.

4.2. Data Analysis

The proposed model was assessed using the set of survey responses. Descriptive statistics for all survey items are presented in Table I.

Table I. Survey scale items

Item	Mean	Std. Dev.
Green Design (Adapted from Zhu et al. (2008), Zhu and Sarkis (2004) and Melnyk et al. (2003))		
To what extent are the following actions enacted within your supply chain management practices? (1 = 'Not considering it', 7 = 'Implementing it successfully')		
GD1. The design or redesign of products/services to reduce consumption of material and/or energy.	4.870	1.981
GD2. The design or redesign of products/services for recovery, reuse, recycling, and/or remanufacturing.	4.457	2.235
GD3. The design or redesign of products/services to avoid or reduce use of hazardous substances.	4.769	2.234
GD4. The design or redesign of products/services to reduce the overall environmental impact of the product/service.	4.303	2.226
Green Environmental Management (Adapted from Zhu et al. (2008) and Bowen et al. (2001))		
To what extent are the following actions enacted within your business unit? (1 = 'Not considering it', 7 = 'Implementing it successfully')		
GEM1. Environmental performance metrics are used regularly by corporate management	3.957	2.424
GEM2. Cross-functional cooperation to create environmental improvements in the supply chain.	3.682	2.248
GEM3. Implementation of total quality environmental management (TQEM).	2.948	2.156
GEM4. Environmental compliance and auditing programs in all departments.	4.006	2.382
GEM5. ISO 14001 certification.	2.893	2.353
Environmental Differentiation (Adapted from Melnyk et al. (2003) and Christmann (2000))		
Respond to each of the following based on the performance of your business unit over the past three (3) years, relative to your competitors (1 = 'Far below competitors', 7 = 'Far above competitors').		
ED1. Eco-friendly reputation.	4.555	1.050
ED2. Breadth of eco-friendly product/service range.	4.621	1.061
ED3. Revenue generated from eco-friendly products/services.	4.251	0.966
ED4. Eco-friendliness of returns programs.	4.370	0.983

Table I. Survey scale items (Continued)

Item	Mean	Std. Dev.
Profitability (Adapted from Min et al. (2007) and Min (2001)) *Respond to each of the following based on the performance of your business unit over the past three (3) years, relative to your competitors (1 = 'Far below competitors', 7 = 'Far above competitors').*		
PP1. Return on assets (ROA).	4.960	1.106
PP2. Supply chain costs as a percent of revenue.	5.020	1.116
PP3. Return on investment (ROI).	5.061	1.048
PP4. Return on sales (ROS).	5.078	1.159
Growth (Adapted from Min et al. (2007) and Min (2001)) *Respond to each of the following based on the performance of your business unit over the past three (3) years, relative to your competitors (1 = 'Far below competitors', 7 = 'Far above competitors').*		
PG1. Market share growth.	5.165	1.240
PG2. Sales growth.	5.159	1.178
Timeliness (Adapted from Min et al. (2007) and Min (2001)) *Respond to each of the following based on the performance of your business unit over the past three (3) years, relative to your competitors (1 = 'Far below competitors', 7 = 'Far above competitors').*		
PT1. Order-to-delivery cycle time.	5.133	1.165
PT2. Order-to-delivery cycle time consistency.	5.202	1.165
PT3. Providing customers real time information about their order.	4.991	1.314
Product/Service Availability (Adapted from Min et al. (2007) and Min (2001)) *Respond to each of the following based on the performance of your business unit over the past three (3) years, relative to your competitors (1 = 'Far below competitors', 7 = 'Far above competitors').*		
PPSA1. Consistent stock availability.	5.283	1.163
PPSA2. Ability to handle customer emergencies (i.e. stock outs).	5.702	1.068
Inventory Management (Adapted from Min et al. (2007) and Min (2001)) *Respond to each of the following based on the performance of your business unit over the past three (3) years, relative to your competitors (1 = 'Far below competitors', 7 = 'Far above competitors').*		
PIM1. Average amount of physical inventory in our pipeline.	4.757	1.242
PIM2. Physical inventory turnover.	4.971	1.221

The measurement model assessment included an analysis of the internal consistency of the constructs, the reliability of the individual indicators, as well as the convergent validity of the constructs. With respect to the measurement model fit, a standardized root mean square residual

(SRMR) value of 0.059 suggested good overall model fit (Henseler et al., 2014; Hu & Bentler, 1998). Reliability estimates were calculated for all constructs to evaluate their internal consistency reliability. The resulting estimates exceeded the 0.70 cutoff recommended by Nunnally (1979), indicating adequate internal consistency for the five constructs (Refer to Table II).

