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Rule-Based Moral Reasoning and CPAs' Political Ideology

Paul W. Allen, Mississippi State University

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ABSTRACT

Certified Public Accountants (CPAs) tend to be very rule-based in their moral reasoning relative to non-accounting groups. Prior research suggests that the rule-oriented nature of accounting and auditing practice may explain a CPA's preoccupation with resorting to rules when faced with resolving an ethical issue. Related studies determined that political liberals tend to be more principled in their moral reasoning whereas political conservatives are less principled and more rule-oriented. This study sought to provide empirical evidence as to one plausible factor behind CPAs' bent toward rule-based moral reasoning. Findings show that CPAs' rule-based moral reasoning is strongly related to their political ideology. Moving from conservative to moderate to liberal, politically, CPAs are less rule-based in moral reasoning. The findings are highly salient to accounting regulators, educators, and recruiters who are working to move the CPA profession toward exercising more principled accounting and auditing judgments.

Introduction

Accounting researchers who have used the Defining Issues Test (DIT) to measure the ethical reasoning processes of CPAs have consistently found CPA respondents, relative to non-accounting groups, to exhibit a tendency to resort to rules when trying to morally reason out resolution of an ethical issue (Rest and Narvaez, 1994). Rest (1979) discusses the development of his widely-used DIT as a measuring device for capturing a respondent's moral reasoning. Using the DIT, Lampe and Finn (1992) suggested that CPAs' tendency to use rule-based moral reasoning, compared to non-accounting groups, is likely a result of the rule-oriented nature of accounting and auditing practice (i.e. generally accepted accounting principles, or GAAP, generally accepted auditing standards, or GAAS, IRS codified rules and regulations, etc.). That is, the very nature of learning compliance with so many rules translates into a bent toward depending on rules when trying to resolve an ethical situation.

While Lampe and Finn's notion is intuitively appealing, it reveals the need for empirically supported factors that delve into why CPAs, as a group, are slanted toward using rule-based moral reasoning relative to other groups. That is, it may make common sense that CPAs are rule-based in moral reasoning due to a preoccupation with following rules derived from a profession inundated with them but the need for empirically testing for a statistical goodness of fit remains. Alternative reasons exist for the rule-oriented moral reasoning that characterizes the CPA profession. For instance, the rule-based structure of an accounting curriculum may appeal to a particular type such that future CPAs have actually been extracted from a group that was rule-oriented long before they

actually started college and met with the need to learn and comply with numerous accounting and auditing standards. Perhaps the CPA profession is circular in that it attracts a particular moral reasoning type and then continues to promote a culture of the same via curriculum and recruitment.

The purpose of this paper is to empirically investigate a potential alternative explanation to the intuitive notion offered by Lampe and Finn as to why CPAs have a strong rule-based moral reasoning slant. This study is viewed as dealing with a most timely and essential issue facing the CPA profession. The public perception of the ethics of CPAs has been tarnished by numerous accounting scandals over the past decade. Following rules cannot guarantee an ethical response.

CPA oversight organizations have been working hard to communicate among their rank and file the need to be principled in exercising moral reasoning during accounting and auditing engagements. Nobe (2005) acknowledges the desire of standard-setters (Financial Accounting Standards Board or FASB, International Accounting Standards Board or IASB) to follow a more principles-based approach to accounting standard-setting to help mitigate problems in the CPA profession deriving from rule-based standards. He suggests that part of the need for rules themselves is the absence of an underlying principle or the existence of inappropriate ones. This sort of thinking implies that CPAs can be changed to become more principled and less rule-based by making rules more principle-based. Such thinking results from assuming that CPAs tend to resort to rules when resolving ethical accounting and auditing matters because they are inundated with rules…..as Lampe and Finn (1992) surmised. What if it is not the rules that are the reason for rule-orientedness in CPAs but something else? If it's something else, accounting regulators, educators, and recruiters may be "barking up the wrong proverbial tree."

Problem and Research Question

The problem addressed by this study is that while the CPA profession acknowledges the need to be more principled in its moral reasoning and less rule-based, there is a glaring lack of empirical evidence that attempts to look into why CPAs are so rule-based in their moral reasoning. Again, Lampe and Finn (1992) may have offered an intuitively appealing notion toward explaining how CPAs become rule dependent in resolving ethical issues. However, the empirical data that is available merely reveals that DIT test results profile CPAs to be more rule-based in moral reasoning than non-accounting groups without revealing empirical evidence as to why.

The research question here is to determine whether CPAs' tendency to be rule-oriented in moral reasoning is statistically related to a variable where established priors exist to support an expected relationship…..a relationship that might help explain why CPAs tend to use rule-based moral reasoning and thereby expand upon the intuitive notion provided by Lampe and Finn. Specifically, the research question is:

Is a CPA's political ideology related to her/his tendency to resort to rules when resolving moral issues (i.e. to be rule-based in moral reasoning)?

Literature Review

Barnett (1985) summarized studies using the DIT to measure moral reasoning in respondents and reported that individuals holding conservative political positions

consistently are more rule-based in their moral reasoning than are individuals holding liberal political positions, the latter being more principal-based in moral reasoning. (Note that the DIT will be explained in detail under the METHOD section of this paper). Nie, Verba, and Petrocik (1976) determined that the U.S. population can be classified according to the pattern of political positions. Asher (1980) found that traditional definitions of conservatism and liberalism are useful when considering attitudes toward political choices. Some researchers have tried to ascertain whether a trichotomy of the electorate into conservative, moderate, and liberal is most descriptive (Fleishman, 2001), or an oversimplified dimensional scheme (Knoke, 1979). Yet, it remains today that the popular view is to trichotomize political ideology into conservative, moderate, or liberal. Ennis and Allen (2009) used the trichotomy of conservative, moderate, and liberal to stratify CPA respondents in capturing the political ideologies of those respondents in order to compare political ideology to the CPAs' support for expanding governmental intervention into the corporate governance of non-public entities.

A central study which prompts this study is that of Lampe and Finn (1992). It leaves an empirical void that needs to be filled and this study attempts to help partially fill that void. These two researchers, in their 1992 work which used the DIT to measure moral reasoning, reported that accounting students and CPA practitioners tend to reflect lower principled moral reasoning than do college-aged students, college-educated students, and other professional groups such as law and medicine. Further, the accounting respondents tended to reflect higher rule-based moral reasoning than those reported by Rest (1986). Lampe and Finn (1992) concluded that accountants "may" develop a strong tendency to reason out moral issues using rules due to the rule-oriented nature of accounting and auditing practice. Further, they concluded that the DIT's profile measure for rule-based moral reasoning may be a better measure when studying professional accountants and auditors than the principled moral reasoning profile measure within the DIT. (See DIT under METHOD for explanation of profile scoring).

Method

The current study investigates the relationship between the political ideology of CPAs and their tendency to use rule-based moral reasoning to resolve ethical issues. This paper has offered literary evidence that establishes that CPAs tend to be rule-based in moral reasoning. Further, it has cited literature reporting on the tendency of political conservatives to be more rule-based in moral reasoning than political liberals who tend to be more principle-based in moral reasoning. Finally, published works documenting the stratification of political ideology into conservative, moderate, and liberal have been cited.

Hypothesis

Coupling the need for identifying potential factors to explain why CPAs tend to be more rule-based in moral reasoning than other groups along with previous works that show political conservatives to be more rule-based in moral reasoning than are political liberals, the following hypothesis is established:

A CPA's tendency to use rule-based moral reasoning will be different, based on her/his political ideology. Specifically, as CPAs' political ideology moves from conservative to moderate to liberal, their moral reasoning will become less rule-based.

Data Collection

A mail survey collected data for this study. A random sample of 941 CPAs belonging to the American Institute of Certified Public Accountants (AICPA) resulted in achieving 292 usable responses, or a response rate of 31 percent. By comparing responses of late respondents from a second mailing to the responses of early respondents from the initial mailing, it was determined than nonresponse bias was not present. A questionnaire and the DIT were both included in the survey to provide the data needed to test the hypothesis. CPAs were asked, via the questionnaire, to select the political ideology that most closely described self….conservative, moderate or liberal. CPAs completed the DIT in order to provide their level of rule-based moral reasoning.

The DIT and How it Measures Moral Reasoning

Rest (1979) discusses the extensive evaluation of his DIT as a measure of moral reasoning to assure the scale's reliability and validity. Rest and Narvaez (1994) present the numerous documented studies among the different professions which have used the DIT to measure a respondent's moral reasoning. This 1994 book includes a chapter which exclusively covers studies performed involving the accounting profession.

While some researchers like Thorne (2000) are critical of using the DIT in accounting settings, again, the test has been used extensively in such settings. Further, the current study would be an "apples to oranges" research application without use of the DIT. Lampe and Finn's (1992) intuitive conclusion as to why CPAs might be more rule-based in moral reasoning than non-accounting groups forms the basis for this current research. Lampe and Finn's conclusions were founded upon the DIT as a measure of rule-based moral reasoning. Thus, it is essential that this study use the DIT in its attempt to delve into the gap opened by Lampe and Finn's "intuitive" explanation.

The DIT profiles individuals, describing moral reasoning types, each type representing a different developmental stage of reasoning. These stages are patterned after Kohlberg's (1976) six-stage set. At stage 1, a person tends to resolve an ethical dilemma by following the type of reasoning that seeks to avoid punishment. At stage 2, the individual seeks to derive an outcome favorable to self. The stage 3 type tries to measure up to expectations of the group in order to gain acceptance. The stage 4 type (the one that is central to this study) turns to compliance with traditional norms, namely laws and rules, to reason out resolution of ethical issues. The stage 5 person follows her/his own opinions in addition to seeking to comply with democratically established norms of society. Finally, the stage 6 type follows a more abstract set of self-chosen ethical principles in her/his moral reasoning, even when those principles disagree with democratically established norms.

To "stage-type" a respondent, the DIT presents the individual with several hypothetical narratives, each representing a different ethical dilemma. This study used the most widely used DIT version, the three narrative one. After reading each dilemma, the respondent ranks 12 items in order of their relative contribution toward resolution of the dilemma. The DIT provides a score based on the 4 highest ranked items selected following each of the three ethical dilemmas presented. The p-score, or principled moral reasoning score, is the most commonly used profile score in studies using the DIT. It represents the relative importance a respondent assigns to stage 5 and stage 6 items.

Lampe and Finn (1992) concluded that profiling professional accountants and auditors by measuring the relative importance respondents assign to stage 4 DIT items may be more important in studying this professional group than is using the p-score. The authors concluded this due to the fact that studies involving professional accountants and auditors had routinely found their stage 4 scores to be significantly higher than the stage 4 scores reported by Rest (1986). Lampe and Finn also reported that, among professional accountants and auditors, DIT stage measures like the stage 4 measure were better predictors of ethical choice on the ethical scenarios than was the p-score. Recall that the stage 4 score represents the relative importance a respondent has put on resorting to traditional norms, namely laws and rules, when reasoning out resolution to an ethical dilemma.

Data Coding

Two variables were measured to test the hypothesis in this study. The DIT stage 4 score was captured to measure the degree to which a CPA used rule-based moral reasoning to resolve ethical issues. A higher stage 4 score represents higher rule-based moral reasoning while a lower stage 4 score indicates a reduced tendency to use rule-based moral reasoning. Rest (1990) describes the process involved in tabulating a respondent's stage 4 score. The score can range from 0 to 90, inclusive.

A CPA's political ideology was captured by asking respondents a simple question as to their political affiliation preference. Choices included conservative, moderate, or liberal. In this study, conservative was coded as 1, moderate as 2, and liberal as 3.

Correlation Analysis AND ANOVA

While Lampe and Finn (1992) drew conclusions that warranted further research into factors that might help empirically explain the strong tendency of professional accountants and auditors (CPAs)' to use rule-based moral reasoning during resolution attempts of ethical scenarios, any causal relationship by them was merely implied. By surmising that CPA's rule-oriented moral compass is developed from close association to the rule-oriented nature of accounting and auditing practice, Lampe and Finn implied causality. While this study does not research the effect of a "rule-oriented accounting and auditing practice" on the rule-based moral reasoning of CPAs, as implied by Lampe and Finn, it does seek to offer an alternative partial answer for the relatively high rule-based moral reasoning of CPAs.

This study recognizes former research showing that political conservatives tend to be far more rule-based in moral reasoning than do political liberals. Accordingly this study investigates whether there is a significant relationship between the political ideology (conservative, moderate, or liberal) of CPAs and their tendency to favor rules to resolve ethical dilemmas. While it is difficult to say which would be the cause and which would be the effect with regard to political ideology as it might relate to level of rule-based moral reasoning of CPAs, Lampe and Finn implied that there is something behind CPAs' tendency to use rule-based moral reasoning more than other groups. To test the hypothesis in this study, both correlation analysis and ANOVA were run to examine the (relational) impact of the CPA's political ideology factor on the extent of her/his rule-based moral reasoning.

Results

Table 1 shows the frequency of CPA responses on both variables in this study, namely political ideology and level of rule-based moral reasoning. Of the 292 respondents, 148 indicated a political position of conservative, 100 indicated moderate, and 44 showed liberal. The mean stage 4 scores (rule-based moral reasoning score which can range from 0 to 90, inclusive) are reflected by the table as 46.0582 for conservatives, 37.9665 for moderates, and 33.2577 for liberals, with a weighted average mean score for the sample of 41.3582.

Table 1: Frequency of CPA Responses		
Political Ideology	Number of:	Mean stage 4 DIT score
Conservative	148	46.0582
Moderate	100	37.9665
Liberal	44	33.2577
Total	292	41.3582

From Table 1, it can be seen that a majority of the 292 respondents are conservatives, politically speaking. Conservatives and moderates together constituted 85% of the respondents in the study.

Table 2 shows the correlations between the political ideologies of CPA respondents and their stage 4 DIT moral reasoning scores. As previously stated, the stage 4 score of the DIT proxies for rule-based moral reasoning. Pearson's R analysis resulted in a coefficient of -.318 while the Spearman's correlation coefficient measured -.310, both significant at the .001 level.

Table 2: Correlations of CPAs' political ideology with rule-based moral reasoning		
	Coefficient Value	Coefficient Value
Pearson's R	-.318	.000
Spearman Rank	-.310	.000

Table 3 shows the results of ANOVA, assuming that the level of rule-based moral reasoning of the CPA, as measured by the DIT stage 4 score, is the dependent variable and that the CPA's political ideology is the independent variable. The analysis yielded an F value of 16.65, significant at the .001 level.

Table 3: ANOVA results of rule-based moral reasoning based on political ideology					
	Sum of squares	df	Mean square	F value	significance
between	7306.92	2	3653.46	16.65	.000
Within	63410.30	289	219.41		
Total	70717.22	291			

The results of correlation analysis reveal a very significant negative relationship between CPAs' political ideology and their level of rule-based moral reasoning. Assuming a directional move in political ideology from conservative to moderate to liberal, it is shown that the level of rule-based moral reasoning declines. ANOVA reveals

a significant outcome assuming the level of a CPA's rule-oriented moral reasoning is dependent on her/his political ideology. The statistical analysis in this study defends acceptance of the hypothesis that based on political ideology, CPAs will reflect a different level of rule-based moral reasoning….specifically that rule-based moral reasoning will decline as political ideology moves from conservative to moderate to liberal.

Conclusions and Suggested Further Research

In this study, CPA respondents who identified self as politically conservative reflected the highest tendency to use rule-based moral reasoning relative to CPA respondents who described self as either politically moderate or politically liberal. As respondents moved from politically conservative to moderate to liberal, they reflected less and less tendency to use rule-based moral reasoning.

Lampe and Finn (1992) prompted this study through their research finding that CPAs reflect a higher tendency to use rule-based moral reasoning than do non-accounting groups. That finding caused them to surmise that this tendency to be rule-based in moral reasoning derives from the rule-oriented nature of accounting and auditing practice. This current study sought to provide some empirical evidence with regard to where the rule-based moral reasoning tendency of CPAs might derive.

Lampe and Finn used the DIT to measure rule-based moral reasoning to reach their conclusions. Thus, the current study employed the DIT to measure rule-based moral reasoning in order to assure a consistent follow-up research effort.

In light of the numerous accounting scandals of the last decade or so, accounting regulators have acknowledged the need for the CPA profession to be more principles-based in its practice and less rules-based. However, this assumes that a rules-based moral reasoning type person can be converted to a principles-based moral reasoning type. Accountants and auditors work in an environment where ethical issues are central and moral reasoning is constantly in play. Thus, accounting regulators have to identify the source of the rule-based tendency, or they may just be trying to treat symptoms only.

This study reveals that a significant component behind CPAs' tendency to be rule-based in moral reasoning may be steeped in their political ideology. The majority of respondents in this study were political conservatives. A random sample was collected from across the United States, so the results point to a profession that is largely conservative, politically speaking.

Political ideology is likely being formed long before a person heads to college. Studies not involving accountants have previously found that political conservatives tend to be much more rule-based in moral reasoning than are political liberals (Barnett, 1985). So the results of this study follow suit in suggesting that there's something going on between the political ideology of CPAs and their tendency to use rule-based moral reasoning. Apparently, political conservatives are "more comfortable" with rules than are political liberals. If true, then among political conservatives, moderates and liberals, it seems reasonable to suggest that conservatives would be most attracted to the CPA profession since the nature of accounting and auditing practice involves a rigorous structure in the form of rules, regulations and standards to be followed. The frequency distribution of CPA responses on political ideology in this study is consistent with the idea that the CPA profession reflects a politically conservative bias.

This study may indicate the need for regulators to "rethink" their approach to seeing the CPA profession become more principles-based and less rules-based. If a person is rule-based in moral reasoning because she/he is politically conservative, that person is not likely to move away from being rule-based. Instead of trying to reform the existing GAAP rule structure to make the rules more "principled" and thereby to require rewriting the college accounting curriculum, it might prove more efficient and effective if, initially, colleges were encouraged by accounting regulators to screen potential entrants to college accounting programs, using the DIT, for example. Rule-based (DIT stage 4) moral reasoning scores could be collected from applicants to business programs and used, for example, to structure incentives toward those with lower rule-based DIT scores, but academically strong based on traditional college entrance exams, to select accounting as their major. Privacy laws and equal opportunity laws would make screening by political ideology difficult, but the profession, at the same time needs to recognize whether its membership is reflective of the population, politically speaking, or not. Iron sharpens iron. The findings of this study suggest that the CPA profession is rule-based, at least in part, due to its high concentration of politically conservative members.

This study reflects the importance of further research to identify variables that may explain why CPAs, as a group, tend to be so rule-based in moral reasoning, relative to non-accounting groups. This study implies that the profession may appeal to political conservatives by the rule-oriented nature of its practice. Further, it implies that the CPA profession may be saying that it wants to be more principles-based while doing little to appeal to those that might enter accounting programs with a lower tendency to heavily depend on rules to reason out the best moral judgments.

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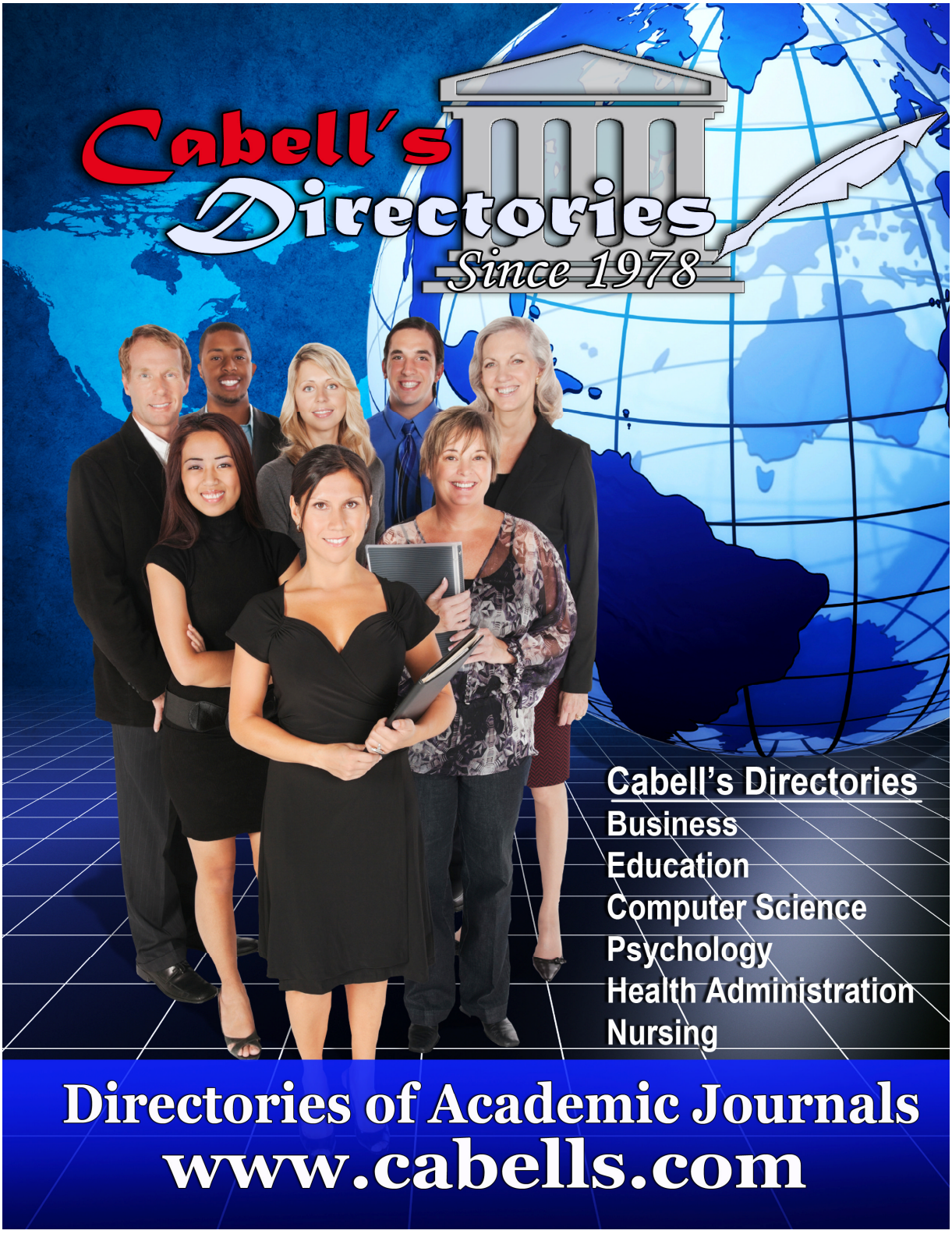
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A Model for Extending Lean/Six Sigma for Business Process Improvement within Financial Reporting Environments

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ABSTRACT

Business process improvement is an issue that has been of importance to information systems and accounting for many years. Defining improvements to workflows can be a complex process. This is particularly true in financial reporting organizations. Lean/ Six Sigma has been used effectively in manufacturing but its use in the service sector has not been as extensive. We present a model to extend the Lean /Six Sigma methodology for use in the analysis of complex financial reporting workflows.

