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A FRAMEWORK FOR ANALYZING DECISION AID USER INTERACTIONS WITH DECISION AIDS

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ABSTRACT

This paper presents a model that describes how decision aid users interact with decision aid recommendations. Past research assumes that users reject a decision aid recommendation if they disagree and rely upon a decision aid recommendation if they agree with the recommendation. In fact, user interaction with an aid may be more complex and is influenced by organizational policy regarding relying upon an aid recommendation and the perceived utility, self-perception, and impression management gained through relying upon an aid. Understanding user interaction with a decision aid recommendation presents opportunities to further decision aid research. The model may also be useful in setting an organization context of using decision aids.

INTRODUCTION

Whether a decision aid is accepted by its users is an important question in decision aid research. Systems acceptance in general is a crucial question in information systems research. This paper presents a framework for analyzing user acceptance of decision aid recommendations. A pair of frameworks already exist that focus on antecedents of decision aid acceptance or rejection. The framework presented in this paper focuses on the decision aid user's actual decision about whether to accept a decision aid recommendation. The framework is based on the Social Response Context Model (MacDonald et al., 2004), and is useful for predicting how decision aid users may react to different social contexts in using decision aids.

This framework is useful in two ways. First, it provides guidance for future research on decision aid reliance. Most research on decision aid reliance focuses on factors that are associated with decision aid reliance without placing those factors within a larger context. This has led to a fragmented understanding of decision aid reliance. Development of a framework can guide the structure of future research. Second, a framework can guide implementers of decision aids both in recognizing pitfalls of an implementation and in devising strategies to increase decision aid reliance. The following sections will review the research literature regarding decision aids and present the framework.

DECISION AIDS

Decision aids may be used for a variety of purposes, such as improving group communications, promoting creativity, or assisting data gathering. For the context of this paper, a decision aid is a tool used to recommend a solution to a problem. Research on decisions aids has sought to answer two related questions. First, does using a decision aid improve the quality of a decision? Second, are decision aid users willing to use a decision aids recommendation?

Decision aids regularly outperform decision makers' un-aided decisions (Dawes et al., 1989). Examples of decisions aids that have been shown to have superior accuracy to experts include bankruptcy prediction (Sun, 2007), management fraud assessment (Hansen et al., 1996; Eining & Jones, 1997; Bell & Carcello, 2000), and audit materiality judgment (DeZoort et al., 2006). In addition to improving accuracy, firms may adopt decision aids to guide or direct a decision process (Silver, 1990).

Even though decision aids tend to improve the quality of a decision and promote firm goals, decision aid recommendations are often ignored by users. Investigating what encourages or discourages users to accept or reject decision aid recommendations has long been an area of interest to researchers. A firm implementing a decision aid would find the aid useless without users being willing to adopt the aid's recommendation. Indeed, may decision aids used by audit firms have fallen into disuse (Gill, 1995).

Probably the most common finding in research is that more expert users are less likely to rely upon a decision aid than novice decision makers (Arkes et al., 1986; Whitecotton, 1996; Glover et al., 1997). This seems intuitive, as more experienced decision makers have more confidence in their decision ability than novices. Other factors such as incentives, perceived validity of the aid, feedback, and user involvement also influence the extent of reliance on an aid (Ashton, 1990; Kottemann et al., 1994; Kaplan et al., 2001). These features are summarized in a pair of models. The first model views decision aid user behavior as a function decision aid features, decision maker characteristics, decision task features, and decision environment (Brown & Eining, 1996). The second model is similar, but makes more explicit predictions that reliance is a factor of user experience, task complexity, familiarity with the decision aid, and cognitive fit (Arnold & Sutton, 1998). Both of these models are mainly summaries of prior research.

A model that relies upon a different approach is based upon the theory of planned behavior (Dowling, 2009), which is commonly used in many research domains to explain behavior. This model has several differences from the other frameworks. Dowling's framework is based upon perceptions of users' actual experience with aids as opposed to a laboratory experiment. The aids varied widely. Reliance was measured as the user's intention to use the aid as the firm intended. The other research measured reliance as the extent that the users' decisions were the same as the decision aid recommendation. The antecedents to reliance included attitude toward the aid, social norms toward using the aid, self efficacy in using the aid, and external control over using the aid. I propose a distinct framework that, rather than viewing

reliance as a simple rely/not rely dichotomy, develops a more diverse description of the actual reliance decision.

DECISION AID SOCIAL RESPONSE

Experimental research on decision aids usually uses a structured method in which study participants are given a set of inputs to a decision aid by the researcher. The participants enter the data into the decision aid, receive a recommendation, and then make a decision. The researcher compares the participants' decision to the aid recommendation to assess the level of reliance.

This is opposite from the optimal use of a decision aid. People are good at making subjective judgments, and aids are superior at combining variables to reach a solution (Kleinmuntz, 1990). People tend to exercise biases when combining variables. The optimal format for a decision aid is to combine subjective judgments from decision users. This is in fact a common format for audit decision aids. For example, audit firms rely upon auditors to make risk assessments about potential new clients; often, a decision aid is used to combine those judgments to make an overall recommendation about client acceptance.

One of the attributes of a decision aid is whether users are restricted to rely upon the aid (Silver, 1990). In most decision aid reliance research, users are restricted in their inputs to a decision aid. They have no choice in the inputs. But in actual practice, users are not restricted in the inputs they use. For example, in the new client acceptance decision, an auditor may make a set of subjective judgments assessing the risk of the potential client and enter these judgments into the aid (Shelton et al., 2001). Decision aids used in audit applications appear to usually follow this format (Dowling & Leech, 2007).

Given the assumption that decision aid users are not restricted to using objective inputs to the aid, this paper presents a model describing how users interact with a decision aid recommendation. The social context of the decision aid use may have a key impact in how users interact with the decision aid recommendation. Users may be required to use the decision aid recommendation or they may be free you regard the recommendation as advisory and adopt their own decision (Silver, 1990). For example, an aid may be used to select a sample size. If a sample size decision aid recommends a sample size of eighty, a user in a restrictive environment would select a sample of eighty items. A user in a non-restrictive environment may use the aid recommendation as advisory, but select a different number of items. Assuming that a decision aid user's opinion prior to using an aid differs from the aid's recommendation, it superficially appears that users interact with an aid in three ways. If the decision is restricted, the user adopts the aid's recommendation. If the decision is not restricted, the user may choose to accept the decision aid recommendation or not. However, the actual interaction may be more complex.

For example, if an aid's user is not restricted in the aids inputs, the aid's recommendation can be managed to equal the user's prior opinion. In a pair of studies, auditors adjusted tolerable

error and risk of material misstatement as aid inputs to manage the aid recommendation to be closer the users' prior opinion of an acceptable sample size (Kachelmeier & Messier, 1990; Messier et al., 2001). In this case, aid users privately disagree with an aid recommendation but are able to give the appearance of publicly agreeing with the aid.

To provide a descriptive model of how users interact with an aid recommendation, I reach into research on how people respond to persuasive efforts. A decision aid recommendation may be regarded as a piece of information intended to persuade the aid user or reviewers of a decision of the proper decision. The model I propose to use to analyze interaction with a decision aid recommendation is based on a model of conformity as a response to social influence (Figure 1) (Allen, 1965). However, Allen's model does not account for the contingency of users being required to publicly agree with a decision aid's recommendation. My model is shown in Figure 2.

FIGURE 1
ALLEN'S SOCIAL RESPONSE MODEL

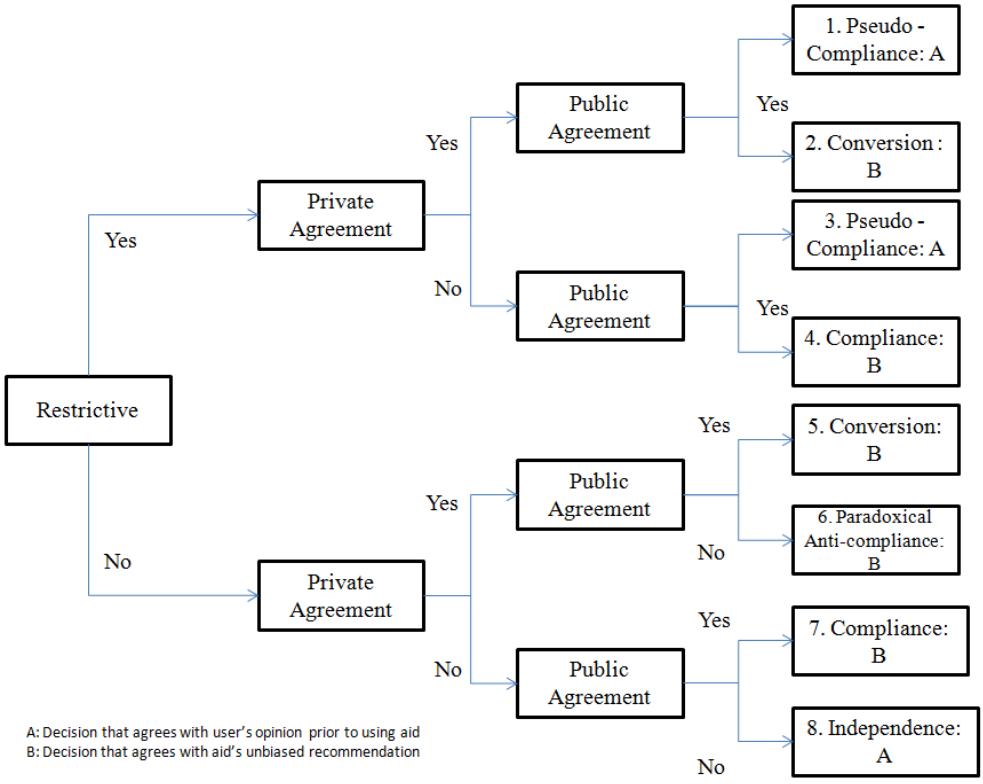
		Post Exposure Public: Agreement	Post Exposure Public: Disagreement
Post Exposure Private	Agreement	Conversion	Paradoxical Anticomplianc
	Disagreement	Compliance	Independence

I will call my model the Decision Aid Social Response model. It applies when a person's belief before using a decision aid is different than the decision aid's recommendation. This model is influenced by the Social Response Context Model (SRCM) (MacDonald et al., 2004). SCRM includes a greater variety of contingencies; for example, if someone has pre-exposure agreement with a social influence. I only adopt the components that fit the use of a decision aid and add environmental restrictiveness of using the aid. I also describe factors that influence different responses to using a decision aid.

The user's strategy is determined by one of three motivating forces involved in attitude change: utility, self-perception, and impression management (Wood, 2000). Utility refers to someone getting some advantage that increases well-being, self-perception refers to minimizing inner conflict (Festinger, 1957), and impression management refers to maintaining a positive

social image (Tetlock, 1991). I will review how these influence choice of strategy in using a decision aid by explaining Figure 2.

FIGURE 2
SOCIAL RESPONSE TO A DECISION AID



The far right hand column of Figure 2 indicates a user's strategy regarding a decision aid recommendation based on the contingencies to the left. Each strategy is labeled either with an A or a B. When users act based on their opinion prior to using an aid, a strategy is labeled A. When users act based on the aid's unbiased recommendation, the strategy is labeled B. Users' strategy are determined by a combination of their belief relative the aid's recommendation and the utility, self-perception, and impression management involved in each strategy.

Boxes 1 through 4 represent using an aid in a restrictive environment in which they are required by policy to act upon an aid's recommendation – a restrictive environment. Boxes 5 through 8 represent using an aid in an environment in which the user may or may not act upon an aid's recommendation – an un-restrictive environment. If a person uses a decision aid in a restrictive environment, that person will have to publicly agree, by policy, to the decision aid's recommendation. Perhaps the aid user is convinced that the aid is correct. This could happen if users' confidence in an aid is higher than their confidence in their own prior opinion. The users'

utility is maximized by acting on the best judgment, which the users believe to be the aid's recommendation. This state is referred to as conversion (box 2).

If the users do not privately agree with the aid's recommendation, but they are publicly compelled to act in compliance with the aid's recommendation, they can respond in one of two ways. Either they can accept the aid's unbiased recommendation (compliance, box 4) or they can give the appearance of compliance by changing the aids inputs to produce a recommendation consistent with their prior opinion (pseudo-compliance, box 3). Their actual strategy is likely to be determined by their relative confidence in or importance given to the inputs to the aid compared to the aid recommendation. Users who are focused more on inputs are more likely to comply with the aid recommendation, whereas users who focus more on the aid recommendation are more likely to manipulate the aid recommendation by changing the input.

In some unusual cases, users may agree with a decision aid recommendation, but act according to their pre-aid opinion (pseudo-compliance, box 1). In a restrictive environment, this would involve manipulating the aid's inputs to produce an output agreeing with the users' prior opinion. A user may follow this strategy because they may gain greater utility by avoiding the aid's unbiased opinion. For example, they may choose a smaller sample size than an aid's unbiased recommendation to avoid labor in situations in wish they perceive slight risk of a negative consequence. Alternatively, a user may use the aid to confirm a prior opinion. By manipulating the aid recommendation, the user is able to convince him- or herself that their opinion is valid, even if distinct from what the aid would recommend if not biased. Finally, a user in box 1 (pseudo-compliance) may manipulate an aid recommendation either to satisfy someone else (perhaps a superior that desires a different decision aid recommendation) or to maintain social status (maybe the user argued for a different position than the aid recommends without bias, so that the user manipulates the recommendation to avoid admitting error, even when the user believe him- or herself to be in error.)

Boxes 5 through 8 are similar to boxes 1 through 4, except that the user is not required to act consistently with an aid recommendation. Users in box 5 are converted to the decision aid recommendation and act upon it. Users in box 5 (paradoxical non-compliance) are converted to the decision aid recommendation, but act according to their prior belief, for the same reasons of utility, self-perception, or utility management that are outlined for pseudo-compliance. However, because these users are not constrained to adopt the decision aid recommendation, they do not need to manipulate it. They simply do not act upon the aid recommendation, even if they agree upon it. This would be most likely when a user is not held accountable for non-compliance with an aid's recommendation.

The final two boxes represent situations in which the user privately disagrees with an aid in an unrestricted environment. If they act upon their opinion rather than the aid's recommendation, they are independent of the aid. They may act based upon the decision aid's recommendation, even if they disagree with it, if they lack confidence or feel greater utility in following the aid for feel a need to satisfy someone else by following the aid's recommendation.

DISCUSSION

The model presented in this paper is designed to increase understanding of how decision aid users interact with decision aid recommendations. Understanding the behavior of decision aid users can aid future research and ultimately the social decision of decision aid implementation.

Prior research shows that decision aids commonly are used in practice and yield superior results to unaided judgment. Nevertheless, prior research also shows that users sometimes choose to not rely upon an aid. This paper's model shows that users' choices to rely upon an aid recommendation are more complex than a simple dichotomous yes/no response based upon whether they agree with the aid or not. User behavior may differ based upon whether decision aid reliance is required by policy. Aid users may publicly agree or disagree with an aid while privately disagreeing with an aid. In some situations, users may publicly disagree with an aid while privately agreeing with an aid. If a decision aid recommendation is a continuous value, such as a sample size, users' actions could be in fact a compromise between their own opinion and the aid's recommendation.

This model offers opportunity for research to validate the fit of the model with actual practice and to test the effect of different user behaviors. Understanding the model can also help implementers. Incentive and expectation structures can change user reliance behavior, and understanding how reliance behaviors are changed and what the effect of those changes are should be a consideration of an organization seeking to further its goals through implementation of a decision aid.

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SATISFACTION AND REPURCHASE INTENTION: B2B BUYER-SELLER RELATIONSHIPS IN MEDIUM-TECHNOLOGY INDUSTRIES

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ABSTRACT

Customer satisfaction and repurchase intentions are examined in B2B markets for medium-technology offerings; overall customer satisfaction and repurchase intention are modeled as functions of three components of overall satisfaction: satisfaction with the interpersonal relationship with the salesperson, satisfaction with vendor performance, and product satisfaction. The Chow test confirms that overall customer satisfaction is different than repurchase intention in medium technology industries. Information theoretic techniques are then applied to variable subset selection to derive optimal linear regression models for overall customer satisfaction and repurchase intention in medium-tech industries. Results explain approximately 64% of the variance of overall satisfaction and 37% of the variance of repurchase intention. The optimal model for overall satisfaction includes terms for all three components of satisfaction while the optimal model for repurchase intention includes terms for only product satisfaction and interpersonal satisfaction.

INTRODUCTION

It is important for supply chain practitioners to understand customers' repurchase intentions and the factors that influence repurchase intentions (Patterson, Johnson & Spreng, 1997) because increased repurchases (customer loyalty) are important to profitability (Fornell, 1992). Patterson, Johnson, and Spreng (1997), Shapiro, Slywotzky and Doyle (1997), and Preis (2003) find increased customer satisfaction is one factor leading to such increased repurchase intentions. Thus, it is important to obtain a good understanding of the factors that affect satisfaction and hence influence repurchase intentions.

While a great deal of research on customer satisfaction has been performed in consumer markets, the influence of customer satisfaction on supply chains has been largely ignored (Patterson, Johnson & Spreng, 1997; Szymanski & Henard, 2001; Homburg & Rudolph, 2000). Kellar and Preis (2003) show that the components of satisfaction that influence repurchase intention are different for high-tech and low-tech industries. This finding naturally leads to the question of whether components of satisfaction for offerings from industries that are neither high-tech nor low-tech, i.e., medium-tech, differ substantially from those from high-tech and

low-tech industries. Researchers have concentrated their attention on high-tech industries (e.g. Dunn & Probstein, 2003; van Hulst & Olds, 1993) but relatively little attention has been paid to medium-tech and low-tech industries. Medium-tech industries include industries that produce products such as coke, rubber products, nuclear fuel, railroad equipment, transport equipment, motor vehicles, trailers, electrical machinery, basic metals, basic chemicals, plastics, and refined petroleum products (OECD, 2009a).

REVIEW OF LITERATURE

As the investigation of customer satisfaction matures, the implicit assumption that customer satisfaction is a uniform construct across all product categories and in all markets has occasionally been questioned. Yi (1994), in a review of consumer satisfaction, anticipates that satisfaction varies from one product category to another when he questions, "Are the links between the variables different across consumers, products, or situations?" (p. 107). This suggests that the nature and characteristics of an industry may influence the aspects of the offerings that consumers use to evaluate their repurchase intentions.

Customer satisfaction has a significant impact on repurchase intention (e.g. Fornell, 1992; Oliver & Swan, 1989; Eggert and Ulaga, 2002) and is modeled as an overall emotion or judgment constructed of many components, i.e., a multi-attribute model. In industrial markets, Patterson, Johnson, and Spreng (1997) find that components of customer satisfaction have different relative weights than in consumer markets. Similarly, Kauffman (1994) shows that product attributes: physical, nonphysical, price, and distribution, are more or less important to industrial buyers depending on the product application, such as capital equipment, administrative, and production process. Kauffman (1994) also finds that differentiated products are evaluated differently than undifferentiated (commodity and hence low-tech) products.

Homburg and Rudolph (2000) state, "many firms producing and marketing industrial goods are strongly technically-minded implicitly assuming that the product is the most important source of customer satisfaction" (p. 30). The TQM and six-sigma concepts are implicitly based on this assumption. Moving beyond the quality of the offering, Homburg and Rudolph (2000) show that customer satisfaction consists of different components depending on the functional role of the individual within the buying organization. Our study builds on and extends this body of work by modeling and analyzing differences in the effects of the components of satisfaction on overall satisfaction and repurchase intention for offerings from medium-technology industries.

For B2B customer satisfaction and repurchase intention, Anderson and Sullivan (1993) find that low or negative measures of satisfaction have a stronger negative influence on repurchase intention than a similar positive measure of satisfaction has on positive intention to repurchase. This asymmetry suggests that customer repurchase intention and overall satisfaction should be modeled separately.

Overall customer satisfaction (*OVERALL*) has three principal components: satisfaction with the product, the company, and the salesperson (Crosby & Stephens, 1987). Product satisfaction (*SAT_PDT*) is the satisfaction that the buyer experiences with the offering and includes factors such as its durability, serviceability, and performance. Satisfaction with the company, or performance satisfaction (*SAT_PERF*), is the buyer's satisfaction with the performance of the vendor organization on such items as on-time delivery, invoicing accuracy, and warranty support. Interpersonal satisfaction (*SAT_REL*) is the buyer's satisfaction with the relationship with the salesperson and includes such evaluations as the salesperson's trustworthiness, knowledge, ability to solve problems, communications ability, and personality. Preis and Kellar (2003a) extend these findings by using the same components of satisfaction to develop optimal linear regression models for customer satisfaction in low-tech industries.

These findings raise the question of how important these same factors are for offerings from medium-technology industries. This study seeks to answer that question. In addition, we seek to extend the findings to repurchase intention (*REBUY*). The conceptual framework of the relationships influencing overall satisfaction and repurchase intention is shown in Figure 1. This study restricts its attention to the shaded area of this conceptual framework.

HYPOTHESIS DEVELOPMENT

Oliver and Swan (1989) and Preis (2003) show that customer satisfaction is related to customers' intentions to repurchase the same product, however no distinction is made between products with different levels of technology. However, as noted above, Anderson and Sullivan (1993) suggest that customer repurchase intention and overall satisfaction should be modeled separately. This conclusion is consistent with previous research focused on offerings from high-tech industries where Kellar and Preis (2003) find that *SAT_PERF* has, at most, weak influence on repurchase intention while all three components of satisfaction have significant influence on overall customer satisfaction (Preis & Kellar, 2003b). Since high-tech industries are proximate to medium-tech in R&D intensity, we expect similar results in medium-tech industries. This leads to our first hypothesis:

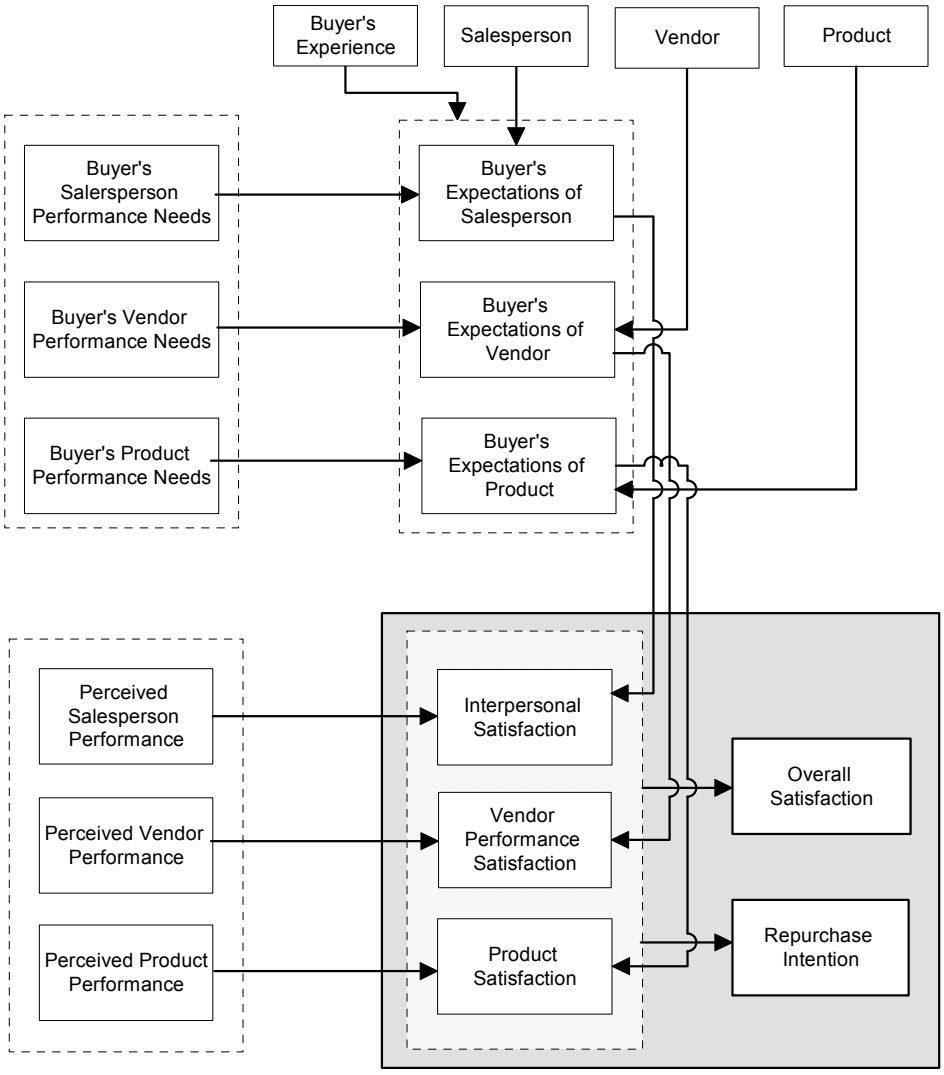
H1: Overall satisfaction and repurchase intention should be modeled separately for medium-technology industries.

Since Preis and Kellar (2003b) find that an optimal model of customer satisfaction for high-tech industries includes all three components of satisfaction, it is natural to question whether or not an optimal model of overall customer satisfaction for medium-tech industries will include all components of satisfaction. Since all three independent variables have been shown to be important in customer satisfaction and since high-tech industries are proximate to medium-

tech in R&D intensity, we expect similar results in medium-tech industries. Therefore, we propose:

H2: The full model should be used to model overall customer satisfaction for medium-tech industries.

Figure 1
Conceptual Framework of Customer Satisfaction and Repurchase Intention. This paper is restricted to examining the relationships in the shaded box.



A quick review of the literature shows repurchase intention is less studied than overall satisfaction (Bloemer & Poiesz, 1989; Hennig-Thurau & Klee, 1997). The dearth of modeling of repurchase intention complicates hypothesis development for medium technology industries. However, previous modeling studies have shown that optimal models for repurchase intention in high-tech industries include only *SAT_PDT* and *SAT_REL* as independent variables (Kellar & Preis, 2003). Since only these two independent variables have been shown to be important in repurchase intention and since high-tech industries are proximate to medium-tech in R&D intensity, we expect similar results in medium-tech industries. Therefore, we propose:

H3: The reduced model containing only the variables SAT_PDT and SAT_REL should be used to model repurchase intention for medium-tech industries.

METHODOLOGY, ANALYSIS, AND RESULTS

The methodology employed in this research involves four steps. The first step is the collection of data. The second step consists of classifying the data into levels of technology. The third step performs appropriate analyses and the final step reports the results. These steps are described next.

Data Collection and Sample

Using the "URL embedded" design (Bradley, 1999), all members of the Institute for Supply Management with e-mail addresses on file with the organization, were contacted by e-mail. The data collection effort was part of a larger more comprehensive study of dyads in which each purchasing agent was requested to recruit one salesperson from whom the purchasing agent had already purchased items, to participate in the study. Salespeople and purchasing agents completed different questionnaires online.

Invitations to participate were sent to 7,298 individuals. Messages were undeliverable to 1,787 addresses due to invalid or improper address information. Responses from 141 recipients claiming ineligibility were received. Thus, 5,370 was the size of the sample frame. In all, questionnaires were received from 193 dyads, yielding a response rate of 3.6%; this response rate was due, in part, to the length of the questionnaire and, in part, to the requirement that both parties in each dyad had to respond in order to achieve a useable response.

The response rate is in line with other e-mail surveys (Weible & Wallace, 1998). Furthermore, in a study comparing mail and e-mail surveys, Bachmann, Elfrink, and Vazzana (2000) find "evidence that nonresponse bias may be less of a problem using e-mail" than using mail surveys.

Purchasing agent participants were asked to respond for one product with which they had previous purchasing experience and for which they had purchasing (decision-making)

responsibility. In order to avoid respondent fatigue and in keeping with recommendations of Drolet and Morrison (2001), single items, each using a seven-point semantic differential scale, were used to assess overall satisfaction, repurchase intention, product satisfaction, vendor (performance) satisfaction, and interpersonal satisfaction. The salespeople provided generic descriptions of the items being purchased.

Bias is a concern in any sample; the response rate in this survey would be of greater concern if the demographics of the sample did not match the demographics of the ISM, the population from which respondents are drawn, as closely as they do. Demographically, 54 percent of the purchasing agent respondents were male and 46 percent were female. The mean age of purchasing agents reporting their ages is 45 years. They are well educated, with 48 percent holding bachelor's degrees and an additional 21 percent holding advanced degrees. The mean number of years of professional purchasing experience of the sample is greater than 14 and the mean number of years of tenure with their present employers is 9. Responses were received from at least 41 different states. On all characteristics for which comparisons could be made the demographics of the sample closely matched the demographics of the overall membership of the Institute for Supply Management, from which the sample was drawn.

Data Classification

To classify levels of technology, we utilize the measure and classifications developed by the Organization for Economic Cooperation (OECD, 2009b). The OECD is an international economic organization with 31 member countries and publishes the OECD Science, Technology and Industry Scoreboard. This publication classifies levels of technology as high-tech, medium-high-tech, medium-low-tech, and low-tech, using the International Standard Industrial Classification (ISIC), which is widely used in classifying data for a large range of economic activities (e.g. Dahlstedt, Salmi, Luoma, & Laakkonen, 1994; Demeter, 2003).

The OECD determines level of technology by calculating the R&D intensity of industries (OECD, 2009a). We classify products' levels of technology according to the respective industry classifications. Thus, the classification of a particular product may not meet common expectations of what constitutes the technology level of the product itself. For instance, penicillin is classified as "high tech" because it is produced by the pharmaceutical industry (a high-tech industry), even though penicillin itself may no longer be a very "high tech" product. For purposes of this study, we combine the medium-low-tech and medium-high-tech categories to obtain a single medium-tech category. Examples of medium technology industries, as defined by the OECD, are shown in Table 1.

Table 1: Examples of medium-tech manufacturing industries
Chemicals excluding pharmaceuticals
Machinery and equipment not elsewhere classified (n.e.c.)
Electrical machinery and apparatus (n.e.c.)
Motor vehicles, trailers and semi-trailers
Railroad equipment and transport equipment (n.e.c.)
Coke, refined petroleum products and nuclear fuel
Rubber and plastic products
Other non-metallic products
Basic metals and fabricated metal products
Building and repairing of ships and boats

ANALYSES

Data from only medium-tech industries were used in this study. First the data were centered and standardized. This allows the values of coefficients to be compared directly to each other, facilitating understanding of their relative importance. The dataset consisted of 71 data points with three independent variables; *SAT_PDT*, *SAT_PERF* and *SAT_REL* and two dependent variables *OVERALL* and *REBUY*. These data are organized as shown in Table 2.

Table 2: Format of Centered and Standardized Dataset					
Observation Number	X_1*	X_2**	X_3***	*Y*^	*I*^^
1	-0.49	-0.15	0.65	0.80	0
2	0.80	0.90	0.65	0.80	0
3	-0.49	-0.15	-0.75	-0.56	0
71	-0.49	-0.15	-0.75	-0.56	0
72	-0.49	-0.15	0.65	0.80	1
140	-0.49	-0.15	-0.75	-0.56	1
141	0.80	0.90	0.65	0.80	1
142	-0.49	-0.15	-0.75	-0.56	1

* X_1: Satisfaction with the product (*SAT_PDT* -- centered and standardized)
** X_2: Satisfaction with vendor performance (*SAT_PERF* -- centered and standardized)
*** X_3: Satisfaction with the relationship with the salesperson (*SAT_REL* -- centered and standardized)
^ Dependent Variable *Y*
^^ Indicator Variable: when *I* = 0, *Y* represents an Overall Satisfaction observation (*OVERALL*);
when *I* = 1, *Y* represents a Repurchase Intention observation (*REBUY*).

This can be formalized as follows. When considering models for overall satisfaction (*OVERALL*), ($I_i = 0$), observations 1 to 71 are used. In this case:

For $1 \leq i \leq 71$
X_{1i} = the i^{th} observation of *SAT_PDT* (satisfaction with the product)
X_{2i} = the i^{th} observation of *SAT_PERF* (satisfaction with the vendor's performance)
X_{3i} = the i^{th} observation of *SAT_REL* (satisfaction with the relationship with the salesperson)

Y_i = the i^{th} observation of *OVERALL* (overall satisfaction with the transaction)
$I_i = 0$

When considering models for repurchase intention (*REBUY*), ($I_i = 1$), observations 72 to 142 are utilized. In this case:

For $72 \leq i \leq 142$
X_{1i} = the $(i - 71)^{th}$ observation of *SAT_PDT* (satisfaction with the product)
X_{2i} = the $(i - 71)^{th}$ observation of *SAT_PERF* (satisfaction with the vendor's performance)
X_{3i} = the $(i - 71)^{th}$ observation of *SAT_REL* (satisfaction with the relationship with the salesperson)

Y_i = the $(i - 71)^{th}$ observation of *REBUY* (intention to repurchase this item from this company).
$I_i = 1$

Since the data are centered and standardized, the constant term is zero. Thus the full regression model takes the form:

$$Y = A_1 X_1 + A_2 X_2 + A_3 X_3$$

Where:

$X_1 = SAT\_PDT$, $X_2 = SAT\_PERF$, $X_3 = SAT\_REL$ and
Y = the dependent variable as seen in Table 2.

Multicollinearity can be a problem when independent variables are redundant. In order to verify that multicollinearity does not exist among the independent variables, we calculated the conditioning index. The result, 2.5, is well below 30, the level at which it becomes problematic (Tabachnick and Fidell, 1996).

We apply the Chow test to answer H1. The Chow test compares the residual sum of square errors from the optimal linear model of the aggregated dataset to the residual sum of square errors from the optimal linear models for the disaggregated datasets. The resulting test statistic is:

$$\frac{(S_c - (S_0 + S_1))/k}{(S_0+S_1)/(N_0 + N_1 - 2k)}$$

where S_c equals the sum of squared residuals for the combined dataset, S_0 equals the sum of squared residuals for the first group in the dataset, and S_1 equals the sum of squared residuals for the second group in the dataset. N_0 and N_1 are the numbers of observations in each group, i.e., 71. The total number of parameters in the model, k, is the last variable in the test statistic. This test statistic follows the F distribution with k and $(N_1 + N_2 – 2k)$ degrees of freedom. If the p-value of the test statistic is less than 0.05, the null hypothesis is rejected, providing statistical evidence that the two groups or datasets should be disaggregated and overall satisfaction should be modeled separately from repurchase intention. In other words, we should model *OVERALL* and *REBUY* separately. On the other hand, failure to reject this null hypothesis indicates insufficient evidence to justify modeling *OVERALL* and *REBUY* distinctly.

The Chow test results in a p-value of 0.0071 (F=4.207 with 3, 136 degrees of freedom) so the null hypothesis is rejected, indicating *OVERALL* and *REBUY* should be modeled distinctly, thus confirming H1.

Preis and Kellar (2003a) utilized information theoretic statistics to identify the optimal model for customer satisfaction in low-tech industries. To test H2, we follow that methodology, employing Akaike's Information Criteria corrected (AICc) (a technique that is useful for selecting optimal models from among many competing models) and find that the full model is preferred.