Table II. Construct reliability and validity

Construct	Cronbach's Alpha	rhoA	Composite Reliability	AVE
Env. Diff._	0.879	0.882	0.917	0.734
Green Design	0.798	0.825	0.869	0.624
Green Env. Mgmt.	0.874	0.890	0.908	0.665
Growth	0.924	0.931	0.963	0.929
Inventory Management	0.738	0.917	0.876	0.780
Prod./Serv. Availability	0.730	0.784	0.878	0.784
Profitability	0.878	0.883	0.917	0.735
Timeliness	0.792	0.821	0.876	0.703

At the item level, reliability was evaluated using outer loadings (Refer to Table III). In this respect, all survey items had loadings above the desired cutoff of 0.70 (Hair, Black, Babin, & Anderson, 2010).

Table III. Outer Loadings

Item	Outer Loading	*p*-Value
ED1	0.850	< 0.001
ED2	0.876	< 0.001
ED3	0.869	< 0.001
ED4	0.830	< 0.001
GD1	0.759	< 0.001
GD2	0.754	< 0.001
GD3	0.745	< 0.001
GD4	0.893	< 0.001
GEM1	0.842	< 0.001
GEM2	0.868	< 0.001
GEM3	0.801	< 0.001
GEM4	0.804	< 0.001
GEM5	0.757	< 0.001
PG1	0.968	< 0.001
PG2	0.960	< 0.001
PIM1	0.815	< 0.001
PIM2	0.946	< 0.001
PP1	0.817	< 0.001
PP2	0.908	< 0.001
PP3	0.789	< 0.001
PP4	0.908	< 0.001
PPSA1	0.923	< 0.001
PPSA2	0.846	< 0.001
PT1	0.807	< 0.001
PT2	0.901	< 0.001
PT3	0.804	< 0.001

Average Variance Extracted (AVE) estimates were calculated for all the different constructs in order to establish convergent validity (Refer to Table II). The results indicated that all constructs explained at least half of the variance of the corresponding indicators, suggesting acceptable convergent validity.

An examination of the constructs' discriminant validity was also included in the assessment of the measurement model. To determine whether the constructs met the conditions

for discriminant validity, the authors analyzed cross-loadings, heterotrait-monotrait (HTMT) ratios of correlations, and the Fornell-Larcker criterion.

Cross-loadings were examined first (Refer to Table IV). In this respect, all the item loaded higher on the hypothesized constructs than on the remaining constructs, providing evidence for the constructs' discriminant validity (Hair et al., 2016).

Table IV. Discriminant validity (Cross-loadings)