Introduction

Lean /Six Sigma is a continuous improvement methodology historically utilized with manufacturing processes to substantially improve product quality. Lean Six Sigma "is a business improvement methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed, and invested capital" (George, 2003, p. 6).

Organizations seek to use information technology to gain competitive advantage through optimization of workflows. In particular, financial reporting environments are tasked with gathering and consolidating a significant amount of information from many sources in a short amount of time. Accountants are concerned with following procedures, ensuring effective controls are in place, and presenting accurate financial information. Often this comes at the expense of efficiency.

Building off the Lean/Six Sigma model, we present an enhanced model that leverages both Lean/ Six Sigma and information systems methodology principles. We demonstrate how this can be applied to financial reporting environments to improve the speed and quality of the reporting infrastructure while maintaining controls and provide expense savings.

Background

Six Sigma

Six Sigma improves processes by providing the necessary concepts, methods, and tools. Using Six Sigma, leaders develop the necessary skills to transform their organization and define a corporate culture that values quality and efficiency within business processes (Hoerl, Snee, Czarniak, and Parr, 2004). Six Sigma companies seek to

encourage continuous process improvement through the use of a standardized, documented and repeatable problem solving methodology. Six Sigma addresses business opportunities and solves business problems by providing a common language and method. It also provides a roadmap identifying the starting point and activities to follow. Through its use of common tools and language, Six Sigma provides flexible application to different challenges throughout an organization, including manufacturing, finance, procurement, sales, and marketing (George, 2003).

Six Sigma combines the best elements from many earlier quality initiatives including the introduction of Eli Whitney's revolutionary uniformity system and other manufacturing processes dating as far back as 1798. Whitney proved that selection of parts in the assembly of muskets could include the production of interchangeable parts similar enough in fit and function to allow for random selection. Other quality initiatives included Henry Ford's moving automobile assembly line in 1913, Walter Shewart's introduction of the process control chart, signaling the beginning of the age of statistical quality control, and Deming and Juran's total quality management work in Japan in the early 1950s. Deming promoted the analysis of statistical analysis through the use of data to quantify variation and the use of the plan-do-check-act (PDCA) cycle of continuous improvement. Juran's work was instrumental in aiding integration of quality initiatives throughout all organizational layers (Folaran and Morgan, 2003).

Over the next 20 years, Japan excelled in quality improvement and manufacturing capability. Japan focused on cycle time reduction and defect elimination as a means to improve productivity. As a result, Japan's efforts using continuous improvement concepts and the United States' focus on volume and maintenance of market share, led to the United States decreased market share in the automobile industry. This prompted the United States to place attention on improving quality. In 1979, Juran introduced training that focused attention on planning, improvement, control, and a focus on project-by-project improvements. Deming came out of retirement in the early 1980s to train American managers on the value of statistical methods and variance analysis, his 14-point management theory, and the seven deadly diseases. The late 1980s brought the introduction of a series of quality standards including the International Organization for Standardization (ISO) and the Malcolm Baldridge Quality Award. The award, sponsored by the United States government, focuses on two key aspects. The first aspect is sharing best practices and the second is the establishment of a benchmark for quality systems that focus on customer satisfaction as a principle driver of business design and execution. The first company to win the award was Motorola. As a by-product of winning the award, Motorola was required to share its quality practices with other companies. Motorola's approach to continuous improvement centered on an aggressive approach to eliminate defects based on a comparison of process performance and product specification. Motorola's approach initiated Six Sigma and was later modified by IBM and others (Folaran and Morgan, 2003).

The philosophies of Six Sigma include customer focus, data driven decision-making, business results focus and process understanding. The methodology is so powerful due to "the combination of these elements coupled with a rigorous, disciplined approach and well-publicized, proven business success" (Folaron and Morgan, 2003).

Six Sigma comprises the following core elements that distinguish this methodology from its predecessors:

- Active involvement and support from senior management. Senior management should regularly communicate and demonstrate engagement in the process and everyone on the management team should be trained on how to lead in the new culture.
- High-priority projects are allocated appropriate staff resources. Usually future leaders of the business are dedicated as full-time resources and provided appropriate training (Black Belts, Master Black Belts, Champions) to lead the projects.
- Everyone effected by or involved in Six Sigma needs to be educated on the principles and methodology.
- Variation in meeting the customer Critical-to-Quality (CTQ) requirement is front and center in development of the improvement process. The roadmap to follow in order to eliminate the variation is the Define-Measure-Analyze-Improve-Control (DMAIC) problem-solving methodology as well as supporting tools that enable data-driven decisions (George, 2003).

Lean

While Six Sigma centers on elimination of variation and defects in quality, Lean centers on speed, efficiency and the elimination of waste. "The goal of Lean is to accelerate the velocity of any process by reducing waste in all its forms" (George, 2003, p.24). In part this is accomplished by separating "value-added" from "non-value added" activities and understanding of the root causes (George, 2003).

Lean/Six Sigma

Lean and Six Sigma reinforce each other. Lean/ Six Sigma increases the reliability of processes through elimination of defects, variation, and optimization of process flow and speed. Combined, the two address the key competitive elements of speed and quality (George, 2003).

Evolution of Lean/Six Sigma

While Six Sigma and Lean have their roots in manufacturing and Six Sigma experienced breakthrough improvements at Motorola, Allied Signal, and GE, it is narrow-minded to think Lean/ Six Sigma can only apply to manufacturing. Lean/ Six Sigma is a generic methodology whose applications should transcend specific industries. Recently, the areas attracting attention to Lean/Six Sigma include financial services and healthcare industries (Hoerl et al., 2004).

Over the past twenty years, two major factors driving the continued evolution of Six Sigma are:

1. A greater emphasis on non-manufacturing Six Sigma environments and,
2. A greater integration of Six Sigma into non-manufacturing business processes (Hoerl et al., 2004)

Lean/Six Sigma Applied To Financial Reporting Processes

The corporate reporting department is the center of the reporting hub with many strategic business units (SBUs) and/or subsidiaries all reporting financial information. Corporate ultimately consolidates the results into financial statements and reports for

external parties (e.g., investors, creditors, regulators). In a typical supply chain scenario the SBUs and subsidiaries represent suppliers who provide financial information using various mechanisms (e.g., data warehouse, ERP system, reports, and the general ledger). Transformation of the inputs occur next and financial statements and reports are the final outputs. The reporting process typically occurs quarterly and often more frequently for internal management decision-making.

In light of the internal control provisions of Sarbanes-Oxley Section 404 (SOX), the financial reporting process would benefit from applying the Lean/Six Sigma methodology. Organizations have incurred significant costs to implement the SOX provisions and conforming to the provisions, anecdotally, considered to cause organizations to become less efficient. Applying the principles and discipline of Lean/Six Sigma provides the tools and discipline to strengthen the internal control environment while at the same time ensuring that the information flows are efficient.

Implementation Challenges

The highest priority for ensuring success of the project is making sure top management drives the effort. This includes allocation of sufficient resources, a culture supportive of change, and employees trained develop the behaviors and skills necessary to reinforce Lean/Six Sigma in their work environment (Blakeslee, 1999). As financial reporting organizations are typically staffed by accounting professionals not trained in project management, continuous improvement techniques, and information systems, it is important they understand how a technology-based workflow project will improve their processes enabling them to complete their information gathering and consolidating tasks more efficiently and accurately while strengthening internal controls.

In a discussion with Roger Hoerl, manager of General Electric's Applied Statistics Lab, Wilson (2005) noted that Hoerl believed the single largest barrier to deploying Six Sigma beyond manufacturing is the cultural resistance to continuous improvement. Typically, finance staff are not accustomed to thinking about continuous improvement as part of their jobs and tend to demonstrate an attitude that says, "We're different; Six Sigma does not apply to us." The mindset of the finance staff seems to portray an adversity to continuous improvement and usually the staff believe they are not paid to improve the way accounting is performed but to make sure existing procedures are being followed (Wilson, 2005).

Another obstacle experienced is resistance to change. Six Sigma efforts are truly successful only when welcomed and supported by the leadership team (Bates et al., 2006). To minimize this obstacle, the leadership team must serve as change agents including creating a sense of urgency and a spirit of cooperation. They must get key people to understand and buy into the need for Six Sigma so others will follow (Brewer and Eighme, 2005).

The Roadmap

DMAIC is the problem solving approach utilized in Lean/Six Sigma. DMAIC consists of five phases: Define, Measure, Analyze, Improve, and Control (Creveling, 2007). This problem solving approach may be applied to any business process. We posit that introducing information systems methodology principles along with the Lean/Six

Sigma methodology improves the problem solving approach when applied to a financial reporting process.

Financial reporting workflows present challenges to workflow optimization due to numerous regulatory requirements. Financial reporting workflows are often complex processes performed by highly technical professionals. Today's demand for financial information from internal and external stakeholders is enormous. Regulatory and legislative bodies are constantly changing the reporting requirements. Internal management is constantly demanding more information and a quick response time to be nimble and competitive. While many systems are available to assist in the information reporting processes (e.g., ERP) applying a continuous improvement methodology to ensure an organization utilizes their systems to the fullest and remains flexible is critical in today's competitive environment.

It is a challenge for many information systems organizations to be able to meet these demands. Programs such as Service Oriented Architecture and Cloud Computing offer the promise of improving IT's ability to respond to business needs but many organizations are still trying to capitalize on this approach.

Lean/Six Sigma provides a methodology that supports the definition of comprehensive business requirements but it is limited to processes that are relatively sequential and have a limited number of variations in workflow. Our model extends the Lean/Six Sigma methodology by including a more robust analysis of possible solutions to be evaluated, prior to implementation.

Our model consists of seven phases: Define; Assessment; Measure; Analyze; Model; Optimize; and Implement.

Define Phase

During the define phase the project scope, goals, and financial and performance targets are set. As the source of the information originates in SBUs or subsidiaries it may be practical to initially kick off the project at the SBU/subsidiary level. This also plants the continuous improvement mindset at the lowest levels.

The project scope, goals and financial metrics should be clearly defined and agreed to by senior management. Project resources should be identified and trained if necessary. At this point the organization needs to begin to adopt a culture of willingness to implement process improvement.

Assessment Phase

One of the challenges of working with technical professionals is managing their need to work independently with their need to work towards commons goals and objectives. Technical professionals have high achievement needs and must see the need for change to effectively implement workflow improvements. Prior to embarking on a Lean/Six Sigma business process improvement project, an organization should assess the technical staff's readiness to accept change. A low level of readiness will negatively impact the organizations ability to effectively implement BPM improvements.

Measure Phase

The purpose of the measure phase is to gain an understanding of the current state and collect data. During this phase process maps are created and document the

information flows and key controls. Data is gathered related to speed, quality, and costs. For example, how many days does it take to report information into corporate, how many hours to close the ledger, and what are the constraints preventing earlier submission. Are there any non-value added controls in the process that can be eliminated? Are the right controls in place (quality)?

The data gathering phase also includes understanding the voice of the customer (VOC). One of many customers would be the federal government (SOX VOC). Here the SOX VOC is understanding and satisfying the provisions of SOX section 404 including what key controls are necessary to ensure a strong control environment. Other customers include executive management, the board of directors, investors, and creditors.

The measure phase establishes a benchmark for the information technology organization to assess future workflow models to determine that key financial objectives will be met. The benchmark data should include speed, quality and performance metrics that are both activity based and time sequenced (Unified Modeling Language (UML) Activity and State Charts could be used to document this phase).

Analyze Phase

The purpose of the analyze phase is to understand the root causes affecting the key inputs and outputs. During this phase root causes related to bottlenecks thus preventing the process from being performed quicker and/or causing errors are identified. In addition, key controls are analyzed to ensure controls are preventing or detecting what is intended.

The analyze phase describes in detail all workflow activities including variations in workflow processes that occur as a result of production or performance issues. Technical staff members are consulted to identify their ideas and suggestions for improvements. Bottlenecks in workflow processes are identified and their impact is documented. All error processing flows are documented along with a description of the sources of errors.

Model Phase

This phase is key to developing automated improvements to complex workflows (simulation workflow software is appropriate for use during this phase). Differing combinations of workflows are modeled and their potential impact analyzed. Each potential workflow is analyzed to determine if it meets all of the objectives set forth in the define phase.

Actions necessary to improve the processes are highlighted and documented. This phase would include identifying and eliminating bottlenecks, remove non-value added activities, and implement controls. New process maps are created showing potential future states.

Optimize Phase

The optimal workflow is considered for implementation. Construction of systems supports to implement the optimal workflow takes place and validation of key financial metrics occurs. A communication plan to explain to technical staff specific impacts to their responsibilities is drafted to improve buy-in during implementation.

Implementation Phase

At this point the organization is ready to adopt the change improvements. The communication plan is implemented and training of technical staff, if necessary, is completed. The implementation phase continues after system implementation to measure actual results for comparison to financial objectives defined during the design phase.

Control Phase

The control phase is the final phase and involves wrapping up the project work, transitioning the improved process to the process owners, with procedures for maintaining the process and control improvements. Control charts are created to ensure that improvements are followed. A continuous improvement culture should be embedded in the reporting areas such that as new systems or variables affect the information flow the process owners are ready to respond.

Future Work

The model presented is an enhancement of the Lean/Six Sigma model developed principally for manufacturing based firms. Our model provides support for the needs of information technology dependent organizations. This model will be tested through a qualitative study of technical professionals who are using Lean/Six Sigma as a means to develop systems specifications to substantively improve their workflow and the results will be reported at a future date.

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Factors that Influence Expatriate Compensation Problems

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ABSTRACT

The overall objectives of multinational corporations (MNCs) compensation policy are to attract, to retain, to motivate high-quality talent, to be externally competitive and to be internally equitable. However, research indicates that there are problems with disparities with regard to compensating expatriates working in a wide variety of environments (Harvey, 1993; Caruth & Handlogten-Caruth, 2002; Lee, 2005; Herrera, 2005; Latta, 2006; Minter, 2008). Human resources (HR) is becoming a moving service for international relocation. However, human resource lacks serious planning in advance for disparities of pay scales, taxation, or even, cultural adaptation; paying little attention to international training and management development for new expatriate assignments. One approach is to ask: What can organizations do to gain a better understanding of international compensation policy? One way to gain a better understanding is through an effective training program for the new expatriate workforce, and compensation policies that are externally competitive and internally equitable for the success of any MNC. The objective of this paper is to review existing literature and analyze the MNC's role in managing expatriate assignments and compensation policies benefit both the expatriate employee and the MNC.

Introduction

The growing global economy has led to many more multinational companies working to relocate their employees in other countries to conduct global business. These employees who have worked in other countries for a period of time are referred to as expatriates. These expatriate employees are placed in various international offices and have international responsibilities. Managing globally requires monitoring numerous political, social, legal, and cultural differences among countries, which could trigger events that would adversely affect the long run profitability or value of the company (Deresky, 2011). It is important for international business individuals to be students of culture. They must have factual knowledge which is relatively easy to gain; but they must also become sensitive to cultural differences, which can be challenging.

Much of the literature on international expatriate assignments concerns itself with issues of selection, training, adjustment, the assignment itself and matters prior to departure (Connelly, et al. 2007). Selecting and rewarding the best international candidates can make a significant difference in the world if a multinational corporation (MNC) successfully competes on a global level (Minter, 2008). When organizations decide to operate internationally or globally, the human resources compensation program supports the way the business is structured, organized, and operated both globally and

locally (Mondy, 2012). Compensation is a significant link between strategy and its successful implementation. There must be a fit between compensation and the goals for which a MNC wants expatriate managers to achieve. In a recent survey of employers with global operations, 85% said they have a global compensation strategy to guide compensation decisions for employees at all levels and in all countries where they operate (Noe, et al. 2011). A MNC employs several types of international managers and must realize the importance and dangers of inequality when awarding expatriate compensation globally and locally. By appreciating the importance of the above factors, Deresky (2011) noted that those MNC expatriate employees would not feel exploited whether they are parent-country nationals (PCNs), host-country nationals (HCNs), or third-country nationals (TCNs). In fact, research shows that the majority of managerial positions in subsidiaries or headquarters are filled by locals instead of foreigners (Dessler, 2011). This indicates that expatriates represent a minority in MNCs'. A research study concluded that MNCs "should uphold the management criteria of social justice, faith and credit, and show much concern for the feelings, jobs, and life quality of expatriates in order to enhance their sense of being identified with and attached to their organization. In this way, corporate managers can avoid exploiting expatriates and enhance the corporation's positive image" (Wang, 2008: 878). Hence, MNC expatriate employees need to feel the sense of equality and belonging in their compensation and benefits.

There is extensive literature on expatriate employees (Harvey, 2008), but the international assignments are failing because the expatriates are not properly trained and fully equipped to adapt, and take on their assignments. There are many reasons for expatriate failure and it is critical that MNCs determine these underlying reasons (Shen & Hall, 2009). MNCs noted that upon expatriates' arrival at their destinations, many found it difficult to adjust to the culture, language, and even climate of their assigned countries. This is sometimes even more difficult if employees do not have the support of the organization, their spouse, family, and if he/she was given no choice in deciding whether or not they wanted the job. MNCs are made aware of the importance of family adjustment for the success of expatriates; therefore, expatriate's spouse should be included in the preparation training program (Andreason, 2008). Failure of the family to adjust is a common reason for expatriates' terminating their international assignments (Shaffer & Harrison, 2006).

Selecting Expatriates

Expatriate managers for global operations should be selected based on their technical knowledge and skill, their level of intelligence and soft skills that will enable them to earn the respect of subordinates (Csizmar, 2008). Multinational companies should consider each candidate's skill, learning style, and approaches to problem solving. Each of these factors should be related to achievement of the organization's goals, such as; solving a particular problem, transferring knowledge to host-country employees, or developing future leaders for the organizations (Noe, et al. 20011). Caruth & Handlogten-Caruth, 2002 also suggested that the best way to build a great global workforce with the right knowledge and ability is to offer a good compensation program and career growth opportunity. This problem became known for many organizations with employees

working globally or internationally that are continuing to face some special compensation issues (Mathis & Jackson, 2011).

As the global economy evolves into a more complex and interrelated system, MNCs are facing an increasingly complicated task in finding, motivating and retaining talented expatriate employees. Most multinational companies use all three (PCNs, HCNs & TCNs) forms of international staffing. It could be extremely difficult to implement all of these tasks into the recruiting and selection process (Deresky 2011). Herod (2009) argued that effective management selection, assignment planning, relocation services, family support, career and repatriation planning, assessing assignment and process results are important principles and practices to be included in the international staffing process. These factors are the main challenges associated with international human resource management (Bohlander & Snell, 2007).

Expatriates' Adjustment

The international relocation of human resources has generated the development of research, which targets the adjustment of expatriates in foreign culture. The opportunities involved in being an expatriate include an increase in developmental skills and providing more tangible outcomes. However, previous research has been developed, designed and conducted most research related to the needs of other expatriates who are preparing for international assignments in the U.S. (Lee, 2005). In his study of Taiwanese financial institution expatriates in the U.S., Lee found that expatriate adjustment was enhanced with greater satisfaction at the host country. He noted that "given the associations between job satisfaction and cross-cultural adjustment, multinationals need to ensure that they have human resource policies and practices to support job satisfaction of their expatriates while abroad" (Lee, 2005: 278).

While MNCs may perceive expatriation as an attractive method for accumulating foreign markets, they face the challenges of selection and management of the appropriate individuals (Lee, 2005). Some researchers noted that expatriate managers must be trained in diversity and organizations have to start employing a more diverse workforce. If a manager has not been around to learn one's culture, how can he/she teach the workforce the trade? The lack of knowledge about another culture will deprive an individual of opportunities to pursue global careers (Olsen & Martins, 2009). The benefit of knowing another language and having knowledge of other cultures gives an individual a competitive edge, this also places them in higher demand rather than those who can only speak one language. In this case, MNCs need to adopt new ways to hire expatriate employees and manage the workforce that they have now. The quality of a company could potentially be enhanced if they not only use the market tools that they possess, but also utilize marketable individuals they have in the company (Fernandez-Araoz, 2007; Inman, 2009). Thus, the factors contributing to the successful expatriation experience are significant to MNCs.

Expatriate failure can be costly if he/she leaves the company (Shaffer, et al., 2006). Pre-departure training programs that involve lectures and other activities have demonstrated an effective way to prepare expatriates (Littrell, et al. 2006). Training programs should provide expatriates information to study what the foreign culture is and what it consists of. Training would also create successful expatriate assignments, as well as provide an important management skill. In doing so, MNCs should have expatriate

policies covering matters such as training programs, compensation, and transfer costs in their international or global operations (Csimar, 2008).

Compensating Expatriates

Research on expatriate assignments has also focused much attention on the issue of global compensation. The globalization of businesses has increased awareness of, and concern for creating internationally equitable compensation systems in many multinational companies (Caruth & Handlogten-Caruth, 2002). Expatriates serve as representatives for their organization when assigned internationally. However, before being assigned, many organizations stress the importance of their overseas assignments and inform these employees of the potential benefits to them as individuals (Shen & Hall, 2009). There is plenty of evidence that one of the major disadvantages of moving people globally is that of significant problems arising in compensation-related matters (Herrera, 2005). It has been noted that a number of suggestions are made as to what companies can do to avoid this problem.