Table 3 shows the AICc scores and Akaike weights for the three models that display the greatest evidence of being the optimal model. The Akaike weight column can be interpreted as the evidence (this is often thought of as the probability) in favor of the respective model being the preferred model, based on the data (Burnham & Anderson, 2002). This identifies the preferred model for overall satisfaction in medium-tech industries as the full model since it has the largest Akaike weight. The reduced model containing only *SAT_PDT* and *SAT_PERF* has the next biggest Akaike weight and is therefore preferred to all remaining models. Since a noticeable difference exists between the AICc weights for the first two models, there is a statistical preference for the first model over the second one. Importantly, the Akaike weights of these first two models indicate that together they capture more than 88% evidence that one of these models is the correct model, and the first three models capture almost 100% of the evidence. Based on the results shown in Table 3, the second hypothesis is confirmed.

Table 3
Results for Top Three Regression Equations for Overall Satisfaction

Model #	*SAT_PDT*	*SAT_PERF*	*SAT_REL*	AICc	Akaike Weight	R^2
1	0.237	0.538	0.152	90	0.5178	0.64
2	0.308	0.558	0	90.7	0.3649	0.62
3	0	0.653	0.234	93.1	0.1099	0.61

The test for H3 employs the same information theoretic methodology used to test H2. Table 4 shows the AICc scores and weights for the three models that display the greatest evidence of being the optimal model for repurchase intention. The Akaike weight identifies the preferred model for repurchase intention in medium-tech industries as the reduced model containing the independent variables *SAT_PDT* and *SAT_REL* since it has the largest AICc weight. The full model has the next biggest AICc weight and is therefore preferred to all remaining models. Importantly, the Akaike weights of these first two models indicate that they capture more than 90% of the evidence that one of these models is the optimal model, and the first three models capture over 95% of the evidence.

The results of this analysis demonstrate that the reduced model mapping only the two independent variables *SAT_PDT* and *SAT_REL* to *REBUY* is preferred to the full model. Further, the coefficients of the preferred model and of the next best model (the full model) are virtually identical. For example, the coefficient for *SAT_PDT* in the preferred model is 0.362 compared with 0.376 in the full model.)

Based on the results shown in Table 4, the third hypothesis is confirmed. It should be observed that consistent with the findings of H1, optimal models for *OVERALL* and *REBUY* differ from each other.

Table 4
Results for Top Three Regression Equations for Repurchase Intention

Model #	*SAT_PDT*	*SAT_PERF*	*SAT_REL*	AICc	Akaike Weight	R^2
1	0.362	0	0.324	136.5	0.688	0.366
2	0.376	–0.025	0.327	138.8	0.220	0.366
3	0.541	0	0	142.0	0.044	0.293

DISCUSSION AND IMPLICATIONS

Notice that R^2 is significantly lower for repurchase intention than it is for overall satisfaction (37% versus 64%). This emphasizes the difficulty in modeling repurchase intention.

In particular, while components of satisfaction influence repurchase intention, further research is needed to detect other, not yet identified, influencers of repurchase intention.

Notice that magnitude of the coefficients for the three independent variables in the top three models of customer satisfaction is highest for *SAT_PERF*. Since all data are centered and standardized, this emphasizes the importance of *SAT_PERF* for medium-tech industries, and that the other two variables, *SAT_PDT* and *SAT_REL* are less influential.

The selected models explain approximately 64% of the variance in overall satisfaction and about 37% of the variance in repurchase intention for medium-tech offerings (Tables 3 and 4). The differences in the models and the difference in the explanatory power between the models for overall satisfaction and repurchase intention is consistent with earlier findings that overall satisfaction influences repurchase intention but does not explain it entirely (e.g. Hellier, Geursen, Carr & Rickard, 2003; Capraro, Broniarczyk & Srivastava, 2003; Keiningham, Perkins-Munn & Evans, 2003). As would be expected, all of the coefficients in the regression models are positive or essentially zero, indicating that an increase in the satisfaction of each component in the model would have either a positive influence or no influence on overall satisfaction and on repurchase intention. While the magnitudes of satisfaction with vendor performance is the dominant factor in determining overall satisfaction, this component of satisfaction is not even included in the model for repurchase intention. However, interpersonal satisfaction and satisfaction with the offering are important components of both models. For overall satisfaction the magnitude of the coefficient for *SAT_PDT* (0.237) is larger than the magnitude of the coefficient for *SAT_REL* (0.152) indicating that satisfaction with the offering has a larger impact on overall satisfaction than interpersonal satisfaction. On the other hand, these same two components have approximately equal coefficients (0.362 and 0.324) for repurchase intention.

MANAGERIAL IMPLICATIONS

Studying customer satisfaction at the attribute level increases understanding of the construct (Mittal, Vikas, Ross & Baldasare, 1998). The results of this study clearly demonstrate the value of emphasizing different components of satisfaction depending on whether one is attempting to influence overall satisfaction or repurchase intention.

Managers work at the attribute level, not at the global or overall level, thus studying customer satisfaction at the attribute level is of greater value to practitioners than studying it at the overall level (Wittink & Bayer 1994). The results of this study clearly show that in medium-tech industries, purchasing agents do not equate customer satisfaction and repurchase intention. Also, salespeople and sales managers with offerings from medium-tech industries would do well to increase satisfaction with the offering and interpersonal satisfaction in order to increase repurchase intention. In contrast, salespeople should keep in mind that increasing vendor performance satisfaction is likely to yield greater overall satisfaction than increasing satisfaction

with the product or interpersonal satisfaction by the same amount but may not have the same impact on repurchase intention.

Both purchasing agents and salespeople should also keep in mind that Olsen (2002) finds a stronger relationship between customer satisfaction and repurchase intention for comparative evaluations than for noncomparative evaluations. If customers are evaluating multiple vendors' offerings (i.e., not sole-source), salespeople might find it worthwhile to induce customers to consider vendor performance as a decision criterion; otherwise they should concentrate on satisfaction with the product and on interpersonal satisfaction as means of increasing repurchase intention.

These relationships are depicted in Figure 2. Purchasing agents may want to refine their decision criteria so that vendor performance has greater influence on repurchase decisions. In a parallel way, marketers attempting to increase repurchase intention by directing high amounts of resources at creating satisfaction with vendor performance for offerings from medium-tech industries may be misdirecting resources.

Figure 2
Relationship of Components of Satisfaction with Overall Satisfaction and Repurchase Intention for Offerings from Medium-Tech Industries.

	Satisfaction With Product	Satisfaction With Performance	Satisfaction With Relationship
Overall Satisfaction	++	+++	+
Repurchase Intention	++		++

\+ weak relationship
++ moderately strong relationship
+++ strong relationship

LIMITATIONS

Caution should be used in interpreting the results of this study. While the results are clear and conform both to theory and prior research, the study uses cross sectional data for analysis. Hence, causal inferences about the effects of satisfaction components on repurchase intention are unwarranted. Furthermore, although components of customer satisfaction explain about 64% of

the variance of overall satisfaction, they account for only 37% of the variance of repurchase intention.

Practitioners are cautioned against changing their purchasing or marketing plans and allocations of resources based solely on these findings until further research confirms the models. Furthermore, individual situations vary and conditions in any particular medium-tech industry may be such that application of these findings could result in less than optimal results.

Other potentially confounding issues include method of classification of level of technology, the bundling of goods and services, and the type of offering, Instead of classifying industries based on R&D intensity, different methodologies might be used, with unknown results on the final outcome. In addition, goods and services are analyzed together; it may be that the ways that purchasing agents make judgments about overall satisfaction and repurchase intention are not the same for goods as they are for services. Furthermore, the sample includes buyers of all manner of offerings; it may be that when buyers of single commodity types are analyzed in isolation, overall satisfaction and repurchase intention might be functions of different factors than are shown to be important in this study. The study examines only three components of overall satisfaction and examines the effects of those factors on overall customer satisfaction and repurchase intention. In spite of the relatively high amount of variance explained, other influential factors remain to be identified and included in the models.

IMPLICATIONS FOR FUTURE RESEARCH

The findings of this study should be replicated in other research. In addition, research should examine whether other factors are important in evaluating overall satisfaction and making repurchase decisions. By including the effects of additional components of satisfaction, such as satisfaction with price, satisfaction with brand, satisfaction with vendor communication, and satisfaction with value, more of the variance of overall satisfaction and repurchase intention might be explained.

Kellar and Preis (2003) advise disaggregation of data and creation of focused models based on disaggregated data in order to achieve more useful analyses. For this study the level of technology of the offerings' industries is the basis for disaggregating data and offerings only from medium-technology industries are examined. Other criteria might be used for disaggregation such as categorizing offerings into capital items, services, consumables, production items, and raw materials. For example, gender might also be an important criterion for disaggregating data; men and women might weight components of satisfaction differently when making overall satisfaction judgments or making repurchase decisions. In addition, research should be undertaken to determine whether different factors are important for specific commodity types. This study examines buyers in industrial markets. It would be interesting to examine similar decisions among consumers.

Keiningham, Perkins-Munn and Evans (2003) find a positive relationship between customer satisfaction and share-of-wallet for services in the B2B sector. Similar research on the relationship between components of satisfaction and share-of-wallet, repurchase intention and share-of-wallet (i.e., between repurchase intention and actual repurchase), and satisfaction and share-of wallet for goods, would all be interesting and useful topics to explore.

CONCLUSION

Models have been developed for the effects of three components of satisfaction on both overall satisfaction and repurchase intention; the three components examined are satisfaction with the product, satisfaction with vendor performance, and interpersonal satisfaction. Results demonstrate that significant differences exist between the components of satisfaction that influence industrial buyers' evaluations of overall satisfaction and the components of satisfaction affecting repurchase intention for offerings from medium-tech industries. More of the variance in overall satisfaction is explained by the components of satisfaction than is explained in repurchase intention.

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LEXICOGRAPHIC GOAL PROGRAMMING APPROACHES TO THE THREE-GROUP CLASSIFICATION PROBLEM

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ABSTRACT

In the three-group statistical classification problem, when mixed-integer programming models are used for the minimization of the number of misclassifications in the training sample, alternative optimal solutions may affect the classificatory performance of the model in the holdout sample. In this paper, we propose lexicographic goal programming models that assign preemptive priority to the minimization of the number of misclassifications. The classificatory performance of the proposed models is compared against that of the classical statistical classification procedures (Fisher's linear discriminant function and Smith's quadratic discriminant function) using the data from a diabetic study.

INTRODUCTION

Over the last thirty years there has been considerable research interest in mathematical programming approaches to the statistical classification problem. Various simulation studies (Lee, Gallagher & Patterson, 2003; Bal, Orkcu & Celebioglu, 2006; Sueyoshi, 2006) have demonstrated that such mathematical programming approaches can outperform the classical statistical procedures for classification, i.e. the linear discriminant function (Fisher, 1936) and the quadratic discriminant function (Smith, 1947), when the conditions for optimality of these parametric methods are violated. These conditions for optimality include multivariate normality and assumptions about the covariance structures.

Mixed-integer programming models for the three-group classification problem (Gehrlein, 1986; Gochet, Stam, Srinivasan & Chen, 1997; Loucopoulos & Pavur, 1997) directly minimize the number of misclassifications in the training sample. It has been shown that mathematical programming models for the three-group classification problem outperform the standard parametric classification procedures (Fisher's linear discriminant function and Smith's quadratic discriminant function) for a variety of data configurations (Loucopoulos & Pavur, 1997b; Bal & Orkcu, 2010). It should be noted that depending on group separation and the number of observations, a mixed-integer programming model may have alternate solutions in the training sample. The choice of the alternate solution used for generating the discriminant function can have a significant effect on the holdout sample classificatory performance of the model. In this paper, various secondary goals are investigated for the three-group classification problem, with

the goal of minimizing the number of misclassifications in the training sample being assigned preemptive priority.

MAXIMIZATION OF MAXIMUM DEVIATION BETWEEN PROJECTED GROUP MEANS AS SECONDARY GOAL

The MIP3G model (Loucopoulos & Pavur, 1997) is a mixed-integer programming model specifically for the three-group classification problem. It assigns a weight a_k to each attribute variable X_k (k = 1, 2, ..., p) and thus generates a discriminant score $a_0 + \sum_{k=1}^{p} a_k X_k^{(i)}$ for each observation i (i = 1, 2, ..., n). Such score is projected onto a line which is divided into three intervals, one for each group, with a gap of width e between adjacent intervals for enhanced group separation. An observation is correctly classified if its discriminant score falls in the interval assigned to its group; otherwise it is misclassified.

Notation:

a_k is the weight assigned to variable X_k

$X_k^{(i)}$ is the value of variable k observation i

a_0 is a locational adjustment to the discriminant function

é is the width of the middle interval

e is the width of the gap between adjacent intervals

M_1 is the maximum deviation of the discriminant score of a misclassified observation from the nearest endpoint of the interval assigned to its group

M_2 is the maximum deviation of the discriminant score of a correctly classified observation, that belongs to either the leftmost or rightmost group, from -e or e+ é, respectively

$$I_i = \begin{cases} 1 & \text{if observation i is misclassified} \\ 0 & \text{if observation i is correctly classified} \end{cases}$$

$$K_2 = \begin{cases} 1 & \text{if group } G_2 \text{ is assigned the interval on the left} \\ 0 & \text{if group } G_2 \text{ is assigned the interval in the middle} \end{cases}$$

$$K_3 = \begin{cases} 1 & \text{if group } G_3 \text{ is assigned the interval on the right} \\ 0 & \text{if group } G_3 \text{ is assigned the interval in the middle} \end{cases}$$

Formulation:

$$min \sum_{i=1}^{n} I_i$$

s.t.

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} - M_1 I_i - (e + e') K_2 + (M_2 + e) K_3 \le M_2 \qquad \forall i \in G_1 \qquad (1)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} + M_1 I_i - (M_2 + e) K_2 + (e + e') K_3 \ge e' - M_2 \qquad \forall i \in G_1 \qquad (2)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} - M_1 I_i + (e + e') K_2 \le e'_2 \qquad \forall i \in G_1 \qquad (3)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} + M_1 I_i + (M_2 + e) K_2 \ge 0 \qquad \forall i \in G_1 \qquad (4)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} - M_1 I_i - (M_2 + e) K_3 \le e' \qquad \forall i \in G_1 \qquad (5)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} + M_1 I_i - (e + e') K_3 \ge 0 \qquad \forall i \in G_1 \qquad (6)$$

$K_2 + K_3 \ge 1$ **(7)**

$I_1, I_2, ..., I_n, K_2, K_3$ binary variables

$a_0, a_1, ..., a_p$ sign-unrestricted variables

The MIP3G model identifies three intervals [-M_2-e, -e], [0, é] and [e+é, e+é+M_2] and assigns one of the following group orderings to the three intervals: (G_1, G_2, G_3), (G_2, G_1, G_3) and (G_2, G_3, G_1). The other three possible group orderings are just mirror images of the aforementioned group orderings that can be generated by the multiplication of the discriminant scores by -1. In the above group orderings G_1 is the only group that can be assigned to any one of the three intervals. However, the choice was arbitrary and does not affect the classification results in any way.

Now let $\bar{X}_h = a_0 + \dfrac{\sum_{k\ldots 0} \sum_{i 0 G_h} a_k X_k^{(i)}}{n_h}$ where h = 1, 2, 3. Also let δ be a non-negative variable.

$$\bar{X}_1 - \bar{X}_2 + (M_1 + M_2 + e + e')(1 - K_2 + K_3) \geq \delta \quad (8)$$

The model is converted into a goal programming formulation (LGP1) by changing the objective function to $min\, P_1 \sum_{i=1}^{n} I_i - P_2\delta$ and adding the following constraints:

$$\bar{X}_3 - \bar{X}_1 + (M_1 + M_2 + e + e')(1 + K_2 - K_3) \geq \delta \quad (9)$$

$$\bar{X}_3 - \bar{X}_2 + (M_1 + M_2 + e + e')(2 - K_2 - K_3) \geq \delta \quad (10)$$

The last three constraints guarantee that the deviation between the projected mean of the group assigned to the leftmost interval and the projected mean of the group assigned to the rightmost interval will be greater than or equal to δ. Finding a discriminant function by maximizing the deviation between projected group means is similar to the approach used in obtaining the linear discriminant function (Fisher, 1936).

The deviation between the lower endpoint of the leftmost interval and the upper endpoint of the rightmost interval is $(M_2 + e) + (e + é + M_2) = 2M_2 + 2e + é$. Furthermore, the maximum deviation of a misclassified observation from its group is M_1. Thus, if $P_1 > P_2(2M_1 + 2M_2 + 2e + é)$, the first goal is preemptive over the second goal. This follows since the first goal consists of binary variables.

$$\bar{X}_1 - \bar{X}_2 - (M_1 + M_2 + e + e')(1 - K_2 + K_3) \leq \delta \quad (11)$$

In order to assess the effect of this secondary goal on the classificatory performance of the MIP model, we will also consider the model with the secondary goal of minimizing the deviation between the projected mean of the group assigned to the leftmost interval and the projected mean of the group assigned to the rightmost interval. If the goal of maximizing the deviation between the projected means enhances the classificatory performance of the model, then the goal of minimizing such deviation should have an adverse effect on the classificatory performance. This model will be referred to as LGP2. For LGP2, the objective function will be $min\, P_1 \sum_{i=1}^{n} I_i + P_2\delta$ and the constraints involving δ will be modified as follows:

$$\bar{X}_3 - \bar{X}_1 - (M_1 + M_2 + e + e')(1 + K_2 - K_3) \leq \delta \quad (12)$$

$$\bar{X}_3 - \bar{X}_2 - (M_1 + M_2 + e + e')(2 - K_2 - K_3) \leq \delta \quad (13)$$

MAXIMIZATION OF MINIMUM DEVIATION BETWEEN PROJECTED GROUP MEANS AS SECONDARY GOAL

Another secondary goal that is proposed in this paper is the maximization of the minimum deviation between projected group means. It is expected that such goal will enhance group separation and thus improve the classificatory performance of the model in the holdout sample.

New Notation:

ϕ is the minimum deviation between projected group means

Formulation:

LGP3: $min\ P_1 \sum_{i=1}^{n} I_i - P_2 \phi$

s.t. constraints (1) - (7)

$$\bar{X}_1 - \bar{X}_2 + (2M_1 + 2M_2 + 2e + e')(2 - K_2 - K_3) \geq \phi \quad (14)$$

$$\bar{X}_2 - \bar{X}_1 + (2M_1 + 2M_2 + 2e + e')(1 + K_2 - K_3) \geq \phi \quad (15)$$

$$\bar{X}_1 - \bar{X}_3 + (2M_1 + 2M_2 + 2e + e')(1 - K_2 + K_3) \geq \phi \quad (16)$$

$$\bar{X}_3 - \bar{X}_1 + (2M_1 + 2M_2 + 2e + e')(2 - K_2 - K_3) \geq \phi \quad (17)$$

$$\bar{X}_3 - \bar{X}_2 + (2M_1 + 2M_2 + 2e + e')(1 + K_2 - K_3) \geq \phi \quad (18)$$

$$\bar{X}_3 - \bar{X}_2 + (2M_1 + 2M_2 + 2e + e')(1 - K_2 + K_3) \geq \phi \quad (19)$$

with φ being non-negative and $P_1 > (M_1+M_2+e+é/2)P_2$. This condition guarantees that the goal minimizing the number of misclassifications is assigned preemptive priority over the goal of maximizing the minimum deviation between projected group means.

In order to assess the effect of the secondary goal on the classificatory performance of the MIP model, we will also consider the model with the secondary goal of minimizing the minimum deviation between projected group means. If the goal of maximizing the minimum deviation between group means enhances the classificatory performance of the model, then the goal of minimizing such deviation should have an adverse effect on the classificatory performance. This model will be referred to as LGP4. For LGP4, the objective function will be $min\ P_1\sum_{i=1}^{n} I_i + P_2\phi$ and the constraints involving φ will be modified as follows.

$$\bar{X}_1 - \bar{X}_2 + (2M_1 + 2M_2 + 2e + e')(2 - K_2 - K_3) \le \phi \quad (20)$$

$$\bar{X}_2 - \bar{X}_1 + (2M_1 + 2M_2 + 2e + e')(1 + K_2 - K_3) \le \phi \quad (21)$$

$$\bar{X}_1 - \bar{X}_3 + (2M_1 + 2M_2 + 2e + e')(1 - K_2 + K_3) \le \phi \quad (22)$$

$$\bar{X}_3 - \bar{X}_1 + (2M_1 + 2M_2 + 2e + e')(2 - K_2 - K_3) \le \phi \quad (23)$$

$$\bar{X}_3 - \bar{X}_2 + (2M_1 + 2M_2 + 2e + e')(1 + K_2 - K_3) \le \phi \quad (24)$$

$$\bar{X}_3 - \bar{X}_2 + (2M_1 + 2M_2 + 2e + e')(1 - K_2 + K_3) \le \phi \quad (25)$$

MINIMIZATION OF SUM OF DEVIATIONS OF MISCLASSIFIED OBSERVATIONS AS A SECONDARY GOAL

Another secondary goal that is considered is the minimization of the sum of the deviations of the discriminant scores of misclassified observations from the nearest endpoint of the interval assigned to their group.

New Notation:

d_i is the deviation of the discriminant score of a misclassified observation from the nearest endpoint of the interval assigned to its group.

Formulation:

LGP5: $min\ P_1\sum_{i=1}^{n} I_i + P_2\sum_{i=1}^{n} d_i$

s.t.

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} - d_i - (e+e')K_2 + (M_2+e)K_3 \le M_2 \qquad \forall i \in G_1 \qquad (26)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} + d_i - (M_2+e)K_2 + (e+e')K_3 \ge e' - M_2 \qquad \forall i \in G_1 \qquad (27)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} - d_i + (e+e')K_2 \le e' \qquad \forall i \in G_2 \qquad (28)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} + d_i + (M_2+e)K_2 \ge 0 \qquad \forall i \in G_2 \qquad (29)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} - d_i - (M_2+e)K_3 \le e' \qquad \forall i \in G_3 \qquad (30)$$

$$a_0 + \sum_{k=1}^{p} a_k X_k^{(i)} + d_i - (e+e')K_3 \ge 0 \qquad \forall i \in G_3 \qquad (31)$$

$$d_i \le M_1 I_i \qquad \forall i \in (G_1 \cup G_2 \cup G_3) \qquad (32)$$

$$\mathbf{K_2 + K_3 \ge 1} \qquad \mathbf{(33)}$$

As long as $P_1 > P_2 M_2 \left[n - \max_h \{n_h\} \right]$, the goal of minimizing the number of misclassified observations is preemptive over the goal of minimizing the sum of the deviations of the discriminant scores of misclassified observations from the nearest endpoint of the interval assigned to their group. In order to assess the appropriateness of the secondary goal of minimizing the sum of the deviations of the discriminant scores of misclassified observations from the nearest endpoint of the interval assigned to their group, we also consider the secondary goal of maximizing the sum of such deviations. It is expected that the secondary goal of maximizing the sum of deviations would have an adverse effect on the classificatory performance of the model. The identification of as an "adverse effect" secondary goal highlights the potential effect of secondary goals on the classificatory performance. Thus, the objective function is changed to

LGP6: $min\ P_1\sum_{i=1}^{n} I_i - P_2\sum_{i=1}^{n} d_i$, while the constraints remain unchanged.

MAXIMIZATION OF THE SUM OF MINIMUM DEVIATIONS OF CORRECTLY CLASSIFIED OBSERVATIONS AS A SECONDARY GOAL

The maximization of the sum of the minimum deviations of the discriminant scores of correctly classified observations from the endpoints of the gaps between adjacent intervals can also be considered as a secondary goal.

New Notation:

$\zeta_{h\ell}$ is the minimum deviation of the discriminant scores of correctly classified observations that belong to group G_h (h=1,2,3) from the lower endpoint of the interval assigned to its group.
ζ_{hu} is the minimum deviation of the discriminant scores of correctly classified observations that belong to group G_h (h=1,2,3) from the upper endpoint of the interval assigned to its group.

Formulation:

LGP7: $min\ P_1\sum_{i=1}^{n} I_i - P_2\sum_{h=1}^{3}(\zeta_{hu}+\zeta_{h\ell})$

s.t.

$$a_0+\sum_{k=1}^{p} a_k X_k^{(i)} - M_1 I_1 - (e+e')K_2 + (M_2+e)K_3 + \zeta_{lu} \le M_2 \qquad \forall i \in G_1 \qquad (34)$$

$$a_0+\sum_{k=1}^{p} a_k X_k^{(i)} + M_1 I_1 - (M_2+e)K_2 + (e+e')K_3 - \zeta_{1\ell} \ge e' - M_2 \qquad \forall i \in G_1 \qquad (35)$$

$$a_0+\sum_{k=1}^{p} a_k X_k^{(i)} - M_1 I_1 + (e+e')K_2 + \zeta_{2u} \le e' \qquad \forall i \in G_2 \qquad (36)$$

$$a_0+\sum_{k=1}^{p} a_k X_k^{(i)} + M_1 I_1 + (M_2+e)K_2 - \zeta_{2\ell} \ge 0 \qquad \forall i \in G_2 \qquad (37)$$

$$a_0+\sum_{k=1}^{p} a_k X_k^{(i)} - M_1 I_1 + (M_2+e)K_3 + \zeta_{3u} \le e' \qquad \forall i \in G_3 \qquad (38)$$

$$a_0+\sum_{k=1}^{p} a_k X_k^{(i)} + M_1 I_1 + (e+e')K_3 - \zeta_{3\ell} \ge 0 \qquad \forall i \in G_3 \qquad (39)$$

$$\mathbf{K_2 + K_3 \ge 1} \qquad \mathbf{(40)}$$

$$\zeta_{h\ell}+\zeta_{hu} \le M_2\left(n_h - \sum_{i\in G_h} I_i\right) \qquad h=1,2,3 \qquad (41)$$

$$\zeta_{1\ell}+\zeta_{3u} \le (1+K_2-K_3)(M_2+e') \qquad (42)$$

$$\zeta_{2\ell}+\zeta_{1u} \le (1-K_2+K_3)(M_2+e') \qquad (43)$$

$$\zeta_{2\ell}+\zeta_{3u} \le (2-K_2-K_3)(M_2+e') \qquad (44)$$

where $\zeta_{h\ell}$, $\zeta_{hu} \geq 0$ (h=1,2,3), $M_1 \geq 2(M_2+e) + é$, and $M_2 \geq é$. The inclusion of constraint (41) assures that the deviations $\zeta_{h\ell}$ and ζ_{hu} will be zero, if all the observations of group G_h are misclassified. Constraints (42-44) guarantee that at most four of the deviations $\zeta_{h\ell}$ and ζ_{hu} (h=1,2,3) will be non-zero. These are the minimum deviations of the discriminant scores of correctly classified observations from the endpoints of the gaps between adjacent intervals. Thus, this secondary goal indirectly maximizes the width of the gaps between adjacent intervals, in order to enhance group separation. It has been shown that increasing the width of the gaps between adjacent intervals can improve the classificatory performance of the model in the holdout sample (Pavur & Loucopoulos, 2001).

Also included in this study, is the model that minimizes the sum of the minimum deviations of the discriminant scores of correctly classified observations from the endpoints of the gaps between adjacent intervals. Thus, the objective function is:

$$\text{LGP8:} \quad min\ P_1 \sum_{i=1}^{n} I_i + P_2 \sum_{h=1}^{3} (\zeta_{hu} + \zeta_{hR})$$

while the constraints remain unchanged. It is expected that the model with the secondary goal of maximizing the sum of the minimum deviations of the discriminant scores of correctly classified observations from the endpoints of the gaps between adjacent intervals, will outperform the previous model. The condition that $P_1 > (2M_2+é)P_2$ guarantees that the goal of minimizing the number of misclassified observations is assigned preemptive priority in the last two models.

COMPUTATIONAL RESULTS

The classificatory performance of the above lexicographic goal programming models was compared against that of Fisher's linear discriminant function (LDF) and Smith's quadratic discriminant function (QDF) using the data of a diabetic study of 145 individuals (Reaven & Miller, 1979). A total of 33 of these individuals were overt diabetic, 36 were chemical diabetic, whereas 76 were non-diabetic. The results of the leave-one-out cross-validation procedure are given below:

Model	LGP1	LGP2	LGP3	LGP4	LGP5	LGP6	LGP7	LGP8	LDF	QDF
Misclassifications	7	8	6	7	9	10	6	8	14	12

Thus, all lexicographic goal programming models outperformed their parametric counterparts. Furthermore, the number of misclassifications yielded by LGP1, LGP3, LGP5 and

LGP7 was lower than the number of misclassifications yielded by the model incorporating the corresponding "adverse effect" goal. On this data set, the LGP model that maximizes the minimum deviation between projected group means as well as the model that maximizes the sum of minimum deviations of correctly classified observations yielded the lowest number of misclassifications using the leave-one-out procedure.

CONCLUSIONS

In this paper, lexicographic goal programming models for the three-group classification problem are proposed that assign preemptive priority to the goal of minimizing the number of misclassifications in the training sample. Using the data of a diabetic study, it is shown that the secondary goals improve the holdout classificatory performance of the model that assigns preemptive priority to the minimization of the number of misclassifications in the training sample. Further studies are needed to assess the classificatory performance of the proposed models under different group configurations and group overlap.

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QUANTITATIVE METHODS PROFESSORS' PERSPECTIVES ON THE COST OF COLLEGE TEXTBOOKS

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ABSTRACT

Textbooks are an integral component of the higher education process. However, a great deal of concern about the high costs of college textbooks has been expressed by those inside and outside of higher education. This paper focuses on the results of a study of a survey of quantitative methods professors' criteria and use of textbooks and their reactions to some of the changes that have been implemented or may be implemented by universities, state legislatures, and publishers to combat these cost escalations. Quantitative method textbooks rely heavily on software such as MS Excel and often publishers must produce a new edition solely based on updated versions of software. The purpose of the study was to determine the role of cost in the textbooks selection process and to get reactions to various options aimed at reducing textbook cost.

Findings indicate that content was the most important selection criteria and cost was second. Respondents appear to have strong resistance to university, legislative, and publisher actions that infringe on their options in selecting textbooks and how long they would have to use a specific textbook before replacing it with a newer edition. This was particularly true of a university policy requiring low cost textbooks be adopted and requiring instructors to keep textbooks for all classes for at least 3 years and publishers sending an invoice after a 30 day review period and sending only one examination per department.

There were also significant differences among respondents based on t-tests and ANOVA. Professors who received complaints concerning textbook cost ranked cost as more important than their counterparts. Similarly professors teaching ten years are less ranked the cost of the text as more important than those who had taught move than ten years. Professors who switched textbooks every two years or less were more opposed to legislation requiring keeping textbooks for longer periods. Similarly, instructors were significantly more favorable to keeping textbooks for longer periods than associate or full professors. Finally, full professors were more inclined to favor tracking systems to identify book collectors.

INTRODUCTION

Textbooks in higher education are used by instructors in varying ways. Some instructors use the text as a supplement to other course material while other instructors use the text as the primary source of course material. In either case, the textbook is a critical element in higher education instruction. Stein, Stuen, Carnine, and Long (2001) noted that textbooks are believed to provide 75 to 90 percent of classroom instruction. This central role of textbooks in the instructional process is normally an impetus for college professors to spend a considerably amount of time selecting the appropriate text for their classes.

One factor of textbook adoption that has received a great deal of interest recently is the cost of the text (Carbaugh and Ghosh, 2005; Iizuka, 2007; Seawall, 2005; Talaga and Tucci, 2001; Yang, Lo, and Lester, 2003). For the first quarter of 2007, college textbook sales totaled $324.3 million (Educational Marketer, 2007). Additionally, the price of college textbooks has increased an average of 6% each year since the 1987-88 academic year. While this growth is twice the rate of inflation, tuition has increased at a 7% annual rate. Textbooks and supplies are estimated to cost students between $805 and $1,229 for the 2007-08 school years (National Association of College Stores). The problem has captured the interest of students, professors, and state legislators. In fact, some states have begun to mandate that instructors offer more choice in textbooks, provide the least costly option without sacrificing content, and work to maximize savings to students (HB, 2103).

This study examined the attitudes of quantitative methods professors toward the cost of textbooks. Specifically, we looked at attitudes toward various options that state legislatures, universities, and publishers are now using or have discussed as a future action to control the increasing costs of textbooks. Additionally, we sought to find out the extent to which faculty understand how their university bookstores are operated and how the profit from these bookstores is allocated within the university. The purpose of identifying key variables assists in reducing the cost of textbooks. Once identified, both academia and publishers can use the information to reduce costs. For this research, quantitative professors were chosen because no similar study existed that focused solely on quantitative methods. Quantitative method textbooks rely heavily on software such as MS Excel and often publishers must produce a new edition solely based on updated versions of software. For example, Winston and Albright's (2009) reason for their *Practical Management Science revised 3e* was

In 2007, Microsoft released its newest version of Office, Office 2007 (also called Office 12). This was not just another version with a few changes at the edges. It was a completely revamped package. Suddenly, many of the screenshots and instructions in our books were no longer correct because of the extensive user interface changes in Excel 2007. To add to the confusion, third-party developers of add-ins for Excel, particularly Palisade for our books, had to scramble to update their software for Excel 2007. (p. xiii).

The paper is organized by first presenting the textbook price problem with a review of the current literature and actions taken by various stakeholders to reduce textbook cost. Then we present our findings from a survey of quantitative methods faculty. Finally, we conclude with the implications of our research for professors, students, and universities.

THE TEXTBOOK PRICE PROBLEM

Several factors contribute to the high cost of college textbooks and the perceptions of students and some faculty that these prices are unreasonable. One suspected cause of increased prices is that there are fewer textbook publishers due to consolidations in the publishing industry. Seawall (2005) refers to this consolidation as a flawed production system noting that just four firms – McGraw-Hill, Pearson/Prentice-Hall, Cengage, and Houghton-Mifflin – dominate the industry. Moreover, barriers to entry in the textbook publishing business are large. Publishers have large fixed costs in printing as well as a need for editors and reviewers. Variable costs can also be substantial depending on the amount of color used in the text and the costs of distribution (Hofacker, 2009; Seawall, 2005).

Although many students and legislators believe that publishers intentionally drive up the costs of textbooks with new editions, the production and marketing of textbooks is very complex and it is difficult if not impossible to assign blame for the higher prices (Carbaugh and Ghosh, 2005). Publishers contend that used texts and conflicts with authors over royalties contribute to reduced profits on the books that are published (Carbaugh and Ghosh, 2005; Iizuka, 2001). This has created a unique relationship among authors, publishers, bookstores, and wholesalers.