	Construct							
Item	**Env. Diff.**	**Green Design**	**Green Env. Mgmt.**	**Growth**	**Inventory Mgmt.**	**Prod./Serv. Availability**	**Profitability**	**Timeliness**
ED1	**0.850**	0.420	0.402	0.206	0.215	0.129	0.257	0.192
ED2	**0.876**	0.448	0.348	0.224	0.240	0.146	0.237	0.233
ED3	**0.869**	0.373	0.335	0.238	0.313	0.148	0.311	0.294
ED4	**0.830**	0.423	0.330	0.267	0.322	0.216	0.273	0.372
GD1	0.315	**0.759**	0.394	0.149	0.086	0.081	0.118	0.138
GD2	0.343	**0.754**	0.375	0.100	0.062	0.089	0.085	0.048
GD3	0.376	**0.745**	0.379	0.076	0.131	0.111	0.087	0.128
GD4	0.475	**0.893**	0.583	0.110	0.097	0.100	0.105	0.062
GEM1	0.345	0.452	**0.842**	0.147	-0.014	0.046	0.106	0.028
GEM2	0.406	0.545	**0.868**	0.124	0.103	0.111	0.134	0.086
GEM3	0.350	0.480	**0.801**	0.117	0.128	0.125	0.178	0.125
GEM4	0.283	0.436	**0.804**	0.098	0.021	0.052	0.139	0.056
GEM5	0.262	0.328	**0.757**	0.109	-0.048	0.054	0.102	0.082
PG1	0.278	0.135	0.154	**0.968**	0.275	0.366	0.531	0.334
PG2	0.251	0.125	0.128	**0.960**	0.239	0.363	0.503	0.314
PIM1	0.192	0.034	0.037	0.197	**0.815**	0.376	0.412	0.496
PIM2	0.344	0.149	0.057	0.265	**0.946**	0.407	0.489	0.629
PP1	0.259	0.110	0.149	0.464	0.401	0.436	**0.817**	0.414
PP2	0.289	0.110	0.144	0.503	0.491	0.480	**0.908**	0.486
PP3	0.253	0.103	0.132	0.353	0.435	0.412	**0.789**	0.429
PP4	0.280	0.103	0.133	0.512	0.430	0.397	**0.908**	0.437
PPSA1	0.191	0.154	0.136	0.304	0.404	**0.923**	0.459	0.523
PPSA2	0.138	0.043	0.022	0.381	0.376	**0.846**	0.434	0.557
PT1	0.294	0.111	0.125	0.258	0.446	0.432	0.348	**0.807**
PT2	0.307	0.127	0.049	0.292	0.634	0.548	0.487	**0.901**
PT3	0.188	0.024	0.053	0.310	0.554	0.563	0.485	**0.804**

The Fornell-Larcker criterion (Fornell & Larcker, 1981) was also used to assess the constructs' discriminant validity. These results are displayed in Table V. The square roots of the AVEs for all constructs were higher than the corresponding correlations with the other latent variables included in the proposed model, suggesting that all constructs represent measures of unique concepts.

Table V. Discriminant validity (Fornell-Larcker criterion)

Construct	1.	2.	3.	4.	5.	6.	7.	8.
1. Env. Diff.	0.857							
2. Green Design	0.486	0.790						
3. Green Env. Mgmt.	0.411	0.559	0.816					
4. Growth	0.275	0.135	0.147	0.964				
5. Inventory Management	0.322	0.120	0.056	0.267	0.883			
6. Prod./Serv. Availability	0.190	0.121	0.099	0.378	0.440	0.885		
7. Profitability	0.316	0.124	0.162	0.537	0.513	0.503	0.857	
8. Timeliness	0.325	0.115	0.093	0.336	0.647	0.603	0.516	0.839

Note: Square root of the AVE on diagonal in bold.

Next, the Heterotrait-Monotrait (HTMT) criterion (Henseler et al., 2015) was used to further analyze the constructs' discriminant validity. Table VI displays the results of this portion of the analysis. Since all of the estimates were smaller than 0.85, the results indicate satisfactory discriminant validity for all constructs (Henseler et al., 2015).

Table VI. Discriminant validity (HTMT Criterion)

Construct	1.	2.	3.	4.	5.	6.	7.	8.
1. Env. Diff.								
2. Green Design	0.570							
3. Green Env. Mgmt.	0.462	0.645						
4. Growth	0.302	0.161	0.162					
5. Inventory Management	0.369	0.133	0.090	0.313				
6. Prod./Serv. Availability	0.227	0.146	0.107	0.470	0.597			
7. Profitability	0.358	0.150	0.185	0.593	0.630	0.629		
8. Timeliness	0.367	0.142	0.118	0.398	0.832	0.810	0.628	

Variance Inflation Factor (VIF) values were finally analyzed to check the theoretical model for collinearity issues. Table VII displays VIF values of all combinations of exogenous and endogenous constructs.

Table VII. VIF values

Construct	Env. Diff.	Growth	Inv. Mgmt.	Prod./Serv. Availability	Profitability	Timeliness
Env. Diff.		1	1	1	1	1
Green Design	1.455					
Green Env. Mgmt.	1.455					

Since all the estimated VIF values were below the suggested threshold of five (Hair et al., 2016), collinearity was not deemed an issue.

5. Results

5.1. Hypotheses Testing

The research hypotheses were simultaneously tested using SmartPLS, a partial least squares structural equation modeling (PLS-SEM) software that has been found to perform well even with small samples (Hair, 2011). A summary of the hypotheses test results is displayed in Table VIII.