The main alternative approaches to "deciding on the types of compensation policies to implement, as well as how to communicate and administer them has become a major strategic and logistical challenge to many companies. What may work for the assignment of a few expatriates who originate from one country, may not be appropriate for the organization that begins to assign individuals from several different countries" (Herod, 2009). Another study stated that there have been plenty of attempts "to determine how and what should be included in an international compensation package" (Harvey, 1993: 785). The how and what questions that Harvey asks regarding the variation in expatriate compensation plans, creates significant differences in cultural identity change. The differences in compensation packages may be seen as necessary in order to compensate for the country's differences in general. These variations in laws, living costs, tax policies, and other factors all must be considered in establishing the compensation for local employees and managers, as well as managers and professionals brought in from other countries (Mondy, 2012 & Herrera, 2005). With these and numerous other concerns, developing and managing a global compensation system becomes extremely complex (Latta, 2006). However, one way to handle the problem is to pay a similar base salary company-wide, and then add on various allowances according to individual labor market levels (Dessler, 2011). For example, in places like Nigeria and China, the supply of managerial skills and abilities has not caught up to the demand; therefore there is a huge gap between the pay for management positions and the pay for clerical workforce (Noe, et al. 2011). Hence, organizations should think globally but act locally.

The survey of 243 MNCs conducted by Lockley (2008-2009) reported that a majority of 86% considers death benefits and long-term disability benefits for expatriate employees a medium to high priority in business related affairs. However, 26% admit to having no overarching policy for providing expatriate benefits. Many companies with benefits for expatriates lack essential provisions. According to the new study by Berdan (2009), 80% of MNCs who provide certain benefits do not consider local social security provisions. Furthermore, the survey shows that some MNCs feel that maintaining benefits for expatriates is too expensive and complicated to deal with. This factor causes companies to miss the opportunity to improve their benefit offering and sharpen their

competitive edge globally. The survey showed that in order for international assignments to end more successfully, companies must make sure that they provide the benefits that expatriates need. Failure to comply could result in international assignments continuing to fail and not being successful (Berdan, 2009). Failure is not an option for success when multinational organizations are operating and competing internationally or globally.

Conclusion

Despite the many benefits of the internationalization of businesses, multinational organizations with employees working globally face significant challenges in compensation-related issues. The globalization of business demands the development and management of employees' compensation from different countries. Also, it must be reasonably cost-effective and at the same time, still attractive and motivating for employees who accepted international assignment. The need for greater compensation and benefits to recruit and retain ambitious foreign employees must not be underestimated by these organizations. These employees expect that the skills and knowledge acquired overseas will benefit in terms of salary growth and external marketability (Benson & Pattie, 2008). These researchers also noted that international experience is beneficial for long-term career success. The challenge for researchers and policy analysts in compensating expatriates is to bridge the variation in expatriate compensation plans that create significant differences in cultural identity changes. These differences in compensation packages may be seen as necessary in order to compensate for the country's difference for local employees and managers, as well as managers and professionals brought in from other countries. Further research is needed that could reveal new insights for multinational organizations concerning the impact of externally competitive and internally equitable management for expatriate assignments.

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The Effectiveness of Outdoor LED Advertising Signs

Hendrikus E.J.M.L. van Bulck, USC Sumter

ABSTRACT

Outdoor LED advertising signs have gained enormously in popularity in recent years. Programmable LED signs offer many advantages over traditional advertising boxes that require manual lettering. LED signs can be found at gas stations and convenience stores, banks, retail stores, shopping malls, churches and colleges and universities. There has been remarkably little research published about the effectiveness of LED signs. This manuscript reports the results of a pilot study of the perceptions of small-business managers towards such LED signs. Managers were asked to express their views regarding effectiveness, customers' likes and dislikes, ease of use and cost effectiveness. The study found a high degree of satisfaction. The study did not sign significant differences between types of businesses and sizes and types of LED signs.

Introduction

Digital signage may be defined as signage that "provides a dynamic real-time, near real-time, or non-real-time information that may be individually adapted to the location, time, situation, and who is actually watching the screen" (Lundstrom, 2008). Programmable, electronic, outdoor, light-emitting-diode (LED) signs offer many advantages, compared to traditional advertising signs. Traditional signage is costly, and it may be difficult or impossible to change the message. Conventional advertising boxes require manual lettering. Even when they are illuminated, they often blend in with the clutter of the environment. By contrast, LED signs are programmable. Hundreds of scrolling messages can be stored, and they tend to be visible from a great distance. The industry is also evolving rapidly. Although most LED signs are relatively small and display mostly text, large LED billboards are beginning to replace conventional billboards. They offer the advantages of dynamic and creative elements. Because they are interactive, they also allow for multiple advertisers to share a billboard with guaranteed delivery and digital display (Buzzle.com, 2011). Advertising managers now have the flexibility to control graphics and message content, and they can change the message instantly in response to the needs or demographics of people passing by. Programmable LED signs are sometimes referred to as electronic variable message centers (EMC) (Screaming Signs, 2011).

Although outdoor LED advertising signs have become enormously popular, very few independent studies of the effectiveness have been published. The authors of a recent paper commented: "Digital signage networks are a newly emerging form of electronic advertising technology that is rapidly growing in popularity but has received little attention in the research literature" (Harrison & Andrusiewicz, 2004).

Review of Literature

The outdoor sign industry periodically refers to a study on outdoor LED signs conducted by The University of San Diego. (Hafacast. LLC, 2011). The study was requested by the International Sign Association (ISA) and controlled for variables such as the number of signs present, location, and operating hours of a well known fast food chain. The study showed that the number of LED displays significantly impact both the annual turnover and the number of transactions. The researchers built upon earlier research on signage. The report included an analysis of a fast-food chain and several car dealerships. The study reported that on-premise signage had a statistically significant impact on both revenues and the number of annual customer transactions of a site. Variables message signs were most effective. The study reported that the number of on-site signs may impact the revenue by as much as 4.75% for each additional sign. Each additional sign was also found to increase the number of transactions by 3.94%. (Ellis, Johnson, & Robin, undated). The Arbitron research firm reported that, in a recent, study more than half of the respondents found digital billboards attractive, and almost 2/3 of the individuals surveyed believed that digital billboards are "a cool way" to advertise. The favorable rating rose to 77 among young adult 18 to 34 years old (Khan, 2011).

Some authors believe that digital signage advertising, if not controlled or regulated, can easily result in "negative externalities." They argued that people may be exposed to so much advertising that the environment becomes uncomfortable. They use examples such as Shibuya Crossing in Tokyo and Times Square in New York and contrast these environments to communities with more regulated advertising such as the Prinzipalmarkt in Muenster, Germany. They proposed metrics for the measurement of consumption of attention and public spaces. They also proposed that the negative effects can be dealt with by establishing maximum permissible values, fees and tradable certificates (Muller & Kruger, Competing for Your Attention: Negative Externalities in Digital Signage Advertising, 2007).

Most LED signs can be integrated into a visual information system. That means that they can be networked and connected to a computer and can be programmed with an infrared wireless remote or by connecting the LED sign directly to a PC via serial ports, or via wireless communication with an integrated Ethernet adapter. The advantage of this is that LED signs can be programmed from a centralized location (LED Sign Authority, 2011). Although cheaper models may be able to display messages only in one color, many signs are tri-colored (red, amber and green) and a built in a single piece of solar grade poly-carbonate protective units from the sun's UV rays (Outdoor Signs America, 2011). Although very little empirical data about the effectiveness of LED signs has been published, a number of commercial websites refer to SBA studies and claim that businesses that have invested in outdoor LED signs saw sales increase between 15% and a hunger that 50%. They claim that based on CPT (Cost per Thousand) LED signs are far more cost-effective than any other form of advertising. They claimed that the average cost to achieve 1000 impressions (CPM) on numerous is less than 10% of the cost to reach the same number using any other marketing medium (Data Masters, 2011). The effectiveness of the sign may be affected by principles of programming. For example, messages that use all caps, avoid using abbreviations, and use messages that can be read at a normal reading speed will make it easier for a driver passing by the redesign at a glance. Also, signs that avoid reverse (negative) copy and at avoid script fonts maximize

readability. In addition, signs may be more effective if they promote specials, differentiate the business, or promote products or services that prospective customers look for (LED Sign Central, 2009).

The effectiveness of LED signs often depends on the frequency with which they are updated and the relevance of the information they provide to traffic passing by. For example, some signs displayed time and temperature or the date. Of course, this information is updated automatically. Other types of messages need to be updated by the operator of design. This may include community messages, information about specials holiday messages, or sales messages. In the signs are not updated pertinent information, people will be "trained" not to look at the sign. It is especially important because, in many cases, the same people drive by to sign, daily. Frequently updating their messages is presumed to lead to consistency in sales (LED sign Central, 2008).

There is a correlation between audience expectations toward what is presented on a digital sign and their attention towards the displays. In other words, if people passing by a sign expect uninteresting content they are more likely to ignore the message. This effect was found in a study of 91 interviews at 11 different public displays. The survey found that when the audience expects boring advertising they ignore the display. These researchers came to similar conclusions in a second study of 17 users. The purpose of this study was to identify dimensions of "display blindness" (Muller, et al., 2009).

The effectiveness of LED signs may also be influenced by the "pitch" of the sign. Pitch is the distance from the center of one pixel to the center of an adjacent pixel, usually measured in millimeters (LED Sign Central, 2009). The effectiveness of the signs may be further impacted by "luminance." Luminance limit based on billboard-to-viewer distances for standardized sign categories. The industry has established research-based limits on the amount of light arriving at the person's eyes. The purpose of these standards is to make sure that the intensity of the light sources is not offense or dangerous (Lewin, 2008).

Size and Significance of the Industry

While little is published about the size of the LED sign manufacturing industry specifically, the economic significance of the overall sign manufacturing industry can be illustrated with the Census Bureau State and Local Key Statistics For 2007 (NAICS industry 339950 "Sign Manufacturing"). In 2007, the overall size (sales) of the industry was more than $13 billion; there were 6,407 establishments with an annual payroll in excess of $3 billion. Industry employed more than 86,000 employees. Industry was concentrated geographically in states such as California ($1.2 billion sales), Illinois (more than $1 billion sales) and Texas ($0.9 billion sales) (US Census Bureau, 2007). These metrics show a significant growth from the year before. 2006 industry sales were reported to be $11.7 billion. During the period 1992 -2006, sign-manufacturing jobs grew at a rate of 1.3% per year. Many sign components are manufactured overseas, but the production of finished signs has been largely protected from foreign competition. The domestic industry remains isolated international competition, because the manufacturing of signs is highly customized and long distance shipping costs are very high (International Sign Association, 2011).

While digital signage is often associated with glamorous urban settings such as Times Square, exterior signage is also found to be adding value to small, rural businesses.

Researchers at Iowa State University argued that successful businesses not only sell goods or services, but they also create memorable experiences for their customers. The report proposes that exterior signage is one of the elements that may affect such experiences offered by businesses and, therefore, may add value to small rural businesses (Fiore, Niehm, Oh, Jeong, & Hausafus, 2007).

Objective of the Study

The objective of this study was to provide empirical evidence of the effectiveness of LED outdoor advertising signs. Because only scant empirical data were available, the survey was intended to be a pilot study. Although expenditures on outdoor advertising has been found to correlate positively to sales, the effectiveness of advertising media is almost always multidimensional, and typically should be viewed relative to certain advertising goals and objectives. With the possible exception of certain short-term sales promotions, relationships between dollars spent on certain advertising media and sales are usually blurred. For example, it may take weeks or months before advertising dollars affects sales. In many cases, outdoor signage may increase customer awareness, while sales may depend on many other factors (Bhargava & Donthu, 1999). For the purpose of this study, effectiveness of LED signs was measured based on perceptions of owners or managers of small businesses.

Managers and owners were asked to express their views regarding the effectiveness of LED signs in terms of increasing customer awareness, increasing traffic, and increasing sales. They were also asked whether they believed customers like or dislike LED signs, and they were asked if they believed LED signs to be cost effective and easy to use, and if they would recommend LED signs of the business.

Research Methods

Procedure

Data for this study was obtained by surveying 36 managers and owners of small businesses and not-for-profit organizations in Sumter, South Carolina that advertise with programmable outdoor LED digital signs. The instrument consisted of six classification variables and nine six-point Likert scales. The data were combined in an Excel spreadsheet. Managers' perceptions were cross-classified with classification variables to determine if there were significant differences in perceptions between various classes of businesses and signs. Responses were classified by type of business, size of the sign, type of sign, and elevation of the sign.

Factor analysis (varimax rotation) was used to determine factors underlying "effectiveness." Pearson correlation and Analysis of variance (ANOVA) tables were used to relate classification variables to the attitude scores. Classification variables were independent variables, and attitude scores were dependent variables. Cochran and Cox provide a classical discussion of this methodology (Cochran & Cox, 1957). Anderson, too, provides support for this methodology (Anderson, 1958).

Subjects

The 36 respondents were believed to constitute the majority of the owners/ managers of businesses and organizations in Sumter that had programmable LED signs.

The location of the signs was determined from a list was compiled by observing where signs were located.

Measures of Variables

The survey included six classification variables:

1. Type of business (retail, not gas station; retail, gas station; service; not-for-profit; and other).
2. Approximate size of the sign.
3. One-sided versus two-sided signs.
4. Mono-color versus multi-color signs.
5. Elevation: low (eye level or below) versus elevated (above eye level.)

The survey included nine Likert psychometric scales to measure perceptions. Survey used 6-points scales, ranging from 'strongly agree' (6) to strongly disagree (1). Attitudes towards effectiveness were measured along five dimensions:

1. Traffic and sales (3 questions)
2. Customer's attitudes (3 questions; 2 positive scales, 1 reversed)
3. Cost-effectiveness (1 question)
4. Ease-Of-Use (1 question)
5. Would Recommend to Others (1 question)

Findings of This Study

Descriptive Analysis – Classification Variables

Most of the entities surveyed were retail stores (20). Five of the entities were gas stations; six were service related entities; and five of the units were "other," including a shopping mall, churches and other not-for-profits. The entities surveyed included a broad range of industries as shown in Table 1.

The subjects were also classified by sign size. Most of the signs in the study were fairly small. It should be noted that many respondents were not sure about the exact sizes of their sign. In several cases, the size had to be estimated and, therefore, sizes are reported as "approximate sizes." The signs ranged in size from 12 ft.² to 300 ft.² About 75% of the signs were 48 ft.² or smaller. The average sign size was 54 ft.² (Figure 1).

Almost 89% of the signs in the study were two-sided, and almost 53% displayed only one color. These Monochrome LED Signs are the most common LED Signs. 47% of the signs displayed two or more colors. The signs were also classified as "low" or "elevated." Almost 70% of the signs were elevated, which was defined as above eye level. The remaining 30% were below eye level or at eye level (Table 2).

Table 1: Type and Description of Subjects

Type of business	n	Proportion
Retail	20	0.556
Gas station	5	0.139
Service	6	0.167
Other	5	0.139

1 or 2 Sided	N	Proportion
1	4	0.111
2	32	0.889

Description	n	Proportion
Appliances	1	0.028
Bank	3	0.083
Brake & Tune ups	2	0.056
Church	2	0.056
College	1	0.028
Electronics	1	0.028
Exhibition Center	1	0.028
Fast food	5	0.139
Gas station	5	0.139
Goodwill store	1	0.028
Insurance	1	0.028
Jewelry	1	0.028
Movie theatre	1	0.028
Pharmacy	5	0.139
Shopping mall	1	0.028
Supermarket	1	0.028
Telephone comp	2	0.056
Used cars	1	0.028
Video store	1	0.028

1 or multi-colored	N	Proportion
1	19	0.528
2	17	0.475

No of lines	N	Proportion
1	4	0.111
2	15	0.417
3	10	0.278
4	7	0.194

Low or elevated	N	Proportion
1	11	0.306
2	25	0.694

Figure 1: Approximate Sizes of Signs in Study (Square Footage)

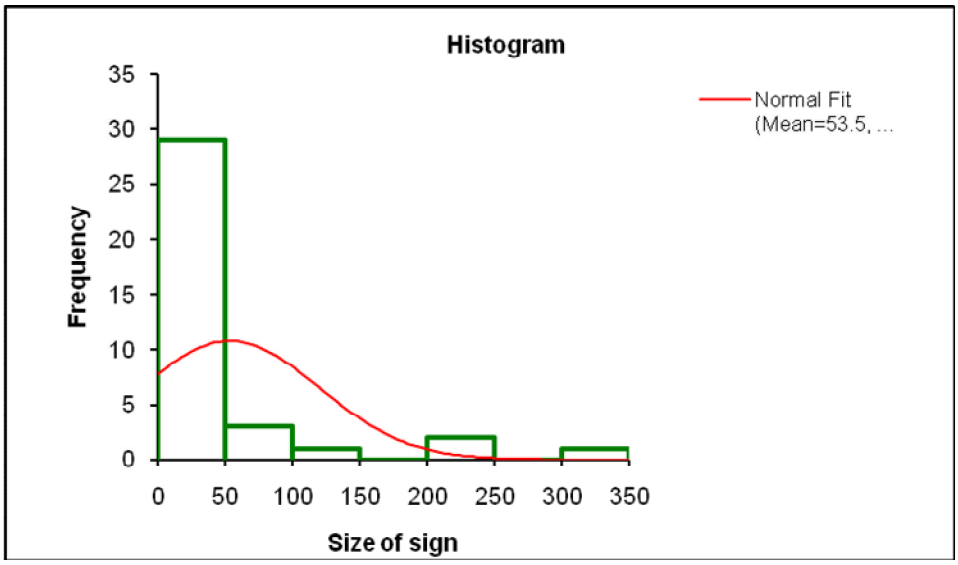

Table 2: Types and Elevations of Signs

1 or 2 Sided	n	Proportion	No of lines	n	Proportion
1	4	0.111	1	4	0.111
2	32	0.889	2	15	0.417
			3	10	0.278
			4	7	0.194
1 or multi-colored	**n**	**Proportion**	**Low or elevated**	**n**	**Proportion**
1	18	0.500	1	11	0.306
2	16	0.444	2	25	0.694
3	1	0.028			
4	1	0.028			

Descriptive Analysis – Classification Variables

Descriptive statistics of the responses to the nine questions are summarized in Table 3. The percentage distribution of the responses is summarized in Table 4. Cumulative percentage responses are summarized in Table 5.

Table 3: Descriptive Statistics of the Attitude Scales

Scale	n	Mean	Median	SE	Variance	SD
The LED sign helps bring in more customers	36	4.72	5.00	0.1852	1.2349	1.1113
Customers often comment that they like the LED sign	36	4.19	4.50	0.2101	1.5897	1.2608
Customers sometimes comment that the sign is unattractive	36	1.75	1.00	0.1612	0.9357	0.9673
The LED helps customers find your location	36	4.56	5.00	0.2502	2.2540	1.5013
I would recommend an LED sign to other businesses	36	4.83	5.00	0.1667	1.0000	1.0000
The LED sign makes people more aware of the location of the store	36	4.75	5.00	0.1967	1.3929	1.1802
LED signs are cost effective	36	4.25	4.00	0.1967	1.3929	1.1802
LED signs are easy to update	36	4.72	5.00	0.1719	1.0635	1.0313
The LED sign measurable increases sales	36	4.42	4.00	0.1562	0.8786	0.9373

Table 4: Percentage Distribution of the Responses on Attitude Scales

Scale	6	5	4	3	2	1
Helps bring in more customers	25.00%	41.67%	19.44%	8.33%	5.56%	
Customers like the LED sign	13.89%	36.11%	16.67%	22.22%	11.11%	
Customers find sign is unattractive			8.33%	11.11%	27.78%	52.78%
Helps customers find location	27.78%	38.89%	16.67%	2.78%	5.56%	8.33%
Would recommend an LED sign	25.00%	47.22%	16.67%	8.33%	2.78%	
Makes people aware of location	22.22%	52.78%	13.89%	2.78%	5.56%	2.78%
Cost effective	11.11%	33.33%	38.89%	5.56%	8.33%	2.78%
Easy to update	22.22%	41.67%	27.78%	2.78%	5.56%	
Measurably increases sales	13.89%	30.56%	38.89%	16.67%		

Table 5: Cumulative Percentages of the Responses on Attitude Scales

Scale	6	5	4	3	2	1
Helps bring in more customers	25.00%	66.67%	86.11%	75.00%	100.00%	
Customers like the LED sign	13.89%	50.00%	66.67%	72.22%	100.00%	
Customers find sign is unattractive	0.00%	0.00%	8.33%	11.11%	47.22%	100.00%
Helps customers find location	27.78%	66.67%	83.33%	69.44%	91.67%	100.00%
Would recommend an LED sign	25.00%	72.22%	88.89%	80.56%	100.00%	100.00%
Makes people aware of location	22.22%	75.00%	88.89%	77.78%	97.22%	100.00%
Cost effective	11.11%	44.44%	83.33%	50.00%	97.22%	100.00%
Easy to update	22.22%	63.89%	91.67%	66.67%	100.00%	100.00%
Measurably increases sales	13.89%	44.44%	83.33%	61.11%	100.00%	100.00%

Traffic and Sales

Respondents agreed almost unanimously, that LED signs were effective. More than 86% of the respondents indicated that LED signs helped bring in more customers. Of the owners and managers surveyed, 25% strongly agreed with this statement. Managers also believed that LED signs helped customers find their locations. 83.33% also agreed that LED signs, measurably increased sales.

Customer Attitudes

Two thirds of subjects answered that they believed that customers liked LED signs, while only 8.33% indicated that customers found such signs unattractive. More than 80% of the respondents disagreed or strongly disagreed that customers complained that signs were attractive. Furthermore, 83.33% agreed with the statement. *"The LED sign makes people more aware of the location of the store."*

Cost-effectiveness

83.33% of the respondents agreed that LED signs and measurably increased sales. Although 16.67% somewhat disagreed, none of the respondents agreed or strongly disagreed with this statement.

Ease-of- use

Almost 92% of the owners and managers that participated in the survey found that LED signs were easy to update.

Would Recommend To Others

88.89% of the individuals surveyed indicated that they would recommend LED advertising signs to other businesses.