Publishers argue that new editions of texts are necessary to offset a reduced sales volume often due to students either purchasing used books or not purchasing a book at all (Carbaugh and Ghosh, 2005). In fact, Iiszuka (2001) found that, like other durable goods producers, textbook publishers engage in planned obsolescence. That is, textbook publishers came out with new editions when the supply of used books increases to the point that sales of the older version are negatively impacted by the supply of used texts. The purpose of the new version is to "kill off" the supply of used books. Publishers are aware that if new versions come out too often, the life of the book is shortened to the extent that people are unwilling to pay a high price for the book. Therefore, publishers have to find an optimal revision cycle coordinated with the supply of used texts.

The result is a distinctive competitive environment among college textbook publishers. Demand for new textbooks is depressed by the comprehensive system of buying and selling used textbooks set up by used book dealers. Since not all students purchase the required text for a class, the demand for both new and used books is reduced. However, professors believe in the instructional value of textbooks and continue to assign them as required reading in courses. Further, professors make these assignments with the expectation that students will purchase the book or attain one for use during the course.

Rather than reduce costs, textbook publishers have been accused of using tactics that actually increase the cost of textbooks. For example, publishers drive up the costs of new texts with extras such as CDs, workbooks, and online material. These items are often "bundled" with the textbook so the student has to purchase these items even if they are not used in the class for which the textbook was purchased. This tactic increases the cost of texts because it requires additional investments by the publishers that have to be recouped in shorter and shorter time frames.

Another player in this picture is the used textbook wholesaler. The used textbook business thrives by purchasing used textbooks from students, college bookstores, and examination copies from professors. Used texts cost between 25% and 50% below the price of a new book and are a frequent substitute for new books. New and used texts present differing merchandising problems for university bookstores. Because of the high costs of new books charged to the bookstore by the publisher, the markup is so low that many university bookstores have low profit margins on new textbook sales and rely on the sale of other merchandise to make a profit (Carbaugh and Ghosh, 2005). The markup for used texts is much better, but there are sourcing problems. Bookstores may have difficulty getting the correct edition of a particular text in the quantity needed. Often this process means contacting several wholesalers for one text. Further, used textbook wholesalers typically do not allow unsold texts to be returned while the publishers do allow returns. If a bookstore miscalculates on used texts, it could find itself with substantial unsold inventory.

Publishers have also found themselves in a difficult situation in terms of the international version of textbooks. Publishers will often "dump" textbooks overseas by selling them for less in a foreign market than they do in the domestic market. The argument is that foreign students cannot afford to pay more than the price charged overseas and that the publisher needs to produce the books to achieve economies of scale (Carbaugh and Ghosh, 2005). A criticism of this practice is that textbook publishers are allowing relatively affluent American students to subsidize students in other countries. In response, many students will purchase the international edition of the text in order to reduce their costs (Paul, 2007).

Authors also pressure textbook publishers to lower the price. Since the author is paid a percentage of the revenue, his or her income is maximized when more books are sold at a lower price. Publishers are more interested in profits and desire a higher price to maximize the difference between revenue and costs (Carbaugh and Ghosh, 2005).

While the textbook industry may be an oligopoly with four major firms, once the decision is made by a professor to adopt a particular text, the publisher has a monopoly for that course (Iizuka, 2007; Talaga and Tucci, 2001). Faced with a monopolistic situation, students have the option to buy the book new, used, or not at all. Other product variables such as quality, brand, and packaging are eliminated so students focus on the only option left – price.

Students combat the high cost of textbooks with some alternative strategies. A National Association of College Stores survey found that only 43% of students buy the required books for

their courses (Carlson, 2005). Students share a textbook with another student taking the same course, borrow a textbook, or rent if from one of the book vendors. Additionally, some students turn to online texts which were preferred by 11% in one survey (Paul, 2007). Online books are generally less expensive than the same texts available at the university bookstore (Yang, et al., 2001). Seventy-three percent of students still prefer traditional texts, however (Carlson, 2005). Other strategies employed by students include renting textbooks online (Foster, 2008), swapping books online (American Association of State Colleges and Universities), and viewing the library copy of the text (Paul, 2007).

CONTROLLING THE COST OF TEXTBOOKS

Universities and faculty are exploring ways to lower the costs of textbooks. For example, the University of Dayton and Miami University use e-textbooks for some courses (Gottschlich, 2008). The faculty of Rio Salado College in Arizona print their own textbooks by picking and choosing only what they need for a course (Guess, 2007). Additionally, there are advertiser supported free textbook downloads (The Campaign to Make Textbooks More Affordable) and textbook reserve programs where texts for basic courses are purchased by the student government association and are put on a two hour reserve in the library.

Textbook publishers are aware of the market's concern with the cost of textbooks and are attempting to address the problem. The methods by which textbooks are marketed also increase the costs. Publishers encourage professors to examine and adopt their books by marketing directly to them. Textbook publisher marketing budgets have increased along with efforts at more effective marketing. Examination copies drive up the cost of textbooks for students, contribute to the used book market, and involve ethical issues (Robie, Kidwell, and Kling, 2003; Smith and Muller, 1998).

The practice of sending out complimentary copies of textbooks for possible adoption has traditionally been the best way to get adoptions for new texts. However, this is also a high cost promotional approach since the books are usually not returned and they also find their way to textbook wholesalers which reduces the profitability of the text for the publisher. Other options that may be explored by publishers include:

1. Send a few unbound chapters of a text, sample cases and instructors' notes, or parts of solution manuals rather than the entire book.
2. Develop a tracking system to identify "book collectors", those who order examination copies of textbooks but never adopt them and have them purchase the examination copy for some nominal fee.
3. Do not send unsolicited copies of a text to professors unless they are using a previous edition of the text. One colleagues' publisher sent out 4000 unsolicited copies of a new marketing text to "get the product in the hands of the decider". The result

was that the wholesale market was flooded with copies of the text and even book buyers wouldn't buy unused copies of the book.

4. Request information from the examination copy requestor of the course name and number, if the course is currently being taught, and the name of the current text being used.
5. Send books out on a 30 day review period for those requesting an examination copy and bill the requestor at the end of the time period for the at least the cost of the book to the publisher.
6. Provide online access to professors requesting an examination copy or a CD of a new text.
7. Provide only one examination copy per department instead of sending one to everyone in the department who request a copy.

While all of these approaches, except the online examination, represent new costs of preparing and mailing, they would reduce the cost of sending out complete packages and reduce the risk of complete texts finding their way to the book buyers. Since reproduction of CDs is relatively low, this could be a way to get the examination copies to faculty although a market may develop for these items.

As be seen from the above review, textbook pricing is a complex issue with many players and economic factors influencing the price charged for any individual book. In an effort to expand our understanding of attitudes toward some of these initiatives to control textbook prices, we conducted a survey of quantitative methods faculty to determine their reactions to various textbook cost issues. The details of the study and the results are presented below.

THE STUDY

This study was conducted using Internet survey methodology. A total of 1,500 quantitative methods professors were selected from universities throughout the United States using university websites. These individuals were sent an e-mail explaining the purpose of the study and a link to click on if they were willing to participate.

The survey consisted of 17 questions addressing the topic of textbook costs and related issues. A 5-point rating scale was used to measure faculty reactions to various potential university, governmental, and publisher actions to control textbook cost. Additional questions dealt with the frequency of adoptions, ownership of the university bookstore, competition from non-campus bookstores, and questions about years of experience, discipline, university size, etc... The final section of the questionnaire permitted respondents to make specific comments about the issue of textbook costs.

The resulting data was analyzed using SPSS. Percentages and means were calculated where appropriate and t-tests or ANOVA were used to analyze differences in responses based on classification variables related to respondents' rank, teaching experience, size of institution, etc.

RESULTS

Of the 1,500 e-mails sent, 126 were returned for various reasons such as a wrong e-mail address, insufficient e-mail address, or the e-mail was viewed as spam by the university's e-mail filter system. Of the 1,374 e-mails that were delivered, 94 responded, yielding a response rate of 6.8%. While this low response rate is problematic for both analysis and generalization, the responses do provide some insight into respondents' views on textbook cost issues.

A typical respondent had been teaching for 20 or more years (54%), held the rank of full professor (47%), and taught at a public institution (59%) with an enrollment of less than 5,000 students (35%). Their institution offered a bachelor's (86%) and/or a master's degree (93%).

As is shown in Table 1, content ranked as the number 1 selection criteria, followed by cost of the text, ancillary material, edition of the text, and length of the text. In earlier studies by the authors, cost was the third most important consideration in textbook adoption, which may indicate little change in sensitivity to cost as a selection criterion.

Table 1
RANKING OF SELECTION CRITERIA

	Mean*
Rank importance of content	1.29
Rank importance of edition	3.65
Rank importance of ancillary material	3.25
Rank importance of cost of text	3.06
Rank importance of length of text	3.79

*1= most important, 2= second most important, 3=third most important, 4=fourth most important, 5=least important

Table 2 shows the frequency of changing textbooks. The majority of respondents changed book within 3 or fewer years. This may coincide with the cycle of new editions introduced by publishers.

When asked about student complaints regarding textbook cost, 81% reported receiving student complaints about textbook cost and they estimated that only 55% of their students actually purchased or rent the required text for their courses.

Table 2 **FREQUENCY OF CHANGING TEXTBOOKS**		
	Frequency	Percentage
Once a year	1	1.1%
Every two years	31	33.0%
Every three years	40	42.6%
Every four years	7	7.4%
Every five years	4	4.3%
Longer than five years	11	11.7%

Most respondents reported that the university's bookstore was outsourced (61%) and 89% reported that they did not know what the profits from bookstore operations were used for. Of those that reported that they knew how profits were utilized, they felt the profits were used for faculty salaries.

Respondents' attitudes toward various state and university actions were measured using a 5 point scale of strongly agree to strongly disagree. High means indicate stronger disagreement with a particular action. As is shown in Table 3, there was disagreement with all of the potential actions measured. This was particularly true of a university policy requiring low cost textbooks be adopted and requiring instructors to keep textbooks for all classes for at least 3 years.

Table 3 **ATTITUDES TOWARD VARIOUS ACTIONS TO CONTROL TEXTBOOK COST**	
Potential Action:	Mean
Legislation to require publishers to provide cost info.	2.97
Legislation require publishers to unbundled textbook material	2.89
Require publishers to provide textbook copies on reserve in library	3.32
Univ. policy require lowest cost textbook be adopted	4.68
Multiple sections use the same textbook	2.92
Multiple sections keep textbooks for minimum of 3 years	3.52
Instructors keep textbooks for all classes a minimum of 3 years	3.83
University purchase and rent textbooks for a low fee	3.09
Scale is 1= strongly agree to 5= strongly disagree	

Respondents' attitudes toward various publisher actions were also measured using a 5-point scale from completely acceptable to completely unacceptable. As is shown in Table 4, the actions that were most acceptable were requesting course name and number for examination copies; providing online or CD versions of the text for review for possible adoption; and sending parts of texts rather than entire text. The two least agreeable actions were sending an invoice after a 30 day review period and sending only one examination per department.

Table 4
ATTITUDES TOWARD VARIOUS ACTIONS BY PUBLISHERS TO LOWER TEXTBOOK COSTS

Publisher action:	Mean
Send parts of text rather than entire text	2.04
Develop a tracking system to identify "book collectors"	2.76
Don't send unsolicited copies unless using previous edition	2.60
Request course name/number be sent with exam copy	1.69
30-day review period after which an invoice for the cost of book is sent to the instructor	3.69
Offer online access or CD of new text for review instead of a hard copy of text	2.01
Send only one examination copy per department	3.82
Scale 1= completely acceptable to 5=completely unacceptable.	

ANALYSIS

Appendix B shows three tables: B1, B2 and B3 of t-tests and ANOVA that were run on the data to compare possible differences in respondents based on classification variables related to respondents' rank, teaching experience, size of institution, etc. Table B1 shows that respondents who had received complaints from students about textbook cost and with less than 10 years of teaching experience were more likely to rank cost of the text more important as a selection criterion.

As might be expected, Table B2 shows that those respondents who switch text every three years or more were more favorable to legislation requiring that textbooks for multiple sections be kept for a minimum of three years. Similarly, instructors tended to favor keeping textbooks for a minimum of three years compared to Assistant, Associate and Full Professors.

Table B3 shows that smaller universities preferred publishers not sending unsolicited copies unless the university was using the current edition. In addition, full professors were more receptive to publishers developing tracking systems to identify "book collectors".

SUMMARY

The concern for the cost of textbooks has led many students, faculty, universities, and some state legislatures to explore actions to reduce textbook cost. Some newer publishers have sought to enter the market based on lower cost options for students, including providing free online access to texts and lowering textbook prices. This may lead to heightened sensitivity to cost as criteria in textbook selection in the future.

Quantitative methods professors appear to have strong resistance to university, legislative, and publisher actions that infringe on their options in selecting textbooks and how long they would have to use a specific text before replacing it with a newer edition. This was particularly true of legislation requiring that textbooks for multiple sections be kept for a minimum of three years.

When faculty were asked for other comments in the survey, several trends were noted in their comments: (1) many felt that online versions of text would eventually replace hard copies of textbooks and (2) that many of the ancillaries offer by publishers increased the cost of textbook without adding real value to a student's learning experience. Thus new technologies and increased publisher competition may cause changes in both the way textbooks are accessed and how they are marketed.

Although opposed to legislation, results do show that faculty respond to student complaints by being cost conscious when selecting textbooks. Similarly, most faculty were not aware of how book store profits were used on campus. These could be key drivers in reducing costs by developing processes that increase faculty awareness.

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APPENDIX A – Survey Questions

Q1. Rank the importance of the following: content, edition, ancillary material, cost of text, length of text. Note: 1= most important, 2= second most important, 3=third most important, 4=fourth most important, 5=least important.

Q2. How often do you switch textbooks? Once a year; every two years; every three years; every four years; every five years; longer than five years.

Q3. Received complaints from students about cost of textbooks?

Q4. Do all of your students purchase or rent the required textbooks for your classes?

Q5. If no, what percentage of your students would you say purchase or rent the required textbooks for your classes?

Q6. How is your university bookstore operated? University operated; outsourced; don't know.

Q7. How does the university utilize the profits or outsource fee from the campus bookstore? Technology upgrades; faculty salaries; student scholarships; campus improvements; student government activities; athletics; don't know.

Q8. Is there one or more off-campus bookstores near your campus? Yes; no.

Q9. For courses with multiple instructors, what is the textbook decision-making process at your institution or within your department? Group; individual.

Q10. Rank the importance of the following: Legislation require publishers to provide cost info.; legislation require publishers to unbundle; require publishers provide textbook copies on reserve in library; Univ. policy require lowest cost textbook; multiple courses use the same textbook; multiple sections keep textbooks for a minimum of three years; instructors keep textbooks for all classes min. 3 years; purchase textbook then rent them for a low fee.

Q11. Rank the importance of the following: Send particle text rather than entire; tracking system to identify book collectors; do not send unsolicited copies unless using previous edition; request course name/number be sent with exam copy; 30-day review period after which invoice the cost of book; online access or CD of new text for review; only one examination copy per department

Q12. How long have you been teaching? 5 years or less; 6-10 years; 11-15; 16-20; more than 20 years.

Q13. What is your current rank? Adjunct; Instructor; Assistant Professor; Associate Professor; Full Professor.

Q15. What is your institution's current student enrollment? Less than 5,000; 5,000 – 9,999; 10,000 – 19,999; 20,000 or more.

Q16. Is your institution public or private? Public; private.

Q17. What business degree programs are offered at your institution? Associate's; Bachelor's; Master's; Doctor's.

APPENDIX B – ANOVA and t-tests
(***, **, * represent significance at 0.01, 0.05 and 0.10 respectively)

Table B1. Question 1 by Questions 2, 12, 13, 14 and 15

Question 1 by Q2 (how often switch textbooks)							
	2 years or less	3 years or more			t	p	
Rank importance of content	1.25	1.31			-0.26	0.79	
Rank importance of edition	3.48	3.74			0.38	0.34	
Rank importance of ancillary materials	3.13	3.31			-0.70	0.49	
Rank importance of cost of text	3.26	2.95			1.39	0.17	
Rank importance of length of text	3.87	3.74			0.51	0.61	
Question 1 by Q3 (receive complaints from students about cost of textbooks)							
	Complaints	No Complaints			t	p	
Rank importance of content	1.30	1.22			0.31	0.76	
Rank importance of edition	3.72	3.39			1.04	0.30	
Rank importance of ancillary materials	3.27	3.17			0.33	0.74	
Rank importance of cost of text	2.90	3.67			-3.02	0.00	***
Rank importance of length of text	3.85	3.56			0.97	0.34	
Question 1 by Q4 (purchase or rent textbooks)							
	Rent/Purchase	No rent/purchase			t	p	
Rank importance of content	1.15	1.39			-1.17	0.25	
Rank importance of edition	3.60	3.76			-0.60	0.55	
Rank importance of ancillary materials	3.29	3.30			-0.02	0.98	
Rank importance of cost of text	3.06	2.97			0.40	0.69	
Rank importance of length of text	3.96	3.57			1.57	0.12	
Question 1 by Q12 (years of teaching)							
	10 years/less	11-20 years			t	p	
Rank importance of content	1.21	1.62			-1.27	0.21	
Rank importance of edition	4.05	3.58			1.30	0.20	
Rank importance of ancillary materials	3.21	3.00			0.61	0.54	
Rank importance of cost of text	2.58	3.21			-2.06	0.05	**
Rank importance of length of text	3.95	3.58			0.97	0.34	
Question 1 by Q13 (rank)							
	Instructor	Assistant	Associate	Full	F	p	
Rank importance of content	1.00	1.29	1.46	1.26	0.53	0.67	
Rank importance of edition	4.25	4.08	3.46	3.45	1.86	0.14	
Rank importance of ancillary materials	3.12	2.92	3.38	3.28	0.48	0.70	
Rank importance of cost of text	2.62	2.69	3.12	3.25	1.60	0.20	
Rank importance of length of text	4.00	4.31	3.58	3.75	1.34	0.27	
Question 1 by Q15 (university enrollment)							
	< 10,000	10,000 or more			t	p	
Rank importance of content	1.30	1.28			0.14	0.89	
Rank importance of edition	3.52	3.75			-0.89	0.38	
Rank importance of ancillary materials	3.25	3.25			0.00	1.00	
Rank importance of cost of text	3.07	3.07			0.00	1.00	
Rank importance of length of text	3.93	3.64			1.22	0.23	

APPENDIX B – ANOVA and t-tests
(***, **, * represent significance at 0.01, 0.05 and 0.10 respectively)

Table B2. Question 10 by Questions 2, 3, 4, 12, and 13

Question 10 by Q2 (how often switch textbooks)							
	2 years or less	3 years or more			t	p	
Legislation require publishers to provide cost information	3.23	2.84			1.29	0.20	
Legislation require publishers to unbundle	3.13	2.77			1.22	0.23	
Require publishers provide textbook copies on reserve in library	3.32	3.31			0.04	0.97	
Univ. policy require lowest cost textbook	4.77	4.64			0.82	0.41	
Multiple courses use the same textbook	3.00	2.89			0.36	0.72	
Multiple sections keep textbook for min. 3 years	4.00	3.28			2.62	0.01	**
Instructors keep textbooks for all classes min. 3 years	4.13	3.67			1.63	0.11	
Purchase textbooks then rent them for a low fee	2.97	3.15			-0.67	0.51	
Question 10 by Q3 (receive complaints from students about cost of textbooks)							
	Complaints	No Complaints			t	p	
Legislation require publishers to provide cost information	2.96	3.00			-0.11	0.91	
Legislation require publishers to unbundle	2.85	3.06			-0.58	0.56	
Require publishers provide textbook copies on reserve in library	3.34	3.22			0.33	0.74	
Univ. policy require lowest cost textbook	4.65	4.83			-0.95	0.35	
Multiple courses use the same textbook	2.85	3.22			-0.97	0.34	
Multiple sections keep textbook for min. 3 years	3.47	3.72			-0.70	0.48	
Instructors keep textbooks for all classes min. 3 years	3.81	3.89			-0.23	0.82	
Purchase textbooks then rent them for a low fee	3.07	3.17			-0.30	0.76	
Question 10 by Q4 (purchase or rent textbooks)							
	Rent/Purchase	No rent/purchase			t	p	
Legislation require publishers to provide cost information	2.77	3.22			-1.52	0.13	
Legislation require publishers to unbundle	2.75	3.11			-1.26	0.21	
Require publishers provide textbook copies on reserve in library	3.15	3.42			-0.91	0.36	
Univ. policy require lowest cost textbook	4.54	4.86			-2.31	0.02	**
Multiple courses use the same textbook	3.00	2.67			1.08	0.29	
Multiple sections keep textbook for min. 3 years	3.52	3.44			0.26	0.80	
Instructors keep textbooks for all classes min. 3 years	3.73	3.92			-0.67	0.51	
Purchase textbooks then rent for a low fee	3.08	2.97			0.38	0.70	

APPENDIX B – ANOVA and t-tests (***, **, * represent significance at 0.01, 0.05 and 0.10 respectively)							
Question 10 by Q12 (years of teaching)							
	10 years or less	11-20 years			t	p	
Legislation require publishers to provide cost information	2.79	3.35			-1.42	0.16	
Legislation require publishers to unbundle	3.00	2.70			0.74	0.47	
Require publishers provide textbook copies on reserve in library	3.00	3.13			-0.31	0.76	
Univ. policy require lowest cost textbook	4.84	4.61			1.07	0.29	
Multiple courses use the same textbook	2.63	3.00			-0.87	0.39	
Multiple sections keep textbook for min. 3 years	3.16	3.65			-1.13	0.27	
Instructors keep textbooks for all classes min. 3 years	3.53	3.91			-0.93	0.36	
Purchase textbooks then rent them for a low fee	2.84	3.00			-0.41	0.69	
Question 10 by Q13 (rank)							
	Instructor	Assistant	Associate	Full	F	p	
Legislation require publishers to provide cost information	2.56	3.21	3.16	2.86	0.66	0.58	
Legislation require publishers to unbundle	2.22	3.21	3.04	2.81	1.16	0.33	
Require publishers provide textbook copies on reserve in library	2.89	3.07	3.16	3.52	0.90	0.44	
Univ. policy require lowest cost textbook	4.22	4.93	4.68	4.71	1.72	0.17	
Multiple courses use the same textbook	2.33	2.79	3.44	2.86	1.64	0.19	
Multiple sections keep textbook for min. 3 years	2.56	3.21	3.76	3.71	2.43	0.07	*
Instructors keep textbooks for all classes min. 3 years	2.56	3.57	4.12	4.05	4.46	0.01	***
Purchase textbooks then rent them for a low fee	2.89	3.31	2.76	3.26	1.08	0.36	
Question 10 by Q15 (university enrollment)							
	< 10,000	10,000 or more			t	p	
Legislation require publishers to provide cost information	2.91	3.02			-0.38	0.70	
Legislation require publishers to unbundle	2.93	2.87			0.21	0.83	
Require publishers provide textbook copies on reserve in library	3.48	3.15			1.17	0.25	
Univ. policy require lowest cost textbook	4.82	4.55			1.76	0.08	*
Multiple courses use the same textbook	2.75	3.11			-1.17	0.25	
Multiple sections keep textbook for min. 3 years	3.55	3.49			0.20	0.85	
Instructors keep textbooks for all classes min. 3 years	3.77	3.87			-0.37	0.71	
Purchase textbooks then rent for a low fee	3.19	2.96			0.88	0.38	

APPENDIX B – ANOVA and t-tests (***, **, * represent significance at 0.01, 0.05 and 0.10 respectively)							
Table B3. Question 11 by Questions 2, 3, 4, 12, 13 and 15							
Question 11 by Q2 (how often switch textbooks)							
	2 years or less	3 years or more			t	p	
Send partial text rather than entire	2.19	1.97			0.81	0.42	
Tracking system to identify book collectors	2.97	2.66			1.01	0.32	
Do not send unsolicited copies unless using previous edition	2.87	2.47			1.26	0.21	
Request course name/number be sent with exam copy	1.74	1.66			0.36	0.72	
30-day review period after which invoice the cost of book	4.13	3.47			2.48	0.02	
Online access or CD of new text for review	2.06	1.98			0.31	0.76	
Only one examination copy per department	4.00	3.73			0.98	0.33	
Question 11 by Q3 (receive complaints from students about cost of textbooks)							
	Complaints	No Complaints			t	p	
Send partial text rather than entire	2.07	1.94			0.37	0.72	
Tracking system to identify book collectors	2.83	2.50			0.90	0.37	
Do not send unsolicited copies unless using previous edition	2.60	2.61			-0.03	0.98	
Request course name/number be sent with exam copy	1.73	1.50			0.87	0.39	
30-day review period after which invoice the cost of book	3.76	3.39			1.06	0.29	
Online access or CD of new text for review	2.04	1.89			0.49	0.63	
Only one examination copy per department	3.91	3.44			1.17	0.26	
Question 11 by Q4 (purchase or rent textbooks)							
	Rent/Purchase	No rent/purchase			t	p	
Send partial text rather than entire	1.82	2.24			-1.58	0.12	
Tracking system to identify book collectors	2.75	2.89			-0.50	0.62	
Do not send unsolicited copies unless using previous edition	2.55	2.55			-0.01	0.99	
Request course name/number be sent with exam copy	1.80	1.61			0.90	0.37	
30-day review period after which invoice the cost of book	3.57	3.84			-0.95	0.34	
Online access or CD of new text for review	2.04	1.95			0.37	0.71	
Only one examination copy per department	3.53	4.32			-3.25	0.00	***

Question 11 by Q12 (years of teaching)							
	10 years/less	11-20 years			t	p	
Send partial text rather than entire	2.16	1.88			0.74	0.46	
Tracking system to identify book collectors	2.74	3.25			-1.30	0.20	
Do not send unsolicited copies unless using previous edition	2.37	2.83			-1.01	0.32	
Request course name/number be sent with exam copy	1.63	1.92			-0.87	0.39	
30-day review period after which invoice the cost of book	3.47	3.71			-0.56	0.58	
Online access or CD of new text for review	2.05	2.17			-0.28	0.78	
Only one examination copy per department	3.84	3.88			-0.09	0.93	
Question 11 by Q13 (rank)							
	Instructor	Assistant	Associate	Full	F	p	
Send partial text rather than entire	1.22	2.07	2.19	2.17	1.52	0.22	
Tracking system to identify book collectors	3.33	2.79	3.19	2.36	2.76	0.05	**
Do not send unsolicited copies unless using previous edition	2.67	2.43	2.69	2.57	0.11	0.96	
Request course name/number be sent with exam copy	2.00	2.14	1.73	1.48	1.85	0.15	
30-day review period after which invoice the cost of book	3.67	3.79	3.73	3.67	0.03	0.99	
Online access or CD of new text for review	1.89	2.14	2.08	2.00	0.11	0.96	
Only one examination copy per department	3.44	4.00	3.58	3.95	0.80	0.50	
Question 11 by Q15 (university enrollment)							
	< 10,000	10,000 or more			t	p	
Send partial text rather than entire	2.27	1.83			1.66	0.10	
Tracking system to identify book collectors	2.67	2.83			-0.56	0.58	
Do not send unsolicited copies unless using previous edition	2.29	2.87			-1.95	0.05	*
Request course name/number be sent with exam copy	1.73	1.64			0.44	0.66	
30-day review period after which invoice the cost of book	3.73	3.66			0.26	0.79	
Online access or CD of new text for review	1.76	2.19			-1.88	0.06	*
Only one examination copy per department	3.80	3.83			-0.11	0.91	

A BINOMIALLY DISTRIBUTED PRODUCTION PROCESS REVISITED: A PEDAGOGICAL APPROACH

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ABSTRACT

A production system with rework cycle and a process yield that follows a binomial distribution has been revisited. Based on a finite number of rework cycles and without assuming any probability distribution, a new formula for determining the number of units that must be started to achieve a required production yield has been proposed. This article makes a pedagogical contribution to the problem of production rework.
Keywords: Rework cycle, Production yield.

INTRODUCTION

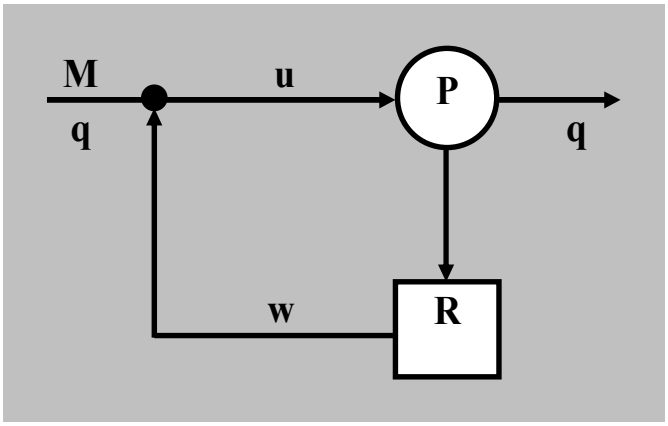
The economics of rework/re-manufacturing in production systems is very important since it affects the time and cost to achieve a required production yield. The goal is to achieve the required production yield within the expected time at a minimum cost. A number of research papers have attempted to address various aspects of this issue. For instance, Abdel-Malek and Asadathorn (1996), Inderfurth and Teutner (2003), Flapper, et al (2002), and Flapper and Teutner (2003), studied planning and control problems of rework; Inderfurth, et al (2003) and Lindner, et al (2001) examined lotsizing issues of rework; and Inderfurth, et al (2005), Chase, et al (2006), and Nevins and Whitney (1989) discussed costs associated with rework. In other papers, Nasr, et al (1998) showed that the area of remanufacturing employs a very significant number of workers in the United States and Lund (1998) discussed the fact that remanufacturing accounts for a very significant portion of the business volume in the United States. Also, Inderfurth and van der Laan (2001) analyzed the relationship between lead-time and stochastic inventory control in remanufacturing. Similarly, Tang and Grubbstrom (2005) examined stochastic lead times and deterministic demands in manufacturing/remanufacturing with returns.

Of interest in this paper is the problem of rework in production systems producing relatively large numbers of products in a single lot, using a stable manufacturing system and performing quality sampling at the manufacturing site. Often, in such production systems, quality sampling is performed less frequently and is usually deferred until the time of shipment of a lot, at which time a sample is drawn to assess the quality of the lot. Also, for such systems, when the probability of producing a defective unit is low, it is desirable to know how many production units must be run in order to reasonably expect to have an adequate number of good

items (i.e., less defectives) to satisfy a given production quota. In fact, we would want to size the production run such that it has a high probability, say 95% or 99%, of satisfying the required production quota.

We first consider the single-level process used by Nevins and Whitney (1989) in their discussion of the effect of recycling and rework. The process is shown schematically in Figure 1.

Figure 1 – Typical Production Cycle with Rework



The following variables for this model are defined as follows:

q – required production yield
M – unit material cost
u – number of units which must be processed to achieve "q"
P – processing cost, including testing
w – number of units which must be reworked
R – cost of rework and/or material replacement
y – capability of process P

In the above process, it is assumed that "q" units of material are started through the production process, each having a cost of "M." As each undergoes the production process, it is tested, and incurs a cost of "P" for production and testing. Some of the units processed will be found good, and contribute toward satisfying the required production yield "q." However, a number "w" of these units will be found defective, and will either have to be reworked or replaced. Thus, "w" is comprised of those units that can be successfully reworked, and some number of makeup units to account for those units that cannot be successfully reworked. Then, as this system arrives at steady state, the number of units "u" to pass through the production process is …

$$\mathbf{u = q + w}$$

Further, Nevins and Whitney describe the process as having a binomial distribution with the number of good items as the binomial random variable and the probability of a good item as the process capability "y," which is expressed as …

$$y = \frac{q + 1}{q + m + 1},$$

where "m" is the mean number of units failing to pass the inspection process.

As indicated earlier, the above process assumes a binomial distribution where the production yield is set equal to the mean of the binomial variable. Thus, if "n" is the number of units entering the process and "q" is the required production yield, then q=n*y. From this relationship, the number of units needed to achieve the required production yield is n=q/y. We argue that this number is too conservative. To mitigate this problem, the above model allows rework of defective units. However, it does not incorporate the number of salvageable units in the formula for determining the number of input units. Thus, while reworking defective units might reduce the number of units actually used to satisfy the required production yield, there would still be a problem of oversupply of input units.

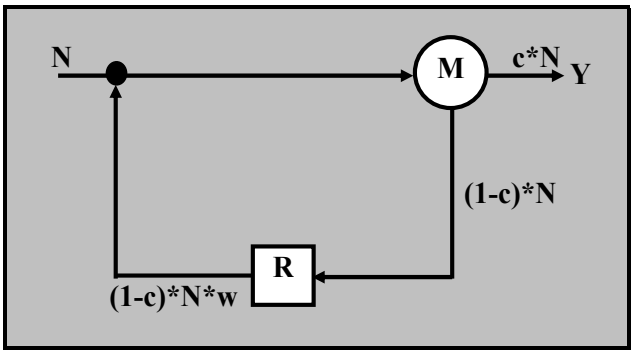
In this paper, we revisit the Nevins and Whitney's single-level process of Figure 1 and reexamine the nature of the process, taking into account salvageable units, to determine a more reasonable number of input units that will result in a given production yield.

METHODOLOGY

The question that is to be answered with this analysis is that given a certain Yield "Y," that must be met by a manufacturing process "M," having capability "c," and given a certain number of times through the rework cycle "R," how many units of "N," must be started? Figure 2 below depicts this process, and is exhibited as the basis for developing the pertinent equations for the proposed approach to the production rework cycle.

As "N" units make their first pass through "M," c*N of them contribute toward meeting the quota "Y," and (1-c)*N are found to be defective and are sent through the rework cycle as indicated by "R." Of those units sent through the rework cycle, a fraction "w" can be reworked and "1-w" cannot be. It is evident that if the production process were perfect, viz, if it had a capability "c = 1," that Y would be equal to N and only one pass would be necessary for each unit produced in order to satisfy the production quota "Y."