Table VIII. Summary of hypotheses test results

Hypothesis	Path	St. Weights	*p*	Conclusion
H1	Green Design -> Env. Diff.	0.372	<0.001	Supported
H2	Green Env. Mgmt. -> Env. Diff.	0.203	<0.001	Supported
H3	Env. Diff. -> Profitability	0.316	<0.001	Supported
H4	Env. Diff. -> Growth	0.275	<0.001	Supported
H5	Env. Diff. -> Timeliness	0.325	<0.001	Supported
H6	Env. Diff. -> Prod./Serv. Availability	0.190	<0.001	Supported
H7	Env. Diff. -> Inventory Management	0.322	<0.001	Supported

In terms of the antecedents of environmental differentiation, *H1*, which examined the relationship between green design practices and perceived environmental differentiation, was supported with a standardized regression weight of 0.372 and a *p*-value significant at the 0.001 level. Green environmental management practices were also found to have a positive impact on perceived environmental differentiation (*H2* supported with a standardized regression weight of 0.203 and a *p*-value significant at the 0.001 level).

The resulting standardized path coefficients are expressed in terms of units of standard deviation and can be interpreted as follows: if green design were increased by one standard deviation while all other variables were held constant, perceived environmental differentiation would be expected to increase by 0.372 standard deviations. On the other hand, an increase equal to one standard deviation in green environmental management would be expected to result in an increase in perceived environmental differentiation of 0.211 standard deviations, all other variables held constant. The study results therefore suggest that, in terms of standardized units, the direct effect of green environmental management practices appears to be smaller than the effect of green design practices on perceived environmental differentiation.

With respect to the performance outcomes of environmental differentiation, *H3*, which examined the relationship between environmental differentiation and profitability, was supported with a standardized regression weight of 0.316 and a *p*-value significant at the 0.001 level. Perceived environmental differentiation was also found to be related to growth (*H4* supported with a standardized regression weight of 0.275 and a *p*-value significant at the 0.001 level), timeliness (*H5* supported with a standardized regression weight of 0.325 and a *p*-value significant at the 0.001 level), and product/service availability (*H6* supported with a standardized regression weight of 0.190 and a *p*-value significant at the 0.001 level). Finally, environmental differentiation was found to have a positive impact on perceived inventory management benefits as *H7* was supported with a standardized regression weight of 0.322 and a *p*-value significant at the 0.001 level. The preliminary results thus suggest that environmental differentiation is significantly linked to all five performance outcomes.

6. Conclusions

While green SCM has received significant attention from both supply chain academics and practitioners, the literature has yet to characterize the impact of environmental differentiation on specific financial and operational performance outcomes.

The purpose of this research was to develop and test a model that highlights the critical role of environmental differentiation as a resource that can improve firm performance. A theoretical model that explored the relationship between environmental differentiation and different antecedents and performance outcomes was proposed. Structural equation modeling and survey data was used to test the research hypotheses.

The preliminary empirical results confirmed the relationships between different enablers and performance outcomes of environmental differentiation. The study findings provide scholars and practitioners with empirical evidence of the financial and operational benefits of successfully implementing green SCM practices. The conceptual model developed in the study presents practitioners with a framework for assessing current green SCM initiatives. Overall, the findings presented in this study provides a relevant foundation for further research and practice in a current and important SCM topic.

6.1. Limitations and Future Research Opportunities

A number of research limitations should be pointed out. First, a longitudinal approach would be preferred over the study's snapshot approach. A longitudinal study would allow researchers to investigate additional issues related to the adoption and outcomes of green SCM practices by measuring changes in managerial perceptions over time.

Another limitation is related to the fact that all survey participants were from the United States, which limits the study's generalizability to different cultures and geographical regions. Researchers should investigate the use and impact of environmental differentiation in non-U.S. companies to see if differences/similarities exist.

Finally, the antecedents to environmental differentiation are limited in their scope. Future research should look at expanding the antecedents to include, for example, corporate culture, industry, and experience with green initiatives.

Limitations notwithstanding, the research presented in this study adds to the growing empirical literature on green SCM, and provides, as discussed above, a springboard for further investigations into efficient and effective green supply chain operations.

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