Factor Analysis of the Responses

A principal components solution was performed on the correlation matrix of the original variables, followed by a varimax rotation on the factor matrix. The inter-item correlations are shown in table 8. A minimum eigen value of lambda equals one ($\lambda = 1$) was used to determine the number of components to be retained for rotation. This common criterion ensured that only components accounting for at least the amount of variants of a single variable was treated as significant (Guttman, 1954). Two significant factors were extracted, cumulatively accounting for 66.452% of the total variance. (See Table 6)

Table 6: Significant Factors

Total Variance Explained

Compo-nent	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.523	50.251	50.251	**4.523**	**50.251**	**50.251**	**2.994**	**33.272**	**33.272**
2	1.458	16.201	66.452	**1.458**	**16.201**	**66.452**	**2.986**	**33.180**	**66.452**
3	.874	9.713	76.165						
4	.842	9.358	85.523						
5	.537	5.966	91.489						
6	.294	3.267	94.756						
7	.229	2.550	97.306						
8	.151	1.675	98.981						
9	.092	1.019	100.000						

Extraction Method: Principal Component Analysis.

Table 7: Component Matrix: Extracted and Rotated 2 Components Extracted

	Extracted Component Matrix		Rotated Component Matrix (varimax)	
	1	2	1	2
Helps bring in more customers	.747	-.305	.313	.743
Customers like the LED sign	.591	-.004	.415	.420
Customers find sign is unattractive	-.349	.473	.087	-.582
Helps customers find location	.770	-.488	.201	**.889**
Would recommend an LED sign	.887	.106	.702	.551
Makes people aware of location	.749	-.368	.270	.789
Cost effective	.613	.633	**.881**	-.015
Easy to update	.641	.542	**.837**	.069
Measurably increases sales	.876	.248	.795	.443
Extraction Method: Principal Component Analysis.				
Rotation converged in 3 iterations.				

A "scree plot" was used to assist in determining the optimal number of factor components to be retained. The initial eigen values were plotted in the scree plot. As a general rule, components on the steep-slope portion of the line are retained, while components of the shallow slope contribute little to the model. In this case, the line dropped sharply during the first and second components. The line leveled off between the second and the third components. This suggested that only the first two components should be retained. The inter-item correlations are shown in Table 8.

Un-rotated factor solutions can be difficult to interpret. The most significant loadings were all on extracted component 1. To test the items for purity and to make the results easier to interpret, we rotated the solution using a varimax rotation. Significant variables should load high on as few factors as possible with as many (close to) zeros as possible in the rotated factor matrix. The rotated component matrix was highly interpretable which represented two thirds of the data (Table 7). It is customary to build attitudes scales around the variables with substantial loadings on a given factor. Several criteria were used in judging which loadings should be considered substantial. Factor scores of .30 or higher were considered substantial scores. Relative distances between factor loadings were also considered. Theoretical justification (content validity) of items and internal consistency (direction of + or -) were also taken into account. Factor names should be brief and should communicate the nature of the underlying constructs. By considering the fact the loads we labeled factor 1 "Cost-Effective and Easy" and factor 2 "Helps Customers" (Table 9). A succinct illustration of this methodology is provided by the Web Center for Social Research Methods (Multivariate Statistics: Factor Analysis).

Figure 2: Scree Plot of Components

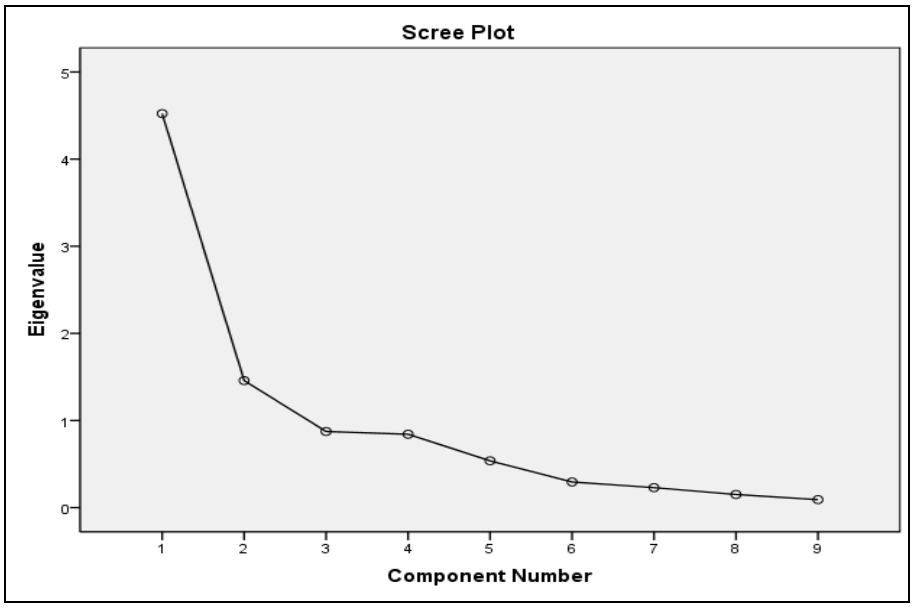

Table 8: Inter-Item Correlation Matrix

	Helps bring in more customers	Customers like the LED sign	Customers find sign is unattractive	Helps customers find location	Would recommend an LED sign	Makes people aware of location	Cost effective	Easy to update	Measurably increases sales
Helps bring in more customers	1.000	.509	-.359	.660	.574	.490	.229	.380	.498
Customers like the LED sign	.509	1.000	-.123	.258	.434	.360	.274	.197	.582
Customers find sign is unattractive	-.359	-.123	1.000	-.374	-.251	-.181	-.069	-.043	-.197
Helps customers find location	.660	.258	-.374	1.000	.634	.839	.194	.269	.521
Would recommend an LED sign	.574	.434	-.251	.634	1.000	.617	.569	.619	.747
Makes people aware of location	.490	.360	-.181	.839	.617	1.000	.210	.246	.588
Cost effective	.229	.274	-.069	.194	.569	.210	1.000	.622	.678
Easy to update	.380	.197	-.043	.269	.619	.246	.622	1.000	.596
Measurably increases sales	.498	.582	-.197	.521	.747	.588	.678	.596	1.000

Table 9: Component Score Coefficient Matrix

	Component	
	1	2
Helps bring in more customers	-.031	.265
Customers like the LED sign	.090	.094
Customers find sign is unattractive	.175	-.284
Helps customers find location	-.116	***.357***
Would recommend an LED sign	.190	.087
Makes people aware of location	-.061	.295
Cost effective	***.403***	-.212
Easy to update	***.363***	-.163
Measurably increases sales	.257	.017
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		

Table 10: Pearson Correlation of size of Sign with Factor 1 and Factor 2

	Cost-Effective and Easy	Helps Customers
Size of sign	**Factor 1**	**Factor 2**
n	36	36
r statistic	0.11	-0.25
95 percent CI (normal approximation)	-0.22 to 0.43	-0.53 to 0.09
t statistic	0.66	-1.48
DF	34	34
2-tailed p (t approximation)	0.5117	0.1481

Table 11: 1-Way ANOVA of Factor 1 with Classification Variables

Type of business	**n**	**Mean**	**SD**	**SE**	
Retail	20	0.0334	0.7496	0.1676	
Gas station	5	0.0554	0.9784	0.4375	
Service	6	-0.5949	1.7667	0.7213	
Other	5	0.5251	0.5805	0.2596	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Type of business	3.5398	3	1.1799	1.20	0.3254
Residual	31.4602	32	0.9831		
One-sided or two-sided	**n**	**Mean**	**SD**	**SE**	
One-sided	4	-0.3987	0.5353	0.2676	
Two-sided	32	0.0498	1.0384	0.1836	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
One-sided or two-sided	0.7152	1	0.7152	0.71	0.4056
Residual	34.2848	34	1.0084		
Mono- or multi-color	**n**	**Mean**	**SD**	**SE**	
Mono-color	19	-0.0953	1.0181	0.2315	
Multi-color	17	0.1065	0.9993	0.2448	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Mono- or multi-color	0.3655	1	0.3655	0.36	0.5532
Residual	34.6345	34	1.0187		
Number of Lines	**n**	**Mean**	**SD**	**SE**	
1	4	-1.4311	1.5630	0.7815	
2	15	0.2753	0.7434	0.1920	
3	10	-0.1176	0.9578	0.3029	
4	7	0.3960	0.4304	0.1627	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Number lines	10.5649	3	3.5216	4.61	0.0086
Residual	24.4351	32	0.7636		
Low or Elevated	**n**	**Mean**	**SD**	**SE**	
Low	11	-0.0630	0.9023	0.9023	
Elevated	25	0.0277	1.0566	1.0566	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Number lines	0.0628	1	0.0628	0.06	0.8062
Residual	34.9372	34	1.0276		

Table 12: 1-Way ANOVA of Factor 2 with Classification Variables

Type of business	**n**	**Mean**	**SD**	**SE**	
Retail	20	-0.2145	0.9119	0.2039	
Gas station	5	-0.3090	1.0053	0.4496	
Service	6	1.0043	0.6773	0.2765	
Other	5	-0.0382	1.1625	0.5199	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Type of business	7.4572	3	2.4857	2.89	0.0507
Residual	27.5427	32	0.8607		
One-sided or two-sided	**n**	**Mean**	**SD**	**SE**	
One-sided	4	-0.9503	1.3028	0.6514	
Two-sided	32	0.1188	0.9131	0.1614	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
One-sided or two-sided	4.0640	1	4.0640	4.47	0.0420
Residual	30.9360	34	0.9099		
Mono- or multi-color	**n**	**Mean**	**SD**	**SE**	
mono-color	19	-0.1100	1.0322	0.2368	
Multi-color	17	0.1230	0.9790	0.2375	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Mono- or multi-color	0.4872	1	0.4872	0.48	0.4931
Residual	34.5127	34	1.0151		
Number of Lines	**n**	**Mean**	**SD**	**SE**	
1	4	0.7517	1.0298	0.5149	
2	15	-0.2615	1.2230	0.3158	
3	10	0.0065	0.8198	0.2592	
4	7	0.1214	0.4901	0.1852	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Number lines	3.3891	3	1.1297	1.14	0.3464
Residual	31.6109	32	0.9878		
Low or Elevated	**n**	**Mean**	**SD**	**SE**	
Low	11	-0.2441	0.9760	0.9760	
Elevated	25	0.1074	1.0110	1.0110	
Source of variation	**SSq**	**DF**	**MSq**	**F-stat.**	**p**
Number lines	0.9436	1	0.9436	0.94	0.3386
Residual	34.0564	34	1.0017		

Discussion

The purpose of the factor analysis was to identify factors underlying the variables. Logical validity was ascertained a priori in that all test items were supported by literature. Construct validity was based constitutive definitions, defining constructs with other constructs. Factor analysis in this study isolated common entities among the variables. Each of these common entities was presumably more basic than the variables themselves. Construct validity was pretested using factor analysis assuring that hypothesized dimensions were represented by the tests. These tests confirmed expectations about the factors, suggesting that the scales were sufficiently valid. However, they were considered valid only in measuring dimensions defined by the content of the test items. Two factors were extracted which we labeled "Cost-Effective and Easy" (Factor 1) and "Helps Customers" (Factor 2). Factor 1 included the component "cost-effective" and "easy to update." Factor 2 included the component "helps customers find location."

Factor scores were used as attitude measures toward the effectiveness of digital signs. Reactions to all items were included even though only the high loadings were considerate in interpreting each factor. This procedure is theoretically justifiable because, in fact, all items contribute to each factor. Low loadings merely mean that the contribution of that item is marginal.

We hypothesized that a relationship existed between the size of the signs and the two factors. The results of the Pearson correlation analysis, however, did not find a significant association between these variables (see Table 10). Factor 1 (cost-effective and easy) correlated somewhat positively with size; however, we do not judge this correlation to be significant. Factors 2 (easy to update) correlated somewhat negatively with size but, we did not judge this correlation to be significant.

We also investigated relationships between the cognitive factors (attitudes) and other classification variables. We hypothesized that the type of business, the type of sign (one-sided versus two-sided), the number of colors, the number of lines of text, and the elevation of the signs affected perceptions of effectiveness. Analysis of variance was used to test differences between these categories. The cognitive factors were entered as independent variables, and the classification variables were treated as independent variables.

We found that the number of lines related to effectiveness. Signs with either two lines or more than three lines were found to be more effective than signs with either one or three lines ($p=0.0086$). We did not find statistically significant differences between the other classification variables, and Factor 1 (See Table 11).

We also found that the type of business and one-sided versus two-sided signs related significantly to perceived effectiveness. Service organizations scored higher on Factor 2 types of business ($p=0.0507$). Not surprisingly, two-sided signs were found to be more effective in helping customers find the business and one-sided signs ($p=0.0420$) (See Table 12).

Contributions and Limitations of This Study

Since few published studies report on the effectiveness of programmable outdoor LED signs, this study was intended to be a pilot study. The study provides a conceptual framework for future studies and clarifies the multi-factor structure of managers' attitudes toward the LED signs.

The study was based on a small group of respondents in a single southeastern community. Questions of statistical significance generally concern sample size, randomness of

the sample, and tolerance levels. Although there is reason to believe that the sample size was sufficient to produce reliable results, especially considering the size of the population, limitations on the sample size should obviously be kept in mind. The study also did not explore the question where or not the results could be generalized to other communities. The scope of the study was limited to six classification variables and nine perception scales. Because of this, the findings of this study should be considered preliminary rather than conclusive. No attempts were made to study consumers' attitudes and perceptions.

Recommendations For Future Research

Future research might expand on this study by considering additional classification variables, and additional perceptual or attitudinal dimensions. Future research would also benefit from larger sample sizes across a broader geographic spectrum. The results of this pilot study could be used to help validate future research. Future studies might also investigate perceptions and attitudes of consumers and contrast these two views held by owners/managers of businesses.

Conclusion

Since there have been very few published studies of effectiveness of LED signs, this study contributes to the literature by providing empirical evidence of the effectiveness of outdoor LED signs. Results of this study suggested that these signs were generally perceived to be cost-effective, easy-to-use, and helped customers find the location of the business. These findings were generally consistent regardless of size of the signs and across types of businesses, types of signs and elevation. Two-sided signs were found to be more effective than one-sided signs. Signs with either to or more of three lines of text were more effective than signs with either one or three lines of text.

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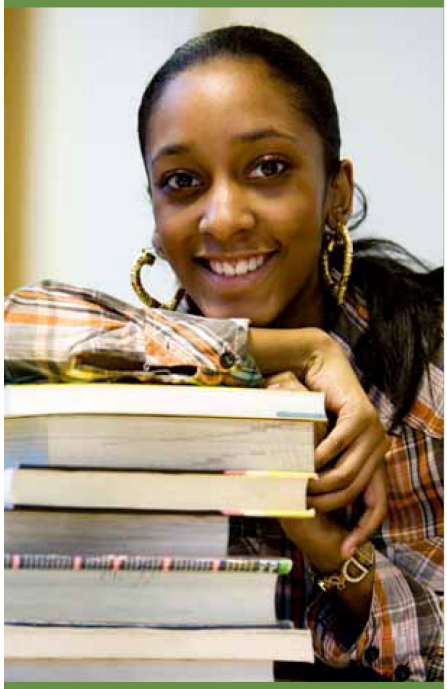

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Proposing a Mathematical Programming Model for Optimization of Supply Chain Scheduling

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ABSTRACT

Supply chain scheduling is an integrated approach to the production planning and inventory control of systems. The purpose of this paper is to formulate the generalized supply chain scheduling issue in which the objective is to minimize sum of the costs incurred within all of the echelons of supply chain. A mixed integer non-linear programming (MINLP) model is proposed for this problem. Variety of constraints such as production capacity in regular and overtimes, inventory holding capacities, and distribution capacity with regard to different modes of transportation, are considered in order to simulate a real situation better. Inventory shortages and lead-times for transporting components and final products among various echelons are also incorporated into the proposed model. Finally, a numerical example in a small-sized problem is presented to show the applicability and performance of proposed model.

Introduction

Supply chain scheduling has been recognized as an integrated approach to the production planning and inventory control, throughout the entire network of cooperating organizations from the source of supply to the final customers. Nowadays, most of the manufacturing enterprises attempt to persue new methods and approaches to improve their competitive advantage. Regarding this matter, aggregate production-distribution planning (APDP) is one of the effective attitudes and can be considered as one of the vital processes in supply chains scheduling. Studying the literature shows that variety of research are conducted in order to deal with this issue. For instance, Xiaoming Yan et al. (2010) extended the model of Coordination in decentralized assembly systems with uncertain component yields and proposed a new kind of contract, surplus subsidy contract, where the leader (the assembler) provides the contract, while the followers (component suppliers) make their choices simultaneously. Yugang Yu and George Q. Huang (2010) considered a VMI supply chain where a manufacturer and multiple retailers interact with each other in order to maximize their own profits. Yuanjie He, Jiang Zhang (2010) studied a supply chain with one supplier and one retailer when the supplier has random yield and the option of trading in a secondary market. They evaluated both the centralized and decentralized systems. Yao et al. (2010) developed an incentive contract that results in benefits for both upstream and downstream supply chain partners under a VMI arrangement. Schmitt et al. (2010) examined optimal base-stock inventory policies using infinite-horizon, periodic-review models, for a single supplier whose single retailer is subject to stochastic disruptions. Xueipng Li andYuerong Chen (2010), based on simulation techniques, investigated the impacts of supply

disruptions and customer differentiation on the minimum average annual total cost of the retailer. They considered different scenarios of disruption frequency and duration. Yang and Yi Lin (2010) proposed a serial multi-echelon integrated just in-time (JIT) model based on uncertain delivery lead time and quality unreliability considerations. In this paper, we analyze a a multi-echelon supply chain scheduling system containing five echelons: multi-supplier, multi-manufacturer, multi-distribution centers (DCs), multi-retailer and multi-customer while there are variety of tranportation mode for transporting the components and products among various echelons. Moreover, a mixed integer non-linear programming (MINLP) model is proposed for this problem.

Problem Description

Production planning and inventory control as well as distribution and logistics systems are the main processes in supply chains scheduling. Aggregate production-distribution planning (APDP) takes both of these processes into consideration simultaneously. Here, supply chain scheduling in a multi-echelon supply chain that entails suppliers, manufacturers, distribution centers, retailers and final customers is considered and a mathematical model for optimization of that will be proposed. There are various modes of transportation in order to carry components and final products from each echelon to another (Figure 1).

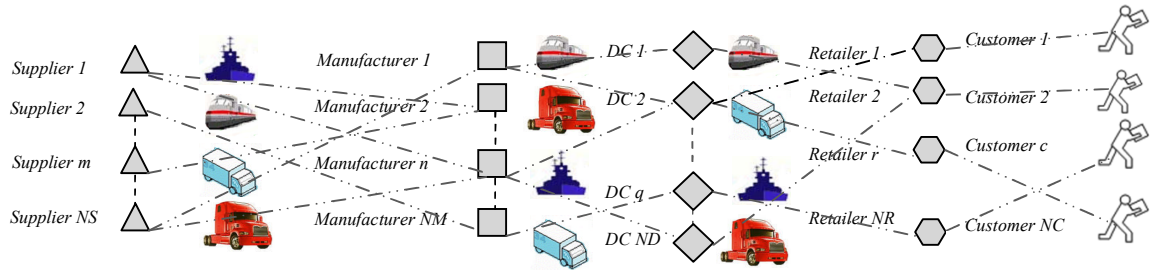

Figure 1 Considered supply chain with various echelons and different modes of transportation.

It is assumed that, in each period, customers' demands are known and deterministic. Each retailer may encounter shortage in meeting customers' demands and there is partial backordering for each type of product. All costs are assumed to be known and accurately determined over the planning horizon. Lead-times of delivering components and products from one echelon to another are considered. The list of indices, parameters and decision variables are introduced by the following.

Indices:	
U	Index of different types of components required for finished products.
I	Index of various finished products.
M	Index of suppliers.
N	Index of manufacturers.
Q	Index of distribution centers.
R	Index of retailers.
C	Index of customers.

J	Index of various modes of transportation.
T	Index of periods.

Parameters:

NS	Number of suppliers.
NM	Number of manufacturers.
ND	Number of distribution centers.
NR	Number of retailers.
NC	Number of customers.
NU	Number of components.
NP	Number of products.
NV	Number of various modes of transportation.
T	Number of periods.
τ_m	Ordering set-up cost of m^{th} supplier.
$S_{u,m}$	Unit selling price of u^{th} component offered by m^{th} supplier to manufacturers.
$CT_{i,n}$	Processing time of i^{th} product at n^{th} manufacturer's site.
$D_{i,r,c,t}$	Demand of i^{th} product at r^{th} retailer's site related to c^{th} customer occurred in t^{th} period.
$CPR_{n,t}$	Regular time Capacity for production at n^{th} manufacturer's site in t^{th} period.
$CPO_{n,t}$	Overtime time Capacity for production at n^{th} manufacturer's site in t^{th} period.
$CC_{i,n,t}$	Fixed cost of producing i^{th} product at n^{th} manufacturer's site in t^{th} period.
$CVR_{i,n,t}$	Variable production cost of i^{th} product in regular time at n^{th} manufacturer's site in t^{th} period.
$CVO_{i,n,t}$	Variable production cost of i^{th} product in overtime at n^{th} manufacturer's site in t^{th} period.
$CTUS_{j,m,n,t}$	Capacity of j^{th} transportation mode for carrying various components from m^{th} supplier to n^{th} manufacturer.
$CTPM_{j,n,q,t}$	Capacity of j^{th} transportation mode for carrying various products from n^{th} manufacturer to q^{th} distribution center.
$CTPD_{j,q,r,t}$	Capacity of j^{th} transportation mode for carrying various products from q^{th} distribution center to r^{th} retailer.
$CTRU_{j,m,n,t}$	Fixed cost of transportation related to j^{th} transportation mode from m^{th} suppliers to n^{th} manufacturer at t^{th} period.
$CTRM_{j,n,q,t}$	Fixed cost of transportation related to j^{th} transportation mode from n^{th} manufacturer to q^{th} distribution center at t^{th} period.
$CTRD_{j,q,r,t}$	Fixed cost of transportation related to j^{th} transportation mode from q^{th} distribution center to r^{th} retailer at t^{th} period.
$CTOU_{j,m,n,t}$	Unit variable cost of transportation related to j^{th} transportation mode from m^{th} supplier to n^{th} manufacturer at t^{th} period.
$CTOM_{j,n,q,t}$	Unit variable cost of transportation related to jth transportation mode from nth manufacturer to q^{th} distribution center at tth period.
$CTOD_{j,q,r,t}$	Unit variable cost of transportation related to j^{th} transportation mode from q^{th} distribution centers to to r^{th} retailer at t^{th} period.
V_u	Volume occupied by each unit of u^{th} component.
W_i	Volume occupied by each unit of i^{th} product.