Figure 2 – Modified Production Cycle with Rework



The following variables for this model are defined as follows:

N – number of units required to realize a production yield of Y, where $N \geq Y$
M – Manufacturing and testing process
R – rework cycle
c – capability of process
Y – required production yield
w – fraction of rejected units that can be reworked

Next, the (1 - c)*N defective units are processed through "M" a second time. Again, some of them are found to be good and contribute toward meeting the production quota "Y" while others are found still to be defective. The number of good units contributing toward satisfying "Y" can be tabulated as a function of the number of passes through the rework cycle. This is as follows:

Passes through P	Good Units	Defective Units	Reworkable Units
1	$c*N$	$(1-c)*N$	$(1-c)*N*w$
2	$c*(1-c)*N*w$	$(1-c)^2*N*w$	$(1-c)^2*N*w^2$
3	$c*(1-c)^2*N*w^2$	$(1-c)^3*N*w^2$	$(1-c)^3*N*w^3$
.	.	.	.
.	.	.	.
.	.	.	.
p	$c*(1-c)^{p-1}*N*w^{p-1}$	$(1-c)^p*N*w^{p-1}$	$(1-c)^p*N*w^p$

Now it is evident that the number of good units can be written as the sum of a series with "p" terms. Letting "S" be the sum of the series, we then have

1) $S = c*N + c*(1 - c)*N*w + c*(1 - c)^2*N*w^2 + \ldots. + c*(1 - c)^{p-1}*N*w^{p-1}$

After factoring out "c*N," the sum in equation 1) becomes …

$S = c*N*[1 + (1 - c)*w + (1 - c)^2*w^2 + \ldots. + (1 - c)^{p-1}*w^{p-1}]$

Now the term inside the brackets is a geometric series, which may be summed by the approach that follows. Multiplying both sides of equation 2) by "(1 – c)*w," equation 3) is obtained as …

$S*(1 - c)*w = c*N*[(1 - c)*w + (1 - c)^2*w^2 + (1 - c)^3*w^3 + \ldots. + (1 - c)^p*w^p]$

Multiplying through equation 3) by minus 1, and adding it to equation 2), equation 4) is obtained as …

$S - S*(1 - c)*w = c*N*[1 - (1 - c)^p*w^p]$

Solving for "S," equation 5) is obtained as …

5) $$S = \frac{c*N*[1-(1-c)^p*w^p]}{1-(1-c)*w}$$

Now, the sum of the series "S" after "p" passes through the rework cycle must equal the required production Yield "Y." Then solving for "N" in terms of "Y," equation 6) is obtained as

6) $$N = \frac{Y*[1-(1-c)*w]}{c*[1-(1-c)^p*w^p]}$$

Thus, in order to arrive at a production quota "Y" after "p" passes through the rework cycle, it is necessary to start "N" units. Again it should be noted that if "M" were perfect (i.e. c=1), "N" would be equal to "Y."

DISCUSSION

In the previous Nevins and Whitney model (Figure 1), the production process is assumed to be binomially distributed and the required production yield is set equal to the mean of the binomial. Thus, using the variables of Figure 2, we have

7) $$Y = N * C$$

Hence, the number of startup units "N" to achieve a required production yield "Y" is

8) $$N = \frac{Y}{C}$$

We will now compare equation 6) with equation 8). Clearly, both equations are the same if p=1 or w=0. However, for $0<c<1$, $0<w<1$, and $p>1$, equation 6) is always smaller than equation 8). This is illustrated in Table 1 below for "c" values of 0.8 and 0.7, w=0.6, and Y=200.

Table 1: Comparison of N Using Equation 8) and N Using Equation 6) for c values of 0.8 and 0.7, w=0.6, and Y= 200.

	N Using Binomial Equation 8)		N Using Proposed Formula Equation 6)	
p	c=0.8	c=0.7	C=0.8	C=0.7
1	250	286	250	286
2	250	286	223	242
3	250	286	220	236
4	250	286	220	235
5	250	286	220	234

In the above illustration, the two approaches give the same results for p=1. However, for p=2 and c=0.8, 27 fewer startup units are required for the proposed approach. As "p" increases beyond 2, the reduction tapers off to 220, resulting in a total reduction of 30 units. For a less capable process with c=0.7, the reduction in startup units is 44 for p=2 and tapers off to 234 for p=5. Even at p=2, if startup units cost $100 each, the proposed approach will reduce production cost by $2700 when c=0.8 and $4400 when c=0.7; and the reduction in cost will grow linearly with production volume.

CONCLUSION

In this paper, we have derived a new formula for determining the number of startup units to achieve a required production yield without assuming any probability distribution. This approach results in fewer startup units than would be required by the current approach of assuming a binomial distribution and using the mean of the binomial to determine the number of startup units. The reduction in startup units is greatest for a rework cycle of 2 and then tapers off as the rework cycle increases beyond 2. Also, the reduction in startup units grows linearly with

production volume resulting in greater savings in production cost, especially for costly startup units.

Although the purpose of this analysis has been primarily pedagogical, an important practical use for which the foregoing model might be employed is as a cost cutting tool for companies having older and less capable equipment since the reduction in startup units also increases with lower process capability. Furthermore, this approach can be used in multistage production systems where a startup unit goes through a series of processes to become a finished product. In this case, one would start with the last process and work backward to the first, treating the estimate of startup units for a succeeding process as the required yield for the previous process. In this way, we can estimate the number of startup units for the first process.

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COMPETITION IN MULTI-CHANNEL SUPPLY CHAINS

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ABSTRACT

Consider a multi-channel supply chain (hereafter SC) system, producing and distributing two substitutable products. Within this framework, we compare and contrast price and quantity competition strategies, and study how the disparity between the two strategies changes with the degree of product substitutability. It is shown that price competition and quantity competition is not equivalent. Neither strategy is superior for all SC configurations discussed in this paper. The disparity between price and quantity competition increases when product substitutability increases.

INTRODUCTION

Two strategies of market competition have been widely observed in SC systems. One strategy is price competition which is often defined as Bertrand competition in economics literature. The other is quantity competition which is typically defined as Cournot competition in economics. In price competition, prices are often compelled to marginal cost while in quantity competition positive price-cost margins are often achieved.

Distribution channel structure has been another major strategic concern for SC system. Many distribution channels have been observed ranging from traditional retail channel to the direct sales model and the clicks-and-mortar channel (Gap/Gap.com, Staples/Staples.com etc.). The contracting arrangement between a manufacturer and a retailer also varies from channel to channel. Some manufacturers use an exclusive arrangement with a retailer while others use multiple channels. The direct channel is a vertically integrated channel often controlled by a manufacturer (Dell, for example).

The efficiency of a decentralized SC system is defined as the ratio of its total equilibrium profit to the optimal profit of the centralized system. The objective of this paper is to study the disparity of SC efficiencies between price competition and quantity competition. To that end, consider two substitutable products, produced either by a single manufacturer or by two manufacturers. The products are sold through utmost two retailers. Within this framework, consider different SC arrangements ranging from a centralized configuration to several decentralized multi-channel ones. The decentralized configurations include the single retailer channel (two manufacturers, each producing one product; both sell their products through a

single retailer), the single manufacturer channel (one manufacturer, two retailers), and the exclusive channel (two manufacturers and two retailers; each manufacturer sells through only one retailer and each retailer carry only one product). This paper is intended to answer the following questions. Does price competition result in the same efficiencies for SC configurations as quantity competition? Is one competition strategy always superior to the other one? How does product substitutability affect competition strategies?

Many of the channel arrangements described above are observed in practice. The factory outlets and the direct distribution channels are the typical examples of centralized SC between a manufacturer and a retailer. The exclusive channel is most often observed in manufacturer-distributor relationships in various industries ranging from chemicals and paper to appliances and Beer. For example, Hercules Inc. is the exclusive distributor for GE Specialty Materials' water treatment solutions to the paper industry (Challener, 2003); Diego Suarez is the exclusive distributor of Coors brand of beers in Puerto Rico (Allio & Allio, 2002). The Wall Street Journal (October 28, 2003) reports that Estee Lauder has created a new company division, called BeautyBank, to develop cosmetic products exclusively for Kohl's (Merrick & Beatty, 2003). Different auto makers often sell vehicles through a single dealer in smaller cities, giving rise to a distribution channel similar to the single retailer channel noted above. Wu et al. (2009 & 2010) have used similar SC configurations in their study.

This paper compares and contrasts price and quantity competition strategies in these decentralized SCs, and studies how the differences between the two strategies change with the degree of substitutability.

LITERATURE REVIEW

SC structure, conflict and coordination have been extensively studied in operations literature. The majority of the works assume a single manufacturer and a single retailer. The typical approach is to study the source of inefficiency (often related to double marginalization), and mechanisms for achieving coordination. Cachon (2001) provides a review of this stream of literature. The channel conflict literature typically considers the scenario where the manufacturer is simultaneously a supplier to and competitor of its retail partners(s). Chiang et al. (2003) consider whether a single manufacturer should sell exclusively through a retailer, direct over the Internet, or through a hybrid channel. Their key finding is that the manufacturer may use a direct channel as a way to combat double marginalization in the retail channel. Ahn et al. (2002) consider the competition between independent retailers and manufacturer-owned stores where parties compete in price. The manufacturer sells an identical product through two spatially separated markets. Tsay and Agarwal (2002) provide a review in modeling channel conflict and coordination. This stream of literature typically considers a single manufacturer selling identical products, whereas our work considers multiple manufacturers selling substitutable products.

Existing comparative work of price and quantity competitions is fruitful in the field of Economics and Supply Chain Management. Singh and Vives (1984) show that in a duopoly game with linear demand and constant marginal cost, firms should employ quantity competition strategy if products are substitutable and take price competition strategy if products are well differentiated. Cheng (1985) studies the equilibrium outcomes of price and quantity competitions with differentiated products and finds that quantity competition is superior to price competition under certain assumptions. There are other studies that show preference to price competition. For example, Amir and Jin (2001) provide support to the result that Bertrand equilibrium is intrinsically more competitive than Cournot equilibrium in an oligopoly model with linear demand, and a mixture of substitute and complementary products under some limitations. On the other hand, Miller and Pazgal (2001) demonstrate the equivalence result in a two-stage differentiated-products oligopoly model under certain assumptions.

The third stream of literature related to our work is product substitutability which has also been studied extensively in both Operations and Marketing literature. In Operations, for instance, Boyaci (2003) considers a multi-channel distribution system in presence of both vertical and horizontal competition. He concludes that there is a tendency for both manufacturer and retailer to overstock due to substitutability. In Marketing, Raju et al. (1995) consider the introduction and performance of store brands vis-à-vis a national brand. Mahajan and van Ryzin (1999) provide a comprehensive survey of research on demand substitutability. However, these studies take the SC structure as given and do not address the issue of SC efficiency. Our work differs from these studies by quantifying SC efficiency.

MODELS

Consider multi-channel distribution systems for two substitutable products, denoted by 1 and 2. The products reach the end consumer through a two-echelon SC involving manufacturer(s) and retailer(s). Multi-channel systems studied in this paper involve utmost two manufacturers and utmost two retailers. The manufacturers are denoted by M_1 and M_2 (or by M, if there is only one manufacturer), while the retailers will be denoted by R_1 and R_2 (or by R, if there is only one retailer) respectively. Vertical competition is introduced by considering decentralized decisions made within the channels; while, the horizontal competition is introduced by substitutable products. Several different multi-channel distribution systems are considered. Figures 1(a) and 1(b) schematically describe these configurations. The configurations in Figure 1(a) involve either one manufacturer or one retailer, while the configurations in Figure 1(b) involve two manufacturers and two retailers.

The centralized system (denoted as C) is a fully integrated system where a single manufacturer produces both products and sells them through an integrated channel. It yields the highest system profit and serves as a benchmark for the decentralized systems. Figure 1(a) describes three decentralized systems. The decentralized single manufacturer single retailer

system (denoted as DS) involves one manufacturer producing both products and selling them through a single retailer. The retailer makes stocking decisions of the two products independent of the manufacturer. A single manufacturer system (denoted as SM) involves one manufacturer and two retailers. The sole manufacturer produces both products and sells each product exclusively through one independent retailer. Under a single retailer system (denoted as SR), there are two manufacturers, each producing one product. The manufacturers sell their products through a single retailer who makes the stocking decisions of each product in its own interest.

Figure 1(b) describes three decentralized multi-channel distribution systems, each involving two manufacturers and two retailers. Under a partially centralized system (denoted as PC), M_1 sells its product exclusively through R_1 while M_2 sells its products exclusively through R_2. In addition, each of the two competing manufacturer-retailer pair is centralized (or vertically integrated) and the stocking decision within each pair is coordinated. However, there exists horizontal coordination between the two channels. Under a minimally coordinated system (denoted as MC) M_1 sells its product exclusively through R_1, and M_2 sells its products exclusively through R_2. In addition, only one of the two vertical channels is coordinated. Assume, without loss of generality, that M_1 and R_1 are coordinated, while the other manufacturer-retailer pair is not. An exclusive system (denoted as E) is similar to the PC and MC systems except that none of the two manufacturer-retailer pairs is coordinated. Thus, under an exclusive system, M_1 sells its product exclusively through R_1, M_2 sells its products exclusively through R_2, and all parties make decisions in self-interest. It is easy to see that the degree of coordination goes down as moving from PC to MC to E.

FIGURE 1(a): MULTI-CHANNEL DISTRIBUTION SYSTEM CONFIGURATIONS

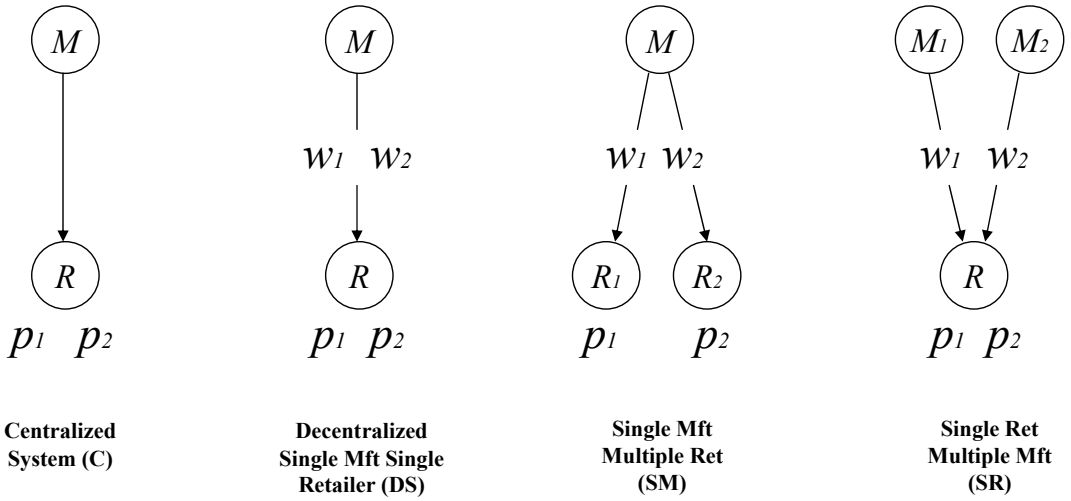
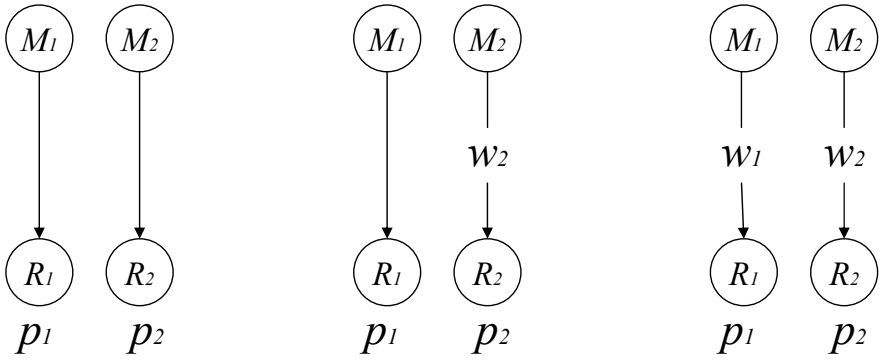


FIGURE 1(b): MULTI-CHANNEL DISTRIBUTION SYSTEM CONFIGURATIONS



Without loss of generality, we assume the common marginal production cost for each product is 0. No fixed cost of production is considered and the production and delivery are assumed to be instantaneous. The manufacturers produce as retailers' orders under a wholesale price contract. Let w_1 and w_2 be the wholesale prices and q_1 and q_2 be the demand of products 1 and 2 respectively. The retailer(s) set the retail prices, denoted by p_1 and p_2 respectively. We model the horizontal competition between two channels under both price and quantity competitions.

Price competition model:

$$q_i = 1 - p_i - \theta(p_j - p_i), \quad i, j = 1,2, i \neq j, \tag{1}$$

where θ is a parameter.

The horizontal competition between the products is captured by making the demand of a product sensitive to the prices of both products. The products are perfectly differentiated when

$\theta = 0$. The products are nearly identical as θ approaches infinity.

Quantity competition model:

$$p_i = \alpha - \beta q_i - \gamma q_j, \qquad \alpha, \beta, \gamma > 0, \gamma \leq \beta; \; i, j = 1,2, i \neq j, \tag{1'}$$

where α, β, and γ are parameters.

The horizontal competition between the products is captured by making the price of a product sensitive to the available quantities of both products. In particular, the products are perfectly substitutable when $\gamma = \beta$; and are perfectly differentiated when $\gamma = 0$. The condition $\gamma \leq \beta$ implies that the demand of a product is more sensitive to its own price rather than the price of the competing product.

These types of demand functions are standard in economics and marketing literature modeling product substitutability (Gal-Or, 1991; Raju et al., 1995). Moreover, Lee and Staelin (2000) show that a linear demand function involving substitutable products is indeed consistent with reasonable buyer behavior and market characteristics.

π, with subscripts and superscripts, is used to denote profit. A subscript of "M" or "R" is used to refer to a manufacturer or a retailer respectively. Superscripts are used to denote a specific SC configuration. Thus, $\pi_{R_i}^{E}$ denotes the profit of retailer *i* under an exclusive system. The notation *j* denotes an index on the SC configurations under consideration. Clearly, *j* = C, DS, SM, SR, PC, MC, E. The total SC profit (i.e. the sum of the profits of retailer(s) and manufacturer(s)) under configuration *j* will be denoted as π^{j} (no subscripts).

The centralized system yields the highest profit and serves as a benchmark for the decentralized systems noted earlier. The profit maximization problem of a centralized system is:

$$\underset{p_1, p_2}{Max}\, \pi^{C} = p_1 q_1 + p_2 q_2 . \qquad (2)$$

The solution of the above optimization problem yields the following results.

Price competition model:

Inserting equation (1) into (2) and the 1st order conditions (the 2nd order conditions are satisfied) yields

$$p_1^* = p_2^* = p^{C*} = \frac{1}{2};\ q_1^* = q_2^* = q^{C*} = \frac{1}{2};\ \text{and}\ \pi^{C*} = \frac{1}{2}. \qquad (3)$$

Quantity competition model:

Similarly, insert equation (1') into (2) and we get

$$p_1^* = p_2^* = p^{C*} = \frac{\alpha + c + s}{2};\ q_1^* = q_2^* = q^{C*} = \frac{\alpha - c - s}{2(\beta + \gamma)};\ \text{and}\ \pi^{C*} = \frac{(\alpha - c - s)^2}{2(\beta + \gamma)}. \qquad (3')$$

For the reasons of brevity, among the decentralized SC configurations only the single retailer (SR) system is described here. The rest will have similar formulations. Under a single retailer system, both manufacturers sell their products through a single retailer. The profit maximization problem of the retailer is:

$$\underset{q_1, q_2}{Max}\ \pi_R^{SR} = (p_1 - w_1)q_1 + (p_2 - w_2)q_2. \qquad (4)$$

Price competition model:

The 1st-order conditions (it is easy to verify that the second order conditions are satisfied) yield:

$$p_i^{SR*}(w_1, w_2) = \frac{(1 + 2\theta) + (1 + \theta)^2 w_i + \theta(1 + \theta)w_j}{2(1 + 2\theta)},\ i, j = 1,2, i \neq j \qquad (5)$$

Quantity competition model:

$$q_i^{SR*}(w_1, w_2) = [\alpha(\beta - \gamma) - \beta(w_i + c) + \gamma(w_j + c)]/[2(\beta^2 - \gamma^2)],\ i, j = 1,2, i \neq j. \qquad (5')$$

The two manufacturers select their wholesale prices by solving the following problems.

$$\underset{w_i}{Max}\ \pi_{M_i}^{SR} = w_i q_i^{SR*}(w_1, w_2),\ i = 1,2. \qquad (6)$$

The equilibrium wholesale prices w_1^* and w_2^* can be found by solving the 1st-order conditions given by (6). Once w_1^* and w_2^* are known, the equilibrium prices, quantities, and profits as well as the total profit can be calculated accordingly under both price and quantity competitions. Similarly, we can solve for the equilibrium prices, quantities, and profits for the other decentralized SC configurations.

Since our focus is efficiencies of SC configurations, only the equilibrium profits are summarized in Table 1.

TABLE 1: EQUILIBRIUM PROFITS OF SC CONFIGURATIONS.

Configuration (*j*)	π^j under Price Competition	π^j under Quantity Competition
C	$\pi^{C*} = 1/2$	$\frac{\alpha^2}{2(\beta+\gamma)}$
DS	$3/8$	$\frac{3\alpha^2}{8(\beta+\gamma)^2}$
SM	$\frac{(\theta+3)(\theta+1)}{2(\theta+2)^2}$	$\frac{\alpha^2(3\beta+\gamma)}{2(2\beta+\gamma)^2}$
SR	$\frac{(\theta+1)\ (\theta+3)}{2(\theta+2)^2}$	$\frac{\alpha^2\beta(3\beta-2\gamma)}{2(\beta+\gamma)(2\beta-\gamma)^2}$
PC	$\frac{2(\theta+1)}{(\theta+2)^2}$	$\frac{2\alpha^2\beta}{(2\beta+\gamma)^2}$
MC	$\frac{(\theta+1)(13\theta^4+82\theta^3+167\theta^2+120\theta+28)}{4(\theta+2)^2(\theta^2+4\theta+2)^2}$	$\frac{\alpha^2(28\beta^2+8\beta\gamma-\gamma^2)}{16\beta(2\beta+\gamma)^2}$
E	$\frac{4(\theta+1)(\theta^2+4\theta+2)(2\theta^2+6\theta+3)}{(\theta+2)^2(\theta^2+7\theta+4)^2}$	$\frac{4\alpha^2\beta(6\beta^2-\gamma^2)}{(2\beta+\gamma)^2(4\beta-\gamma)^2}$

RESULTS AND ANALYSIS

This section compares and contrasts the efficiencies of SC configurations under price competition with those under quantity competition and also examines the effects of product substitutability on the comparison. Under quantity competition, the relative magnitudes of the parameters β and γ determine the degree of substitutability between the two products. The product substitutability can be parameterized by defining $\lambda = \gamma/\beta$. Since $\beta \geq \gamma$, $0 \leq \lambda \leq 1$.

Recall that the *efficiency* of decentralized SC *j* is defined as the ratio of equilibrium total SC profit under configuration *j* to that of the centralized SC; i.e., $R^j = \pi^{j*}/\pi^{C*}, \forall j$. Given that the centralized system yields the highest system profit, $0 \leq R^j \leq 1, \forall j$.

Table 2 summarizes the efficiency for each SC configuration under different horizontal competition.

Let $\lambda' = 1 - e^{-\theta}$. Hence $\lambda' \in [0,1]$ and $\theta = -\ln(1-\lambda')$. Now product substitutability under price competition is rescaled from $[0,\infty]$ to [0, 1] and captured by λ'.

Among all SC configurations, C and DS have the same efficiencies. Figure 2 (a)-(e) compare the efficiencies of other configurations under price and quantity competitions.

TABLE 2: EFFICIENCIES OF SC CONFIGURATIONS

Configuration (*j*)	R^j **under Price Competition**	R^j **under Quantity Competition**
C	1.0	1.0
DS	0.75	0.75
SM	$\frac{(\theta+3)(\theta+1)}{(\theta+2)^2}$	$1-\frac{1}{(2+\lambda)^2}$
SR	$\frac{(\theta+3)(\theta+1)}{(\theta+2)^2}$	$\frac{(3-2\lambda)}{(2-\lambda)^2}$
PC	$\frac{4(\theta+1)}{(\theta+2)^2}$	$\frac{4(1+\lambda)}{(2+\lambda)^2}$
MC	$\frac{(\theta+1)(13\theta^4+82\theta^3+167\theta^2+120\theta+28)}{2(\theta+2)^2(\theta^2+4\theta+2)^2}$	$\frac{(1+\lambda)(28+8\lambda-\lambda^2)}{8(2+\lambda)^2}$
E	$\frac{8(\theta+1)(\theta^2+4\theta+2)(2\theta^2+6\theta+3)}{(\theta+2)^2(\theta^2+7\theta+4)^2}$	$\frac{8(1+\lambda)(6-\lambda^2)}{(4-\lambda)^2(2+\lambda)^2}$

Theorem.

(i) Price and quantity competitions are equivalent only if the two products are perfectly differentiated.

(ii) Neither price competition nor quantity competition is a dominant strategy.

(iii) As the product substitutability increases, a large difference of the efficiencies between price and quantity competition is observed (except when the two products are almost identical).

Comparing price with quantity competition analytically, we find the same efficiency is achieved for each configuration only when $\lambda = \lambda' = 0$. So the two competitions are never equivalent if the two products are not perfectly differentiated.

It is easy to see that quantity competition is not always better in terms of higher efficiency for SC configurations. Neither is price competition. Actually in SM and E SC configurations, price competition almost always yields higher efficiency (except when the two products are almost identical in E SC configuration) while in SR, PC, and MC configurations, quantity competition always yields higher efficiency.

It is also interesting to notice that as the product substitutability increases, the difference between quantity and price competitions increases too (except when the two products are almost identical in SR and E SC configurations).

Figure 2(a): Comparison between Single Manufacturer SCs

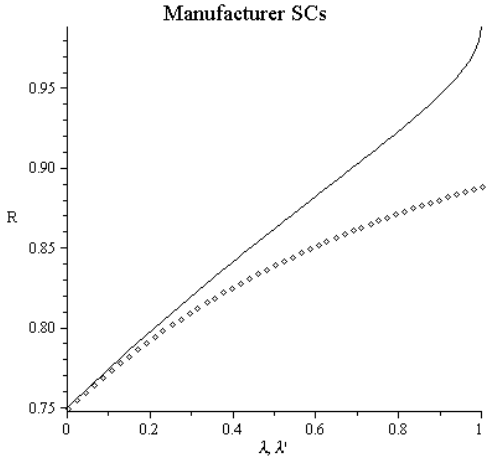


Figure 2(b): Comparison between Single Retailer SCs

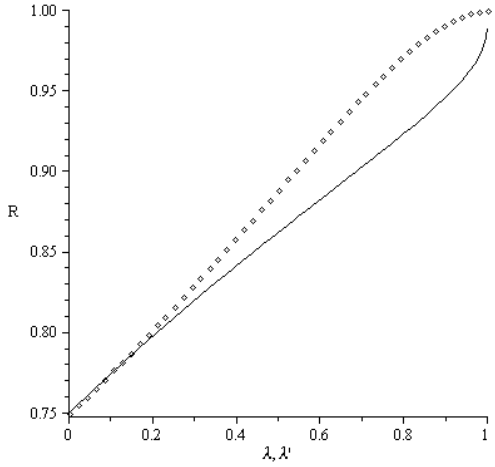


Figure 2(c): Comparison between Partially Centralized SCs

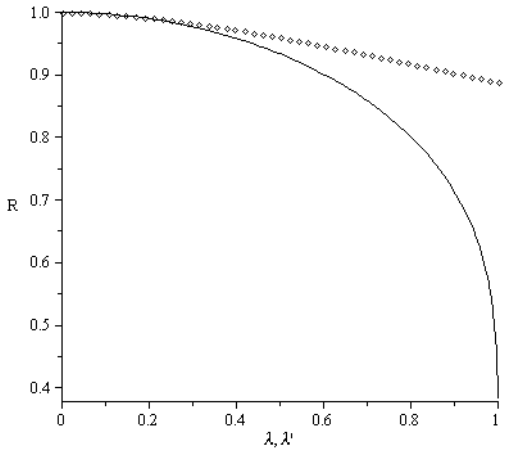


Figure 2(d): Comparison between Minimally Coordinated SCs

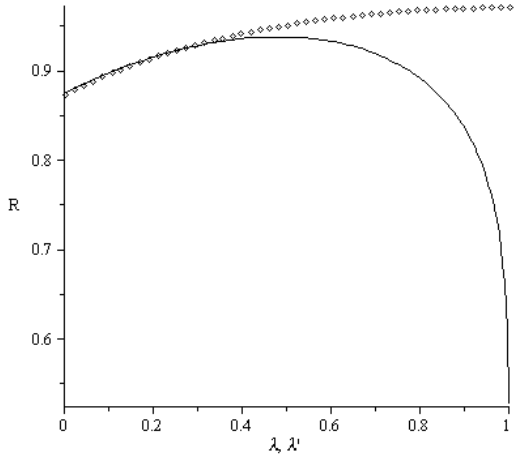
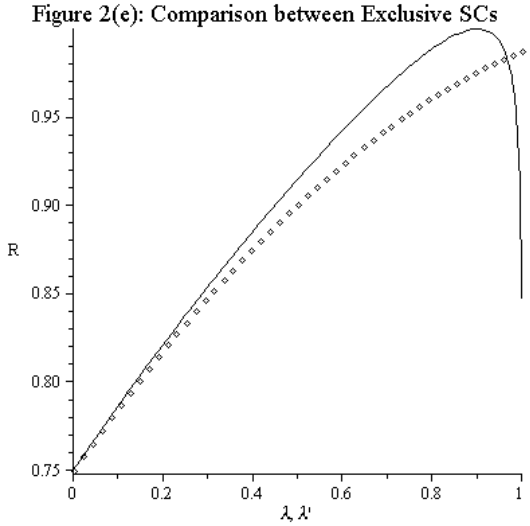


Figure 2(e): Comparison between Exclusive SCs



Quantity Competition
Price Competition

SUMMARY AND CONCLUSION

Multi-channel distribution systems with differing channel configurations are widely observed in practice. This paper studies price and quantity competitions of dual-channel-dual-echelon SC systems. Six decentralized SC configurations with different degree of horizontal and vertical integration were discussed. We compare and contrast the equilibrium SC efficiencies of different SC structures under price with those under quantity competition.

The most important contributions of this paper are that price competition and quantity competition are not equivalent, and that neither of them is a dominant strategy for the SC configuration systems discussed in this paper.

Another important finding is that for each dual-channel (either two retailers or two manufacturers or both) SC configuration the difference of efficiencies under price and quantity competitions increases with increased product substitutability.

The metrics used in this paper for comparison is the efficiency of SC configurations. It will be interesting to examine what will be the results if other metrics are used, such as price. It will also be interesting, although difficult, to investigate the comparison using more complex SC configurations, such as SC systems with more than two echelons or with more than two manufacturers/retailers. If SC systems of three or more echelons are considered, the tractability of the resulting analytic models significantly decreases. Another extension we consider pursuing is to relax the assumption in this paper that the demand functions of two retailers are symmetric. It will be very intriguing to see how sensitive the results in this article are to the changes in the demand function structures.

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OPEN INNOVATION MODELING USING GAME THEORY

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ABSTRACT

Companies use open innovation approach to collaborate with external partners in research and development to reach new technologies that otherwise may not be easy or economical to achieve. This collaboration may cause them to lose control of their research, development, and operational processes which may create a higher risk for using open innovation. In this paper, we use the results of previous researches to discuss different aspect of risks in open innovations and specifically, the three risks of Arrow of Information Paradox, Contamination, and Not Invented Here Syndrome. We suggest that open innovation deals must include not only the potential rewards of the partnership for partners, but should also consider the risks involved in the collaboration. We illustrate how n-person game theory can be used as a decision making tool for a fair reward distribution, a tool to justify open innovation strategic alliances, the core value concept to identify the dominating partner, and Shapley value to generate a fair reward distribution which considers both risks and revenues of partnership deals.

INTRODUCTION

Open innovation approach is a paradigm for sharing the new technologies resulted from research and development by collaborators and partners. This approach treats research and development as an open system and assumes that firms can and should use both external and internal ideas as they advance their technology (Chesbrough, 2003a). The shift from closed to open innovation is a result of many changes occurring in the today's business world. These changes include the increasing availability and mobility of skilled workers, the growth of the venture capital market, the external options for ideas sitting on the shelf, and the increasing capability of external suppliers (Chesbrough 2003b).

From a risk perspective, the paradigm of closed innovation assumes that successful innovation requires control. Traditionally, companies would protect their own ideas during all stages of the new product development cycle: research, development, production, as well as marketing, distribution, servicing, financing, and supporting. The closed innovation approach leads companies to create their own research and development departments to be able to control their innovation process. Google is an example of understanding the risk-averse nature of

closed innovation. Google does not share details about its search algorithms, "which is the single most important body of code at the company" (Gralla, 2010). Simultaneously, Google understands the significance of open innovation. Jonathan Rosenberg, Google's Senior Vice President for Product Management noted in a recent memo about "the meaning of 'open' as it relates to the Internet:

> *Open systems win. This is counter-intuitive to the traditionally trained MBA who is taught to generate a sustainable competitive advantage by creating a closed system, making it popular, and then milking it through the product life cycle. The conventional wisdom goes that companies should lock in customers to lock out competitors … A well-managed closed system can deliver plenty of profits — but eventually innovation in a closed system tends towards being incremental at best … Complacency is the hallmark of any closed system* (Rosenberg, 2009).

On the other side, anxiety is the hallmark of any open system. In an attempt to gain advantages of new technologies at lowest possible cost and shortest possible time, firms which implement an open innovation approach have to take additional risks. There is always less control and more uncertainty when scientific community outside an organization becomes involved in the research and development of the organization's potential next technology. Open innovation approach is no longer designed around self sufficient "islands" to produce all the components of a final product. Instead, open innovation firms allow other firms to start producing some of the components that are required in their final product. Open Innovation approach is a development process that is highly open to ideas from many players and at all stages (Orszag and Holdren, 2009).

In his book about open innovation Henry Chesbrough (2003a, p. 13) compares the process of developing new technologies to a poker game. He quotes the phone interview with James McGroddy, an IBM research director:

> *When you're targeting your technology to your current business, it's like a chess game. You know the pieces; you know what they can and cannot do. You know what your competition is going to do, and you know what your customer needs from you in order to win the game. You can think out many moves in advance, and in fact, you have to, if you're going to win. In a new market, you have to plan your technology entirely differently. You're not playing chess anymore; now you're playing poker. You don't know all the information in advance. Instead, you have to decide whether to spend additional money to stay in the game to see the next card.*

Open innovation assumes that ideas, products, or technology can be easily transferred inward and outward. This is an inherently risky process. Companies assume a certain risk when they cannot afford to rely entirely on their own research and instead decide to buy or license processes or patents from other companies. Also, companies assume less control and more risk when they decide to take their internal ideas outside the company through licensing, joint ventures, spin-offs.

RISKS INVOLVED IN OPEN INNOVATION

For the purpose of this paper, we define a risky event as the one that is low in probability and high in consequence (Wenk, 1982). Risk in a system can exist when one or more components in the system are risky, or it can result from components that are themselves relatively safe, but interact in ways that increase risk (Perrow, 1984). As discussed in the previous section, open innovation paradigm possesses a greater risk for the organizations because there are more external and internal partners involved in the research, development, and production process. The relationship between these partners is based on limited collaboration with significant amount of limited information. Next, we summarize three major sources of risk in open innovation as discussed in the previous research: *Arrow Information Paradox* (Arrow, 1971), *Contamination Risk* (Chesbrough, 2006), and *Not Invented Here Syndrome* (Nash, 2004).