STS_m	Maximum store volume related to m^{th} supplier for holding components.
$STMU_n$	Maximum store volume related to n^{th} manufacturer for holding components.
$STMP_n$	Maximum store volume related to n^{th} manufacturer for holding products.
STD_q	Maximum store volume related to q^{th} distribution center for holding products.
STR_r	Maximum store volume related to r^{th} retailer for holding products.
$\pi_{i,r}$	Unit backorder cost of i^{th} product at r^{th} retailer's site in t^{th} period.
$F_{u,i}$	Coefficient of consumption related to u^{th} component in i^{th} product.
$hus_{u,m}$	Unit inventory holding cost of u^{th} component at m^{th} supplier's site per unit time.
$hum_{u,n}$	Unit inventory holding cost of u^{th} component at n^{th} manufacturer's site per unit time.
$hpm_{i,n}$	Unit inventory holding cost of i^{th} product at n^{th} manufacturer's site per unit time.
$hpd_{i,q}$	Unit inventory holding cost of i^{th} product at q^{th} distribution center's site per unit time.
$hpr_{i,r}$	Unit inventory holding cost of i^{th} product at r^{th} retailer's site per unit time.
$Lus_{u,m,n}$	Lead-time of delivering u^{th} component from m^{th} supplier to n^{th} manufacturer.
$Lpm_{i,n,q}$	Lead-time of delivering i^{th} product from n^{th} manufacturer to q^{th} distribution center.
$Lpd_{i,q,r}$	Lead-time of delivering i^{th} product from q^{th} distribution center to r^{th} retailer.
$MUS_{u,m,t}$	Minimum quantity of u^{th} component required at m^{th} supplier's site in t^{th} period.

Decision variables:

$QUMV_{j,u,m,n,t}$	The amount of units which is related to the u^{th} component delivered from m^{th} supplier to n^{th} manufacturer by j^{th} transportation mode in t^{th} period.
$QPDV_{j,i,n,q,t}$	The amount of units which is related to the i^{th} product delivered from n^{th} manufacturer to q^{th} distribution center by j^{th} transportation mode in t^{th} period.
$QPRV_{j,i,q,r,t}$	The amount of units which is related to the i^{th} product delivered from q^{th} distribution center to r^{th} retailer by j^{th} transportation mode in t^{th} period.
$IUS_{u,m,t}$	Amount of inventory related to u^{th} component at m^{th} supplier's site in the end of t^{th} period.
$IUM_{u,n,t}$	Amount of inventory related to u^{th} component at n^{th} manufacturer's site in the end of t^{th} period.
$IPM_{i,n,t}$	Amount of inventory related to i^{th} product at n^{th} manufacturer's site in the end of t^{th} period.
$IPD_{i,q,t}$	Amount of inventory related to i^{th} product at q^{th} distribution center's site in the end of t^{th} period.
$IPR_{i,r,t}$	Amount of inventory related to i^{th} product at r^{th} retailer's site in the end of t^{th} period.
$B_{i,r,t}$	The amount of i^{th} product backordered by r^{th} retailer in the end of t^{th} period.
$RTP_{n,t}$	Overall regular time which must be allocated for production at n^{th} manufacture's site in t^{th} period.
$OTP_{n,t}$	Overall overtime which must be allocated for production at n^{th} manufacture's site in t^{th} period.
$X_{i,n,t}$	The amount of produced units which is related to the i^{th} product at n^{th}

manufacturer's site in t^{th} priod.

$Y_{j,m,n,t}$	$\begin{cases}1\\0\end{cases}$	If j^{h} transportation mode is utilized for carrying components from u^{th} suppliers to n^{th} manufacturer in t^{th} period. Otherwise
$\psi_{j,n,q,t}$	$\begin{cases}1\\0\end{cases}$	If j^{h} transportation mode is utilized for carrying products from n^{th} manufacturer to q^{th} distribution center in t^{th} period. Otherwise
$\eta_{j,q,r,t}$	$\begin{cases}1\\0\end{cases}$	If j^{th} transportation mode is utilized for carrying products from q^{th} distribution center to r^{th} retailer in t^{th} period. Otherwise
$\phi_{i,n,t}$	$\begin{cases}1\\0\end{cases}$	If i^{th} product is set to be produced at n^{th} manufacturer in t^{th} period. Otherwise
$\beta_{m,n,t}$	$\begin{cases}1\\0\end{cases}$	If n^{th} manufacturer places order to m^{th} supplier in t^{th} period. Otherwise

Regarding the aforementioned notations, a generalized model is proposed as following in order to formulate the problem of scheduling aggregate production and distribution in supply chain:

$$Min \quad TC = Z_1 + Z_2 + Z_3 + Z_4 + Z_5 + Z_6 \tag{1}$$

Subject to:

$$Z_1 = \left\{ \sum_{u=1}^{NU} \sum_{m=1}^{NS} \sum_{t=1}^{T} hus_{u,m}.IUS_{u,m,t} \right\} \tag{2}$$

$$Z_2 = \begin{cases} \left(\sum_{m=1}^{NS} \sum_{n=1}^{NM} \sum_{t=1}^{T} ((\tau_m.\beta_{m,n,t}) + \sum_{u=1}^{NU} S_{u,m}.(\sum_{j=1}^{NV} QUMV_{j,u,m,n,t})) \right) + \left(\sum_{j=1}^{NV} \sum_{m=1}^{NS} \sum_{n=1}^{NM} \sum_{t=1}^{T} CTRU_{j,m,n,t}.Y_{j,m,n,t} \right) - \\ \left(\sum_{j=1}^{NV} \sum_{u=1}^{NU} \sum_{m=1}^{NS} \sum_{n=1`}^{NM} \sum_{t=1}^{T} CTOU_{j,m,n,t}.QUMV_{j,u,m,n,t} \right) + \\ \left(\sum_{i=1}^{NP} \sum_{n=1}^{NM} \sum_{t=1}^{T} ((\sum_{u=1}^{NU} hum_{u,n}).IUM_{i,n,t} + hpm_{i,n}.IPM_{i,n,t}) \right) \end{cases} \tag{3}$$

$$Z_3 = \left\{ \left(\sum_{n=1}^{NM} \sum_{t=1}^{T} ((\sum_{i=1}^{NP} CVR_{i,n,t}).RTP_{n,t} + (\sum_{i=1}^{NP} CVO_{i,n,t}).OTP_{n,t}) \right) + \left(\sum_{i=1}^{NP} \sum_{n=1}^{NM} \sum_{t=1}^{T} CC_{i,n,t}.\phi_{i,n,t} \right) \right\} \tag{4}$$

$$Z_4 = \begin{cases} \left(\sum_{j=1}^{NV} \sum_{n=1}^{NM} \sum_{q=1}^{ND} \sum_{t=1}^{T} CTRM_{j,n,q,t}.\psi_{j,n,q,t} \right) + \left(\sum_{j=1}^{NV} \sum_{i=1}^{NP} \sum_{n=1}^{NM} \sum_{q=1`}^{ND} \sum_{t=1}^{T} CTOM_{j,n,q,t}.QPDV_{j,i,n,q,t} \right) + \\ \left(\sum_{i=1}^{NP} \sum_{q=1}^{ND} \sum_{t=1}^{T} (hpd_{i,q}.IPD_{i,q,t}) \right) \end{cases} \tag{5}$$

$$Z_5 = \left\{ \begin{array}{l} \left(\sum_{j=1}^{NV} \sum_{q=1}^{ND} \sum_{r=1}^{NR} \sum_{t=1}^{T} CTRD_{j,q,r,t}.\eta_{j,q,r,t} \right) + \left(\sum_{j=1}^{NV} \sum_{i=1}^{NP} \sum_{q=1}^{ND} \sum_{r=1`}^{NR} \sum_{t=1}^{T} CTOD_{j,q,r,t}.QPRV_{j,i,q,r,t} \right) + \\ \left(\sum_{i=1}^{NP} \sum_{r=1}^{NR} \sum_{t=1}^{T} (hpr_{\mathrm{i,r}}.IPR_{i,r,t}) \right) \end{array} \right\} \quad (6)$$

$$Z_6 = \left\{ \sum_{i=1}^{NP} \sum_{r=1}^{NR} \sum_{t=1}^{T} \pi_{i,r}.B_{i,r,t} \right\} \quad (7)$$

$$IUS_{u,m,t} = IUS_{u,m,t-1} - (\sum_{j=1}^{NV} \sum_{n=1}^{NM} QUMV_{j,u,m,n,t}) + MUS_{u,m,t} \quad \forall \quad u,m,t \quad (8)$$

$$IUM_{u,n,t} = IUM_{u,n,t-1} + (\sum_{j=1}^{NV} \sum_{m=1}^{NS} QUMV_{j,u,m,n,(t-Lus_{u,m,n})}) - \sum_{i=1}^{NP} F_{u,i}.X_{i,n,t} \quad \forall \quad u,n,t \mid t > Lus_{u,m,n} \quad (9)$$

$$IPM_{i,n,t} = IPM_{i,n,t-1} + X_{i,n,t} - (\sum_{j=1}^{NV} \sum_{q=1}^{ND} QPDV_{j,i,n,q,t}) \quad \forall \quad i,n,t \quad (10)$$

$$IPD_{i,q,t} = IPD_{i,q,t-1} + (\sum_{j=1}^{NV} \sum_{n=1}^{NM} QPDV_{j,i,n,q,(t-Lpm_{i,n,q})}) - \sum_{j=1}^{NV} \sum_{r=1}^{NR} QPRV_{j,i,q,r,t} \quad \forall \quad i,q,t \mid t > Lpm_{i,n,q} \quad (11)$$

$$IPR_{i,r,t} - B_{i,r,t} = IPR_{i,r,t-1} - B_{i,r,t-1} + (\sum_{j=1}^{NV} \sum_{q=1}^{ND} QPRV_{j,i,q,r,(t-Lpd_{i,q,r})}) - \sum_{c=1}^{NC} D_{i,r,c,t} \quad \forall \quad i,r,t \mid t > Lpd_{i,q,r} \quad (12)$$

$$(\sum_{l=t}^{T} \sum_{i=1}^{NP} F_{u,i}.(\sum_{j=1}^{NV} \sum_{q=1}^{ND} QPDV_{j,i,n,q,t})).\beta_{m,n,t} \geq \sum_{j=1}^{NV} QUMV_{j,u,m,n,t} \quad \forall \quad u,m,n,t \quad (13)$$

$$(\sum_{i=1}^{NP} CT_{i,n}.X_{i,n,t}) - (RTP_{n,t} + OTP_{n,t}) \leq 0 \quad \forall \quad n,t \quad (14)$$

$$RTP_{n,t} - CPR_{n,t} \leq 0 \quad \forall \quad n,t \quad (15)$$

$$OTP_{n,t} - CPO_{n,t} \leq 0 \quad \forall \quad n,t \quad (16)$$

$$X_{i,n,t} \leq \phi_{i,n,t}.M^{\infty} \quad \forall \quad i,n,t \quad (17)$$

$$MUS_{u,m,(t-Lus_{u,m,n})} \geq F_{u,i}.X_{i,n,t} \quad \forall \quad i,u,m,n,t \mid t > Lus_u \quad (18)$$

$$\sum_{u=1}^{NU} QUMV_{j,u,m,n,t} \leq CTUS_{j,m,n,t}.Y_{j,m,n,t} \quad \forall \quad j,m,n,t \quad (19)$$

$$\sum_{i=1}^{NP} QPDV_{j,i,n,q,t} \leq CTPM_{j,n,q,t}.\psi_{j,n,q,t} \quad \forall \quad j,n,q,t \quad (20)$$

$$\sum_{i=1}^{NP} QPRV_{j,i,q,r,t} \leq CTPD_{j,q,r,t}.\eta_{j,q,r,t} \quad \forall \quad j,q,r,t \quad (21)$$

$$\sum_{u=1}^{NU} V_u.IUS_{u,m,t} \leq STS_m \quad \forall \quad m,t \quad (22)$$

$$\sum_{u=1}^{NU} V_u.IUM_{u,n,t} \leq STMU_n \quad \forall \quad n,t \quad (23)$$

$$\sum_{i=1}^{NP} W_i.IPM_{i,n,t} \leq STMP_n \quad \forall \quad n,t \quad (24)$$

$$\sum_{i=1}^{NP} W_i . IPD_{i,q,t} \le STD_q \qquad \forall \quad q,t \qquad (25)$$

$$\sum_{i=1}^{NP} W_i . IPR_{i,r,t} \le STR_r \qquad \forall \quad r,t \qquad (26)$$

$$QUMV_{j,u,m,n,t}, QPDV_{j,i,n,q,t}, QPRV_{j,i,q,r,t}, IUS_{u,m,t}, IUM_{u,n,t}, IPM_{i,n,t}, IPD_{i,q,t}, IPR_{i,r,t}, B_{i,r,t}, RTP_{n,t}, OTP_{n,t}, X_{i,n,t} \in Z^+ \cup \{0\} \qquad \forall \quad i,j,u,m,n,q,r,t \qquad (27)$$

$$Y_{j,m,n,t}, \psi_{j,n,q,t}, \eta_{j,q,r,t}, \phi_{i,n,t}, \beta_{m,n,t} \in \{0,1\} \qquad \forall \quad i,j,m,n,q,r,t \qquad (28)$$

Objective function (Eq.1) minimizes sum of the production, transportation, and inventory costs through the whole supply chain system. Term Z_1 refers to the holding inventory costs of components at suppliers 'sites (Eq2). Term Z_2 denotes fixed ordering costs of components to suppliers, purchasing costs of components from suppliers, fixed and variable costs of transporting components from suppliers to manufacturers and holding inventory costs of components at manufacturers 'sites (Eq.3). Term Z_3 is related to the fixed and variable costs of production in regular and over time situation at manufacturers 'sites (Eq.4). Term Z_4 is associated with fixed and variable costs of transporting products from manufacturers to distribution centers and holding inventory costs of products at distribution centers 'sites (Eq.5). Similarly, term Z_5 represents fixed and variable costs of transporting products from distribution centers to retailers and holding inventory costs of products at retailers 'sites (Eq.6). Term Z_6 stands for backordering costs of products at retailers' sites. Equations (8)-(12) are inventory balance constraints. Constraint (13) certifies that there is not an order for procuring components without charging an appropriate transaction cost (ordering cost). Constraints (14)-(16), (18) are resource constraints. Constraint (17) refers to this fact whether production of products sets up at manufacturers' sites or not. Constraints (19)-(21) refer to transportation capacity. Constraints (22)-(26) are inventory capacity constraints. Moreover, constraint (27) shows that all decision variables except the aforementioned binary variables are nonnegative real variables. Furthermore, constraint (28) sets the values of binary variables.

Solution Method & Numerical Example

In this section, in order to solve the proposed mixed integer non-linear programming (MINLP), the branch and bound algorithm by applying the lingo software is utilized. To illustrate the proposed model and the solution schemes, a numerical example is applied. The model is implemented to small-sized instances and satisfactory results are obtained. It is given that a supply chain system has five echelons containing three suppliers, three manufacturers, three distribution centers, three retailers and three customers. There are two different components which are applied to form two kinds of finished products. Consider that the supply chain scheduling will be determined for three periods (It is given that each period is equal to 3 month). Moreover, it is taken into account that there are two different modes of transportation and lead-times are negligible. Tables (1)-(26) denote the values of various parameters regarding this numerical example. This problem is formulated by applying the proposed model. Then it is solved to optimality using LINGO (LINDO Systems Online, 2007) and run on a Pentium (R) 4CPU 3.000 GHz PC. The Objective value obtained equal 6499450 (Figure 2) and optimal scheduling policy for considered supply chain achieved.

Table 1. Ordering set-up cost of suppliers.

Supplier 1	Supplier 2	Supplier 3
100	200	150

Table 2. Unit sale price of components by suppliers

	Component 1	Component 2
Supplier 1	10	12
Supplier 2	15	11
Supplier 3	20	20

Table 3. Processing time of products at manufacturers' sites

	Product 1	Product 2	Product 3
Manufacturer 1	0.5 hour	0.8 hour	1 hour
Manufacturer 2	0.3 hour	0.6 hour	0.9 hour
Manufacturer 3	1 hour	1 hour	0.7 hour

Table 4. Demand of customers occurred at retailers' sites

			Period 1	Period 2	Period 3
Retailer 1	Customer 1	Product 1	770	500	550
		Product 2	600	480	500
		Product 3	690	500	510
	Customer 2	Product 1	700	510	510
		Product 2	710	500	520
		Product 3	560	500	510
	Customer 3	Product 1	760	500	500
		Product 2	710	500	520
		Product 3	770	500	550
Retailer 2	Customer 1	Product 1	740	510	520
		Product 2	690	500	510
		Product 3	700	510	510
	Customer 2	Product 1	590	510	500
		Product 2	560	500	510
		Product 3	760	500	500
	Customer 3	Product 1	710	500	520
		Product 2	760	500	500
		Product 3	560	500	510
Retailer 3	Customer 1	Product 1	690	500	510
		Product 2	740	510	520
		Product 3	760	500	500
	Customer 2	Product 1	560	500	510
		Product 2	590	510	500
		Product 3	740	510	520
	Customer 3	Product 1	570	510	500
		Product 2	520	520	600
		Product 3	560	500	510

Table 5. Regular time Capacity for production at manufacturers' site in each period

	Period1	Period 2	Period 3
Manufacturer 1	1344 hour	1300 hour	1200 hour
Manufacturer 2	1100 hour	1300 hour	1200 hour
Manufacturer 3	1220 hour	1310 hour	1220 hour

Table 6. Overtime time Capacity for production at manufacturers' site in each period

	Period1	Period 2	Period 3
Manufacturer 1	400 hour	300 hour	450 hour
Manufacturer 2	380 hour	400 hour	420 hour
Manufacturer 3	320 hour	350 hour	380 hour

Table 7. Fixed cost of producing products at manufacturers 'sites in each period

		Period1	Period 2	Period 3
Manufacturer 1	Product 1	40	70	30
	Product 2	30	50	60
	Product 3	70	80	60
Manufacturer 2	Product 1	50	60	40
	Product 2	70	60	40
	Product 3	50	60	40
Manufacturer 3	Product 1	50	40	30
	Product 2	40	60	60
	Product 3	40	50	60

Table 8. Unit variable production cost in regular time at manufacturers 'sites in each period

		Period1	Period 2	Period 3
Manufacturer 1	Product 1	12	13	10
	Product 2	17	16	12
	Product 3	14	10	10
Manufacturer 2	Product 1	16	15	11
	Product 2	15	10	15
	Product 3	12	15	10
Manufacturer 3	Product 1	13	12	10
	Product 2	16	10	12
	Product 3	16	12	10

Table 9. Unit variable production cost in overtime at manufacturers 'sites in each period

		Period1	Period 2	Period 3
Manufacturer 1	Product 1	14	15	11
	Product 2	19	18	14
	Product 3	19	15	14
Manufacturer 2	Product 1	18	16	16
	Product 2	18	15	17
	Product 3	18	17	16
Manufacturer 3	Product 1	14	16	11
	Product 2	19	16	14
	Product 3	19	17	14

Table 10. Capacity of transportation modes for carrying components from suppliers to manufacturers

			Period 1	Period 2	Period 3
Transportation mode 1	Supplier 1	Manufacturer 1	1000	2000	2500
		Manufacturer 2	1000	2200	1200
		Manufacturer 3	4000	2000	3000
	Supplier 2	Manufacturer 1	1500	3000	3200
		Manufacturer 2	3000	2000	1000
		Manufacturer 3	3000	2000	2000
	Supplier 3	Manufacturer 1	2000	2500	3000
		Manufacturer 2	2000	2000	2000
		Manufacturer 3	2500	1000	1200
Transportation mode 2	Supplier 1	Manufacturer 1	1100	1400	1500
		Manufacturer 2	4000	2000	3000
		Manufacturer 3	1500	3000	3200
	Supplier 2	Manufacturer 1	3000	2000	1000
		Manufacturer 2	1000	1200	1500
		Manufacturer 3	3000	2000	2000
	Supplier 3	Manufacturer 1	2000	2500	3000
		Manufacturer 2	2000	2000	2000
		Manufacturer 3	2500	1000	1200

Table 11.Capacity of transportation modes for carrying products from manufacturers to DCs

			Period 1	Period 2	Period 3
Transportation mode 1	Manufacturer 1	DC 1	1100	2000	2500
		DC 2	1000	2200	1200
		DC 3	4000	2000	3000
	Manufacturer 2	DC 1	1500	3300	3200
		DC 2	3000	2200	1000
		DC 3	3000	2000	2000
	Manufacturer 3	DC 1	2000	2700	3000
		DC 2	2000	2500	2000
		DC 3	2500	1000	1200
Transportation mode 2	Manufacturer 1	DC 1	1200	1400	1500
		DC 2	4000	2000	3000
		DC 3	1500	3200	3200
	Manufacturer 2	DC 1	3000	2000	1000
		DC 2	1000	1200	1500
		DC 3	3000	2000	2000
	Manufacturer 3	DC 1	2000	2500	3000
		DC 2	2000	2000	2000
		DC 3	2500	1200	1200

Table 12. Capacity of transportation modes for carrying products from DCs to retailers

			Period 1	Period 2	Period 3
Transportation mode 1	DC 1	Retailer 1	1100	2000	2500
		Retailer 2	1000	2200	1200
		Retailer 3	4000	2500	3000
	DC 2	Retailer 1	1500	3300	3200
		Retailer 2	3100	2200	1000
		Retailer 3	3000	2000	2000
	DC 3	Retailer 1	2500	2700	3000
		Retailer 2	2000	2500	2000
		Retailer 3	2500	1000	1200
Transportation mode 2	DC 1	Retailer 1	1200	1400	1500
		Retailer 2	4000	2200	3000
		Retailer 3	1500	3200	3200
	DC 2	Retailer 1	3000	2000	1000
		Retailer 2	1800	1200	1500
		Retailer 3	3000	2000	2000
	DC 3	Retailer 1	2000	2500	3000
		Retailer 2	2300	2200	2000
		Retailer 3	2500	1200	1200

Table 13. Fixed cost of transportation related to transportation modes from suppliers to manufacturer in each period

			Period 1	Period 2	Period 3
Transportation mode 1	Supplier 1	Manufacturer 1	60	40	70
		Manufacturer 2	90	30	40
		Manufacturer 3	70	40	60
	Supplier 2	Manufacturer 1	50	70	60
		Manufacturer 2	60	40	30
		Manufacturer 3	60	70	90
	Supplier 3	Manufacturer 1	60	40	50
		Manufacturer 2	60	50	40
		Manufacturer 3	30	40	30
Transportation mode 2	Supplier 1	Manufacturer 1	50	40	30
		Manufacturer 2	40	30	30
		Manufacturer 3	50	40	30
	Supplier 2	Manufacturer 1	40	30	30
		Manufacturer 2	50	40	30
		Manufacturer 3	40	30	50
	Supplier 3	Manufacturer 1	30	30	40
		Manufacturer 2	50	40	30
		Manufacturer 3	40	30	30

Table 14. Unit variable cost of transportation related to transportation modes from suppliers to manufacturer in each period

			Period 1	Period 2	Period 3
Transportation mode 1	Supplier 1	Manufacturer 1	18	15	16
		Manufacturer 2	20	13	14
		Manufacturer 3	20	18	16
	Supplier 2	Manufacturer 1	30	12	15
		Manufacturer 2	14	15	11
		Manufacturer 3	20	30	16
	Supplier 3	Manufacturer 1	14	15	12
		Manufacturer 2	18	19	20
		Manufacturer 3	18	19	16
Transportation mode 2	Supplier 1	Manufacturer 1	14	12	10
		Manufacturer 2	18	12	20
		Manufacturer 3	19	12	14
	Supplier 2	Manufacturer 1	18	12	16
		Manufacturer 2	18	17	16
		Manufacturer 3	18	20	19
	Supplier 3	Manufacturer 1	14	12	10
		Manufacturer 2	12	14	16
		Manufacturer 3	11	12	14

Table 15. Fixed cost of transportation related to transportation modes from manufacturer to DCs in each period

			Period 1	Period 2	Period 3
Transportation mode 1	Manufacturer 1	DC 1	70	40	60
		DC 2	40	50	30
		DC 3	70	40	50
	Manufacturer 2	DC 1	60	40	70
		DC 2	90	30	40
		DC 3	70	40	60
	Manufacturer 3	DC 1	50	70	60
		DC 2	60	40	30
		DC 3	60	70	90
Transportation mode 2	Manufacturer 1	DC 1	40	50	40
		DC 2	60	70	50
		DC 3	40	50	40
	Manufacturer 2	DC 1	60	70	50
		DC 2	40	40	50
		DC 3	30	40	60
	Manufacturer 3	DC 1	40	50	60
		DC 2	60	50	40
		DC 3	30	40	50

Table 16. Unit variable cost of transportation related to transportation modes from manufacturer to DCs in each period

			Period 1	Period 2	Period 3
Transportation mode 1	Manufacturer 1	DC 1	19	15	16
		DC 2	20	13	14
		DC 3	20	18	16
	Manufacturer 2	DC 1	30	12	15
		DC 2	14	20	11
		DC 3	20	30	16
	Manufacturer 3	DC 1	14	15	12
		DC 2	18	19	20
		DC 3	18	14	16
Transportation mode 2	Manufacturer 1	DC 1	14	22	10
		DC 2	18	12	20
		DC 3	19	12	14
	Manufacturer 2	DC 1	19	12	16
		DC 2	18	17	16
		DC 3	18	20	19
	Manufacturer 3	DC 1	14	12	10
		DC 2	12	14	16
		DC 3	14	12	14

Table 17. Fixed cost of transportation related to transportation modes from DCs to retailers in each period

			Period 1	Period 2	Period 3
Transportation mode 1	DC 1	Retailer 1	30	40	50
		Retailer 2	70	40	60
		Retailer 3	40	50	30
	DC 2	Retailer 1	70	40	50
		Retailer 2	60	40	70
		Retailer 3	90	30	40
	DC 3	Retailer 1	40	50	40
		Retailer 2	40	30	50
		Retailer 3	60	40	50
Transportation mode 2	DC 1	Retailer 1	60	50	40
		Retailer 2	30	40	30
		Retailer 3	50	40	30
	DC 2	Retailer 1	40	30	30
		Retailer 2	50	40	30
		Retailer 3	40	30	30
	DC 3	Retailer 1	50	40	30
		Retailer 2	40	30	50
		Retailer 3	30	30	40

Table 18. Unit variable cost of transportation related to transportation modes from DCs to retailers in each period

			Period 1	Period 2	Period 3
Transportation mode 1	DC 1	Retailer 1	20	15	16
		Retailer 2	20	15	14
		Retailer 3	20	18	16
	DC 2	Retailer 1	30	12	15
		Retailer 2	14	20	11
		Retailer 3	20	30	16
	DC 3	Retailer 1	14	15	22
		Retailer 2	19	19	20
		Retailer 3	18	14	16
Transportation mode 2	DC 1	Retailer 1	14	22	10
		Retailer 2	18	14	20
		Retailer 3	19	12	14
	DC 2	Retailer 1	19	12	16
		Retailer 2	18	17	16
		Retailer 3	18	20	19
	DC 3	Retailer 1	14	12	10
		Retailer 2	12	14	16
		Retailer 3	14	12	14

Table 19. Volume occupied by each unit of components and products

Component 1	Component 2	Product 1	Product 2	Product 3
0.2	0.18	0.7	0.3	0.5

Table 20. Maximum store volume for holding components in various members of supply chain

Supplier 1	Supplier 2	Supplier 3	Manufacturer 1	Manufacturer 2	Manufacturer 3
20	25	30	40	25	30

Table 21.Maximum store volume for holding products in various members of supply chain

Manufacturer 1	Manufacturer 2	Manufacturer 3	DC1	DC2	DC3	Retailer 1	Retailer 2	Retailer 3
20	35	45	40	25	30	30	25	30

Table 22. Unit backorder cost of products at retailers' sites

	Retailer 1	Retailer 2	Retailer 3
Product 1	200	210	150
Product 2	180	210	200
Product 3	190	200	210

Table 23. Coefficient of consumption related to components in forming products

	Component 1	Component 2
Product 1	1	2
Product 2	2	1
Product 3	2	2

Table 24. Unit inventory holding cost of components at suppliers and manufacturers' sites

	Component 1	Component 2
Supplier 1	1	1
Supplier 2	2	1
Supplier 3	1	2
Manufacturer 1	2	1
Manufacturer 2	2	1
Manufacturer 3	1	2

Table 25. Unit inventory holding cost of products at manufacturers, DCs and retailers' sites

	Product 1	Product 2	Product 3
Manufacturer 1	2	2	1
Manufacturer 2	1	1	1
Manufacturer 3	1	2	1
DC 1	2	2	1
DC 2	1	1	1
DC 3	1	1	2
Retailer 1	2	1	2
Retailer 2	1	1	2
Retailer 3	1	1	1

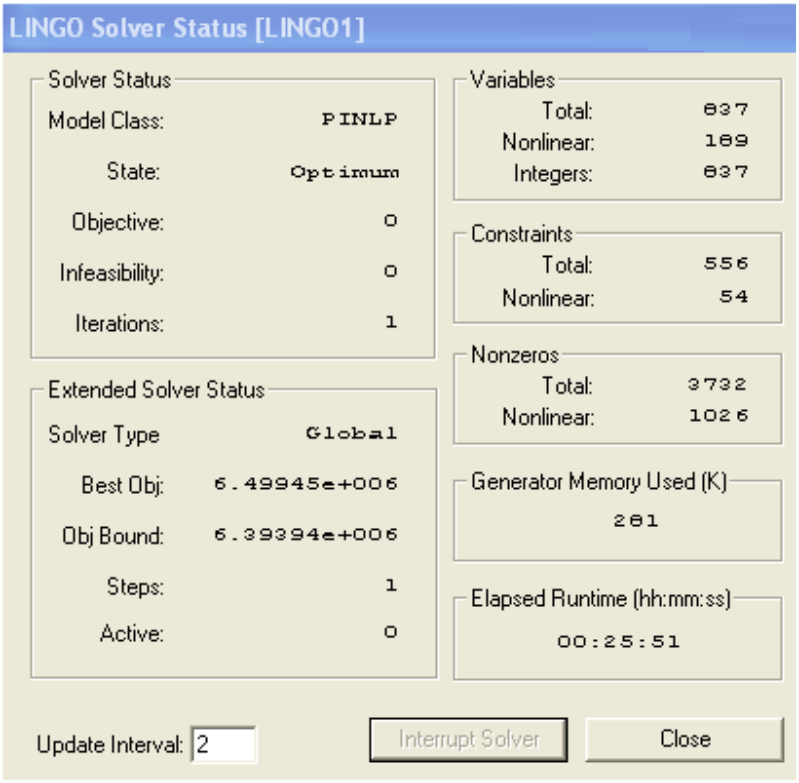

Figure 2. The result of solving model by lingo software

Conclusions and Future Research

The current paper aims at providing a mathematical model capable of production planning and controlling the inventory in supply chain scheduling issue. The proposed aggregate model is able to balance the costs at different levels and define the lot size of ordering among various echelons considering the existence of various modes of transportation and lead-times. This model can provide an efficient guideline for managers and experts to deal with supply chain scheduling issue effectively.

An open line for future research is to deal with the location of facilities and routing of vehicles through them. Moreover, due to the complexity of this problem, heuristic and meta-heuristic algorithms can be utilized to solve large scale instances.

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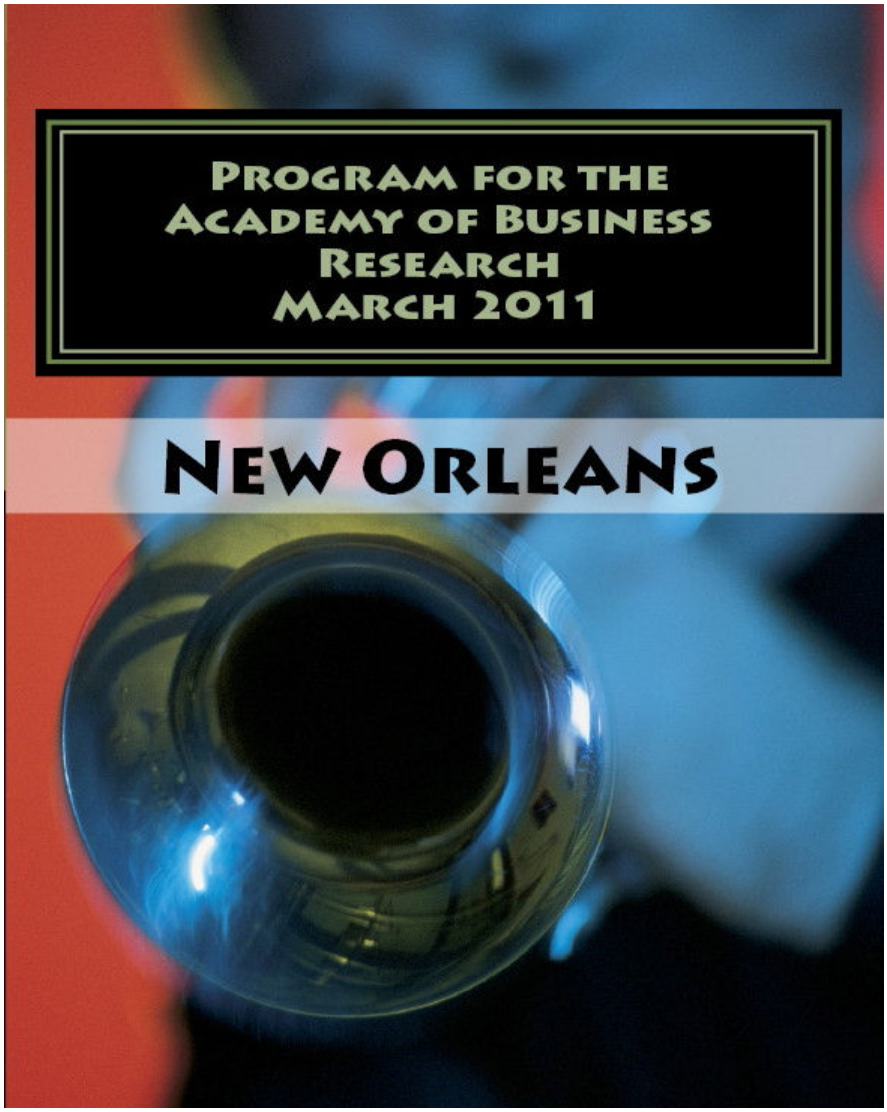

The Academy of Business Research will have the Spring 2012 International Conference at the Ritz Carlton-Iberville Suites in New Orleans March 14-16. The Spring 2011 conference was held March 16-18 and featured scholars from 42 states and 13 countries.

The Impact of Perception Factors on Consumer Reaction Under Product Recalls

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ABSTRACT

This paper examines how consumers respond to product recall situation. Despite the increase in the number of product recalls and its negative effect on consumers' perceptions and consumers' high defection rates, most studies address the company's response than consumers' response. This study tries to explain consumers' reactions to product recalls by using perception variables. Perceived danger from the recalled product, perceived brand difference, perceived corporate response, perceived expertise difference, and perceived corporate social responsibility variables are considered as factors influencing consumers' retention or defection. Data are collected from target consumers who are the actual or potential purchasers and survey examines the perception factors influencing on their retention or defection decisions from the recalled product or brand. Through the results and findings, theoretical and managerial implications and suggestions for further research are derived.

Introduction

Ries and Trout (1993) say there are two distinct streams to answer the question that "what marketing is about?" in marketing arena. One stream is that marketing is explained as a battle of products. Product oriented marketers are preoccupied with doing marketing research and finding out the facts by analyzing the situation to make sure that truth is on their side. They finally conclude that they have the best product and the best product will ultimately win. The other stream is that marketing is explained as a battle of perceptions. In this perspective, marketers see that all that exists in the world of marketing are perceptions in the minds of the customer or prospect, and then the perception is the reality.

There is a range of literature on the research links in product harm crises and frequencies of research topic in this area have been concentrating on corporate response. The literature on the research links in product harm crises and corporate response can be regarded as an approach of the product oriented perspective, a battle of products. According to Siomkos and Kurzbard (1992), during a product harm crisis, the market often receives negative information about both the company and the product. Companies assume that since a crisis is associated with events and information, consumer attitudes after the crisis will change negatively. Then, the company may communicate information to consumers about the crisis situation and inform them of its efforts to manage the crisis. These are attempts to change consumer attitudes and perceptions or to hold them at their pre-crisis levels. Siomkos (1989) showed three major primary factors to dealing with a product harm crisis: a company's reputation, external effects (e.g. the impact of media coverage), and a company's response to the crisis. It has been shown that the crisis effect on a well-known company with a positive image may be minimal. On the contrary, the effect can be devastating for unknown companies. This research indicates that a company may face either negative or positive external effects during a crisis. Those effects can directly influence the

company's success in dealing with it. Recent research indicates that specific negative effects of a crisis may be mitigated by the press when it reports the troubled company is acting in a socially responsible way in recalling the harmful product (Jolly and Mowen 1984; Siomkis and Kurzbard 1992).

Recent research indicates that a company is perceived to be more responsible if it acts before a government agency steps in and orders it to take action, since consumers are more likely to perceive a company as more responsible if it acts prior to the intervention of an agency.

Responses to a crisis can be classified with four responses; denial (a company may simply deny any responsibility for a defective product that it markets), involuntary recall (it can recall the product only after an agency orders such action), voluntary recall (it may choose to recall the defective product prior to governmental intervention), and super effort (it may respond by demonstrating concern with consumer welfare by being socially responsible and by being honest in its communications related to the crisis). The last response category may also involve making the recall process extremely easy for the consumer by offering discount coupons or free samples of other products and by widely advertising the recall (Siomkis 1989; Siomkis and Shrivartara 1993; Shrivartara and Siomkis 1989).

While there is a range of literature on the research linked to product harm crises and the frequencies of research topic in this area, the importance of study on consumers' response to product recall seems to have been overlooked compared to the importance of study on the company's perspective. Few studies (Mowen et al, 1981; Siomkos and Kurzbard, 1994; de Matos and Rossi, 2007) have been concerned how consumers respond to product recall. Mowen et al. (1981) found that impressions of the companies which were involved with product recalls were influenced by the knowledge that a recall had been made, and recalls made by other companies, and perception factors such as the perceived danger of the defective product and the perceived corporate responsibility of the company. Siomkos and Kurzbard (1994) tested that the mitigating effects of company's reputation, external reaction and company response to product recalls using perceived degree of danger and future purchase as dependent variables. De Matos and Rossi(2007) examined the factors influencing consumers' product judgment and behavioral intention due to product recalls. Even though few studies (Mowen et al., 1981; Siomkos and Kurzbard, 1994; de Matos and Rossi, 2007) above have been concerned with how consumers react to product recall, those studies have limitations to be challenged by new trial.

Actually product recalls are critical situation for consumers to change their existing perception and attitude toward the product or company involved. Consumer's perception is over reality. If the company doesn't communicate effectively following a product recall, this company may never recover from the loss. Even though few studies (Mowen et al, 1981; Siomkos and Kurzbard, 1994; de Matos and Rossi, 2007), have been concerned how consumers respond to product recall, have been touched perception factors in part, used one of many explanatory variables or only limited fragment of perception, those are not enough to explain product recall in perception perspective. Because product recall is highly emotive and the consumers' perception is very much pre-geared towards feeling everything is in hand, there are enough reason to use perception constructs to explain the influencing factors on consumer reaction under product recall situation. Therefore, this paper is going to focus on the perception oriented perspective, a battle of perceptions, which all that exists in the world of marketing are perceptions in the minds of the customer or prospect. We will use extended perception constructs to understand consumer's reaction under product recalls in this paper.

Conceptual Model

How consumers respond to the product recall situation if it really happened to them is addressed by a recent study by marketing research firm Harris Interactive (2007) which shows that consumers are very concerned about the recent string of products recalls. In a poll of over two thousand of adults surveyed, 79% said they were aware of recalls that have occurred during the past three years. Almost a third of respondents (29%) considered recalls to be a serious concern. This survey provides in details of consumers' reactions: while 55% of people said they would switch brands temporarily in the case of a safety and health recall on a product they usually purchase, a full 15% said they would never again purchase the recalled brand. Additionally, 21% of those polled said they would avoid using any brand made by the manufacturer of the recalled product.

This study will note on consumers' reactions under a product recall situation especially to different perceptions. When a product recall happen, a consumer can respond to his/her two different perceptions concept. According to time sequence, a consumer's reaction will depend on ex ante perceptions, which formed before the product recall, for the company, the brand, and the product in one way. Also this consumer's reaction will depend on ex post perceptions, which formed after the product recall, for how risky the product recall situation and how the company responds to the product recall. Therefore, perceived danger from product recall, perceived corporate response, as consumers' ex ante perceptions, perceived brand difference, perceived expertise difference, and perceived corporate social responsibility, as consumers' ex post perceptions will be considered as factors influencing in consumers' retention or defection from this product or brand. This study expects purchase intention, which is an analogical inference from three different groups, will show different reactions to different levels of perception which are defined by five constructs: perceived risk, perceived corporate response, perceived brand difference, corporate expertise difference, and corporate social responsibility.

For this model, multiple regression is an appropriate tool, because it tells us which factors affect the dependent variable, which way (the sign) each factor influences the dependent variable, and how much (the size of slope) each factor influences it. The multiple regression model describes how the dependent variable (response variable) is related to the independent variables (explanatory variables). The explanatory variables may be continuous or discrete with dummy, in other words, the predictors can be quantitative, qualitative, or of both types.

The following model for purchase intention is:

$$PI_{ji} = \beta_0 + \beta_1 RISK_i + \beta_2 RSPS_i + \beta_3 BRND_i + \beta_4 EXPT_i + \beta_5 SORE_i + \ldots\ldots\ldots + \mu'_i \quad \ldots\ldots\ldots\ldots (1)$$

where PI_{ji} is a discrete dependent variable measuring how the respondent i predicts the level of purchase for the product he/she bought [j=1 (very unlikely), . . . , 7 (very likely)] , μ'_i is the error term, β 's are parameters to be estimated (β_0 = intercept term). $RISK_i$ denotes the level of perceived risk for recalled product [i=1 (not dangerous at all), . . . , 7(very dangerous)], $RSPS_i$ denotes the level of perceived corporate response [i=1 (very slowly), . . . , 7 (very quickly)], $BRND_i$ denotes the level of perceived brand value[i=1 (much worse), . . . , 7 (much

better)], $EXPT_i$ denotes the level of perceived corporate expertise difference[i=1 (not reliable at all), . . . , 7 (very reliable)], $SORE_i$ denotes the level of perceived corporate social responsibility [i=1(not well at all), . . . , 7 (very well)]. This overall model will check how our five perceived constructs important to purchase intention under the intervention of product recall.

In each hypothesis, this study answers questions that each perceived construct affects purchase intention according to product involvement, product failure experience and expert/novice in skill. To examine hypotheses, purchase intention can be described as the response variable has only two possible values: yes or no. Also we can call the two values of the response variable "success" and "failure" and represent them by 1 (for a success) and 0. When response variable y is just 1 or o (success or failure), the mean is the probability p of a success. Logistic regression models the mean p in terms of an explanatory variable x. Then the logistic regression model uses the term log odds for p/(1-p) transformation. As p moves from 0 to 1, the log odds move through all negative and positive numerical values. Therefore, we model the log odds as a linear function of the explanatory variable and the statistical model for logistic regression.

Extended model for the multiple explanatory variables is as follows.

$$\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 RISK_i\, PIN_i + \beta_1 RISK_i\, PFE_i +$$

$$\ldots\ldots\ldots + \beta_i SORE_i\, PFE_i + \beta_i SORE_i\, PK_i \text{ ---------- (2)}$$

where p is a binomial proportion and x_i are the explanatory variables for interaction terms among perception variables, product involvement, product failure experience and product knowledge ($RISK_i\, PIN_i$, $RISK_i\, PFE_i$, $RISK_i\, PK_i$, ….,

$SORE_i\, PIN_i$, $SORE_i\, PFE_i$, $SORE_i\, PK_i$), and β_0 , β_1 , β_i are the parameters of this multiple logistic model; Purchase intention (yes=1, no=0) as response, product involvement level (yes = 1, no=0), product failure experience (yes=1, no=0) and the level of individual consumer's product knowledge (novice=1, expert=0), which were coded by binary categorical dummy and each perception variables measured by quantitative as predictors.