THE ARROW INFORMATION PARADOX

Kenneth Arrow defined the Arrow information paradox (Arrow, 1971) as a problem that companies face when managing intellectual property across their boundaries. The risk associated with the paradox occurs when companies seek external technologies for their business or external markets for their own technologies. The paradox is paraphrased below:

> *A potential purchaser of the technology needs to know the technology and what it does in sufficient details as to understand its capabilities and decide whether or not to buy it. Once the customer has this detailed knowledge, however, the seller has in effect transferred the technology to the customer without any compensation (Arrow, 1971).*

In order to avoid the risks associated with the Arrow information paradox, many open innovation firms use intermediary companies to match innovation seekers and suppliers (Anthes, 2004). Some innovation network companies include InnovationNet, InnoCentive, NineSigma Inc., and YourEncore Inc.. Alph Bingham, vice president at Lilly Research Laboratories describes how a third player, such as InnoCentive, helps reduce the risk associated with the Arrow information paradox:

> *A company like Lilly traditionally would look on the outside for the very best person -- perhaps even a Nobel laureate -- to solve a hard research problem. But it might pay that person $50,000 for six months of work and still not get a solution. InnoCentive pays its award money -- typically between $5,000 and $100,000 per problem - only when someone comes up with a workable solution. ... I don't pay the $50,000 until I know the problem was solved (Anthes, 2004).*

THE CONTAMINATION RISK

Contamination risk usually occurs when large companies are approached by smaller companies or even individuals for cooperation in a new product or service. Entrepreneurs, start-ups, and individual inventors often seek to bring a new product or service to a corporation for licensing or acquisition face. Chesbrough (2006) describes contamination risk as a David versus Goliath battle, where the jury might be sympathetic to a small company although the large firm may be working in the same area and might imitate the small company's value without directly infringing on its protected intellectual property. Chesbrough (2006, p. 136) raises the following question:

> *The desire to avoid contamination causes both large and small companies to adopt numerous practices to minimize the risk. These practices also, however, reduce the ability to leverage Open Innovation… How can companies identify potentially valuable external ideas, and how can they access those ideas without compromising their own internal development activities within the general area?*

Many companies that may talk about open innovation actually practice fairly closed innovation and shut out outside ideas. Risk of contamination is a good reason for this (Lindsay et al. 2009). Innovation network firms can also be used to avoid the contamination risk. An external innovation procurer can preserve the anonymity of both buyer and seller as such it can avoid the risk of contamination.

NOT INVENTED HERE SYNDROME

Not Invented Here (NIH) syndrome is formally defined as a situation where an external solution is rejected only because it was not internally developed (Nash, 2004). In open innovation NIH refers to the tendency of organizations to reject suitable external ideas and technologies in favor of internally-developed solutions. As a matter of definition, NIH syndrome is formally explained by an attitude of xenophobia. However, there is a rational component that might induce internal employees to reject external technologies (Chesbrough, 2006). Here is how Chesbrough describes the rationale:

> *Externally sourced technologies, coming from a much wider variety of sources about which much less is known … may greatly increase the perceived risk to the project. So an externally sourced technology may have the same average estimated time to complete, but it may have a wider range or variation in that estimated time relative to an internally created technology (Chesbrough, 2006, p. 23).*

Chesbrough and Schwartz (2007) suggest that the degree of open innovation risks depends on the type of technological capabilities the firm is seeking to develop in their

partnership with external firms. These capabilities are classified as core, critical, and contextual. Chesbrough and Schwartz (2007) note:

> *Core capabilities are the key sources of the company ... creating a business model that involves co-development of such capabilities can be a risky venture. Critical capabilities are vital to the success of a given product or service and their offering in the marketplace... such capabilities are easier to be partnered on a win-win basis. Contextual capabilities provide little of the differentiation or value added for the business ... in such cases, it is more effective to leverage ... the expertise of a core firm that possesses such capabilities than it is to try to develop and manage them internally.*

It is shown that open innovation may increase the revenue of research and development by leveraging the capabilities of other partner firms. Simultaneously, such partnerships can pose significant hazards if they are poorly designed or implemented (Chesbrough and Schwartz, 2007). The greatest risk of Open Innovation lies not in the sharing of the idea or the invention but in the structure of the deal (Rigby and Zook, 2002).

Models of open innovation offer significant advantages and promise that firms can achieve a greater return on their innovative activities and their intellectual property. When comparing the relative performance of an 'open' versus a 'closed' regime, the practice and research have explicitly characterized the circumstances in which an open approach results in a higher level of innovation (Pollock, 2009). However, as discussed above, such benefits are associated with challenges. Innovation networks, in the form of intermediaries, are an effective framework to mitigate the risks which result from the Arrow information paradox, contamination of information, or not invented here syndrome. The main challenge for the open innovation paradigm lies in the question why would firms spend money on research and development efforts if the results of these efforts are available to rival firms (West and Gallagher, 2006)?

MODELING OPEN INNOVATION

Open innovation business models increase the chances that partnerships can be sustained over time and perhaps even expanded. Decision making model in open innovation involves several stages and can be represented as a decision tree. Figure 1 shows a decision tree model based on a logic diagram developed by Chesbrough (2003a, p. 139) describing the open innovation approach at Lucent's New Ventures Group. The process starts the first stage, organizational responsibility. The outcome of the decision in this stage is based on whether the new product or technology fits the strategic goals or business model of the organization. A decision is made to develop the product internally within the existing business models or look for other business models inside or outside organization. In the latter case, if the product offers a new business opportunity for the organization, a new business model inside the firm is explored. Otherwise, the organization looks for external partner through licensing opportunities.

Another set of decisions are made at the business model stage. Internally, the product is developed either through existing business models or through incremental changes to existing models. In both existing model situations the value of the product is realized through revenues and operating incomes. Organization can also create a new business model for the technology or product. Then a decision must be made to either maintain long term relationship interest (resulting in acquisition or internal sale) or the new model is externally sold to another company or go public itself. Another branch of the decision tree consists of the company deciding not to commercialize the technology. In that case, the technology will be available for external licensing to other companies. Of course, theoretically a decision to do nothing exists in which case the company realizes no value.

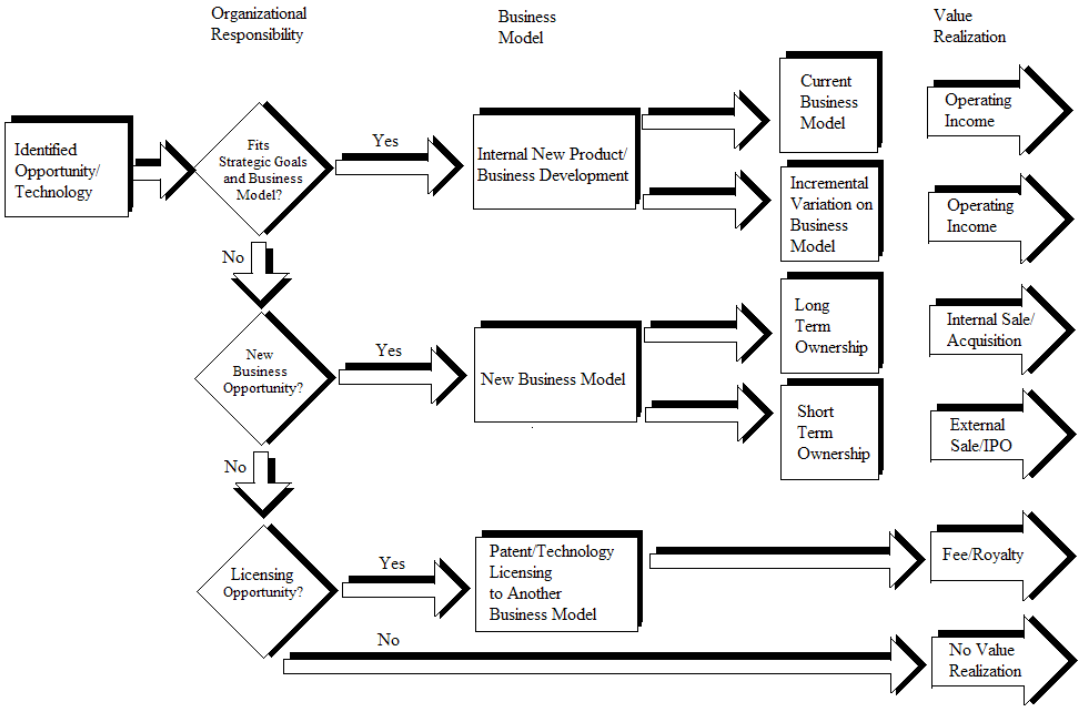

Figure 1: An Example of a Decision Making Model in Open Innovation Environment
Source: Adopted from Chesbrough, H.W. (2003). Open Innovation: The new imperative for creating and profiting from technology. Boston: Harvard Business School Press, p. 139.

Game theory is useful tool for making decisions in cases where two or more firms have conflicting interests. For example, previous research (Myatt and Wallace, 2002; Hippel and Krogh, 2003) uses game theory to investigate the rationale and conditions for participating in open source-software development project. Bringing a game theory perspective in the open innovation business models will allow firms to establish strategic alliances for collaboration with outside partners to exploit internal innovation, incorporate external innovation into internal developments, and motivate outsiders to supply an ongoing stream of external innovations.

OPEN INNOVATION PROBLEM FORMULATION AS AN N-PERSON GAME

Let $N = \{1, 2, ..., n\}$ be the set of players for the *n*-person game. For each subset S of N, the characteristic function v of a game gives the amount $v(S)$ that members of S can be sure of receiving if they act together and form a coalition. The characteristic function in our model is calculated as the expected value of the profit, incorporating both risk and profit. Letting SPF be Player 1, Partner A be Player 2, and Partner B be Player 3, we find the characteristic function for this game to be:

$$v(\{\}) = v(\{2\}) = v(\{3\}) = v(\{2, 3\}) = 0 \quad (1)$$
$$v(\{1\}) = 0.9*1{,}000{,}000 = 900{,}000 \quad (2)$$
$$v(\{1,2\}) = 0.6*6{,}200{,}000 = 3{,}720{,}000 \quad (3)$$
$$v(\{1,3\}) = 0.5*5{,}000{,}000 = 2{,}500{,}000 \quad (4)$$
$$v(\{1,2,3\}) = 0.42*9{,}000{,}000 = 3{,}780{,}000 \quad (5)$$

The above statements satisfy the *superadditivity* property, which assumes that every player, to be accepted in a given coalition, must add value to that coalition. The rewards that each player receives in a given game are indicated by a solution concept. There are many solution concepts for *n*-person games (Owens, 1982). We will use two solution concepts: the core and the Shapley value.

THE CORE SOLUTION CONCEPT

The core value is based on two important concepts in game theory: *imputation* and *domination*. As defined in literature (Owens, 1982), imputations allow us to identify a set of reasonable candidates for a solution to the game.

When applied to our drug game, $x=\{x_1, x_2, x_3\}$ is a vector indicating the rewards for Player 1, 2, and 3 respectively. By definition, a reward is not a reasonable candidate solution unless x satisfies:

$$V(\{1, 2, 3\}) = x_1+x_2+x_3 = 3{,}780{,}000 \quad (6)$$
$$x_1 \geq v(\{1\}) = 900{,}000 \quad (7)$$
$$x_2 \geq v(\{2\}) = 0 \quad (8)$$
$$x_3 \geq v(\{3\}) = 0 \quad (9)$$

(6) - (9) can be used to define the area of feasible solutions. Now, let us assume that x and y are two imputations for the game. Imputation $y = (y_1, y_2, y_3)$ dominates $x = (x_1, x_2, x_3)$ through a coalition S if each member of S prefers y to x and members of S can attain the rewards given by y (Owens, 1982). By definition, the core of the game is defined as the set of all *un-*

dominated imputations. This definition allows us to find the core of the drug game. As shown from (6)- (9), $x = (x_1, x_2, x_3)$ will be an imputation if (10) - (13) are true, and will be in the core if (14) - (17) are true:

$$x_1+x_2+x_3 = 3{,}780{,}000 \quad (10)$$
$$x_1 \geq 900{,}000 \quad (11)$$
$$x_2 \geq 0 \quad (12)$$
$$x_3 \geq 0 \quad (13)$$
$$x_1+x_2 \geq 3{,}720{,}000 \quad (14)$$
$$x_1+x_3 \geq 2{,}500{,}000 \quad (15)$$
$$x_2 + x_3 \geq 0 \quad (16)$$
$$x_1+x_2+x_3 \geq 3{,}780{,}000 \quad (17)$$

A quick check shows that $(3{,}780{,}000, 0, 0)$ is an imputation which satisfies (10) – (17). Thus, the core of the game $(3{,}780{,}000, 0, 0)$ emphasizes the importance of Player 1, small pharmaceutical company which owns the formula for the new drug.

THE SHAPLEY VALUE CONCEPT

Shapley value provides a more equitable distribution of rewards among the players in a coalition (Owens, 1982). For any characteristic function, Shapley (1953) showed that there is a unique reward vector. However, for the vector to be found, a set of four axioms should be assumed valid. So, before calculating Shapley value, we briefly discuss those axioms and their validity in an open innovation business model.

Axiom 1: *The players' rewards are interchangeable when the labels of the players are changed*

This is a basic assumption which satisfies the conditions of reward distributions under an open innovation model. Let us say that our initial player SPF is labeled Player 3 and not Player 1. Then, the core value solution will be shown as $(0, 0, 3780000)$ and not $(3780000, 0, 0)$.

Axiom 2: *The sum of individual rewards is equal to the total reward of the game*

This is simply group rationality which we assumed to be true when calculating the core value as indicated in equation (10). The same assumption will remain when calculating the Shapley value.

Axiom 3: *If a player adds no value to any coalition, then this player receives no reward*

This assumption is also valid due to the *superadditivity* property: every player to be accepted in a given coalition must add value to that coalition. In an open innovation model, firms cannot become part of a given coalition if they bring no value to this coalition.

Axiom 4: *If there exist two games among the same set of players, then the Shapley value for both games is equal to the individual Shapley values for each game*

Assume that a coalition between firms in an open innovation model helps companies to increase revenue (Game 1) and reduce cost (Game 2). Let $r = (r_1, r_2, r_3)$ be the Shapley value for Game 1, and let $c=(c_1, c_2, c_3)$ be the Shapley value for Game 2. Axiom 4 assumes that profit (revenue – cost) game has a Shapley value vector $(r\text{-}c) = (r_1\text{-}c_1, r_2\text{-}c_2, r_3\text{-}c_3)$. The validity of this axiom is sometimes questioned because adding up rewards is like adding oranges to apples. However, this assumption is reasonable for open innovation collaboration. Rewards of the open innovation games are generally converted into easily addable monetary rewards.
If Axioms 1 – 4 are assumed to be valid in the open innovation game, we can use the following Theorem offered by Shapley (1953) to calculate a solution to our game:

Shapley Theorem: *Given any n-person game with a characteristic function v, there is a unique reward vector $x=(x_1, x_2, \ldots, x_n)$ satisfying Axioms 1-4. The reward of the i^{th} player (x_i) is given by:*

$$x_i = \sum_{all\ S\ for\ which\ i\ is\ not\ in\ the\ S} p_n(S)[v(S \cup \{i\}) - v(S)] \quad (18)$$

In 18,

$$p_n(S) = \frac{|S|!(n-|S|-1)!}{n!} \quad (19)$$

where $|S|$ is the number of players in *S*.

(18) above implies that the Shapley value solution assigns a reward to player *i* equal to the expected amount that player *i* adds to the coalition made up of the players who are present when player *i* arrives. To compute the *Shapley value* for player 1 (SPF), we use Table 1 and list all coalitions S for which SPF is not a member. Then, we compute $v(S \cup \{1\}) - v(S)$ and $p_3(S)$

Table 1: Computation of Shapley Value for Player 1: Pharmaceutical Firm (SPF)

S	v(S)	$v(S \cup \{1\})$	$v(S \cup \{1\}) - v(S)$	$p_3(S)$
{ }	0	900,000	900,000	2/6
{2}	0	3,720,000	3,720,000	1/6
{3}	0	2,500,000	2,500,000	1/6
{2, 3}	0	3,780,000	3,780,000	2/6

As such, SPF contributes to the partnership on the average:

$(\frac{2}{6})(900000) + (\frac{1}{6})(3720000) + (\frac{1}{6})(2500000) + (\frac{2}{6})(3780000) = 2{,}596{,}667$

To compute the Shapley value for Player 2 (Partner A) we use Table 2 and list all coalitions S for which Partner A is not a member. Then, we compute $v(S \cup \{2\}) - v(S)$ and $p_3(S)$

Table 2: Computation of Shapley Value for Player 2: Partner A				
S	v(S)	$v(S \cup \{2\})$	$v(S \cup \{2\}) - v(S)$	$p_3(S)$
{ }	0	0	0	2/6
{1}	900,000	3,720,000	2,820,000	1/6
{3}	0	0	0	1/6
{1, 3}	2,500,000	3,780,000	1,280,000	2/6

Similarly, player 2 (Partner A) contributes to the partnership on the average:

$(\frac{2}{6})(0) + (\frac{1}{6})(2820000) + (\frac{1}{6})(0) + (\frac{2}{6})(1280000) = 896{,}667$

As a result, player 3 (Partner B) contributes to the partnership on the average:

3,780,000-(2,596,667+ 896,667) = 286,666

Table 3: Reward Distribution among Players			
Players	Shapley Value	% Distribution	Reward
SPF	2,596,667	69%	$ 6,182,540
Partner A	896,667	24%	$ 2,134,921
Partner B	286,666	8%	$ 682,538
Total	3,780,000	100%	$ 9,000,000

A FINAL NOTE

We should note that the above calculation of the *Shapley value* uses the *expected value* as the characteristic function of the game. This allows us to consider both aspects of collaboration: risk and the outcome. As shown in Table 3, solution based on the expected value (2596667, 896667, 286666) indicates a (69%, 24%, 8%) distribution among the three players, which results in an actual reward of ($6,182,540; $2,134,921; $682,538).

CONCLUSIONS

This paper offers a game theory perspective for modeling collaborations which occur in the open innovation approach. The purpose of the model is to allow business partners to justify strategic alliances when looking for collaboration and indicate a reward distribution scheme which incorporates both risks and outcomes of the collaboration. Previous research indicates several advantages of the open innovation paradigm. Firms are able to leverage the capabilities of external collaborators and increase the revenue of their research and development. While sharing of ideas and technologies can significantly improve the rewards of a partnership deal, the structure of the deal can pose significant risks. The risk is especially great when firms collaborate on developing core capabilities. This paper discusses in more details three major risks: Arrow Information Paradox, Contamination Risk, and Not Invented Here Syndrome. In order to mitigate the three types of risks, open innovation firms are currently taking advantage from innovation networks.

We suggest a quantitative approach which can be used by firms to incorporate the risks in the distribution of the rewards attained in an open innovation partnerships. Open Innovation implies that firms will establish strategic alliances for collaboration. As such, we believe that a game theory perspective is a proper approach for open innovation paradigm. We demonstrate that the existing theory of an *n*-person game can be used to (1) incorporate the risks taken by collaborating firms into the reward structure, (2) identify the dominating firm in an open innovation partnership, and (3) estimate a fair distribution reward among partners considering both risks and overall profit of the open innovation deal.

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INFORMATION SECURITY ACTIVITIES OF COLLEGE STUDENTS: AN EXPLORATORY STUDY

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ABSTRACT

Academic institutions prepare students for their professional field of study, but student awareness of Information Technology (IT) security issues continues to be poor (Livermore, 2006; McQuade, 2007). Most college students communicate via email and social networking sites, such as Twitter, MySpace, and Facebook. However, students are at risk for identity theft through fraudulent emails, stolen passwords, unsecured systems, and inadequate network practices (Harwood, 2008). This exploratory study identifies key findings and recommendations regarding information security attitudes, behaviors and tools used by college students along with suggestions for improving information security awareness at institutions of higher education.

INTRODUCTION

Communication, instruction, registration, advising, and administrative functions at institutions of higher education are increasingly conducted through technology-mediated communication (Allen & Seaman, 2010; Chueng & Huang, 2005; Jones, Johnson-Yale, Perez & Schuler, 2007; Salas & Alexander, 2008), including email (Jones, 2008; S. Jones, et al., 2007; Weiss & Hanson-Baldauf, 2008), blogs (Nackerud & Scaletta, 2008), learning management systems (Hawkins & Rudy, 2007; Jacob & Issac, 2008), and social media (Allen & Seaman, 2009; Ashraf, 2009; Ellison, 2007; Gilroy, 2010; Rosen & Nelson, 2008; Saeed, Yang, & Sinnappan, 2009).

Traditional data centers and corporate networks administrators control the types of data permitted on their networks and the methods used to access data. Because web sites and programs use the same port as a user's Web browser, hackers and cyber criminals often attempt to bypass security controls on computer networks. Thus, corporate network administrators often ban users from accessing private email accounts, instant messenger programs, and social networking sites, such as Twitter, MySpace, and Facebook (Brodkin, 2008). High school networks also commonly block access to these sites and filter email for malware and other unwanted content (Waters, 2007). Because institutions of higher education openly share a substantial amount of information and data, web sites are rarely banned and message content is not filtered, increasing the likelihood that students will encounter hackers or identity thieves while using institutional networks (Allison & DeBlois, 2008; Ziobron, 2003).

While institutions of higher education prepare students for professional careers (Cheung & Huang, 2005), effective information security awareness training has taken a back seat as prospective employers are expected to accept responsibility for training of college graduate hires (Okenyi & Owens, 2007; Turner, 2007). However, this approach is ineffective as sound IT security practices continue to fall through the cracks. Regardless of a student's vocational goals, colleges and universities must take a proactive approach to educate students about the potential risks associated with Internet usage and message security, as reported dollar losses from Internet crime have reached new highs (Internet Crime Complaint Center, 2009).

The need to plan, develop and implement IT security awareness training is crucial to ensure the security of student, faculty, and institutional data and information (The Campus Computing Project, 2007). In order to adequately develop training, a profile of end-user college student security attitudes and behaviors must be determined. Do information security attitudes and behaviors of college students differ based on factors such as age, gender, ethnicity, classification level, academic major, identity theft victimization, and use of computer security tools? Also, does the effective use of computer security tools differ based on factors such as age, gender, ethnicity, classification level, academic major, identity theft victimization, installation of PC anti-virus software, or installation of PC anti-spyware software?

The present study explores information security attitudes and behaviors of college students, and their use of computer security tools. The paper also highlights end-user security awareness practices to promote a better understanding of information security given the inherent dangers in the virtual world, and discusses strategies that institutions can employ to better protect personal information and data.

LITERATURE REVIEW

Human-caused security threats lurking in virtual spaces are ever-evolving. Under the Clery Act, university campuses are required to release yearly crime statistics on crimes including aggravated assault, burglary, theft, vandalism, and driving under the influence ("*The Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act*" [Clery Act], 1990). However, cybercrime, a 24/7/365 threat (Computer Security Institute, 2009), is not tracked by universities. Yet, cyber thieves do an incredible amount of damage to individuals across all spectrums of society (Internet Crime Complaint Center, 2009). While campus safety programs addressing crimes covered by the Clery Act are clearly important, institutions of higher education should also proactively address end-user electronic data security and identity protection, particularly as it pertains to undergraduate and graduate students in the ubiquitous online world.

A variety of information security threats and attack methodologies exist and continue to evolve as technology progresses globally. Social engineering is a common tactic used by attackers and involves persuading people that the perpetrator is someone other than who he/she

really is (Mitnick, 2002). Social engineers use deceit to convince people to release information or perform actions. In addition to threats from viruses and worms (Luo & Liao, 2007), the Computer Security Institute (2009) reports the most common attacks to be malware (64.9%), bots and zombies (23%), phishing messages (34%), denial of service attacks (29.2%), password sniffing (17.3%), browser exploitation (11%), social network profile exploitation (9%), and financial fraud (19.5%). Spyware, another worrisome threat, is client-side software that monitors and tracks computer activity and sends collected data secretly to remote machines. Spyware is often found in free downloadable software and may use the CPU and storage for tasks unknown to the end-user (Luo & Liao, 2007). Users running Windows operating systems are targets of most spyware, but Macintosh operating systems may also be vulnerable (InfoWorld, 2010). Offline threats also exist which include shoulder surfing, dumpster diving (Okenyi & Owens, 2007), and laptop/mobile device theft, which is currently a major threat to organizations and individuals (Computer Security Institute, 2009; Young, 2009).

Identity theft, often associated with social engineering, involves someone gaining access to personal data without a person's knowledge often for purposes of committing identity fraud (Javelin Strategy & Research, 2009) and includes financial and non-financial crimes, such as criminal, government, and medical identity theft (Identity Theft Resource Center, 2010). The Identity Theft Resource Center (2010) cites financial identity theft, such as opening a new line of credit (55%) and stolen credit cards and debit cards (34%) as the most common types of identity theft, followed by governmental/benefit fraud, which includes tax return and employment fraud, and phone/utilities fraud. Data breaches and the Internet as sources of identity theft are up 5.3% from 2003 (Identity Theft Resource Center, 2009). According to the Identity Theft Resource Center (2010), the percentages of adult identity theft victims were 18-29 year-olds (20%), 30-39 year-olds (15%), 40-49 year-olds (25%), and 50-60 year-olds (20%). While 37% of victims knew the thief, 63% of victims did not know the thief (Identity Theft Resource Center, 2010). Most victims discover the crime within the first six months. Intangible costs include time lost from work, lost vacation time, and emotional losses (Identity Theft Resource Center, 2010). Victims spend 68 to 141 hours on average repairing the damage over several months. In terms of dollar costs, fraud committed on an existing account averaged $527 in 2008 and $2,104 for new accounts. Approximately 10% of victims required 2 years or more to clear their names and were also "secondarily wounded" by denial of or inability to get credit, increased insurance or credit card rates, and repeated contacts by collection agencies (Identity Theft Resource Center, 2010). While college students are concerned about identity theft (Trocchia & Ainscough, 2006), the measures they take to protect personal data and information may be lacking (Livermore, 2006).

SECURITY BEHAVIORS OF COLLEGE STUDENTS

As the interests and practices of Internet users change, institutions of higher education much ensure that students are continually educated about online risks. Popular online venues

include social networking websites, which provide people with the opportunity to create an online profile to share with others (Barnes, 2006) and even create fictitious lives (Gorge, 2007). Social networking sites are "now visited by over two-thirds (67%) of the global online population… which includes both social networks and blogs,"… and has become "the fourth most popular online category - ahead of personal email" (Nielsen/NetRatings, 2009b, para. 1). Social networking is growing twice as fast as any of the other five most popular sectors which include search, portals, software manufacturers, member communities, and email (Nielsen/NetRatings, 2009a, p. 2).

Fogel & Nehmad (2008) found that 77.6% of college students use social networking sites and Ellison (2007) reports that 79-95% of college students have Facebook accounts. Half of Fogel & Nehmad's (2008) participants included instant messenger names on personal profiles, 65% included a personal email address, 74% allowed anyone to view their profiles, 10% provided a phone number, and 10% provided their home address. This scenario is a major concern as malware and viruses may be sent through email and instant messenger programs. Social networking sites are also subject to hijacking and fake log-in pages, and password management is lacking since people often use the same password and username for various sites(Mansfield-Devine, 2008).. Therefore, once an a user's Facebook credentials are known, it is easy to gain access to a bank account with the same username and password (Mansfield-Devine, 2008). Many social network users are also not aware that the applications endorsed by a social network are not supplied by the site and there is no assurance of who wrote the software or where it's hosted (Mansfield-Devine, 2008).

Personal data from social networks can also be mined for purposes of conducting phishing attacks. Jagatic, Johnson, Jakobsson & Menczer (2007) conducted a study of college students where 72% of the social network group clicked on the phishing link. Phishing success rates were highest among sophomores (26%) and those classified as "other" (50%) for the control group (receivers of a phishing email from an unknown person with a university address), and highest among freshmen (76%) and "other" (76%) for the social network group. Phishing success rates also were highest among education majors (50%) in the control group, and science (80%) and business (72%) majors in the social network group. Students in technology-related majors had the lowest phishing success rates (0% control; 36% social network). Jagatic, et al. (2007) also spoofed an email message as forwarded from a friend to a group of friends and, even though the experiment contained a coding flaw, 53% of the sample still clicked on the phishing link). Social networking is now recognized as a concern by security professionals as social network profile attacks were added to the Computer Security Institute's 2009 survey for the first time. Many of these attacks are hatched as a result of successful social engineering efforts by attackers, including bots and zombies that originate from the infected computers of end-users. For purposes of this study, security attitudes and behaviors surveyed includes elements such as online account password management, anti-virus and anti-spyware software installation and use, propensity to click on email or instant message hyperlinks, wireless computing behaviors,

identity theft victimization, and offline security measures (credit report monitoring, document shredding, etc.). The present study generated the following hypotheses to analyze security attitudes and behaviors of undergraduate and graduate students:

H1: There are no significant differences in overall information security attitudes of college students based on factors such as age, gender, ethnicity, classification level, academic major, identity theft victimization, installation of PC anti-virus software, or installation of PC anti-spyware software.

H2: There are no significant differences in information security behaviors of college students based on factors such as age, gender, ethnicity, classification level, academic major, identity theft victimization, installation of PC anti-virus software, or installation of PC anti-spyware software.

END-USER SECURITY SOFTWARE

A variety of security software is available to end-users including, firewalls, anti-virus software (Mitnick, 2006), and anti-spyware software. Browser-based tools, such as pop-up blockers and phishing filters, are also available. The question is whether end-users employ security tools and how diligent users are about updating security software (Jokela & Karlsudd, 2007). Also, college students may not know if anti-virus is installed on their computers and may not know how to remove a virus once it's discovered (Jokela & Karlsudd, 2007). The present study generated the following hypothesis to analyze the use of computer security tools by undergraduate and graduate students:

H3: There are no significant differences in college students' use of computer security tools based on factors such as age, gender, ethnicity, classification level, academic major, identity theft victimization, installation of PC anti-virus software, or installation of PC anti-spyware software.

THE C.I.A. TRIAD

Modeling is an important facet when studying information security. Models help researchers explain abstract, often complex, concepts and relationships. The basis for information security models originated in 1994 when the National Security Telecommunications and Information Systems Security Committee (NSTISSC) derived the Comprehensive Model for Information Systems Security, also known as the C.I.A. triad (Whitman & Mattord, 2009) and graphically represented by the McCumber Cube (McCumber, 1991). In the model, information systems security concerns "three critical characteristics of information: confidentiality, integrity, and availability" (NSTISSC, 1994). Confidentiality, the heart of any security policy, encompasses a set of rules that determine access to objects and involves access control of data by users (or groups). An important facet of confidentiality is "the assurance that access controls are enforced" (NSTISSC, "Critical Information Characteristics", para. 2.). This component was further defined by Bell & LaPadula (Bell, 1973) and the U.S. Department of Defense (Trusted

Computer System Evaluation Criteria, 1983). The second characteristic is integrity, which Pfleeger defined as "'assets' (which) can only be modified by authorized parties" (1989). Integrity relates to the "quality of information that identifies how closely the data represent reality" (NSTISSC, "Critical Information Characteristics", para. 5). The construct was further defined by Graham & Denning (1972), Biba (1977), and Clark & Wilson (1987). The third characteristic, availability, "ensures the information is provided to authorized users when it's requested or needed" and serves as a "check-and-balance constraint" on the model (NSTISSC, "Critical Information Characteristics", para. 7). Two additional concepts have been added to the CIA triad by many security practitioners. Authenticity involves verifying the authenticity of the user and ensures that inputs to a system are from a trusted source (Stallings & Brown, 2008). Finally, accountability requires an entity's actions to be traced uniquely to that entity (Stallings & Brown, 2008).

SECURITY AWARENESS AND TRAINING

Information systems are composed of six components: software, hardware, data, people, procedures and networks (Whitman & Mattord, 2009). Technological controls are only a part of the security solution. People and procedures are components that are often overlooked in security considerations (Whitman & Mattord, 2009) and people are the most important part of the solution (Hall, 2005, para. 5). The fact that college students are technologically-savvy in using information technology (Kirkwood & Price, 2005) does not assure that they also understand the risks and take appropriate measures to protect personal information and data from hackers and thieves. Policy, education and training, awareness and technology are required to assure information security for both individuals and organizations (Whitman & Mattord, 2009). Awareness training reduces risk and is essential to prevent hacking success rates at both the individual and organizational levels (Okenyi & Owens, 2007*)*. Thus, a successful security awareness program must shift the paradigm from "ad hoc secure behavior to a continuous secure behavior" (Okenyi & Owens, 2007, p. 306).

METHODOLOGY

The population sample for the present study consisted of 2,000 undergraduate and graduate students from a mid-sized eastern university. University policies restricted the use of emails to 2,000 addresses; email addresses were randomly chosen by the graduate research office and sent to full-time undergraduate and graduate students enrolled in all degree programs at the university. The email sent by the graduate research office to the 2,000 students noted above encouraged participation in the study and provided a link to the survey via Survey Monkey; participation was voluntary. A reminder email was sent by the graduate research office one week following the initial email notification. An approved informed consent form was completed by all student participants. Participants were identified by a unique identification number to

maintain confidentiality. The data collected was downloaded into the Statistical Package for the Social Sciences 14.0 (SPSS) where all analysis and statistical tests were performed.

INSTRUMENTS

Based on a review of the literature and theoretical standpoints, the researchers developed and pilot tested a 6-item Likert scale consisting of 21 items to determine the security awareness of undergraduate and graduate students the previous academic year using an informal sampling of several classes that included students from several discipline areas across campus. Likert scaling is designed to measure people's attitudes and awareness (Nachmias & Nachmias, 1987). The survey used in the present study was administered via a web-based system to all current undergraduate and graduate students. Survey research has its advantages and disadvantages. Advantages include lower costs, relatively small biasing error, greater anonymity, and accessibility. Disadvantages include "a low response rate, opportunity for probing, and the lack of control over who fills out the questionnaire" (Frankfort-Nachmias and Nachmias, 1996, p. 248).

RESEARCH DESIGN

The study followed a descriptive research design using survey methods with statistical treatments. The design was a cross-sectional survey. Cross-sectional design is the most frequently used study design (Babbie, 1990, p. 65). Descriptive statistics, such as frequency distributions, means, and standard deviations, were utilized to analyze student demographic characteristics, and correlation tests (Cohen, 1988) were performed to determine if significant relationships exist between each of the categorical variables. T-tests of independent samples and analyses of variance (ANOVA) were also conducted to compare differences in security attitude scores and sub-scale scores among the groups. Post hoc multiple comparison tests (Gabriel, 1987) were conducted to determine where differences between means existed. Statistical significance for all tests was set at the 95% level ($p > .05$).

VARIABLES

The study featured an independent variable consisting of scores derived from the 21-item security attitudes survey. To provide additional analysis, the Likert scale was divided into four subscales, categorized as follows: security behaviors (7-item subscale), use of computer security tools (5-item subscale), wireless security (5-item subscale), and data privacy (4-item subscale). Results from the data privacy and wireless security subscales will be discussed in subsequent articles.