Hypotheses

Perception is our sensory experience of the world around us and involves both the recognition of environmental stimuli and actions in response to these stimuli. Through the perceptual process, we gain information about properties and elements of the environment that are critical to our survival. Perception not only creates our experience of the world around us; it allows us to act within our environment. Perception has been defined by Severin and Tankard (1997) as "the tendency for people's perception to be influenced by wants, needs, attitudes, and other psychological factors". The issue of selective perception has been the core of the marketing dogma. It has been said so many times that we stop seeing the reason behind that. That means we act with the selective attention. Knowing consumers' reaction implies that you are able to understand the way the product or situation is perceived, what part of the factors the target group will selectively retained and how will they act. One of the most important aspects of

product recall is being able to evaluate the situation of product and company objectively and see how they are viewed by consumers (customers and prospects).

Perceived Risk

A consumer's decision to modify, postpone, or avoid a purchase decision is heavily influenced by perceived risk. Perceived risk is the risk a customer believes exists in the purchase of goods or services from a specific retailer, whether or not a risk actually exists. The notion of perceived risk was introduced by Bauer (1967) to consumer behavior research. This notion was developed by Jacoby and Kaplan (1972) distinguished between five risk dimensions: financial, performance, psychological, physical and social risks in the overall risk construct. Recently, Bhatnagar and Sanjoy (2004) developed two dimensions of perceived risk in Internet shopping study; product risks related to the consumers' inability to examine products online; security risks related to the consumers' fear that the open Internet network would allow their personal data to be compromised. In the product recall context, we will consider two dimensions of risks, product performance risk and consumers' psychological risk as perceived risk.

In the product recall situation, perceived risk (how the recalled product would be dangerous to consumer) should be very influential to consumers. In general consumers often feel vulnerable if they are not fully informed about the product attributes and given overwhelming commercial information. Therefore, a higher risk level will inhibit an exploratory tendency. In addition, perceived risk also affects consumers' behavior in terms of the extensiveness of their purchase intention process and their processing of information. If consumers perceive a high level of risk and are very concerned about the consequence of a wrong purchase, they will not stick to the recalled product and brand.

H1: Perceived risk negatively affects consumers' willingness to buy (purchase intention) the recalled product.

H1-a: There are significant effects of perceived risk on purchase intention according to product involvement.

H1-b: There are significant effects of perceived risk on purchase intention according to product failure experience.

H1-c: There are significant effects of perceived risk on purchase intention according to product knowledge level.

Perceived corporate response

Mowen (1980) used variables such as consumer knowledge of the company making the product recall, whether or not the company was compelled to make the recall by a consumer product safety commission, and whether or not other manufacturers had had a similar defect, and found that participants perceived a familiar company more significantly less responsible for the defect than an unfamiliar one. Contrary to the author's expectations, when the company acted prior to intervention, it was considered more responsible.

According to Dawar (1998), in a product recall, an ambiguous response can have a negative impact on brand equity if the firm does not enjoy the benefit of the doubt derived from positive customer expectations. However, where positive customer expectations guide the interpretation of a firm's response, even an ambiguous response has the potential to increase brand equity.

The perceived corporate response difference will influence consumers' motivation for staying with or leaving the recalled product. If consumers confronted very active response from the company for the recalled product, they may be positive to stay. On the other hand, if they

perceived very inactive response from the company for the recalled product, they may go away to other brands.
H2: Perceived corporate response positively affects consumers' willingness to buy (purchase intention) the recalled product.
H2-a: There are significant effects of perceived corporate response on purchase intention according to product involvement.
H2-b: There are significant effects of perceived corporate response on purchase intention according to product failure experience.
H2-c: There are significant effects of perceived corporate response on purchase intention according to product knowledge level.

Perceived Corporate Expertise

According to Keller (1998), corporate expertise is 'the extent to which a company is seen as able to competently make and sell its products or products or conduct its services. Consumers often form assumptions about companies and products. These market beliefs then become the shortcuts that guide their decisions. If consumers believe some companies will be more competent to deliver a certain product than some others, they will be assured in using the recalled product by knowing it is coming from this company.

The importance of corporate expertise in influencing consumers' brand decisions (retention or defection) under product recall is moderated by some factors such as the difficulty of making the product. If the product is easy to make and the technology involved in the production is standardized, consumers tend to assume that there is only a minor difference in production expertise among the competing companies. If consumers perceived high corporate expertise difference for the recalled product, they will stick to the brand. However, if consumers did not perceive a high enough corporate expertise difference for the recalled product, they will try to move to other brands. Therefore we construct the following hypothesis:
H4: Perceived corporate expertise positively affects consumers' willingness to buy (purchase intention) the recalled product.
H4-a: There are significant effects of perceived corporate expertise on purchase intention according to product involvement.
H4-b: There are significant effects of perceived corporate expertise on purchase intention according to product failure experience.
H4-c: There are significant effects of perceived corporate expertise on purchase intention according to product knowledge level.

Perceived Corporate Social Responsibility

A company's corporate social responsibility will be given more attention in consumers' purchase decisions if it is strong and positive. Zenisek (1979) proposes a definition of social responsibility based on the notion of a fit between two components, business ethic and societal expectations of the private economic sector. Turban and Greening (1997) define corporate social performance as a company's responsibility to multiple stakeholders, such as employees and the community at large, in addition to its traditional responsibilities to economic stakeholders. They also note that whereas earlier work on corporate social performance focused on firms' alleged wrong-doings, recent attention has been directed toward identifying how socially responsible actions may be associated with certain competitive advantages. In very recent research by de

Matos and Rossi (2007), the importance of corporate social responsibility was proved under the product recall situation.

Product judgment and behavioral intention were significantly affected by corporate social responsibility. Now we can say that a strong and positive corporate social responsibility may tend to help the company maintain a high level of trust in consumers' minds even under the product recall situation. Therefore this study hypothesizes that:

H5: Perceived corporate social responsibility positively affects consumers' willingness to buy (purchase intention) the recalled product.

H5-a: There are significant effects of perceived corporate social responsibility on purchase intention according to product involvement.

H5-b: There are significant effects of perceived corporate social responsibility on purchase intention according to product failure experience.

H5-c: There are significant effects of perceived corporate social responsibility on purchase intention according to product knowledge level.

Research Methodology

The dependent variable is measured by consumers' reaction (purchase intention) to the recalled product. According to Harris Interactive survey results, consumers' reaction to the product recall results in three different types: retention of the recalled product or brand (55%), defection from the recalled product or brand (36%), and other (9%). Therefore, it is possible to classify the respondents into two groups according to their reaction to the product recall, especially to note on their retention or retention. By asking binary yes/no question, these two different groups can be explained by purchase intention level of the recalled product.

This study will derive which factors are important for consumers' decisions to stay or leave this product or brand under a product recall situation. There are five independent variables in this study, which are: perceived risk, perceived corporate response, perceived brand difference, corporate expertise difference and corporate social responsibility. The variables will be measured by single item or multiple items.

Pretest: Most questions asked respondents to indicate their agreement with a few statements. Respondents were supposed to choose from 1 (completely disagree) to 7 (completely agree). Only the items that provided the highest reliability were used to operationalize the variables.

They were asked to give their opinion on the following points from a respondent's perspective:

Is the meaning of the question clear? Are instructions understandable? Are the terms precise?

Are there any loaded or charged words? Using the pretest results based on 20 respondents, the actual survey questionnaire was finalized with following items in Table 1.

Since the dependent variable will be measured on a continuous 7 point Likert type scale, multiple regression analysis will be employed to process the data, which can help examine how the dependent variable, consumers' reaction (repurchase intention) under the product recall situation, can be influenced differently by independent variables, the five perception constructs in terms of the consumers' perceived risk level, perceived corporate response level, perceived brand difference, corporate expertise difference and corporate social responsibility.

Table 1. Research constructs and measuring items: Influencing factors on consumer's reaction

Construct Variable	Measuring Items	
Repurchase Intention	- Level of repurchase intention on recalled product	Dependent Variable
Perceived Risk	- Level of perceived risk on recalled product	Independent Variable
Perceived Corporate Response	- Level of quickness of response on recalled product	Independent Variable
Perceived Brand Difference	- Level of brand value compared to similar other brand	Independent Variable
Perceived Expertise Difference	- Level of product reliability	Independent Variable
Perceived Social Responsibility	- Level of corporate social responsibility	Independent Variable

Data Collection and Analysis Tool

In order to accomplish this objective, data was collected from consumers, who were the actual or potential purchasers of cars and computers in the mid-western adjacent two states. The survey was conducted for few weeks in two cities. For effective data collection in a given time, two different ways of access to respondents was pursued. One way was using a mall interception interview. A survey was delivered by the face to face interview in big marketplaces. The second way was using a big community group. The survey was executed with the cooperation of churches which consist of over one thousand members. For the influencing factors for consumer reaction under product recalls, surveys which were asked by the level of perceived risk (high/low), the level of perceived corporate response (high/low), perceived brand value (difference) (high/low), corporate expertise difference (high/low) and corporate social responsibility (high/low) were randomly distributed to each participant. Subjects were instructed to answer each question by reflecting on the company and recall situation for automobile and laptop computers. Multiple regression analysis, t-test and descriptive statistics were generated to confirm the research model discussed. The relative importance of 5 perceived constructs (independent variables) on purchase intention (dependent variable) were examined via a multiple regression analysis. Five test hypotheses for perceived risk, perceived corporate response,

perceived brand difference, corporate expertise difference and corporate social responsibility were tested by t-test to examine whether those have significant effects or not on purchase intention.

For individual perceived variable, to test the underlying process, multiple logistic regression was used; purchase intention (yes=1, no=0) as response, product involvement level (yes = 1, no=0), product failure experience (yes=1, no=0) and the level of individual consumer's product knowledge (novice=1, expert=0), which were coded by binary categorical dummy and each perceived variables were measured quantitatively as predictors.

Results and Findings

Demographic Characteristics of Respondents

Respondents were asked about their gender, age, income, education and heritage. These data were collected using survey questionnaires. ANOVA test was performed to examine whether these samples have differences in age and income or not. The results indicated that these groups were homogeneous in terms of age and income. Also, chi-square tests were performed to see group differences for categorical variables such as gender, age, income, education and heritage. The results showed that none of these tests was significant.

Table 2. Respondents' profile

			(%)
Gender	Male	93	(46)
	Female	110	(54)
Age	18~22	12	(6)
	23~29	15	(7)
	30~39	41	(20)
	40~49	45	(22)
	50~59	42	(21)
	60~69	34	(17)
	70~	14	(7)
Income	~$24,999	41	(20)
	$25,000~$34,999	18	(10)
	$35,000~$49,999	41	(20)
	$50,000~$74,999	49	(24)
	$75,000~$99,999	27	(13)
	$100,000~	27	(13)
Education	High School	30	(15)
	College	100	(49)
	Graduate School	73	(36)
Heritage	Asian	44	(22)
	African American	22	(11)
	Hispanic	20	(10)
	Caucasian	108	(53)
	Other	9	(4)

Results: Relative Importance of Perceived Variables

Perceived risk from the product being recalled, perceived corporate response, as consumers' ex post perceptions, perceived brand difference, perceived expertise difference, and perceived corporate social responsibility, as consumers' ex ante perceptions will be considered

as factors influencing consumers' retention or defection from this product or brand. According to multiple regression results, ex ante variables (perceived corporate brand value, perceive corporate expertise difference and perceived corporate social responsibility) showed significantly different p-values in t-test, and this means that ex ante variables will mitigate, to some extent, the negative impact from product recall on purchase intention.

On the contrary, ex post variables (perceived risk and perceived corporate response) did not show significant p-value by t-test. Test for Hypothesis1 shows that there's no relationship between perceived risk and purchase intention. Consumers may consider the perceived risk factor as an intrinsic attribute of product recall. In other words, the risk factor is an integral part and inseparable from the product recall. Therefore, consumers who confronted product recall take risk into first consideration and are supposed to take action in an early stage. Test for Hypothesis 2 shows that there's no relationship between perceived corporate response and purchase intention. As consumers' ex post perception, corporate response cannot offset the negative effect of product recall on purchase intention. Therefore, while quick corporate response may satisfy the customer, it may not be possible to erase all the negative perceptions or feelings associated with the product recall. Customers may accept the apology and the compensation and take the recovery process for granted, but they may not forget the incident and not trust the company not to make similar mistakes in the future.

In detail, from regression analysis for laptop computer (See table 3), the results of t-tests indicated that there were significances for ex ante variables: perceived corporate brand value ($p < 0.01$), perceived corporate expertise difference ($p < 0.01$) and perceived corporate social responsibility ($p < 0.01$).

Table 3: Regression Analysis for laptop computer

Predictor	**Coef**	**SE Coef**	**T**	**P**
Constant	-0.2486	0.5449	-0.46	0.649
RISK	0.01468	0.07022	0.21	0.835
RSPS	0.00435	0.04958	0.09	0.930
BRND	**0.31787**	**0.07093**	**4.48**	**0.000**
EXPT	**0.27969**	**0.07293**	**3.84**	**0.000**
SORE	**0.36463**	**0.07210**	**5.06**	**0.000**

(S = 1.16893 R-Sq = 45.4% R-Sq(adj) = 44.0%)

For automobile, from regression analysis (See table 4), the results of t-tests indicated that there were significances for two ex ante variables: perceived corporate brand value ($p < 0.01$) and perceived corporate social responsibility ($p < 0.01$). Therefore, consumers who confronted automobile recall may show reactions to perceived corporate brand value and perceived corporate social responsibility. Respectively, while H3 and H5 are supported by data, H1, H2 and H4 are not supported by data.

Table 4: Regression Analysis for automobile

Predictor	Coef	SE Coef	T	P
Constant	0.0070	0.8427	0.01	0.993
RISK	-0.0686	0.1113	-0.62	0.538
RSPS	-0.00010	0.05721	-0.00	0.999
BRND	**0.4007**	**0.1124**	**3.57**	**0.000**
EXPT	0.0511	0.1107	0.46	0.645
SORE	**0.4822**	**0.08414**	**5.73**	**0.000**

(S = 1.31750 R-Sq = 43.6% R-Sq(adj) = 42.1%)

Results: Interactions between Perception Variables and Consumers' Characteristic Variables

To test Sub-Hypotheses of Hypotheses 1 to 5, this study introduced multiple logistic regressions to capture the interaction effects among perception variables, product involvement level, product failure experience and product knowledge level of individual consumer.

Perceived Risk vs. Consumers' Characteristic Variables

For laptop computer, the test for Hypothesis 1-a, b and c showed that there is an interaction between perceived risk and product involvement. As in the result of H1, consumers are expected to consider the perceived risk factor as an intrinsic attribute of product recall. In other words, the risk factor is an integral part and inseparable from the product recall. Therefore, consumers who confronted product recall take risk into first consideration and are supposed to move over the threshold level right after product recall. Respectively, H1-b and H1-c are not supported by data. However, if consumer product involvement level is high, perceived risk and product involvement show interaction effect on purchase intention, and H1-a is confirmed by the data (see Table 5).

For automobile, contrary to laptop computer, test for Hypothesis 1-a, b and c showed that there is no relationship between perceived risk and purchase intention (p-value > 0.05). Along with perceived risk, consumer characteristics (high car involvement, car failure experience and low car knowledge) do not show any effect on purchase intention. Therefore, respectively, H1-a, H1-b and H1-c are not supported by the data (see Table 6).

Perceived Corporate Response vs. Consumers' Characteristic Variables

For laptop computer, test for Hypothesis 2-a, b and c showed that there are no interactions between perceived corporate response and consumer characteristic variables. Consumers may consider the perceived corporate response factor as taken for granted for the recalled company. Therefore, consumers who confronted product recall may not show any reaction to corporate response level. Respectively, any of H2-a, H2-b and H2-c are not supported by the data (see Table 5).

For automobile, test for Hypothesis 2-a, b and c showed that there is an interaction between perceived corporate response and one of consumer characteristic variables. Perceived corporate response and car failure experience have significant effect on purchase intention (p-value=0.035 < 0.05), and H2-b is confirmed. However, H2-a and H2-c are not supported by the data (see Table 6).

Perceived Brand Value vs. Consumers' Characteristic Variables

For laptop computer, in test for Hypothesis 3-c, there is a positive interaction effect between perceived corporate brand value and computer knowledge (p-value = 0.005 < 0.05). Along with perceived brand value, computer novice has a significant effect on purchase intention. Therefore, H3-c is supported, but respectively, H3-a, H3-b are not supported (see Table 5).

For automobile, in test for Hypothesis 3-a, b and c, there is a positive interaction between perceived corporate brand value and car involvement. Along with perceived brand value, individual car involvement has a significant effect on purchase intention (p-value is 0.021 < 0.05). Therefore, H3-a is supported, but respectively, H3-b, H3-c are not supported (see Table 6).

Perceived Corporate Expertise vs. Consumers' Characteristic Variables

For laptop computer, test for Hypothesis 4-a, b and c showed that there is no interaction between perceived corporate expertise and consumer characteristic variables. Therefore, respectively, H4-a, H4-b and H4-c are not supported by the data (see table 5).

For automobile, test for Hypothesis 4-a, b and c showed that there are interactions between perceived corporate expertise and consumer characteristic variables. Along with perceived brand value, individual car failure experience and involvement to cars have significant effects on purchase intention (p-values are respectively, 0.019 and 0.001 < 0.05). Therefore, respectively, H4-a, H4-b are supported. But H4-c is not supported by the data (see table 6).

Perceived Corporate Social Responsibility vs. Consumers' Characteristic Variables

For laptop computer, test for Hypothesis 5-a, b and c showed that there are no interactions captured between perceived corporate social responsibility and consumer characteristic variables. Confronting perceived corporate brand value, individual computer involvement, computer failure experience and computer knowledge have no significant effect on purchase intention. Therefore, respectively, H5-a, H5-b and H5-c are not supported by the survey data (see Table 5).

For automobile as in the laptop computer case, test for Hypothesis 5-a, b and c showed that there are no interactions between perceived corporate social responsibility and consumer characteristic variables. Therefore, respectively, H5-a, H5-b and H5-c are not supported by the survey data (see Table 6).

Table 5: Logistic Regression Interactions for laptop computer

Predictor	**Coef**	**SE Coef**	**Z**	**P**	**Odd Ratio**	**95% CI**	
						Lower	**Upper**
RISK*PIN	**0.56845**	**0.28786**	**1.97**	**0.048**	**1.77**	**1.00**	**3.10**
RISK*PFE	0.15122	0.28917	0.52	0.601	1.16	0.66	2.05
RISK*PK	-0.06622	0.29193	-0.23	0.821	0.94	0.53	1.66
RSPS*PIN	0.120259	0.187991	0.64	0.522	1.13	0.78	1.63
RSPS*PFE	-0.070843	0.195466	-0.36	0.717	0.93	0.64	1.37
RSPS*PK	-0.194476	0.189920	-1.02	0.306	0.82	0.57	1.19
BRND*PIN	0.450825	0.283184	1.59	0.111	1.57	0.90	2.73

BRND*PFE	-0.384064	0.283940	-1.35	0.176	0.68	0.39	1.19
BRND*PK	**0.791344**	**0.279572**	**2.83**	**0.005**	**2.21**	**1.28**	**3.82**
EXPT*PIN	0.222035	0.278239	0.80	0.425	1.25	0.72	2.15
EXPT*PFE	-0.180119	0.303272	-0.59	0.553	0.84	0.46	1.51
EXPT*PK	0.574445	0.312767	1.84	0.066	1.78	0.96	3.28
SORE*PIN	-0.143191	0.302196	-0.47	0.636	0.87	0.48	1.57
SORE*PFE	0.733480	0.449891	1.63	0.103	2.08	0.86	5.03
SORE*PK	-0.263377	0.299442	-0.88	0.379	0.77	0.43	1.38

(PIN: Product Involvement, PFE: Product Failure Experience, PK: Product Knowledge, RISK: Perceived Risk, RSPS: Perceived Corporate Response, BRND: Perceived Brand, EXPT: Perceived Expertise, SORE: Perceived Corporate Social Responsibility, Interaction Terms: RISK*PIN, RISK*PFE, RISK*PK, RSPS*PIN, RSPS*PFE, RSPS*PK, BRND*PIN, BRND*PFE, BRND*PK, EXPT*PIN, EXPT*PFE, EXPT*PK, SORE*PIN, SORE*PFE, SORE*PK)

Table 6: Logistic Regression Interactions for Automobile

Predictor	**Coef**	**SE Coef**	**Z**	**P**	**Odd Ratio**	**95% CI**	
						Lower	**Upper**
RISK*PIN	0.138526	0.31410	0.44	0.659	1.15	0.62	2.13
RISK*PFE	-0.46853	0.62546	-0.75	0.454	0.63	0.18	2.13
RISK*PK	-0.66186	0.66457	-1.00	0.319	0.52	0.14	1.90
RSPS*PIN	0.396422	0.327155	1.21	0.226	1.49	0.78	2.82
RSPS*PFE	**-0.565507**	**0.268639**	**-2.11**	**0.035**	**0.57**	**0.34**	**0.96**
RSPS*PK	-0.385948	0.271223	-1.42	0.155	0.68	0.40	1.16
BRND*PIN	**1.54550**	**0.671001**	**2.30**	**0.021**	**4.69**	**1.26**	**17.47**
BRND*PFE	-0.448476	0.394661	-1.14	0.256	0.64	0.29	1.38
BRND*PK	-0.431040	0.660381	-0.65	0.514	0.65	0.18	2.37
EXPT*PIN	**1.703830**	**0.724555**	**2.35**	**0.019**	**5.49**	**1.33**	**22.74**
EXPT*PFE	**-0.899105**	**0.274430**	**-3.28**	**0.001**	**0.41**	**0.24**	**0.70**
EXPT*PK	0.266035	0.525354	0.51	0.613	1.30	0.47	3.65
SORE*PIN	0.244111	0.55372	0.44	0.659	1.28	0.43	3.78
SORE*PFE	-0.572309	0.53325	-1.07	0.283	0.56	0.20	2.60
SORE*PK	0.488088	0.52451	0.93	0.352	1.63	0.58	4.55

(PIN: Product Involvement, PFE: Product Failure Experience, PK: Product Knowledge, RISK: Perceived Risk, RSPS: Perceived Corporate Response, BRND: Perceived Brand, EXPT: Perceived Expertise, SORE: Perceived Corporate Social Responsibility, Interaction Terms: RISK*PIN, RISK*PFE, RISK*PK, RSPS*PIN, RSPS*PFE, RSPS*PK, BRND*PIN, BRND*PFE, BRND*PK, EXPT*PIN, EXPT*PFE, EXPT*PK, SORE*PIN, SORE*PFE, SORE*PK)

Findings

Overall perceived constructs level, the multiple regression results indicated that the ex post variables (perceived risk and perceived corporate response) did not significantly affect purchase intention, contrary to the expectation. These results may reflect that consumers are shocked by the happening of product recall and sense imminent danger right after. In other words, because the happening of product recall impacts the consumer at a threshold, consumers' perception of risk or corporate response is on the boundary beyond which a radically different

state of affairs exists. However, the ex ante variables (perceived corporate brand value, perceived corporate expertise difference and perceived corporate social responsibility) affected purchase intention after product recall as was expected. These results may imply that the importance of relationship marketing which considers consumers as business partners cannot be too much. Lesson learned may be that relationship marketing is best defense strategy for customer retention even in worst situation such as product recall.