Several categorical variables were included in the study. Age was categorized into four groups (1 = 18 to 23 years of age, 2 = 24 to 30 years of age, 3 = 31 to 36 years of age, 4 = 37+

years of age). Gender was categorized as male or female. Ethnicity was categorized into six groups (1 = White, 2 = Hispanic, 3 = African-American, 4 = Asian, 5 = Native American, 6 = Other [race not specified or non-resident alien]). Major was categorized into nine groups (1= Education, 2= Humanities & Social Sciences, 3= Health & Human Services, 4= Business, 5 = Fine Arts, 6 = Criminology, 7 = Natural Science, 8 = Information Technology, 9 = Other). Classification was categorized into six groups (1 = Freshman, 2 = Sophomore, 3 = Junior, 4 = Senior, 5 = Graduate, 6 = Other). Additional categorical variables included identity theft victimization with responses classified into three response groups (1 = Yes, 2 = No, 3 = Don't know). Participants were also asked if antivirus was installed on their personal computers. Responses were classified into four groups (1 = Yes, 2 = No, 3 = Yes, but not updated, 4 = Don't know). Participants were asked if anti-spyware was installed on their personal computers. Responses were classified into four groups (1 = Yes, 2 = No, 3 = Yes, but it expired, 4 = Don't know). Participants who affirmatively answered that they had a home wireless network were also asked if they changed the wireless router's default administrator password. Responses were classified into four groups (1 = Yes, 2 = No, 3 = Don't know).

RELIABILITY ANALYSIS

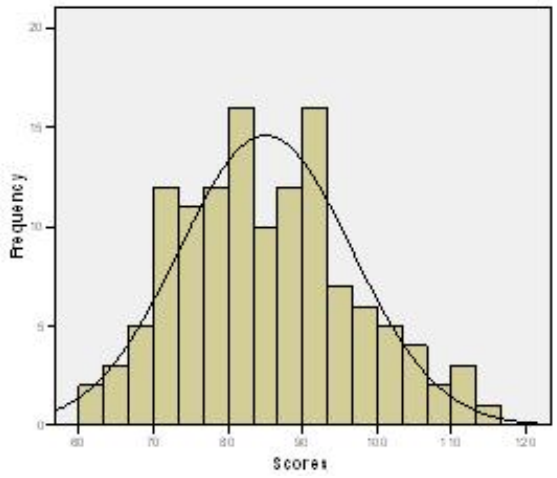
Internal consistency reliability analysis was performed on the Likert subscales of the measure to provide a reliability measurement. Results revealed an internal consistency of $\alpha = .69$ for the total scale computed from the raw scores of 21 Likert items. Tukey's test for additivity was significant ($F = 130.083$, $p = .000$, $\alpha = .05$) indicating that several scale items may be related. Exploratory factor analysis was conducted to determine if the instrument accurately measured the study's variables and to serve as an estimate to identify unobserved or latent variables that may account for the true variance of the observations. Eigenvalues of 1.0 indicate that a factor is significant (Gorsuch, 1983). Results revealed that 64.9% of the variance could be explained by the first seven factors with eigenvalues of 1.0 or more. Fifteen percent of the variance is explained by a single factor, 11.7% of the variance is explained by a second factor, 11.6% of the variance is explained by a third factor, 8% of the variance is explained by a fourth factor, 7% of the variance is explained by a fifth factor, 6.6% of the variance is explained by a sixth factor, and 5% of the variance is explained by a seventh factor. Scale items 7 through 11 loaded high on factor 1 (security and browser tools). Items 5 and 6 loaded high positive on factor 2 and item 12 loaded high negative on factor 2 (security behaviors – communication tools). Items 14 through 17 loaded high on factor 3 (wireless security). Items 18 through 20 loaded high on factor 4 (data privacy). Items 1, 2 and 21 loaded high on factor 5 (security behaviors – personal identification/passwords). Items 3 and 13 loaded high on factor 6 (security behaviors – public spaces). Item 4 loaded high on factor 7 (financial security – electronic data privacy).

RESULTS

Descriptive statistics were used to analyze demographic data and Likert scale results. Correlation tests were also performed to determine if significant relationships exist between the categorical variables. Initially receiving 134 responses, the researchers eliminated incomplete responses, yielding a final sample size of N = 127 participants. Participants were mostly freshman and sophomores (45.6%) or graduate students (21.3%), female (63%), Caucasian (81.9%), and 18 to 23 years of age (71.7%). Most majored in Education (18.9%), Humanities & Social Sciences (17.3%), Business (16.5%), or Healthcare (12.6%). The majority of participants have not been a victim of identity theft (85.8%), have anti-virus software installed (80.3%), and have anti-spyware software installed on their PCs (74.8%).

Due to the way the questions were structured, five survey items were reverse coded prior to analysis. Security attitude score ranges were classified as: Very Low = 0-21; Low = 22-42; Moderately Low = 43-63; Moderately High = 64-84; High = 85-105; and Very High = 106-126. Only 6% of participants recorded very high scores (n = 8) and 44% recorded high scores (n = 56). Another 48% recorded moderately high scores (n = 61) and 1.5% recorded moderately low scores (n = 2). Mean security attitude scores overall were 85.02 (SD = 11.579). Participant scores ranged from 63 to 116 (Figure 1).

Figure 1: Distribution of Scores



This figure shows the distribution of scores fromthe security attitudes survey.

SECURITY ATTITUDES SURVEY AND SUB-SCALES

Security attitude survey. As summarized in the first data column of Table 1, the lowest mean scores, 24-30 year olds, were 6+ points lower than the 18-23 year-old group. On average, male security attitude scores were 4+ points higher than female scores. In terms of ethnicity,

scores of Hispanics averaged 20+ points lower than those self-classified as "other," the highest scoring ethnic group, and 10 points lower than African-Americans and Asians. The lowest scores by classification were among juniors and graduate students, who scored 10+ points lower than the highest scoring groups, sophomores and those self-classified as "other". Attitude scores of information technology majors were 16+ points higher than healthcare majors, the lowest scoring group by major. Attitude scores of identity theft victims averaged 8+ points higher than the lowest scoring participants (those that didn't know if they were an identity theft victim). Participant attitude scores regarding anti-virus software installation averaged 6+ points higher than those that were unsure if anti-virus software is installed, and attitude scores regarding anti-spyware software installation averaged 13+ points higher than those that were unsure if anti-spyware software is installed.

Correlation tests conducted on security attitudes scores by categorical variables revealed significant positive relationships between age and classification (R = .421, p = .000, α = .05, two-tailed), and a significant negative relationship between age and ID theft victimization (R = -.185, p = .037, α = .05, two-tailed). A significant negative relationship exists between gender and classification (R = -.236, p = .008, α = .05, two-tailed) and a significant positive relationship exists between installation of PC anti-virus software and installation of PC anti-spyware software (R = .273, p = .002, α = .05, two-tailed).

Security behaviors subscale. As summarized in the second data column of Table 1, scores on the 7-item security behaviors subscale ranged from 6 to 42. Security behavior scores among 24-30 year olds were slightly higher than the other groups. In terms of academic major, scores of fine arts majors and information technology majors were 3 points higher on average than scores of criminology majors. Mean scores for males and females were comparable. In terms of ethnicity, scores of those self-classified as "other" were 6+ points higher on average than scores of Hispanics, the lowest scoring group. In terms of academic classification, scores of participants self-classified as "other" were 3 points higher on average than the lowest scoring groups, juniors, freshmen and graduate students. Scores on the identity theft item were comparable. Scores of participants that don't know if anti-virus software is installed were 3 points higher on average than the lowest scoring group, those with anti-virus software installed, but not updated. Scores by anti-spyware installation averaged 3 points higher among those that don't have anti-spyware installed compared to the lowest scoring group, those that have anti-spyware installed, but not updated.

Security tools subscale. As summarized in the third data column of Table 1, scores on the 5-item subscale ranged from 6 to 30. The highest subscale scores by age group were among those aged 37+ years and those aged 18-23 years; 24-30 year-olds recorded the lowest mean subscale scores. Scores of information technology and criminology majors were 6 to 7 points higher than mean scores of "other" majors and natural science majors, the lowest scoring groups by major. Scores for males averaged 4% higher than female scores. With regard to ethnicity, scores for Asians and African-Americans averaged 4 to 5 points higher than Hispanics, the

lowest scoring group. Scores for sophomores and those self-classified as "other" averaged 4 to 5 points higher than the lowest scoring groups, juniors and seniors.

Table 1: Means and Standard Deviations – Security Attitudes scale and sub-scales.

		Security Attitudes Scale		*Security Behaviors Sub-scale*		*Security Tools Sub-scale*	
Variable	Category	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age	18to23	85.97	11.278	32.27	3.222	18.35	4.895
	24to30	79.94	8.095	33.25	2.082	15.50	4.336
	31to36	85.17	16.469	31.75	3.696	16.92	6.082
	37+	84.13	11.813	31.88	3.834	19.63	5.449
Gender	Male	87.74	11.648	32.62	2.747	18.40	4.911
	Female	83.41	11.304	32.15	3.409	17.66	5.124
Ethnicity	Caucasian	84.70	11.542	32.37	3.220	17.81	5.076
	Hispanic	75.67	3.055	28.33	1.155	15.00	5.292
	African-American	85.88	12.856	33.13	1.458	19.38	4.502
	Asian	85.20	10.035	30.40	1.817	20.60	6.580
	Native American	83.50	14.849	31.50	.707	18.50	2.121
	Other++	96.20	10.756	34.80	4.147	17.20	4.658
Classification	Freshman	83.57	11.976	31.93	3.290	18.53	4.974
	Sophomore	90.11	11.416	32.18	3.232	19.57	4.887
	Junior	80.68	10.149	31.79	2.347	15.53	4.247
	Senior	85.67	10.459	33.60	3.869	16.67	5.150
	Graduate	82.22	9.764	31.96	3.287	17.56	5.228
	Other+	91.13	15.533	34.38	1.408	19.38	5.208
Major	Education	85.79	13.309	32.33	3.088	18.71	4.796
	Humanities/soc sci.	82.82	8.198	32.27	3.089	17.14	4.622
	Healthcare	81.75	13.424	31.38	3.538	17.88	6.141
	Business	86.29	10.937	32.00	3.619	18.14	4.757
	Fine arts	90.60	11.546	33.60	2.966	18.40	5.367
	Criminology	82.63	9.870	30.63	2.825	19.88	4.086
	Natural science	82.62	10.211	33.46	2.696	16.46	5.010
	Information tech	98.50	7.609	33.50	2.429	22.00	4.050
	Other	84.75	13.011	33.00	3.247	15.67	5.549
Victim of ID theft?	Yes	89.55	13.765	32.09	3.590	20.09	5.108
	No	84.81	11.568	32.36	3.128	17.89	5.065
	Don't know	81.14	5.900	32.14	3.761	15.29	3.352
PC anti-virus installed?	Yes	85.85	11.884	32.39	3.090	19.04	4.620
	No	85.33	10.727	32.83	3.430	11.00	1.789
	Yes, not updated	80.92	10.501	30.67	4.008	14.83	3.689
	Don't know	79.57	7.721	33.71	1.976	13.14	5.610
PC anti-spyware installed?	Yes	87.57	11.283	32.61	3.102	19.52	4.458
	No	84.38	8.123	33.63	2.200	12.50	2.673
	Yes, expired	77.75	8.812	30.63	2.134	15.38	3.249
	Don't know	73.81	7.600	30.81	3.834	12.56	3.829

+participants earning enrolled in post-baccalaureate courses
++Middle Eastern and multi-racial
**This table shows of mean survey and sub-scale scores by categorical variables*

Scores for identity theft victims were 5 points higher than the lowest scoring group, those who did not know if they were identity theft victims. Scores for those with anti-virus software installed were 8 points higher than the lowest scoring group of participants, those that said it was not installed. Scores for those with anti-spyware software installed were 7 points higher than the lowest scoring group of participants, those that said it was not installed.

RESEARCH QUESTIONS

Statistical analysis was performed on the data collected. The significance level was set at the 95% level ($p > .05$).

Security attitudes. ANOVA tests were conducted to compare security attitude scores by the categorical variables of age, gender, major, ethnicity, identity theft victimization, and installation of anti-virus or anti-spyware programs, along with interaction effects between age and classification, age and identity theft victimization, gender and ethnicity, and PC anti-virus and PC anti-spyware installation. No statistically significant interaction effects in security attitude scores were found between the categorical variables, age and classification $F(9,109)$ 1.663, $p = .107$, $\alpha = .05$; age and identity theft victimization $F(4,117)$ .698, $p = .595$, $\alpha = .05$; gender and ethnicity $F(5,115)$ .890, $p = .490$, $\alpha = .05$; or PC anti-virus installation and PC anti-spyware installation $F(6,114)$ .970, $p = .449$, $\alpha = .05$.

Statistically significant differences in security attitude scores exist by gender, $t(125) = 2.062$, $p = .041$ (two-tailed), $\alpha = .05$, 95% CI [.174, 8.49]. Male scores ($M = 87.74$, $SD = 11.648$) were significantly higher than female scores ($M = 83.41$, $SD = 11.304$).

Statistically significant differences in security attitude scores exist by classification $F(5,121)$ 2.639, $p = .027$, $\alpha = .05$, $R^2 = .167$. Multiple comparison tests revealed no significant differences in mean scores by classification group.

Statistically significant differences in security attitude scores exist by installation of PC anti-spyware software $F(3,123)$ 9.044, $p = .000$, $\alpha = .01$, $R^2 = .18$. Multiple comparison tests (Gabriel, 1987) revealed statistically significant differences in mean scores between participants that answered "Yes" to having anti-spyware installed and those that answered "Yes, but expired" ($MD = 9.818$, $p = .029$, $\alpha = .05$, 95% CI [.68, 18.96], and between those that answered "Yes" and those that answered "Don't know" ($MD = 13.756$, $p = .000$, $\alpha = .01$, 95% CI [6.69, 20.82]. Participants that answered "Yes" to having anti-spyware installed scored significantly higher ($M = 87.57$, $SD = 11.283$) than those that answered "Yes, but expired" ($M = 77.75$, $SD = 8.812$), or "Don't know" ($MD = 73.81$, $SD = 7.600$).

No significant differences in security attitude scores exist by age $F(3,123)$ 1.255, $p = .293$, $\alpha = .05$, major $F(8,118)$ 1.644, $p = .120$, $\alpha = .05$, ethnicity $F(5,115)$ .894, $p = .488$, $\alpha = .05$, identity theft victimization $F(2,117)$ 1.669, $p = .193$, $\alpha = .05$, or installation of PC anti-virus software $F(3,114)$ .361, $p = .782$, $\alpha = .05$.

Security behaviors. ANOVA tests were conducted to compare security behaviors sub-scale scores by the categorical variables of age, gender, major, ethnicity, identity theft victimization, and installation of anti-virus or anti-spyware programs, along with interaction effects by age and classification, age and identity theft victimization, gender and ethnicity, and PC anti-virus and anti-spyware software installation. No significant interaction effects exist between age and classification $F(9,109)$ 1.124, $p = .352$, $\alpha = .05$; age and identity theft victimization, $F(4,117)$ .242, $p = .914$, $\alpha = .05$; gender and ethnicity, $F(5,115)$ .685, $p = .635$, $\alpha = .05$; or PC anti-virus and anti-spyware software installation, $F(6,114)$ .370, $p = .897$, $\alpha = .05$.

Statistically significant differences in security behaviors sub-scale scores exist by PC anti-spyware software installation $F(3,123)$ 2.788, $p = .043$, $\alpha = .05$, $R^2 = .064$. Multiple comparison tests yielded no statistically significant mean differences between the groups.

No significant differences in security behaviors sub-scale scores exist by age $F(3,123)$ .639, $p = .592$, $\alpha = .05$, gender $t(125) = .799$, $p = .426$ (two-tailed), $\alpha = .05$, ethnicity $F(5,121)$ 2.146, $p = .064$, $\alpha = .05$, classification $F(5,121)$ 1.456, $p = .209$, $\alpha = .05$, major $F(8,118)$ .970, $p = .463$, $\alpha = .05$, identity theft victimization $F(2,124)$ .046, $p = .955$, $\alpha = .05$, or PC anti-virus software installation $F(3,123)$ 1.626, $p = .187$, $\alpha = .05$.

Security tools. ANOVA tests were conducted to compare security behaviors sub-scale scores by the categorical variables of age, gender, major, ethnicity, identity theft victimization, and installation of anti-virus or anti-spyware programs, along with interaction effects by age and classification, gender and ethnicity, and anti-virus and anti-spyware software installation. No significant interaction effects exist between age and classification $F(9,109)$ 1.284, $p = .254$, $\alpha = .05$, or gender and ethnicity $F(5,115)$ .548, $p = .740$, $\alpha = .05$. Statistically significant interaction effects exist between anti-virus and anti-spyware software installation $F(6,114)$ 2.543, $p = .024$, $\alpha = .05$, $R^2 = .118$ (Figure 2).

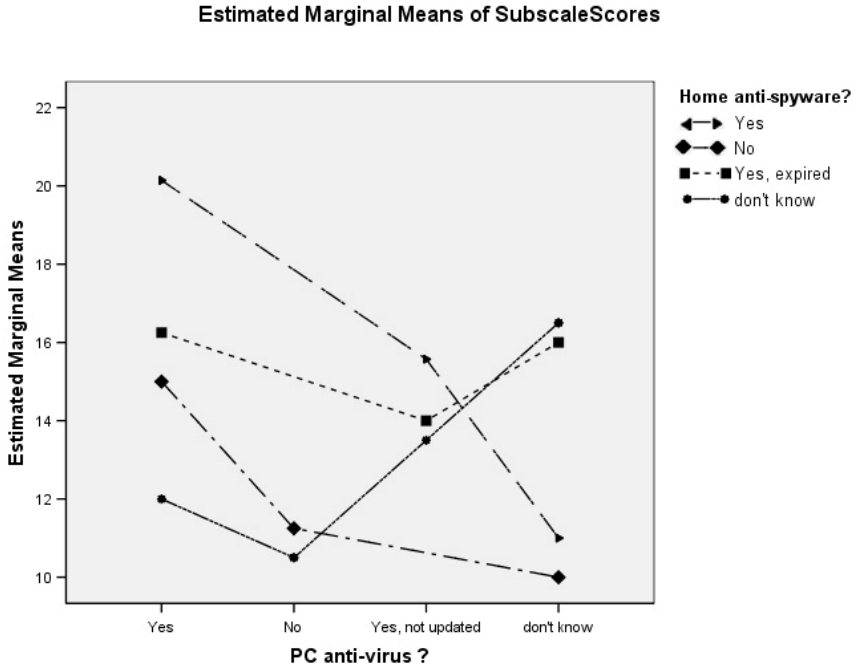
SECURITY ATTITUDES

The study revealed several interesting results with regard to security attitude scores. The highest security attitude scores by age were among the youngest participants, 18-23 year-olds ($M = 85.97$), while the lowest security attitude scores were among 24-30 year-olds ($M = 79.94$). Of 18-23 year-olds, those classified as "other" and sophomores achieved the highest scores ($M = 92.80$ and $M = 88.60$, respectively). Sophomores also comprised 27% of 18-23 year-olds ($n = 91$). Graduate students comprised half of all 24-30 year-olds ($n = 16$).

Results by academic major were comparable to the findings of Jagatic, et al. (2007) and Weber, Safonov, & Schmidt (2008) as mean scores of information technology majors were among the highest. Mean scores of fine arts majors were also among the highest in this study. By contrast, mean scores among healthcare majors and criminology majors were among the lowest by academic major. Low attitude scores among criminology majors is a surprising result given that these students are destined for law enforcement and security-related careers that

require security-conscious individuals. Low attitude scores for students destined for the healthcare industry are particularly troubling given the fact that this group will ultimately be responsible for protecting patient confidentiality and complying with healthcare laws, policies, and regulations, such as the *Health Insurance Portability and Accountability Act of 1996* (McClanahan, 2008). The results of the present study may indicate a possible need for security awareness training of college students in criminology and healthcare disciplines.

Figure 2: Interaction Plot



No significant differences in security tools sub-scale scores exist by age $F(3,123)$ 1.960, $p = .124$, $\alpha = .05$, gender $t(125) = .800$, $p = .425$ (two-tailed), $\alpha = .05$, ethnicity $F(5,121)$ .644, $p = .666$, $\alpha = .05$, classification $F(5,121)$ 1.967, $p = .088$, $\alpha = .05$, major $F(8,118)$ 1.248, $p = .277$, $\alpha = .05$, or identity theft victimization $F(2,124)$ 2.010, $p = .138$, $\alpha = .05$.

Male security attitude scores (M = 87.74, SD = 11.648) were significantly higher than female scores (M = 83.41, SD = 11.304). This finding appears to support prior research that there is a digital divide with regard to gender (Cooper, 2006; Jones, Johnson-Yale, & Millermaier, 2009) and a lack of self-confidence in dealing with computer security issues (Jackson, 2007; Jackson, Ervin, Gardner, & Schmitt, 2001; Jokela & Karlsudd, 2007). In terms of ethnic minority groups, this study also found that the lowest mean security attitude scores by ethnicity were among Hispanics and Native Americans, while mean scores of African-Americans and those self-classified as "other" were among the highest. Scores of Caucasians were also slightly below the average sample mean (M = 85.02). These findings may indicate that Hispanics are less security aware (Norum & Weagley, 2006) and appear to contrast survey

results from Unisys Security Index (2010) which found that Hispanics are more concerned about unauthorized access or misuse of personal information than Caucasians or African-Americans.

In terms of academic classification, there appears to be a wide disparity of results as the lowest mean scores were among juniors and graduate students, while the highest scores were among sophomores, seniors, and those self-classified as "other" [5 of n = 8 were > age 30]. Freshmen mean scores were slightly below average mean attitude scores for the sample (M = 85.02). As one might expect, identity theft victims had the highest mean security attitude scores compared to non-victim participants or those who don't know if they are an identity theft victim.

Participants that have active anti-spyware software installed appear to be more security-conscious than those that either let their anti-spyware license expire or don't know if anti-spyware software is installed. Participants that had anti-spyware installed on their computers usually had anti-virus software installed. Four participants had no anti-virus or anti-spyware software installed (Mensch & Wilkie, 2009). Perhaps this provides a partial explanation for the millions of PCs that are infected with viruses and/or malware worldwide (Young, 2009).

SECURITY BEHAVIORS AND SECURITY TOOLS

Additional analysis was conducted on two subscales of the security attitude scale: security behaviors and security tools. The highest security behavior subscale scores by age were among 24-30 year-olds (M = 33.25) and 18-23 year-olds (M = 32.27), while 31-36 year-olds and 37+ year-olds recorded the lowest mean security behavior subscale scores (M = 31.75 and M = 31.88, respectively). Interestingly, mean security tools subscale scores were highest among 37+ year-olds (M = 19.63) and 18-23 year-olds (M = 18.35). Security tools scores were lowest among 24-30 year-olds (M = 15.50) and 31-36 year-olds (M = 16.92). While one might expect that maturity and experience would result in more security-conscious behaviors, the results of this study do not support that assumption. It appears that age does not necessarily portend wisdom when it comes to security behaviors, such as clearing Internet history/data, updating anti-virus and anti-spyware software, logging out of financial institution web sites, or installing and using security tools, especially with regard to the 31-36 year-old age group. Also, while 24-30 year-olds more effectively exhibit security behaviors, the failure to complement those behaviors with the use of basic security tools (anti-virus and anti-spyware software) may give this age group a false sense of security when it comes to protecting personal information and data. Future studies should be conducted to delve more deeply into behavioral profiles by age to determine if these results occur more widely through the general end-user population and to discover additional underlying factors that may contribute to these findings.

While the differences in mean security behavior scores and security tools scores by gender did not significantly differ, mean scores for males were higher than females on both subscales. Again, this result is in line with research by Jones, et al. (2009) and Jokela & Karlsudd (2007) on gender differences with regard to security measures.

With regard to ethnicity, Asians and African-Americans seem to be more likely to adopt security-conscious behaviors and use security tools more readily than Hispanics, a group that scored consistently lower than other groups on the two security subscales reported on herein. Future studies should investigate underlying factors which might contribute to these results.

In terms of academic classification, security behavior scores varied. The lowest security behavior subscale scores by classification were among juniors, freshmen and graduate students, while the highest scores were among those classified as "other" and seniors. With regard to the security tools subscale, the lowest mean scores by academic classification were among juniors and seniors, while the highest scores were among sophomores and those classified as "other." Since juniors recorded low mean scores for both the security behavior and security tools subscales, future studies should investigate contributing factors to this finding and determine if targeted security awareness training is warranted for this group.

In terms of academic major, one would expect criminology majors to be among the most security-conscious of all college students; however, mean security behavior scores of this group were among the lowest by major. Security behavior scores for healthcare majors were also low, another a troubling finding. With regard to the use of security tools, mean subscale scores were highest for criminology majors. As with the prior findings on security behaviors and age, use of security tools may give criminology majors a false sense of security when it comes to protecting personal information and data. Not surprisingly, information technology majors routinely received some of the highest scores on both the security behavior and security tools subscales, supporting similar research findings (Jagatic, et al., 2007); however, fine arts majors also recorded high security tools scores. Future research studies should investigate the factors attributed to security behaviors, as well as installation and use of various security tools by academic discipline.

Another surprising result was that identity theft victims recorded mean security behavior scores comparable to the other two groups. It is puzzling that mean scores for victims of identity theft were not significantly higher given that security-conscious behaviors might prevent future loss of financial and personal information. This finding may indicate a need for targeted security awareness training for identity theft victims. By contrast, the highest security tools subscale scores were among identity theft victims. As with the findings on security behaviors by age and academic major, the installation and use of security tools may give identity theft victims a false sense of security when it comes to protecting personal information and data.

On both the security behavior and security tools subscales, the highest mean scores were among those with anti-virus and anti-spyware installed (M = 19.04 and M = 19.52, respectively). The lowest mean scores were among those that don't have anti-virus or anti-spyware software installed (M = 11.00 and M = 12.50, respectively), or don't know if anti-virus software or anti-spyware software is installed (M = 13.14 and M = 12.56, respectively). Significant interaction effects exist between the PC anti-virus software installation and PC anti-spyware software

installation variables. Thus, people that have anti-virus software installed also have anti-spyware software installed.

In this study, 80.3% of participants have anti-virus installed, slightly lower than the 88% of participants in Jokela & Karlsudd's (2007) study. Jokela & Karlsudd's (2007) study also reported that "quite a few students (5%)" do not know whether antivirus software is installed or updated. In the present study, a much higher percentage of students don't know if anti-virus software is installed or updated (14.1%) and another 15% of participants do not have anti-virus installed at all (Mensch & Wilkie, 2009). Also, almost 15% of participants hardly ever or never run anti-virus software on their computers (n = 19) and only 44% do so always or most of the time (Mensch & Wilkie, 2009). Further, 70.9% of participants hardly ever or never run anti-virus software on USB memory devices (n = 90) and only 11% do so always or most of the time (Mensch & Wilkie, 2009). Also, 74.8% of participants have anti-spyware installed, 6% of participants don't have anti-spyware installed, or do not know if it is installed (13%), and 6% have it installed, but it is expired. Further, 23.6% of participants hardly ever or never update anti-spyware software (n = 29), and 22.8% hardly ever or never run anti-spyware software on their computers (n = 29). Only 40.2% update anti-spyware software always or most of the time, while 40.1% run anti-spyware always or most of the time (Mensch & Wilkie, 2009). Perhaps this explains why corporate IT managers often restrict use of USB and other devices on corporate networks (Goodchild, 2008) and the concerns expressed about end-users by security professionals (Young, 2009). These findings clearly indicate a need for end-user training on the installation, use and routine updating of security tools to better protect personal information and data. Future studies should investigate additional factors that contribute to ineffective or non-existent use of computer security tools.

CONCLUSION

The results of this study reveal a troubling disconnect among many undergraduate and graduate students with regard to information security attitudes, effective security behaviors, and use of computer security tools. The researchers agree with Okenyi & Owens (2007) that a paradigm shift is needed towards continuous secure behavior. What actions should end-users and organizations take to protect personal information and data? For individuals, a multi-pronged approach will ensure secure Internet-related communication and access, including measures (Heinrichs, 2007; Luo & Liao, 2007; Mitnick, 2006) such as:

Installing and enabling a personal firewall;
Regularly scanning computers, storage devices and email with updated anti-virus and anti-spyware software;
Using browser-enabled pop-up blockers and other built-in browser technologies.

The results of this study lend credence to Schneier's (1999) statement that "security is not a product, it's a process" (para. 6). A reliance on technological controls to the exclusion of people and processes is insufficient (Okenyi & Owens, 2007). Organizations should provide security awareness training (Allison & DeBlois, 2008; Jagatic, et. al., 2007; Turner, 2007) to end-users to promote sound behavioral practices (Jones, 2008) in order to protect the confidentiality, integrity, and availability of personal and organizational data. Security awareness practices should include end-user training on topics (Agee & Chang, 2009; Goodchild, 2009; Gorge, 2007; Luo & Liao, 2007; Mansfield-Devine, 2008; Mitnick, 2002) such as:

Social engineering methods and tools used by attackers especially with regard to social media;
The risks of peer-to-peer file sharing networks and downloading unknown programs or files;
The risks of unsecure or unknown web sites and measures to identify and avoid these sites;
The risks of clicking on unknown email links and the risks associated with social networking sites;
The importance of regular data backups and alternative storage options such as external drives, CD/DVD's, or virtualization technologies; and
The importance of applying software patches and security updates on a regular basis.

Network users should be trained how to identify email message threats before clicking on links or attachments (U.S. Department of Justice, n.d.), including examination of email headers and message source code to differentiate a suspicious message from a legitimate one (Goldsborough, 2008; TechRepublic, 2006), and to open a browser and manually navigate to the web site address rather than clicking on a messaged hyperlink. Network user training should also include strong password construction techniques (Thomas, 2005; Weber, et al., 2008), including the following elements:

8 or more characters in length;
Combination of letters, numbers, and symbols; and
Mixed uppercase and lowercase letters, numbers, and symbols.

Organizations should also take proactive steps to reduce the likelihood of identity theft and personal data loss (Allison & DeBlois, 2008). First, written password management guidelines should be adopted and widely dispersed, and regular training sessions should be conducted regarding the routine use of these guidelines at school and at home. Suggested password guidelines (Mansfield-Devine, 2008; McDowell, Rafail, & Hernan, 2009) include:

Change passwords often;
Use different passwords for each account (especially financial institutions);
Don't share passwords with others;
Don't store passwords in the computer memory/history;
Don't use words that can be found in a language dictionary;
Use a mnemonic to remember a complex password;
Never email passwords or reply to emails with passwords or other sensitive data; and
Store password lists in a secure place.

Second, end-users should be taught how to construct a passphrase, which combines the first letters of a phrase coupled with numbers which substitute for words, as a more secure alternative to passwords (Charoen, Raman, & Olfman, 2008; Weber, et al., 2008).

Third, training should also be provided to configure phishing filters and privacy settings in browsers and email clients, and to help users determine if a web site is legitimate, especially for sites using Secure Sockets Layer (SSL) or with bad SSL certifications (Goodchild, 2009; Krebs, 2006).

Lastly, educational institutions should update privacy and security policies to include all IT resources (Allison & DeBlois, 2008), while balancing the academic environment's need for openness with the need for individual privacy and data security (Agee & Yang, 2009). Institutions of higher education should also update end-user conduct policies to address standards of conduct on social networking sites (Gorge, 2007; Mitrano, 2006; Timm & Duven, 2008) while balancing students' freedom of expression. While computer usage policies are an integral part of computer security, a reliance on end-users to read policies may prove to be unreliable (Foltz, Schwager, & Anderson, 2008).

Despite training efforts, organizations cannot guarantee that end-users will practice security measures after training (Welander, 2007). For example, McMillan (2006) reported that 80% of West Point cadets still clicked on a fake email link even after hours of training. Attackers are also getting more sophisticated in their use of social media to target individuals for fraud and identity theft (Collins, 2009). In response, social media companies are working to improve the security and privacy of users (Zuckerberg, 2010). However, end-users must still proactively implement and monitor security procedures at social networking sites.

The results of this study bolster Mitnick's (2002) assertion that "the human factor is truly security's weakest link" (p. 3). When considering information security, no matter how sophisticated the technological solutions, the end-user must learn to accept responsibility and take proactive measures to stay educated about available security tools and procedures to protect personal data and information in both online and offline venues. People and systems must work together to minimize vulnerabilities (Welander, 2007). Educational institutions are the first line of defense to provide training to the end-user student population to stem the tide of compromised

computers that are used by thieves and hackers to steal identities and wreak havoc on the Internet.

LIMITATIONS OF THE STUDY

This study is exploratory in nature, is limited to the undergraduate and graduate student population, and does not extend to individuals in the same age groups that are not enrolled in a 4-year college or post-graduate studies. Additional factors may exist which contribute to a better understanding of attitudes, behaviors, and use of computer security tools by college students.

FUTURE RESEARCH

While $\alpha = .69$ is acceptable for purposes of internal consistency and reliability, the scale should be refined to increase internal consistency and reliability. Future studies should be conducted with larger sample sizes to increase effect size and should use an expanded population group. Future studies should also investigate use of additional computer security tools commonly available to end-users, such as pop-up blockers, browser-based filters, social network and IM privacy settings, and email junk mail filtering.

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MANAGING RISK IN OPERATIONS

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ABSTRACT

Risk is an intrinsic part of business in a market economy. The ability to control risk in operations is essential to productivity and profitability. Typically, actions to control operational risk and its effects are the result of an ad hoc process, adopted without a comprehensive analysis of alternatives. Risk mitigation in supply chains requires closer analysis since coordination across multiple organizations is required. Effective risk management requires an assessment of both the locus of control and the range of alternative control actions. We describe the nature of operational risk, its locus, and present a taxonomy of mitigation tactics. We observe that operations adopt a mix of control actions and that this mix must evolve in response to changes in the environment. Finally, we present a discussion of the issues and processes required to revise the mix of risk mitigation tactics.

INTRODUCTION

Risk is defined in a variety of ways, depending on context and the presumed interest of the reader. Amram & Kulatilaka (1999) assert, "The adverse consequence of a firm's exposure is risk." Mandel (1996) employs two broad categories for risk: idiosyncratic and structural. Idiosyncratic risks affect a single company while structural risks affect economies, sectors or industries. Usual treatments of risk (Weston & Copeland, 1998) address market risk, financial risk, and business risk. Business risk is the combination of revenue risk and operating leverage, that is, the variability of EBIT (earnings before interest and taxes) and the ratio of fixed costs to total costs.

Notions about the inevitability of, and appropriate response to, risk vary around the world. In economies that practice Strategic Trade (as contrasted to Free Trade), risk is viewed as inherently bad and economic policy and governmental action are devoted to reducing risk and variability in markets, (Fallows, 1994). State capitalism (Bremmer, 2010) exhibits similar characteristics. Significant inefficiencies typically result. At the firm level, excessive attention to risk can result in overspending on risk reduction with corresponding reductions in operating margins. Excessive inventories are a common and visible manifestation of this phenomenon.

As our interest centers on operations in the organization, we apply the treatment suggested by Weston & Copeland (1998), and recognize operational risk as a major source of variability in EBIT. Risk in Operations arises from internal variation and from the environment.

Further, risk may be due to either *common* or *special* causes (Deming, 1982). In the following, we provide a structure for categorizing the ways in which operations can mitigate risk or its effects on the organization.

OPERATIONS

We define Operations as revenue-producing activities carried out by the firm, specifically, those activities that 'deliver' the value proposition of the enterprise. The measure of the performance of an operation is its productivity. Economic theory defines productivity as (McConnell, 2008):

$$\text{Productivity} = \text{output}/\ \text{inputs} \qquad (1)$$

In this form, the equation is may be applied to a firm, an industry, a sector of an economy, or an entire economy. As defined, output and inputs are flow rates stated in physical terms. Converting the equation to "per period" terms moves towards a construct useful to the manager and establishes consistency with accounting convention. Converting inputs and output to their monetary equivalents illustrates the relationship between Productivity and EBIT. Output monetized is revenue and current inputs become COGS (Cost of Goods Sold). Variability in productivity relates directly to variability in EBIT.

Typically, discussions of productivity proceed with a focus on the partial factor productivity of labor (output stated in terms of labor input). Eschewing this direction, we pursue a path that acknowledges the variety of inputs and has the objective of developing the relation between productivity and the managerial decisions that affect it. As developed, this relation will provide a framework for characterizing risk in operations. We develop what we call the "Productivity Equation," in (2) through (4) following.

Begin with a restatement of the definition to emphasize both period and linkage to financial statements.

$$\text{Productivity} = \frac{\text{output delivered}}{\text{inputs acquired}} \qquad (2)$$

The Equation (2) (still in physical terms) defines the scope of operations as ranging from input sourcing and hiring decisions (including both fixed and variable inputs) to outbound logistics management. In this form, the expression may represent a supply chain or may be limited to the internal operations of a single enterprise.

The operating manager's objective is to produce steady growth in productivity, contributing to growth in EBIT. Variability in the components of productivity (particularly unanticipated or uncontrolled variability) compromises the ability to achieve steady growth.

Risk due to common cause variation is mitigated through management action while special cause variation usually requires a special response.

An alternative elaboration of the definition of productivity illustrates the crucial impact of utilization on productivity:

$$\text{Productivity} = \frac{\text{output}}{\text{inputs used}} \times \frac{\text{inputs used}}{\text{inputs}} \qquad (3)$$

$$\text{Productivity} = \text{technology} \times \text{utilization} \qquad (3a)$$

The first factor of this expression addresses the technology of the conversion of inputs to outputs and the second factor illustrates the importance of the utilization of inputs. This expression provides insight into how variability in demand may affect productivity by decreasing utilization of the inputs.

A more complete picture results from combining (2) and (3).

Productivity =

$$\underset{\text{(a)}}{\frac{\text{Output Delivered}}{\text{Output Produced}}} \times \underset{\text{(b)}}{\frac{\text{Output Produced}}{\text{Inputs Used}}} \times \underset{\text{(c)}}{\frac{\text{Inputs Used}}{\text{Inputs Available}}} \times \underset{\text{(d)}}{\frac{\text{Inputs Available}}{\text{Inputs Acquired}}} \qquad (4)$$

The terms of this equation illustrate how both management decision and variability affect productivity. The close relationship between productivity and profitability (by monetizing output delivered and inputs acquired) remains clear. Germain (2008) notes, "Supply chain process variability has an inverse relationship with financial performance, regardless of the demand environment; and organizational structure provides managers with the mechanisms to mitigate this variability's detrimental impact on financial performance." Lee (2002) presents a framework that distinguishes between supply uncertainty and demand uncertainty, concluding that managing a supply chain with high uncertainty (of either type) presents greater challenges than managing one with low uncertainty. Demand uncertainties manifest in terms (a), uncertainty about volume, and (b) uncertainty about product characteristics. Supply uncertainties manifest in terms (c) and (d) and involve the nature and characteristics of inputs.

Observe that (4) is a trailing measure of performance, an assessment of outcomes. The operating manager is properly concerned with decisions that determine productivity. Four principal categories of operating decisions determine the factors of (4). These are:

Capacity decisions principally determine factor (d). Capacity exists in the context of both process design and anticipated volumes. Here, capacity is used in its broadest sense and includes both current and fixed inputs.

Volume decisions determine (a). These have a basis in either anticipated demand (from a forecast) or actual customer orders (for specific products).

Design decisions, specifically, process design determine (b). Process design arises from the capability of capacity (technology) and product design. Design decisions include both process and product design and these jointly specify the exact nature of the product and its production.

Schedule decisions determine (c) and are constrained by capacity, volume and design. These decisions affect capacity utilization (both labor and machine), (materials) inventory turns, throughput (WIP utilization), and utilization of labor.

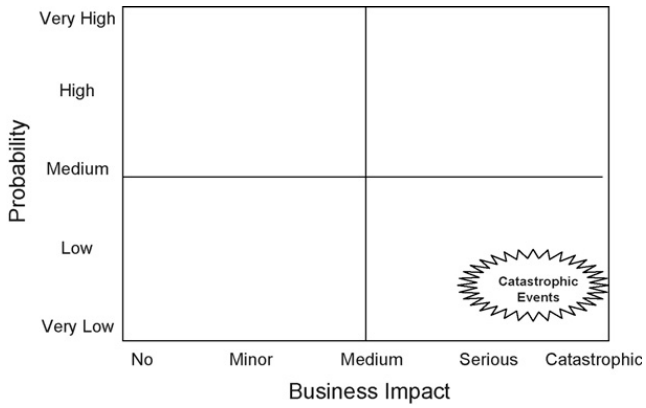
As a group, these decisions are called *productivity decisions* and will be characterized as "CVD&S" (for Capacity, Volume, Design and Schedule) decisions. Their exact nature varies depending on operational characteristics. They are, as indicated, interdependent.

CVD&S decisions are ongoing and typically routinized, specifying the conduct of operations on a daily, often hourly, basis. Operations value stability, even in the face of wide swings in the behavior of their environment. Operating managers typically structure productivity decisions to occur at the lowest possible levels in the organization, minimizing the distance between the locus of the decision and its implementation. Decision guidelines and rules are typically formulated as if the decision environment were deterministic, offsetting the effects of variability using buffers. These organizational responses to variability are common and appear throughout the organization. Morgan (1986) describes the principal means of accommodating variability as routinization and buffering.

RISK IN OPERATIONS

Knemeyer (2009), in a discussion of supply chain risk asserts, "Risks falling in the upper half of the risk categorization scheme could be described as primarily operational risks. These are regularly occurring events such as variability in demand or the chance that products are damaged during transportation." Figure 1 presents the risk categorization scheme, as adapted from Brindley (2004)

Fig. 1. Risk categorization scheme.



The principal use of the scheme is to provide context for a discussion of LP-HC (Low Probability – High Consequence) events that produce catastrophic consequences for a supply chain. The work of Kleindorfer and Saad (2005); Martha and Subbakrishna, (2002), and Knemeyer (2009) is representative of this line of inquiry. Adopting this scheme, one would suppose, requires accepting the existence of HP–HC events. These are problematic for both operations and supply chains and it is difficult to conceive of an illustrative example in a continuing operation. Other approaches to risk identification, e.g., Dina (2009) or Miller (1992) avoid the problems with the Brindley scheme.

Our interest lies in those events characterized as MP–MC (for medium probability – medium consequence), events associated with the "operational risks" of Knemeyer. These events are common and expected to impact profitability: on-time satisfaction of customer needs, product quality, market share or competitive position, and so forth.

Research and practice into effective means for avoiding or mitigating operational (and supply chain) risk has proceeded well beyond the "buffer and routinize" tactics mentioned above. A complete summary of interesting and relevant research would be lengthy and is not undertaken here. Instead, we present several interesting and differentiated approaches in the interest of providing insight into the variety of perspectives brought to this problem.

Lee (2002), following the classification of supply chain risks into supply uncertainty and demand uncertainty, suggests four general categories of response to uncertainty. These are in Table 1.

Table 1.

Strategy	**Characteristic**
Efficient	Seek maximum efficiency through integration of information across the supply chain and optimization of production and distribution schedules
Risk-Hedging	Hedge against supply uncertainty through pooling and resource sharing across the supply chain,
Responsive	Improve responsiveness to changing customer needs by adopting build-to-order and mass customization techniques
Agile	Combine the "hedging" and "responsive" strategies to achieve an "agile" supply chain.

Braunscheidel (2009) also presents agility as valuable for both risk mitigation and response although in context, agility is associated with the organization's market and learning orientation.

D'Souza (2000) addresses manufacturing flexibility in an approach broadly related to Lee's "responsive" category. Weiss (2009) explores the effectiveness of operational and

financial hedging for risk mitigation, providing an additional perspective on the "Hedging" strategy

A different perspective is presented by Juttner (2003), adapting the general perspective of Miller (1992) to supply chain risk. Table 2 presents these strategies as categorized.

Table 2.

Strategy	**Characteristic**
Avoidance	Dropping specific products/geographical markets/supplier and/or customer organisations
Control	Vertical integration Increased stockpiling and the use of buffer inventory Maintaining excess capacity in productions, storage, handling and/or transport Imposing contractual obligations on suppliers
Co-operation	Joint efforts to improve supply chain visibility and understanding Joint efforts to share risk-related information Joint efforts to prepare supply chain continuity plans
Flexibility	Postponement Multiple sourcing Localised sourcing

Providing yet another perspective, Tomlin (2006) identifies "a number of tactics to manage the risk of disruptions." Table 3 includes the tactics presented.

A different perspective is provided in the work of Kleindorfer (2003) and Wu (2005). Response to risk is conceived and modeled as a choice between committing to a forward contract to guarantee the availability of (potentially) necessary resources and acquiring the resources in the spot market. A real options framework facilitates decision-making and illustrated in several contexts. Cohen (2007) summarizes the central risk management problem as involving the determination of "how should contract duration and design be selected to balance the risk reduction value of a forward contract against the contingency that a spot purchase may be more profitable."

Table 3.

Category	**Tactic**
Financial mitigation	Business interruption insurance
Operational mitigation	Inventory Sourcing
Operational contingency	Rerouting Demand management

This brief summary serves to indicate the scope and variety of approaches to managing operational risk. We note that the actions described are tactical in nature, rather than "strategic." In the following, the term "tactics" will describe categories of risk-mitigating actions.

The categories described in Tables 1 – 3, represent alternative framings of the risk mitigation problem and corresponding action alternatives. Additional tactics, e.g., diversification, will be included in the more comprehensive categorization presented below.

LOCUS OF RISK

Risk mitigation must acknowledge the location of the risk as well as the mitigating action. In the context of the productivity decisions (related to Equation 4), it is apparent that the risks associated with, say, design decisions differ intrinsically from the risks associated with volume decisions.

To identify the locus of variation, we follow the structure presented by Porter (1998, p 78) which introduces the concept of a "Value System," differentiating "Upstream" value, "Firm" value, and "Downstream" value. In broad usage, the term "Supply Chain" includes all these elements. To effectively address risk, a structure that distinguishes risks that occur in supply (input or upstream) processes from those associated with value production (internal or conversion) from those of demand (output or downstream) seems appropriate. Lee (2002) acknowledges these differences in the discussion of supply uncertainty and demand uncertainty. This categorization is also consistent with the factors of Equation 4. Supply risk impacts factor (d), value risk occurs in factors (b and c) and demand risk affects factor (a).

MITIGATING RISK

Every operation, and supply chain, has developed means of responding to risk using some of the tactics described above. Often, tactics arise as the result of an *ad hoc* process, based on the intuition and experience of the operating manager and applied in response to a developing situation. Other tactics arise from analysis that reaches beyond experience or intuition. The real options methodology for determining the optimal mix of hedging and spot market operations illustrates a non-intuitive tactic. The effectiveness of any particular tactic will vary, depending on the nature of the operation and its environment.

In view of the foregoing, two observations are appropriate:

> Operations and supply chains employ multiple tactics to mitigate risk and its consequences. This gives rise to the notion of a "mix" of risk mitigating tactics.
> In view of a rapidly changing competitive, economic, and technological environment, this "tactical mix" should undergo continual assessment to verify appropriateness and cost effectiveness.

How should the tactical mix be modified? How might an alternative mix be identified? One could posit an evolutionary process involving reduction in the use of one tactic while increasing another. The objective would be to achieve steady incremental progress by phasing

out ineffective tactics and introducing (or increasing the use) of those that demonstrate greater effectiveness.

An objective analysis of tactical alternatives requires a reasonably complete set of alternatives. Specific alternatives will depend on the characteristics of the operation or supply chain and their formulation must acknowledge the unique nature of the operation. A structure for organizing tactical alternatives is extremely useful in describing and revising a tactical mix because: (1) it provides a consistent basis for describing an existing tactical mix, (2) it provides a framework for describing new tactical alternatives, (3) by indicating unemployed tactical categories, it suggests the nature of new tactics, and (4) it provides a structure for comparing tactical alternatives..

TAXONOMY OF RISK MITIGATING TACTICS

It is to the advantage of the operating manager to understand the full array of available tactics in order to select the most cost-effective combination. Adoption of a tactical mix involves the selection of specific actions from several categories to achieve the greatest benefit at lowest cost.

A tactical mix combines actions from seven sub-categories in two major categories. Table 4 illustrates the categories. Sub-categories are broad and include a variety of specific actions. The major categories are insulating and adapting. These represent two opposing approaches to mitigating risk and its effects. Insulating tactics seek to protect the operation from the effects of variability by disassociating the operation from variation. Adapting tactics work to equip the operation (supply chain) to accommodate variability and, potentially, use it to advantage.

TABLE 4.: Risk Mitigating Tactics

Insulating tactics	Adapting tactics
Buffer/Hedge	Buy, sell, or exchange information
Standardize	Diversify
Share	Improve responsiveness
Alter Environment	

A brief discussion of the tactical sub-categories follows.

Insulating tactics:

Buffer The function of a buffer is to decouple the operation from its environment so that it is relatively unaffected by environmental variation. Use of buffers abound. One of the most common uses is in finished goods inventories. In-process inventories are also buffers and

buffering is the main purpose of the order release function in production control. Buffers are less common in service operations but they typically act to assure availability of materials or supplies required to support the provision of the service. Service providers also pre-sell service using quantity discounts, contractual arrangements, and k-th item free (after purchase of k-1 items). Consistent with its pervasive use, this tactic is included in the summaries of Lee (2002), Weiss (2009), Juttner (2003), Tomlin (2006), Kleindorfer (2003), and Wu (2005).

Standardize Standardization limits the ways in which the operation will respond to variation. Standardization, necessary for modularity and interchangeability, is widespread in product and process design. Production of standardized goods and services is virtually always more economical than production of unique, custom products. Though widely used, this tactic appears in only two of the summaries cited Juttner (2003) Avoidance and Tomlin (2006) Demand management,

Share Sharing risk is widely employed in many forms. Sharing includes the purchase of insurance, hedging, joint ventures and outsourcing. Monetization of risk (Amram & Kulatilaka, 1999, Mandel, 1996, Stewart, 1998) has become widespread, facilitating the creation and evaluation of alternatives. Futures markets in a wide variety of "commodities" have arisen (Kennett, 2000). Insurance is an ancient industry (Bernstein, 1996) and companies are willing to participate in a variety of risky situations. The optimal share of a joint venture can even be determined (Howard, 1988). Sharing is prominent in the summaries of Juttner (2003) and Tomlin (2006)

Alter environment In its most primitive form, this tactic involves modifying (doing away with) sources of risk. The ancient practice of killing one's competitors has given way to lobbying, public relations, PAC contributions and similar activities. The avoidance strategy of Juttner (2003), in some of its aspects, falls in this category. Just in time (JIT) sourcing (Monden, 1983) with particular respect to required delivery timing is also an example of this tactic. This tactic can also involve directly influencing customer alternatives or behavior, for example, by designing product characteristics (or the nature of the business relation between supplier and customer) to create switching costs (Klemperer, 1995). Depending on scope of application, this tactic can assume strategic attributes. An example appears in Kaplan (2004) and is described as a generic "system lock-in" strategy.

Adapting tactics:

Buy, sell, or exchange information The simplest of the adapting tactics is to buy information. Operations employ advance information about the nature and extent of variation to counteract its negative effects. Expert opinion, market studies and forecasts are typical elements of this category. These alternatives are well known and a significant body of theoretical and practical knowledge about them exists. In a supply chain, information sharing is crucial. Lee (2002) and Juttner (2003) make explicit mention of this tactic.

Diversify Diversification, in the form of Markowitz diversification is well known. The benefit of diversification in operations arises from having offsetting variation from two or more activities. In simple form, this is to make snow blowers in a lawn mower factory, utilizing offsetting seasonal patterns of variation to smooth demands on operations. Financial theory (Weston & Copeland, 1998) identifies diversifiable and non-diversifiable risks. Juttner (2003) and Tomlin (2006) identify source diversification as a risk mitigation tactic. Customer diversification and process diversification go unmentioned.

Improve responsiveness This tactic generally involves use of technology to improve responsiveness to variation, enabling the operation avoid disruptive consequences. Use of flexible manufacturing systems (FMS) is an illustration of this tactic as is *JIT/Kanban*, to cite both a technology intensive application and a "manual" one. Recent developments involve coordination and integration along the supply chain, lessening risk for all participants. Improvements to responsiveness may be either "high tech" or "low tech," involving something as simple as cross training or as complex as web mediated customer access to the company's knowledge base. The "responsive," "agile," and "flexible" tactics of Lee (2002), Braunscheidel (2009), D'Souza (2000), and Juttner (2003) are further illustrative of actions in this category.

It might be hypothesized that insulating tactics would be most appropriate for mitigating risks on the "supply side" and adaptive techniques for risks on the "demand side" based on the premise that the operation can control how it responds to its customers and has relatively less influence over suppliers. Internal processes, at the intersection of supply and demand, would use a combination of tactics. This, however, is not the case. Actions in both tactical categories find effective application across the chain.

Each of the categories in the taxonomy represents a variety of actions to mitigate risk, whatever its locus. Consider, for example, the diversity category. On the input side of the supply chain, both supplier diversification and materials diversification such as use of substitutes are included. In the value processes, diversification would include use of alternative routings or adapting equipment to use multiple power sources. The output side includes product diversification such as building snow blowers in a lawn mower factory, customer diversification such as producing for both final users and value adding intermediaries, and industry diversification such as producing for commercial, government, and educational organizations. Other categories represent a similarly broad spectrum of actions.

As employed, the tactics improve productivity performance by enhancing the quality of productivity (CVD&S) decisions. The quality improvement does not arise from better decision-making, but rather from having better decision alternatives from which to make a selection. Specific results of an improved tactical mix include: (1) simplifying the structure of productivity decisions, (2) improving in the number and quality of decision alternatives, (3) improving the quality of information about decision outcomes, and (4) providing more complete knowledge of the implementation environment for the decision.

ILLUSTRATIONS

In addition to providing a structure to aid the operating manager in improving the cost-effectiveness of the tactical mix for an operation, the taxonomy also provides a context for interpreting business activity reported in the current media. The following paragraphs illustrate this use.

Southwest Airlines hedged its fuel costs prior to the oil price run-up of 2007-08, maintaining profitability, while carrying more US passengers than any other airline. This tactic produced huge benefits for Southwest in a period when most other airlines were experiencing operating losses due to high fuel costs. When fuel prices dropped, Southwest's hedges lost value. It booked a quarterly loss in the fourth quarter of 2008 (Koenig, 2009), illustrating that the appropriate tactical mix should be dynamic and should change in response to changing competitive and economic conditions.

"Less than one month after receiving $100,000 from Houston homebuilder Bob Perry, Gov. Rick Perry named a top executive from Perry Homes to a commission implementing a new law designed to reduce lawsuits against builders" (Elliott, 2003). The commission controls the nature and extent of recourse a Texas homebuyer has against the homebuilder. The commission has acted to require binding arbitration in all disputes, precluding lawsuits. The homebuilder-controlled commission selects arbitrators placing homebuyers at a significant disadvantage. The company and the industry in Texas, through application of the alter environment tactic have effectively limited their exposure to lawsuits by changing the legal environment in which they do business.

The ubiquity of supply chain management demonstrates the effectiveness of exchange information - improve responsiveness combination of tactics. The Federal Reserve Bank of Dallas (2005) demonstrates how this combination reduces supply volatility, production volatility, and inventory and logistics costs, while improving productivity in the manufacturing sector.

Famously, the comparison of Dell's business model with Compaq's (Bernasek, 2001) demonstrates the advantage of a responsive supply chain in replacing slow moving and expensive inventories. The remarkable success of Dell in using technology to limit inventories to two days (while Compaq held sixty) is an extreme, but striking example of a combined buffer (reduction) and responsiveness (improved through sharing and technology) tactic.

New technologies particularly innovative new uses of existing technologies are a rich source of new tactics in the improve technology category. Attention to new (and newsworthy) uses of technology in other (perhaps dissimilar) operations may provide valuable insights into innovative applications. For example, Byrne (2009) suggests that US automakers ought to adopt Google-like characteristics in product design. General summaries of technological trends (Manyika, 2007) may also be a rich source of insight.

Engardio (2009) reports the recession of 2008-09 has prompted businesses to make "… factories superefficient - they are gearing output to current demand rather than to three– to six–

month forecasts …" While these changes were prompted by changes in market and economic conditions, there is no reason they could not have been adopted months, or even years, earlier.

Several of these illustrations are noteworthy because they demonstrate the effectiveness of departing from common or accepted practice. The natural tendency to continue the use of current tactics (e.g., find a better inventory decision rule) may preclude the discovery of a superior approach such as using information technology and responsive systems to minimize inventories.

IMPLICATIONS

The foregoing suggests several conclusions about risk mitigation in operations and the supply chain. These have relevance for both researchers and operating managers.

First, organizations employ a variety of specific actions to mitigate risk. These actions represent specific instances of tactics from the categories in the taxonomy of Table 4. In combination, these actions represent a tactical mix. Discussions of risk mitigation and investigation of the effectiveness of a risk mitigating actions should acknowledge the existence of the mix and indicate the impact of results or conclusions on the mix.

Second, changes to the environment of the operation or the supply chain require changes to the tactical mix motivated by changes to the degree and character of risks present. Major motivating categories include the environment, technology and competitive forces. The operation may embrace change with one tactical dynamic or resist change with a completely different response. The commoditization process illustrates this point. Commoditization may be resisted (Christensen, 2003) or embraced (Davenport, 2005). Treatments of risk should attend to risk dynamics and suggest appropriate tactical responses.

Third, the locus of risk in the operation or the supply chain is an important variable when determining the appropriate response to risk. The variety of supply chains and the different ways in which risk manifests preclude treating it as an amorphous phenomenon. To be generally useful, assessments of risk mitigating actions should indicate the locus and origin of the risk as well as reports of effectiveness.

Fourth, when modifying the tactical mix, consider candidate actions from all tactical sub-categories. A routine assessment might identify an action currently in use and consider whether another action might achieve the same or superior result at lower cost. The obvious illustration is to consider replacing inventories by a more responsive system. Reduce finished goods inventories by improving the flexibility of the production system - achieved by shortening production cycles through reducing setup times or by adopting flexible processes. Reduce in-process inventories using a Kanban system (Monden, 1983) or application of TOC (Theory of Constraints) (Goldratt, 1986). Reductions to materials or components inventories result from supplier integration and coordination.

Fifth, questions of how to assess the effectiveness of an existing tactical mix and how best to formulate changes to the mix remain unanswered. Required is a metric for assessing the effectiveness of an existing tactical mix and a means of evaluating potential changes. Resolution of these larger questions is unlikely with a risk-centric approach. Risk mediation actions have broad effects that may change organization structure and processes, producing changes to productivity and organizational effectiveness. A singular focus on risk effects may distort the analysis.

The objective is to identify changes to the mix of tactics that will produce productivity improvement while decreasing variability or its effects. Each prospective change will potentially produce both a productivity effect and a risk effect. Proper analysis must consider both and must recognize that superior alternatives produce benefits to both measures. Unlike financial alternatives where higher returns come with higher risks, operating improvements can produce higher returns in productivity and simultaneously reduce risk or its effects. Operations that identify the best combination of productivity and risk enjoy superior performance just as do financial portfolios drawn from the efficient set of investment alternatives (Weston & Copeland, 1998).

A comprehensive compilation of risk mitigating tactics will be, for many operations, a significant undertaking. Some tactics may not be obvious. For example, "Virtually all firms depend on a constant flow of credit to carry them smoothly through the ups and downs of the business cycle." (Colvin, 2009). Short-term borrowing, while common, might escape notice as a "share" tactic. While it may appear that financing decisions are beyond the purview of the operating manager, increases or decreases in inventories do produce corresponding changes in current asset accounts and impact working capital needs.

Many tactics, as implemented, involve other functions in the organization, emphasizing the systemic interactions among them. A change in the extent of diversification will involve marketing and some of the share possibilities, particularly hedging, involve finance. Taking a broad perspective, the tactical assessment and revision process described provides a basis for enhanced functional integration in the organization. The operations manager is in a unique position to identify opportunities for improved integration and potentially can lead the organization to achieve improvements in performance.

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THE IMPACT OF SOCIAL, ECONOMIC AND GENETIC FACTORS ON STUDENTS' ALCOHOL CONSUMPTION DECISIONS

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ABSTRACT

Using a random sample of ninety students from a Catholic college, factors influencing drinking decisions have been identified. Students from non-divorced families tend to drink less. Students from high salaried families (combined salaries of parents) tend to drink more, and students from high wealth families tend to drink less. Separate college GPA equations for drinkers and non-drinkers have been estimated after looking for self selection bias. The main result found that drinking had a negative impact on their GPA. A significant contribution of this research lies in the presentation of the results through a decision tree analysis.

Keywords: Self Selection, Probit, Alcohol Effect

INTRODUCTION

The abuse of alcohol is widely recognized as a major social problem with significant consequences related to health, safety and other societal factors. Much has been made of the influence of alcohol on the ability of adults to function appropriately and completely in various capacities, such as drinking and working (Aquilino, 1994; Venturelli, 2000; Wyatt, 1992). One related area that has remained largely opaque is the direct causal relationship between alcohol consumption and the ability of college students to function constructively and appropriately, that is, receive certain academic achievements or grades. Despite the profusion of research done primarily in the last three decades on the topic, relatively few studies have looked distinctively at alcohol use and college student grades, absent other factors. In addition, the research that does exists, presents conflicting findings that shows a negative experience with other factors (loss of job, low grades, expulsion from school) that may/may not lead to increased alcohol consumption (Dee and Evans, 2003; McMorris and Uggen, 2000). The reverse relationship that being proposed in this paper. This is in a similar vein to other research that purport that drug intake is a by-product of the negative circumstances that have developed from a prior context for the abuser, that is, a loss of job, family income, low grades, etc. (Miranne, 1979; Aquilino, 1994). More specifically, the paper asks what is the influence of social, economic and genetic factors on students' alcohol consumption choices.

There are numerous literatures exploring the effect of alcohol use on physical or mental health and also on wages and performances. Researchers have studied the effect of excessive alcohol use on youth motor vehicle fatalities (Cook, P. J. and Tauchen, G.,1984 and Coate, D. and Grossman, M., 1986). Researchers have also found that moderate alcohol use has beneficial physical and psychological effect (Turner, T.B., Bennett, V.L. and Hernandez, H., 1981). Finally, it has also been found that drinkers earn higher wages than non-drinkers (Berger, M.C. and Leigh, J.P., 1988). This paper develops an argument for addressing the influence of alcohol use on educational attainment, a paradox that may relate to an inter-causal relationship. The article takes into consideration mitigating circumstances. In this context, a key mitigating circumstance is the fact that the sample was taken from a catholic College and religion has been touted as a key predictor of alcohol consumption and level of tolerance (Hadaway, Elifon and Petersen, 1984; Perkins, 1987; Perkins, 1985). The analysis of the results and findings are based on a theoretical model that emphasizes the relationship between alcohol, consumption and educational attainment, while incorporating the existence of other variables such as social, economic and genetic factors.

LITERATURE REVIEW

The following section highlights the extensive literature review that exists in this areas of research. Studies dealing with religion and alcohol use have been consistent in their findings more so than those concerned with other types of delinquent acts. Hadaway, Eliifson and Petersen (1984) found that even when controlling for other important influences, religion still had a significant effect on alcohol use. More specifically, Perkins (1987) found that students are more ardent drinkers if (1) they are from a gentile religious tradition as compared to being Jewish (2) not strongly attached to a religious faith. In a follow-up study, the said author found that Catholics were more ardent drinkers than their Jewish counterparts (Perkins, 1985). Both studies used an undergraduate student population to serve as their data sample.

Work, work intensity and their relation to participation in activities such as alcohol use among teenagers and post teenagers has been the subject of much focus by researchers. Drawing on a sample of ninety, 10^{th} and 12^{th} graders, Safron, Schulenberg and Bachman (2001), the authors concluded that increases in work intensity among these adolescents were related to negative outcomes such as drug and alcohol use. These results were further confirmed by McMorris and Uggen (2000) who used longitudinal data from the Youth Development Study (YDS). A later research paper, which also engaged in a longitudinal study, showed differing results. Specifically, Johnson (2004) found that the effect of work intensity on alcohol use was mostly limited to Whites and not so much for other racial groups (Johnson, 2004).

The impact of alcohol use on the lives of the adolescent and college age students have been shown to be far-reaching and not as distinctive as the previously detailed studies. For example, Hoffman (2006) looked as the effect of alcohol use and adolescents across gender lines

while also factoring in the impact on athletic activities and including mitigating factors, such as race, socioeconomic status and school resources. The author found that there is in fact a negative association between non-athletic activities and alcohol use (Hoffman, 2006). However, this was stronger among males in minority population schools (Hoffman, 2006). Morover, the positive association between athletic involvement and alcohol use is strongest among females in lower-economic status schools and males in higher socio-economic status schools (Hoffman, 2006).

In a similar vein, but with a college sample, Perkins (1987) found that students with Gentile parents or those with weak faith, experienced greater alcohol problems. This indirect relationship had an additional effect upon the collegiate child's drinking, as children of alcohol abusers were more likely to become abusers themselves (Perkins, 1987).

Other factors such as stress, race, ethnicity, peer pressure, community influences and family structure have been shown as having an influence on alcohol use (Kuh, 1995; Mensch and Kandel, 1988; Dornsbusch, Ritter and Steinberg, 1991; Reno and Arnold, 2003; bettes, Dusenberry, Kerner, Botvin and James-Ortivi, 1990; Gaviria and Raphael, 2001, Aquilino, 1994; Johnson, 2004). The overall conclusion is that the negative features associated with the preceeding factors will in turn have a negative influence on students' alcohol use (Kuh, 1995; Mensch and Kandel, 1988; Dornsbusch, Ritter and Steinberg, 1991; Reno and Arnold, 2003; bettes, Dusenberry, Kerner, Botvin and James-Ortivi, 1990; Gaviria and Raphael, 2001, Aquilino, 1994; Johnson, 2004). A few studies that have provided divergent perspectives on the impact of alcohol use, have proposed a reverse effect. They concluded in essence that: (1) it is not alcohol use that causes low grades, but rather low grades, through a depression effect, that causes alcohol use (Crosnoes, 2006); (2) there is not a proven causal relationship between alcohol use and low educational attainment, but rather a relationship where there is some correlation between alcohol use and low educational attainment, and that there are other factors that impact this relationship in differing ways (Dee and Evans, 2003; Sell and Robson, 1998).

This preceding presentation on the effect of alcohol use and students' educational attainment levels, provides a forum to foster a discussion on the two variables, as well as others. The current study uses an approach similar to others, to examine the relationship between alcohol use and educational attainment levels of college students. However, it expands the focus by considering religion and other variables and assess whether they create mitigating circumstances. Although considerable research has examined the effect between the key variables of alcohol use and educational attainment levels, much less attention has been paid to the effect of intervening variables.

This article studied the effect of alcohol use on their academic performances. A random sample of ninety students from a Catholic college has been studied for this research. The drinking decision is made endogenous by first estimating probability of drinking decision (a probit model). The probit model identified the variables affecting the drinking decision. The second part is the least squares model estimation correcting for "self selection bias" to study whether drinking affected their overall GPA. The data set provided the opportunity to examine

the impact of religion and other variables on the relation between alcohol use and educational attainment levels.

DATA

In addition to other relationships, this study assessed if certain demographic characteristics and family background influenced students' choice of drinking decision. Also, we inquired if a students' drinking choices have any effect on their academic performance. The survey questionnaire was distributed to an upstate New York catholic four year college students. Ninety students were selected randomly from four classes and their voluntary participation were sought. Institutional Review Board allowed us to collect the data from these randomly selected ninety students. The survey is attached in the Appendix.

One key analysis that will be undertaken in the current paper is through a Decision Tree approach. Unlike other studies on this topic that have employed regression analyses or correlation tables, use of decision tree vaults the analyses to premium level and thus contributes significantly to the research in this area.

A decision tree method in statistical analysis has been described as a general approach to a wide range of operations and supply chain decisions (Oliver et al, 2009). It is particularly valuable for evaluating different capacity expansion alternatives when demand is uncertain and sequential decisions are involved (Oliver et al, 2009). It is sometimes called a sequential decision tree and then simply defined as a graphical method for analyzing decision situations that require a sequence of decisions over time (Russell and Taylor, 2009). A decision tree is a schematic model of alternatives available to the decision maker, along with their possible consequences (Oliver et al, 2009). The name derives from the tree-like appearance of the model. It consists of square nodes, representing decision points, that are left by branches, which read from left to right, representing the alternatives (Oliver et al, 2009).

Descriptive data for these 90 students and their families are provided in Table 1. Correlations among most of the variables are provided in the Appendix. The most interesting correlations among these variables were: If the students were ever cited for violating School Alcohol policy, that has high correlation with (a) level of Family wealth, (b) number of drinks they consumed while they were in high school (c) after coming to college, number of drinks they consume per week. The correlation data also showed that males consume relatively more alcohol than females. This was true during their high school years as well as after they came to college. College GPA has significant correlation with high school GPA and SAT scores. College GPA has negative correlation with number of college drinks they consume per week. The number of drinks fathers consume per week has significant correlation with the number of drinks that their mothers consume every week. In addition, in this sample data, parents' educations are significantly correlated to each other, while the number of drinks for students during college years is significantly correlated with the parents' salary.

Table 1: Summary Statistics of the Sample Data	
90	Total # students surveyed
18.01	average age
49	# males
24	students were cited for school alcohol policy violations
3.44	high school GPA
3.15	college GPA prior to the survey taken
64.99	SAT score converted to a scale between 0 to 100
9	students were expelled/suspended
7	students had prior arrest records
75	students come from non-divorced families
4.29	is the average # drinks/week for father
2.44	is the average # drinks/week for mother
3.27	average # of years of post high school years of education for the father
3.14	average # of years of post high school years of education for the mother
$163,789	average parents' salary
$847,667	average family wealth
5.66	average drinks per week during high school
62	students regularly have at least 5 drinks per week
46	students regularly have at least 9 drinks per week

METHODOLOGY AND ANALYSIS

Students initially go to college to obtain a four year degree and become a professional after they leave college. Perhaps drinking is part of the fun that they do beyond study time. We observe that some students drink heavily during school years, and some do not. Some students work hard to get higher GPA. Is it a conscience decision for some students to drink less in order to score higher GPAs? Do some demographic variables during their upbringing influence their drinking decision during their stay at college? We like to investigate these two areas of decision making, namely: (a) what factors influence their decision to drink and (b) students want to get higher GPA, and knowing certain behaviors are detrimental to getting higher academic achievements, will students still indulge in those activities? We investigate what are those factors (positive and negative) that may have influenced their decision to score higher GPA?

After drawing a decision tree, it is solved by working from right to left, calculating the expected payoff for each node (Oliver et al, 2009). For an event node, the payoff of each event branch is multiplied by the event's probability and then added to get the event node's expected

payoff (Oliver et al, 2009). For the decision node, the alternative that has the best expected payoff is picked (Oliver et al, 2009). If an alternative leads to an event node, its payoff is equal to that node's expected payoff (Oliver et al, 2009). The branches not chosen are pruned, the decision node's expected payoff is the one associated with the single remaining unpruned branch(Oliver et al, 2009). The process is continued until the leftmost decision node is reached.

One challenge in our decision theoretic frame work is "unknown pay off" for the nodes. Because of this "unknown pay-off", decision making is done based on "homogeneity" of the groups. If the two decision branches are homogeneous (in distribution), it is inconclusive. That means, we cannot really decide in favor of one group to the other. However, if the decision branches are heterogeneous, i.e., relatively more of these people weigh to one side (distribution wise) that group is favored for decision making. Chi-square test of homogeneity is used to test for homogeneity and decide which decision branch is favored. In reality, this is what exactly the students do. For example, students do not know the exact pay off for drinking (to drink or not to drink) on GPA (high or, low). However, students talk about "# students get good GPA even after drinking regularly", or, "# students do not get decent score even if they do not drink". This relative distribution can be used to test for homogeneity between groups, and the groups having relatively higher distribution are favored by the students to make their decision. If the groups are inseparable (or, homogeneous) students may say "why should I not drink if drinking has no effect on GPA". In this case, decision is inconclusive; students' decision may tilt in either way.

Further, in the second part of this paper, we used probit analysis to look into what factors are responsible to make their drinking decision. Results from Probit analysis were compared with the results found in Decision theoretic framework. Then the third part of this paper deals with if students' decision to drink has any effect on their academic performance measured by their GPA.

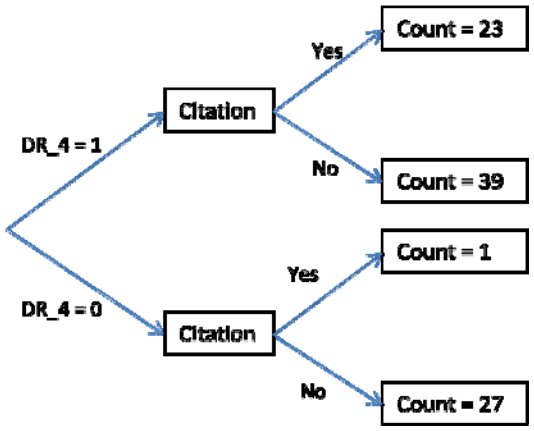
Decision #1: Does it help get cited for violating College's alcohol policies?

School authorities make certain policies to curb drinking behavior in the college campus. One of them is to serve written notice of violation of alcohol policies if a student violates the alcohol policy. One example of this violation is "finding alcoholic beverages in their dorms during weekdays". If the authority finds such activities, they issue a written alcoholic policy violation notice with the hope that students will learn and avoid doing such activities. Crosstab #1 is a two by two table. Dr_4 is a variable name that means "Drinks more than 4 alcoholic beverages a week". Dr_4 = 1 if they do drink more than 4 alcoholic beverages a week" and Dr_4 = 0 otherwise. Chi-square test of homogeneity shows that these two groups (drinkers and non-drinkers) are not homogeneous in terms of citations.

Twenty four students were cited for violating school alcohol policy. Twenty three out of these twenty four continued to drink more than 4 drinks a week. This fact clearly shows that "citing" a "friendly reminder" for violating school alcohol policy does not work. This decision mechanism is in a similar vein with the probit results (discussed later in the paper).

Crosstab #1: Drinking more than 4 alcoholic beverages a week vs Citations					
			Citation		Total
			0	1	
Dr_4	0	Count	27	1	28
		Expected Count	20.5	7.5	28.0
	1	Count	39	23	62
		Expected Count	45.5	16.5	62.0
Total		Count	66	24	90
		Expected Count	66.0	24.0	90.0
Computed Chi-Sq. value = 11.01, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706,\ \ 3.841,\ \ 5.412,\ \ 6.635 \quad for \quad \alpha = 0.10,\ \ 0.05,\ \ 0.02,\ \ 0.01$					

Decision Diagram #1



Decision #2: "Relatively higher GPA" influences their decision to drink?

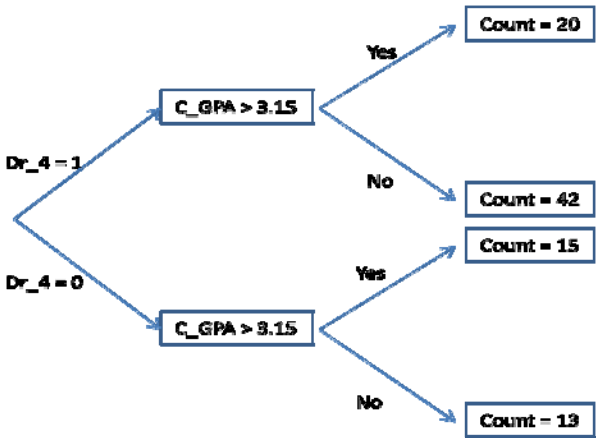
In the Crosstab #2 table, C_GPA means cumulative GPA. Chi-square test of homogeneity shows that the drinker and non-drinker groups are homogeneous when their GPA's (More than 3.15 or not) are considered.

Twenty students with more than 3.15 GPA drinks 5 or more drinks (drinkers) a week, whereas 15 students with higher GPA (more than 3.15) comes from "non-drinker" category. Chi-square test also shows that these two groups are homogeneous in their decision to drink or not.

So, the decision tree is inconclusive if students make decision to drink based on their academic performance.

Crosstab #2: Drinking more than 4 alcoholic beverages a week vs Cumulative GPA>3.15?					
			C_GPA > 3.15		Total
			0	1	
Dr_4	0	Count	13	15	28
		Expected Count	17.1	10.9	28.0
	1	Count	42	20	62
		Expected Count	37.9	24.1	62.0
Total		Count	55	35	90
		Expected Count	55.0	35.0	90.0
Computed Chi-Sq. value = 1.154, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706,\ 3.841,\ 5.412,\ 6.635 \quad for \quad \alpha = 0.10,\ 0.05,\ 0.02,\ 0.01$					

Decision Diagram #2



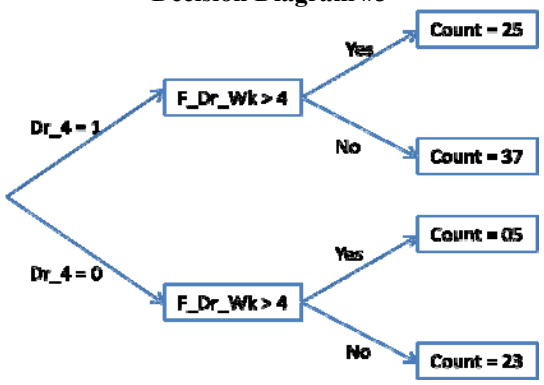
Decision #3: Father's number of drinks per week, does it influence students' drinking decision?

The Crosstabs #3 Table shows that at 5% level of significance, student drinkers and student non-drinkers are homogeneously distributed based on if their fathers are drinker or not. The variable name "F_Dr_Wk > 4" means, a student's father takes more than 4 drinks per week. Looking into the decision diagram, 25 students drink if the father drinks and 37 students drink if the father does not drink. 5 of the students do not drink of their fathers drink, whereas 23 students do not drink if their fathers do not drink. Looking into the chi-square test, these two

groups of students (drinker and non-drinkers) are not homogeneously distributed (at 1% or 2% level of significance) based on their fathers' drinking habits. The probit estimates (described later on) substantiates it further.

Crosstab #3: Drinking more than 4 alcoholic beverages a week vs Father's drink per week					
			F_Dr_Wk > 4		Total
			0	1	
Dr_4	0	Count	23	5	28
		Expected Count	18.7	9.3	28.0
	1	Count	37	25	62
		Expected Count	41.3	20.7	62.0
Total		Count	60	30	90
		Expected Count	60.0	30.0	90.0
Computed Chi-Sq. value = 4.38, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706, \quad 3.841, \quad 5.412, \quad 6.635 \quad for \quad \alpha = 0.10, \quad 0.05, \quad 0.02, \quad 0.01$					

Decision Diagram #3



Decision #4: Mother's drinking decision, does it influence students' drinking decision?

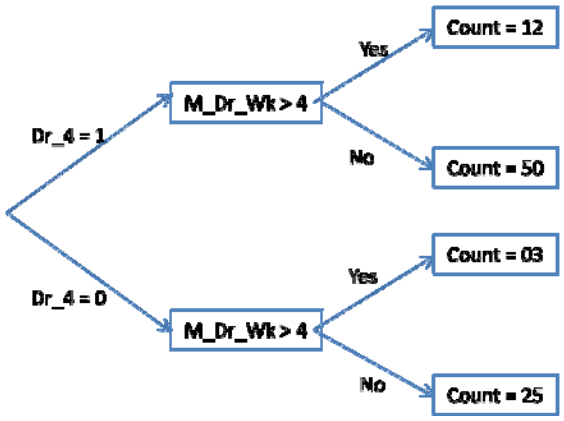
The variable name "M_Dr_Wk > 4" means, a student's mother takes more than 4 drinks per week. The chi-square test cannot distinguish between students' drinking decision based on their mom's drinking decision. The chi-square test shows that students' drinking decision is independent of their mom's drinking decision.

If the mother does not drink, 50 students make drinking decision, and 25 students do not drink. If the mother drinks, 12 students drink and 3 students do not drink. These two groups of students (drinkers and non-drinkers) based on their mom's drinking habit are homogeneous

groups. That means mom's drinking habit does not influence student's drinking decision. This result was further substantiated by the Probit estimates.

Crosstab #4: Drinking more than 4 alcoholic beverages a week vs Mother's drink per week					
			M_Dr_Wk > 4		Total
			0	1	
Dr_4	0	Count	25	3	28
		Expected Count	23.3	4.7	28.0
	1	Count	50	12	62
		Expected Count	51.7	10.3	62.0
Total		Count	75	15	90
		Expected Count	75.0	15.0	90.0
Computed Chi-Sq. value = 1.036, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706,\ 3.841,\ 5.412,\ 6.635 \quad for \quad \alpha = 0.10,\ 0.05,\ 0.02,\ 0.01$					

Decision Diagram #4



Decision #5: Does higher parents' salary influence their decision to drink?

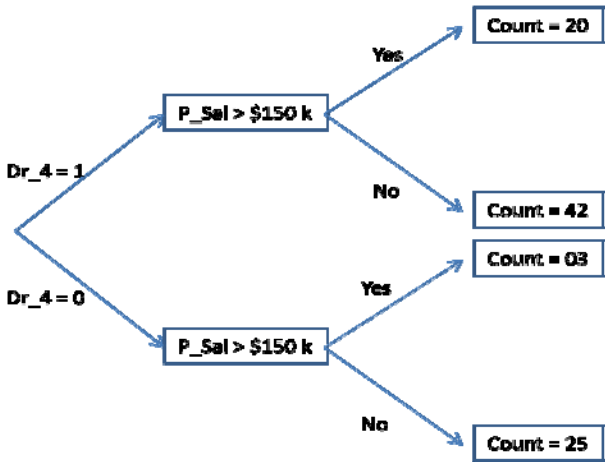
The variable name "P_Sal > $150 k" means, both the parents together earn more than $150k per year. If parents' salary is higher, relatively more students drink. Chi-square test distinguishes this at 1% and 2% levels of significance. However at 5% or higher levels of significance, it cannot be distinguished.

If the parent's salary is more than $150 k a year, 20 students drink, whereas 3 students do not drink. If the parents' salary is lower than $150 k per year, 42 students drink and 25 students

do not drink. Relatively, more students drink (as opposed to not drink) if their parents salary is higher.

Crosstab #5: Drinking more than 4 alcoholic beverages a week vs Parents' salary					
			P_Sal > $150 k		Total
			0	1	
Dr_4	0	Count	25	3	28
		Expected Count	20.8	7.2	28.0
	1	Count	42	20	62
		Expected Count	46.2	15.8	62.0
Total		Count	67	23	90
		Expected Count	67.0	23.0	90.0
Computed Chi-Sq. value = 4.70, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706,\ \ 3.841,\ \ 5.412,\ \ 6.635 \quad for \quad \alpha = 0.10,\ \ 0.05,\ \ 0.02,\ \ 0.01$					

Decision Diagram #5



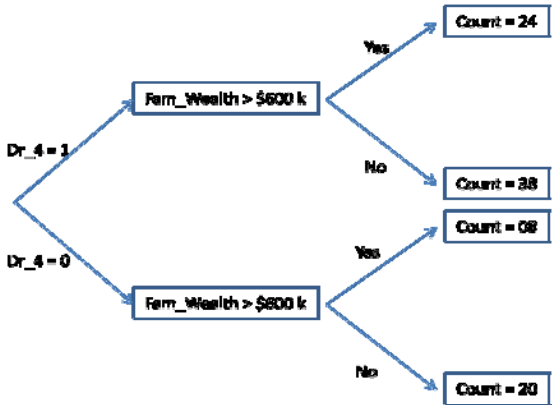
Decision #6: Does higher family wealth influence their decision to drink?

The variable name "F_Wlth > $600k" means students with Family Wealth more than $600k. We have looked into students with family wealth more than $600 k and their drinking decisions. The chi-square test of homogeneity is accepted.

The drinker and non-drinker student groups cannot be distinguished by the chi-square test of homogeneity. We need to look at the probit results considering the influence of other variables. This result is described later on.

Crosstab #6: Drinking more than 4 alcoholic beverages a week vs Family' Wealth					
			F_Wlth > $600 k		Total
			0	1	
Dr_4	0	Count	20	8	28
		Expected Count	18.0	10.0	28.0
	1	Count	38	24	62
		Expected Count	40.0	22.0	62.0
Total		Count	58	32	90
		Expected Count	58.0	32.0	90.0
Computed Chi-Sq. value = 0.86, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706,\ 3.841,\ 5.412,\ 6.635$ *for* $\alpha = 0.10,\ 0.05,\ 0.02,\ 0.01$					

Decision Diagram #6



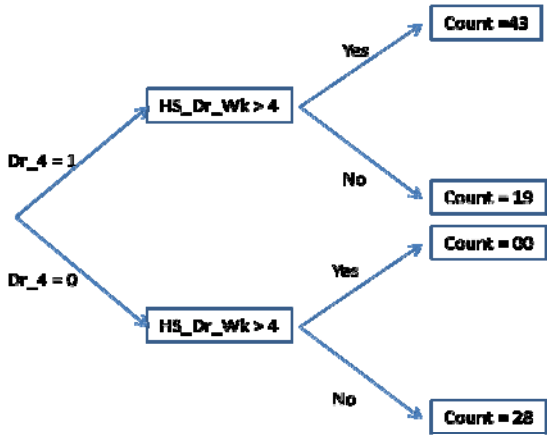
Decision #7: Does their past behavior of drinking in high school affect their decision to drink at college?

The variable name "HS_Dr_Wk > 4" implies students who used to drink more than 4 drinks per week during their high school period. The college student drinkers/non-drinkers is clearly two non-homogeneous groups based on whether they used to drink at high school. Chi-square value strongly suggests that. It means, students who had a history of drinking at high school will more likely will drink at college.

Among non-drinkers at college, none of them drank in high school. Among the drinkers at college, 43 of them used to drink at high school, and 19 did not drink. This suggests drinking decision at college is strongly influenced by their decision to drink during high school.

Crosstab #7: Drinking more than 4 alcoholic beverages a week vs Drinking in HS					
			HS_Dr_Wk > 4		Total
			0	1	
Dr_4	0	Count	28	0	28
		Expected Count	14.6	13.4	28.0
	1	Count	19	43	62
		Expected Count	32.4	29.6	62.0
Total		Count	47	43	90
		Expected Count	47.0	43.0	90.0
Computed Chi-Sq. value = 37.186, The tabulated value of chi-sq distribution: $\chi^2_\alpha = 2.706,\ \ 3.841,\ \ 5.412,\ \ 6.635 \quad for \quad \alpha = 0.10,\ \ 0.05,\ \ 0.02,\ \ 0.01$					

Decision Diagram #7



PROBIT ANALYSIS

The above results are based on decision theoretic frame work which looks at two variables at a time. The rationale behind such analysis is, perhaps when students make a conscience drinking decision they look at certain variables at a time to make their drinking decisions, like, my parents never drank, should I drink? Or, My GPA is good, if I drink regularly, my grades may go down. Or, I was cited for violating school alcohol policies, if I drink too much and get caught for violating school alcohol policies, it could be bad for me, etc.

However, there are many variables perhaps affecting the students' decision to drink. We can consider a "Probit Analysis" to look into the effect of different variables on the students'

drinking decision. If they drink more than four drinks a week, they will be considered a drinker, and accordingly "Drink" variable will assume value 1, else, "Drink" variable will assume value 0. Then we use "drink" variable as dependent variable to analyze the effect of other independent variables like (a) age, (b)gender, (c) Citation, (d) HS_GPA, (e) College GPA, (f) SAT, (g) Expelled/suspended in the past, (h) Arrested in the past, (i) non-divorced family, (j) # drinks/week by Father, (k) # drinks/wk by Mother, (l) Father's education, (m) Mother's Education, (n) Parents' Salary, (o) Family Wealth (p) #drinks/week taken during high school. Please see Table #2: Probit Estimation in the Appendix.

The probit result (Table #2) shows that if the students were cited by the school authorities for violating college alcohol policies, they are more likely to drink. Earlier result based on decision diagram also supports this (Decision #1). It shows mere "slap in the arm" for violating school alcohol policy has no effect in curbing students' drinking habits. Probit result also shows that the college GPA does not influence their drinking decisions. Previous chi-square test shows (previously, Decision #2) similar result. Probit equation also shows that the father's drinking habit does not affect student's drinking habit. For more than 5% levels of significance, this result was supported by the previous chi-square test (Decision #3). Probit result shows, that the mother's drinking decision does not affect student's decision to drink. Previous chi-square test also supports this result (Decision #4). Influence of higher parent's salary had relatively more influence on students drinking decision (Decision #5). Probit analysis clearly shows that higher parents' salary have influenced student's decision to drink. Chi-square test was inconclusive if higher parents' wealth influenced students' drinking decision (Decision #6). However the probit analysis shows that the higher the parents' wealth, the lower is the students' propensity to drink. Previous decision framework along with the chi-square test strongly suggested that the high school drinking habit influences college drinking decision (Decision #7). Probit analysis also shows this result. Students' drinking decisions were not influenced by gender. Probit equation also shows that Students' college academic standing or past academic record (College GPA, HS GPA, or SAT score) did not influence their drinking decision.

If the students were from non-divorced families (family with both parents staying together), they tend to drink less often. We did not do the decision diagram for this variable as only 15 students were from divorced families. If a student was expelled or suspended any time in the past, that had influenced student's drinking decision. However, we did not consider this variable in the previous decision diagram because only 9 out of 90 students were suspended in the past. Due to lack of enough data variability, we decided not to include in the decision diagram.

DOES DRINKING DECISION AFFECT ACADEMIC PERFORMANCE?

One interesting issue is if students' drinking decisions affect their academic performance. A student decides whether to drink or not, and that decision to drink may have an impact on their

grades. So, students "self select" whether to drink or not, which in turn may have an effect on their GPA. In case of "self selectivity", running a simple regression without correcting for "self selectivity bias" may produce biased estimates. We obtained "mills ratio" from the probit equation, and inserted "mills ratio" into the regression equation as one of the independent variables and ran the regression. It turned out that the "mills ratio" was insignificant. Because of this insignificance of the "mill's ratio", running a regression without "mills ratio" in the regression equation will produce unbiased estimates. For the same reason, we have omitted "Mills Ratio" from our regression estimations. Please see Table #3: Regression results in the Appendix.

We ran three regressions with dependent variable being College GPA: (1) Regression on sample data of "drinkers" (drinks more than 4 drinks a week), (2) Regression on sample data of "non-drinkers" (drinks less or equal to 4 drinks a week), (3) Regression on all students in our data set. Table header for Table #3 clearly shows these three sets of regressions. We ran these three sets of regressions to understand if certain variables affect drinkers more than the non-drinkers and vice versa.

We found that high SAT scores impacts positively on drinker's college GPA, whereas it does not affect the non-drinkers. It may be because, among drinkers with high GPA, they know how to organize time for fun and time for study and that results in better GPA even if they drink during fun time. For non-drinkers, age came negatively significant. That means higher the age, lower is the GPA. For drinkers, it did not show such results. Among the non-drinkers, if they were expelled/suspended perhaps that taught them a lesson and they tend to score higher in the college. Among drinkers, this effect is not significant.

One of the most interesting results we discovered is: Among drinkers, if fathers have higher education, students tend to get significantly higher GPA. This result is just opposite if the mothers have higher education. The rationale could be that if mothers have higher education, perhaps both the parents tend to get busier with their professions. Kids did not get enough time from parents while they were growing up, that could result in lower college GPA. And may be because of less attention from parents, they may have turned into drinkers. This regression for drinkers also shows more they drink, their GPA gets lower. It shows clearly that drinking affects academic performance negatively. This is amply supported by existing literatures.

Next we look at the combined (for both drinkers and non-drinkers) student sample data. We did stepwise regression (gradually dropping insignificant variables). For this combined sample data, only factors affecting their GPA are (a) higher their past academic performance in terms of higher SAT score or higher High School GPA, better their college GPA is. And (b) more they drink in the college, lower their GPA is. These three regressions clearly separate different influencing factors that affect their GPA's.

CONCLUSION

We have looked into college student's decision to drink from a sample of 90 students in a Catholic College at upstate New York. We first analyzed looking into a decision diagram considering two variables at a time. Perhaps from students' perspective, they may decide, "should I drink? My grades may go down". And accordingly a decision theoretic framework with two variables is more applicable. However, the final decision may be influenced by many factors simultaneously. We also considered a probit analysis to to look into all the factors that may have influenced their drinking decision. And finally, we investigated, the influence of the factors including decision to drink on their academic performance as measured by college GPA.

The distinguishing feature of this paper is, it analyses two variables that the previous papers on similar topic failed to include in their discussions. The two variables are (a) whether parents' salary influences students' drinking decision, and (b) whether family wealth has any impact on students' decision to drink. The result we found is thought provoking: higher the parents' salary, students tend to drink more. However, if the family wealth is higher (than $600K) then they tend to not drink (or, not drink that often). May be families with higher family wealth, tend to raise their kids with more values or self control, they tend to drink less. May be adding few more questions in later surveys may throw more light on this area. Higher the parents income could influence parents to provide less time on their kids (as they may be busy with their work), give more pocket money to their kids, that may influence their kids to have little bit more fun in drinking.

The other variables influenced the drinking decision as was anticipated (or, discussed by previous authors). Students from family of both parents together, tend to drink less. Past citations for violating college drinking policies did not stop students from drinking. If a student violates drinking policy, just citing that violation through a letter is not good enough. Perhaps a stronger policy against drinking is needed. Past academic performance did not influence their drinking decisions. Parents' education levels did not influence students' drinking decision. Also, Parents decision to drink did not influence student's decision to drink.

Next we investigated if the drinking decision affected their college grades. We found a very interesting result for the drinkers. With higher mothers' education, drinkers (among students) tend to perform worse in academics (as signaled by their GPA). This could be due to the fact that as mothers have higher education, both parents tend to get busy with their professions. So, they can offer less time for the kids. That may translate into lower GPA and higher drinking. For the combined sample data (for both drinkers and non-drinkers), more they drink, lower their GPA gets. This result is supported by most previous authors.

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Appendix: A1

Anonymous Survey

Please DO NOT write your name on this survey so that you can not be identified. This information is for research purposes only and will be kept confidential. This survey was approved by the college "Institutional Review Board".

How old were you at the beginning of your freshman yea _____years old

What is your gender? _____MALE _____FEMALE

Have you ever violated Siena College's alcohol policy? _____YES _____NO

Have you ever been issued a citation ("written up") for violating Siena College's alcohol policy? __YES__NO

What was you high school GPA as a percentage of 100 _____

What was the highest combined score that you received on the SAT Examination? ___/1600 OR /2400

How many times have you been suspended or expelled from high school? (If you have never been suspended or expelled from high school answer 0) _____times

How many times have you been arrested? (If you have never been arrested answer 0) ___times

Are your biological parents still married? _____YES _____NO

On average how many alcoholic beverages does your biological father consume per week? (Guess if you are not sure. If your biological father abstains from alcohol consumption write 0)_____Beverages/week

On average how many alcoholic beverages does your biological mother consume per week? (Guess if you are not sure. If your biological mother abstains from alcohol consumption write 0) _____Beverages/week

How many years of post high school education did your biological father complete? (approximately) _____years

How many years of post high school education did your biological mother complete? (approximately) __years

What is the approximate combined annual salary of your biological parents? (regardless of your parents marital status (approx) $_____

In high school approximately how many alcoholic beverages do you consume per week? (if you abstain from alcohol use write 0) (approx) _____beverages/week

Estimate the combined net worth of both of your biological parents (Net worth is defined as assets (the sum of value of home, land, stocks & bonds, etc.) less liabilities (borrowings). A rough estimation is acceptable.) _____$

Appendix: A2

Pearson Correlation Coefficient, Table A

	age	Gender	Citation	HS_GPA	College_GPA	SAT	Expelled_susp	Arrested	Not Divorce	Father_drinks_week
age	1	.160	-.091	-.366**	-.172	-.215*	.119	.037	-.061	-.110
Gender	.160	1	.148	-.144	-.061	.090	.156	.087	.010	-.053
Citation	-.091	.148	1	-.053	.045	.176	.134	.257*	.135	.050
HS_GPA	-.366**	-.144	-.053	1	.393**	.485**	-.097	.105	-.057	-.231*
College_GPA	-.172	-.061	.045	.393**	1	.348**	.075	.099	-.082	-.021
SAT	-.215*	.090	.176	.485**	.348**	1	-.035	.071	.047	.015
Expelled_susp	.119	.156	.134	-.097	.075	-.035	1	.157	-.050	-.026
Arrested	.037	.087	.257*	.105	.099	.071	.157	1	-.081	-.093
Not Divorce	-.061	.010	.135	-.057	-.082	.047	-.050	-.081	1	.078
Father_drinks_week	-.110	-.053	.050	-.231*	-.021	.015	-.026	-.093	.078	1
Mother_drinks_week	-.032	-.005	.204	-.069	.069	.213*	-.082	.260*	-.052	.446**
Father_edu	-.088	.177	.183	.078	.074	.157	-.233*	.257*	-.032	-.078
Mother_edu	-.026	.255*	.110	.042	-.013	.216*	-.190	.015	.089	.131
Parent_Salary	-.067	.011	.167	-.075	.063	.086	-.108	.163	-.157	.094
Family_wealth	-.083	.036	.224*	.003	.040	.230*	-.094	.083	.077	.110
HS_drinks_week	-.067	.240*	.266*	-.079	-.180	.040	.113	.298**	.004	.142
Dr_4	.008	.205	.351**	-.225*	-.210*	.032	-.016	.171	-.043	.203
Dr_8	-.161	.177	.338**	-.061	-.155	.008	.104	.248*	-.080	.152
College_drinks_week	-.058	.323**	.407**	-.166	-.243*	.015	.041	.283**	-.035	.133

**.Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Pearson Correlation Coefficient, Table B:

	Mother_drinks_ week	Father_edu	Mother_edu	Parent_Salary	Family_wealth	HS_drinks_week	Dr_4	Dr_8	College_drinks_ week
age	-.032	-.088	-.026	-.067	-.083	-.067	.008	-.161	-.058
Gender	-.005	.177	.255*	.011	.036	.240*	.205	.177	.323**
Citation	.204	.183	.110	.167	.224*	.266*	.351**	.338**	.407**
HS_GPA	-.069	.078	.042	-.075	.003	-.079	-.225*	-.061	-.166
College_GPA	.069	.074	-.013	.063	.040	-.180	-.210*	-.155	-.243*
SAT	.213*	.157	.216*	.086	.230*	.040	.032	.008	.015
Expelled_susp	-.082	-.233*	-.190	-.108	-.094	.113	-.016	.104	.041
Arrested	.260*	.257*	.015	.163	.083	.298**	.171	.248*	.283**
N_Divorce	-.052	-.032	.089	-.157	.077	.004	-.043	-.080	-.035
Father_drinks_week	.446**	-.078	.131	.094	.110	.142	.203	.152	.133
Mother_drinks_week	1	.175	.025	.158	.282**	.122	.242*	.268*	.142
Father_edu	.175	1	.576**	.477**	.216*	.120	.152	.179	.216*
Mother_edu	.025	.576**	1	.275**	.169	.100	.096	.026	.088
Parent_Salary	.158	.477**	.275**	1	.556**	.053	.217*	.201	.315**
Family_wealth	.282**	.216*	.169	.556**	1	.142	.132	.184	.248*
HS_drinks_week	.122	.120	.100	.053	.142	1	.500**	.650**	.774**
Dr_4	.242*	.152	.096	.217*	.132	.500**	1	.687**	.535**
Dr_8	.268*	.179	.026	.201	.184	.650**	.687**	1	.626**
College_drinks_week	.142	.216*	.088	.315**	.248*	.774**	.535**	.626**	1

* Correlation is significant at the 0.05 level (2-tailed).
**.Correlation is significant at the 0.01 level (2-tailed).

Table # 2: Probit Estimation: Dependent Variable Drnk = 1, if they drink more than 4 drink/weeks, else, Drnk = 0											
	Probit Estimation #1			Probit Estimation #2			Probit Estimation #3			Final Probit Eqn.	
Variable	Coefficient	Prob.	Remove	Coefficient	Prob.	Remove	Coefficient	Prob.	Remove	Coefficient	Prob.
C	-2.85658	0.8244		-0.302059	0.9352		2.038465	0.3451		-0.591821	0.3428
Age	0.105417	0.8435	x								
Gender	0.79703	0.1746		0.820988	0.1459		0.668651	0.1808	x		
Citation	2.831571	0.0187		2.781879	0.0104		2.744464	0.0063		2.660322	0.0033
Hs_Gpa	-1.063576	0.2448		-1.072077	0.1819		-0.86135	0.1343	x		
College_Gpa	-0.611098	0.3977		-0.715461	0.256	x					
Sat	7.702684	0.2105		7.405718	0.2121	x					
Expelled_Susp	-2.283198	0.1854		-2.278482	0.1046		-2.448451	0.0509		-2.32808	0.0455
Arrested	4.709097	1	x								
Divorce_Not	-1.496362	0.1172		-1.410899	0.0907		-1.218784	0.1079		-1.14265	0.1055
Father_Drinks_Week	-0.00622	0.9216	x								
Mother_Drinks_Week	0.072954	0.5659	x								
Father_Edu	0.029932	0.8253	x								
Mother_Edu	0.025695	0.8649	x								
Parent_Salary	7.68E-06	0.0619		8.52E-06	0.0473		7.96E-06	0.0384		8.51E-06	0.0267
Hs_Drinks_Week	0.599084	0.0035		0.581543	0.0006		0.53901	0.0002		0.51357	0
Family_Wealth	-9.32E-07	0.0375		-9.05E-07	0.033		-8.42E-07	0.0355		-9.51E-07	0.0112
McFadden R-Sq	0.658478			0.653331			0.627151			0.578226	
Akaike info criterion	0.801257			0.674305			0.662323			0.678544	
Schwarz criterion	1.273443			0.979837			0.912304			0.872973	
n	90			90			90			90	

Table # 3: Regression Results: Dependent Variable: College GPA											
		Reg #1: Non drinker		Reg #2: Drinker		Reg #3 (Stepwise) : All (Drinker and Non Drinkers)					
Variable	DF	Parameter	Pr > |t|	Parameter	Pr > |t|	Parameter	Pr > |t|	Parameter	Pr > |t|	Parameter	Pr > |t|
		Estimate		Estimate		Estimate		Estimate		Estimate	
Intercept	1	8.58059	0.0119	-0.23064	0.8491	1.6027	0.1676	1.245	0.0118	1.27437	0.009
age	1	-0.34402	0.02	0.05037	0.306	-0.02024	0.6685				
Gender	1	-0.07856	0.7366	0.0527	0.583	0.05093	0.5646				
HS_GPA	1	0.39278	0.2949	0.18036	0.2123	0.26942	0.037	0.24846	0.0279	0.24316	0.028
SAT	1	-1.04472	0.5652	2.58994	0.007	1.41557	0.086	1.55876	0.0397	1.54259	0.036
Expelled_susp	1	0.65569	0.076	0.17405	0.2399	0.16948	0.2061	0.17167	0.18		
Divorce_Not	1	-0.00589	0.9837	-0.08828	0.4664	-0.05016	0.6402	-0.04785	0.6377		
Father_drinks_week	1	0.01906	0.5712	0.01069	0.2838	0.00739	0.4346				
Mother_drinks_week	1	-0.04771	0.5646	-0.00592	0.6416	0.00155	0.9066				
Father_edu	1	-0.02083	0.6906	0.0583	0.009	0.01778	0.3815	0.01556	0.3922		
Mother_edu	1	0.02322	0.6191	-0.05439	0.026	-0.025	0.2472	-0.01963	0.3091		
Parent_Salary	1	0.00000194	0.5975	1.383E-07	0.6818	3.70742E-07	0.3023	3.39E-07	0.2433		
College_drinks_week	1	0.05079	0.2002	-0.00859	0.023	-0.00956	0.009	-0.00848	0.0103	-0.00653	0.036
Family_wealth	1	-2.3775E-07	0.7456	1.444E-09	0.9686	-7.1814E-09	0.8598				
n =		28		62		90		90		90	
R-Sq:		0.5134		0.4495		0.2914		0.2776		0.2279	