In addition to consumers' perception variables before and after product recall, product involvement, product failure experience and product knowledge as consumers' characteristic factors also introduced to explain consumer response to recall situation better than previous research. In individual perceived variable, according to tests on the underlying process, each test had somewhat mixed results by the product difference. The results make it possible to explain product recall impact on purchase intention via perceived constructs, product involvement, product failure experience, and product knowledge level. For the product involvement, previous researchers decided involvement level by themselves (e.g., automobile is high involvement, hair dryer is low involvement), but this study determines product involvement level by each consumer's decision because consumer involvement level is subjective to individual perception.

For H 1-a, 1-b and 1-c, while perceived risk and consumer characteristic variables had no interactions to automobile purchase intention, laptop computer purchase intention was partly interacted by perceived risk and car involvement level. For the hypothesis 2-a, 2-b and 2-c, while perceived corporate response in any consumer characteristic had no impact on laptop computer purchase intention, automobile purchase intention was influenced by consumers' perceived corporate response and automobile failure experience. In H3-a, H3-b and H3-c, perceived corporate brand value related to computer knowledge has an impact on laptop purchase intention, but in automobile purchase intention, perceived corporate brand value related to consumers' automobile involvement has an impact on car purchase intention. For the hypothesis 4-a, 4-b and 4-c, while perceived corporate expertise had no interactions with consumer characteristic variables on laptop computer purchase intention, automobile purchase intention was influenced by perceived corporate expertise difference with car breakdown experience and car involvement level. In H5-a, H5-b and 5-c, perceived corporate social responsibility did not show any interaction with consumers product involvement, product failure experience and product knowledge on neither laptop purchase intention nor on automobile purchase intention.

Contribution, Limitation and Future Study

Here are summarized the research contributions to existing literature for the influencing factors on consumer reaction under product recall. While many product-recall related researches so far have focused on the company's point of view such as company's response, this research focuses on the consumers' reaction by perception perspective such as perceived risk, perceived corporate response, perceived brand value, corporate expertise and corporate social responsibility. The first contribution of this paper is to provide a different perspective to the existing product recall literature by examining the influence of different factors through the consumers' perception of the product, brand and company when consumers make decisions for retention or defection under a product recall situation. This paper may contribute to the understanding of how the company involved with product recalls utilizes this crisis as a starting point of a so called 'reverse marketing' opportunity with extended knowledge about consumers who will be away from the recalled product. Finally, this study enhances the understanding about

whether the typical behavioral pattern exists or not in a consumer behavior context, especially in a product recall situation.

Some limitations and future study should be recognized. Firstly, even though this study is based on actual product recall experiences, many respondents may not have actual product recall experiences. So this study does not reflect the real situation perfectly. Future studies should consider this point and cover target audiences who experience actual product recalls. Secondly, because the demographic characteristics of respondents are restricted to two big cities of Mid-western states, it may not be enough to generalize findings of this study to the full population. Future research should be conducted with a large pool of subjects from various demographic and geographic backgrounds. Thirdly, cars and computers are not enough to generalize test results toward all product categories. Additional research should be conducted to gain more understanding of consumers' reactions under product recall situations. Finally, this study used a multiple regression and a multiple logistic regression as analysis tools because survey design was not that much complex and sample size was not big. However, additional research should be conducted to use a structural equation model with appropriate complex survey design to see if we can explain product recall differently.

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Modeling the Impact of not Using Copper in Florida Grapefruit Production

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ABSTRACT

This article deals with the economic impact of withdrawing copper from grapefruit production in Florida. A mathematical programming model of the world market for Florida grapefruit is developed and solved using data on yield/pack-out impacts from a National Agricultural Pesticide Impact Assessment Program study. The model is first run with copper included in the production process assuming 2003-04 as the base year to forecast production and on-tree prices of grapefruit for the next eleven years. Then, the yield and pack-out impacts without copper are incorporated into the model to look at the changes in forecasted production and on-tree prices. Without using copper in grapefruit production, on-tree prices increase leading to increased grower revenue, decreased fresh marketing and increased prices for domestic and exported fresh grapefruit. Consumer prices also increase. Even though the cost of production increases, net revenue to growers using no copper is greater than that when copper is used.

Introduction and Background

Historically, agriculture and pesticides have had a close relationship. Pesticides contribute to agriculture through higher productivity, lower cost of production, resulting in relatively inexpensive and unblemished products to customers. Agricultural policy, which sought to promote land and labor productivity and low food prices for consumers, tended to promote the use of pesticides. But increasingly, environmental concerns have raised issues about the unmitigated use of pesticides and their possible effects on environment quality and human health through its impacts on wildlife and the ecological system, its potential impacts on soil and water quality and its direct impacts on human health. Hence, there exists an inherent conflict between these two policies and this motivates regulatory concerns. Agencies such as the United States Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) have been charged to administer the provisions of various acts and regulations on pesticide usage. The Food Quality Protection Act (FQPA) of 1996 required EPA to reassess the tolerances of all pesticides in use by the year 2006 depending on environmental risk and health hazards (National Agricultural Pesticide Impact Assessment Program (NAPIAP), 1996; Federal Register, 1997; USDA, 1997).

The project has been undertaken for Florida grapefruit production because it accounted for 72.0 percent of U.S. grapefruit production in the 2007-2008 crop year. Even more importantly, it accounted for 91.6 percent of U.S. fresh grapefruit exports in 2007-2008 crop year (Florida

Agricultural Statistics Service (FASS), Citrus Summary 2007-2008). Florida grapefruit represented 3.39 percent of farm cash receipts in Florida in 2007 where all citrus accounted for 19.70 percent and oranges accounted for 15.40 percent (USDA-National Agricultural Statistics Service (NASS), 2008, 2009). This positions Florida grapefruit as the second largest commodity in the citrus sub-sector in terms of cash receipts from farming.

Copper is a pesticide extensively used as a fungicide in the production of grapefruit for controlling diseases such as greasy spot, melanose and scab. It has been found (NAPIAP-USDA, 1999) that on average, copper is being used on about 90 percent of fresh grapefruit acreage and about 60 percent of non-bearing grapefruit acreage. The study also provides estimates of the direct impact of copper on grapefruit production in Florida by withdrawing it from the production process and using available alternatives in its place (Table 1).

Table 1. The Impacts of Alternatives to Copper.

Alternatives	To Control	Yield Impact	Packout Impact	Cost Impact/acre (*in dollars*)
Benomyl (50%)	Scab	0	0	+ 20.19
Ferbam (50%)	Scab	0	0	+ 277.15
Benomyl (100%)	Melanose	0	- 35%	+ 120.27
Petroleum (100%)	Greasy Spot	- 7%	- 15%	+ 20.34

** + (Positive sign) means increase in cost and - (negative sign) means decrease in yield/pack-out.

Source: NAPIAP, USDA. NAPIAP Report No. 1-CA-99

Suspending copper and using alternatives in its place has a direct impact on the cost of production in general and decreasing yield and pack-out in some cases. This makes it necessary to have an economic model for evaluating the overall economic impact thereon. With this motivation in mind, this paper develops an economic model for evaluating the impact of prohibiting the use of copper in Florida grapefruit production.

In the process of reassessing pesticide tolerances, the suspension of copper from fresh grapefruit production causes substantial economic impacts in terms of higher cost and lower yield and pack-out which eventually influences (through supply & revenue earned) both domestic and export markets. If copper is withdrawn from grapefruit production and other available alternatives are used instead, the cost of production will be increased and the yield and pack-out will be decreased. This in turn, will influence revenue to producers. Thus, the domestic market as well as the export market will be affected.

The objectives of this article are (1) to describe the fresh grapefruit market, both domestic and export, (2) to develop a model that will represent fresh grapefruit marketing, which will include the domestic and export markets and (3) to determine the economic impact of eliminating copper on grapefruit growers.

Pesticide and Grapefruit

Grapefruit is susceptible to diseases such as greasy spot, melanose, scab etc. The pesticides that can be used to control these diseases are benomyl, ferbam, petroleum oil, benlate and copper. Yet as copper successfully controls the above-mentioned diseases in grapefruit production, its role as a pesticide in grapefruit production could be eliminated in the future because of an environmental problem such as a copper buildup in the soil.

As for copper substitutes, a study by an Assessment Team (NAPIAP-USDA, 1999) shows that the use of pesticides as alternatives to copper in the production of grapefruit in Florida leads to an increase in cost of materials and application and in some cases, a decrease in yield and/or pack-out rate. In the aforementioned study, information on pesticides in use for a specific pest on a specific crop in a specific state are the figures reported by a survey. One or more alternative pesticides are identified for each target pest with a pesticide currently in use. Yield and pack-out impacts are taken from survey data. In order to get the cost impacts, the total cost of use for both current and alternative pesticides are calculated. Thus, the production impacts and the cost impacts are eventually translated into the economic impacts of withdrawing a specific pesticide from use.

To assess such an impact, in this paper we develop a multi-market allocation model. The model accounts for the specific characteristics of the fresh and juice grapefruit markets. Two main producer regions in Florida with two commodities, white grapefruit and pink grapefruit are included in the model. The yearly production is estimated using data on the number of grapefruit trees and the tree yield based on tree age. The number of trees multiplied by the age related tree yields equals total production. Thus, the production of each tree age group will be summed to get the supply of grapefruit. Then, total supply will be allocated to fresh and processed markets, both domestic and foreign. The production of seedy grapefruit, being negligible in quantity, has not been included in the model.

The demand side of the equation consists of five relevant markets, four for fresh grapefruit and one for processed juice. These are (1) domestic market for fresh white grapefruit, (2) domestic market for fresh red grapefruit, (3) export market for fresh white grapefruit, (4) export market for fresh red grapefruit and (5) the market for processed juice. No distinction is made between juice from white and juice from red grapefruit. Red Seedless and white seedless grapefruit are sold in both the domestic and export markets. The main export markets are Japan, the European Union and Canada. Each market has specific preferences especially with respect to fruit size and external appearance. Pana (1991) used a similar model, albeit an explicit specification for the domestic market and export market for processed juice was included. The supply and demand components of each market are integrated through the market equilibrium conditions.

Theoretical Multi-Market Equilibrium Model

A market allocation model is developed to depict the process of distributing grapefruit production across alternative markets. To simplify the exposition, assume there are two relevant fresh markets for both red seedless and white seedless Florida grapefruit. The derived markets are domestic and export. Let the inverse derived demand in each fresh market at the output door of the packinghouse be

$$P_{vj} = \alpha_{vj} - \beta_{vj} Q_{vj}^{D} \qquad (1)$$

where P_{vj} is the price per box (one and three fifth bushels) of variety v (red and white) and market j (domestic and export); α_{vj} and β_{vj} are positive parameters and Q_{vj}^D is the quantity (i.e., number of boxes) of variety v and market j.

Let the supply X_{vj} be the boxes of variety v available to market j. The quantity packed for the fresh market is

$$Q_{vj}^D = \lambda_{vj} X_{vj} \tag{2}$$

where X_{vj} differs from Q_{vj}^D because only a portion of the fruit intended for market j will meet the quality standard associated with market j. In the industry, the proportion of fruit that meets the fresh market standard is called the pack-out rate, denoted in equation (2) by λ_{vj}. The portion of fruit that does not meet the specification of the fresh market is called eliminated fruit or "eliminations." Eliminations are sent to the processing plant to be processed into juice. Let the eliminated fruit be denoted by Q_{vj}^E and

$$Q_{vj}^E = \left(1 - \lambda_{vj}\right) X_{vj}. \tag{3}$$

Since differences in eliminated fruit is mainly cosmetic and not size of the fruit, it is safe to assume that the juice content of eliminated fruit is the same regardless of whether it was intended for the domestic or export market. Let JU be the juice yield associated with one box of grapefruit. In this analysis no attempt is made to differentiate between the juice derived from red seedless and white seedless grapefruit. Therefore, juice production is given by

$$JP = \sum_v JU \left(\left(\sum_j \left(1 - \lambda_{vj}\right) X_{vj} \right) + FR_v \right) \tag{4}$$

where JP denotes the single strength equivalent (SSE) gallons of juice produced in a particular season; JU is gallons of juice per box (4.8 gallons) that does not vary by variety; and FR_v is the quantity of variety v that goes from the grove directly to the processing plant (field run). The inverse derived demand equation (Free on board (FOB) the packinghouse) for grapefruit juice is

$$P_J = \alpha - \beta Q_J \tag{5}$$

where P_J is the price per SSE gallon and Q_J denotes the gallons consumed. If juice inventory adjustment is ignored, then in any particular season

$$JP = Q_J. \tag{6}$$

Define PD_v as the total boxes of variety v in a particular season. Let PC_j be the packing costs per box associated with fruit destined for market j. The absence of a subscript for variety implies that packing costs do not depend upon variety. Let PR denote processing costs expressed in dollars per SSE gallon of final product.

With these assumptions and definitions, an allocation model can be written in which the competitive allocation of fruit by variety is

$$\text{Max} \sum_v \sum_j \int \left(\alpha_{vj} - \beta_{vj} Q_{vj}^D\right) dQ_{vj}^D + \int \left(\alpha - \beta Q_J\right) dQ_J - \sum_v \sum_j PC_j Q_{vj}^D - PR\, Q_J \tag{7}$$

$$s.t. \quad \sum_j X_{vj} + FR_v \leq PD_v \qquad v = \text{red, white} \tag{8}$$

$$Q_{vj}^{D} \leq \lambda_{vj} X_{vj} \qquad j = \text{domestic, export} \qquad (9)$$

$$Q_j \leq \left(\sum_v JU \left(\left(\sum_j \left(1 - \lambda_{vj}\right) X_{vj} \right) + FR_v \right) \right). \qquad (10)$$

All variables are non-negative.

This model is a multi-market equilibrium model; however, supply is predetermined each season (i.e. supply is perfectly inelastic) and there are no transportation costs. The output markets are FOB the packinghouse. The objective function (equation 7) maximizes the area under the derived demand functions at the equilibrium quantities for all the markets. It allocates fruit to fresh and processed markets to attain equilibrium prices given that the supply of grapefruit is fixed in the short run. Thus, the supply is perfectly inelastic as the producers cannot respond to a price change in the short run. It takes at least three years for new trees to bear fruit after producers plant them. The first constraint (set of equations 8) in the model represents the balance between total derived demand and supply. The boxes sent to the packinghouse for fresh domestic and export markets along with the boxes sent directly to the processing plant (field run) for the juice market must be less than or equal to the total production of each type of grapefruit. The second constraint (set of equations 9) is the balancing constraint between boxes sent to the packinghouse and the boxes actually packed for fresh use. The last constraint (set of equations 10) balances the juice from the boxes not qualified for the fresh market (eliminations) plus the juice from the field run boxes with total consumption of juice. One box of grapefruit produces 4.8 gallons of juice and no storage of juice is considered in the model. The model determines the equilibrium prices and quantities FOB the packinghouse. One derived supply point and five derived demand points (two domestic and two exports for fresh red and white, and one for juice) are specifically described in this model. Since juice exports are minimal, the two juice demand points (domestic and export) are considered to be one. The model is run taking 2003-2004 as the base year using actual data from that period and model results are projected for eleven more years.

The mathematical model starts with a supply sub-model based on Pana (1991). After the base year model is run, the tree inventory is updated before the model is run for year two. The total number of trees for year two is determined by adjusting the base year's tree inventory by the number of trees that survived the base year and the number of new trees that were planted in the base year. The age of each tree coming into year two is increased by one year. This process of updating the tree inventory is completed each year before the multi-market equilibrium model is run for the next year.

Data

The yield data for grapefruit trees by age groups are available from the Statistical Reporting Services of USDA. Yield data for different age groups have been collected from various issues of the Citrus Summary published by Florida Agricultural Statistics Services (FASS). The data are for the age groups 3-5 years, 6-8 years, 9-13 years, 14-23 years and 24 and above years old. Since the data are for a range of age of the trees, it is difficult to have the yield for a tree of particular age. So, the data has been interpolated to get a continuous yield of the trees over age.

The tree inventory numbers are taken from FASS publication (Commercial Citrus Inventory, 2002). The problem of unidentified trees (of less than 3 years' old) to be allocated into white or red grapefruit has been minimized by using the percentage of their respective identified

numbers. The tree inventory data used in the model has been collected from FASS (2002) publication and unpublished data from the Department of Citrus.

Demand equations for both red and white fresh domestic grapefruit have been calculated using an average price and quantity plus an estimated price elasticity, assuming a linear demand. The equations for domestic red and white fresh grapefruit are estimated based on an own price elasticity of -0.2178. This was calculated using a retail price elasticity of -1.113 (Brown and Lee, 2002, p. 25) and multiplied by a price ratio composed of the FOB packinghouse price of $6.85 per 4/5 bushel carton (FASS, 2005) and the retail price of $0.74 per pound times 42.5 pounds per 4/5 bushel carton (USDA, 2006, p. 36). The equations for red and white fresh grapefruit exports to Canada are estimated based on an own price elasticity of -1.67 (Lee, 2004, p. 8). The price elasticity of demand for both fresh red and white grapefruit exported to Europe has been estimated to be -0.39 while that of white and red fresh grapefruit exported to Japan has been estimated to be -0.66 and used in this model (Lee, 2004, p. 8). The juice price elasticity of demand is -0.1435. This was calculated using a retail elasticity of -1.294 (Brown and Lee, 1993, p. 431) and multiplied by a price ratio composed of the processing plant FOB price of $0.54 per single strength equivalent gallon (Florida Citrus Mutual, 2007) and the retail of $4.87 per single strength equivalent gallon (Florida Department of Citrus, 2005, p. 64).

The pack-out rates used are 60 percent for red and white U.S. domestic grapefruit as well as exports to Canada, 58 percent for red and white exports to Europe, and 40 percent for red and 35 percent for white exports to Japan (Muraro, 2004).

The processing cost is $0.22 per single strength gallon (Muraro, Spreen, and Pozzan, 2003). Packing cost is $7.38 per 1 and 3/5 bushel box for grapefruit packed for the U.S. and Canadian markets and $8.237 per 1 and 3/5 bushel box for the markets in Europe and Japan (Muraro, 2005; Muraro et al., 1998-99 and various issues). The number of red grapefruit 1 and 3/5 bushel boxes sent to different markets is 4,267,627 to the U.S., 852,727 to Canada, 3,294,743 to Europe, and 3,675,995 to Japan (Florida Department of Agriculture and Consumer Services, 2004). The number of white grapefruit 1 and 3/5 bushel boxes sent to different markets is 230,894 to the U.S., 37,175 to Canada, 158,818 to Europe, and 2,384,798 to Japan (Florida Department of Agriculture and Consumer Services, 2004). Single strength gallons of juice produced was 120,400,000 gallons (Florida Department of Citrus, 2005, p. 28) and was sold for $0.76 per single strength gallon (Florida Citrus Mutual, 2004, p. 46).

Empirical Results

The model with the use of copper is considered to be the base model. The base model is run using actual data from the 2003-04 season as well as historical information from 1945 to 2004, and then simulated for eleven more years. Then, it is re-run with the changes in data to reflect a ban on the use of copper. In order to validate the model, assumptions were made regarding the percentage of field run red and white grapefruit. These percentages are based upon estimates found in Brown et al. (1999). In the baseline model 20 percent of all red grapefruit and 100 percent of the white grapefruit produced outside of the Indian River region are assumed to be field run. These percentages also reflect that the primary market for fresh white grapefruit is Japan, which is primarily supplied from the Indian River region.

Base Results

Analyzing the production and utilization of red grapefruit in the base model, it is observed that right after the base year (2003-04), there is a jump in production as well as utilization. This is due to the fact that the model uses actual production and utilization figures in the base year. For the other years production and utilization are endogenously estimated. Production changes are based on the total number of trees (including new plantings), their age composition and respective yields. After the base year and the subsequent year's increase, production is projected to decrease through 2014-15 (Table 2). Similarly, the total tree numbers show a continuous decline throughout the entire period except for an increase in 2014-15. Utilization follows the same pattern as production. On-tree prices are also low in 2004-05 even though they increase through 2014-15. Revenue from red grapefruit drops initially and then increases through 2014-15. The revenue depends on the quantities utilized and on-tree prices (Table 2).

For white grapefruit, the base model shows that there is increased production and increased utilization in 2004-05 compared with the base year's actual figures (Table 3). After 2004-05, production declines through 2014-15 as do the total tree numbers. After the base year, utilization increases through 2009-10 and then decreases through 2014-15. The on-tree price declines right after the base year, then increases for the remaining years. As a result of variations in on-tree prices and utilization, revenue from white grapefruit is lower than the base year for eight years (2011-12), and then it is higher than the base year in 2012-13 and continues to increase through 2014-15 (Table 3).

Table 2. Estimated Production, Utilization, On-tree Price, Total trees and Revenue for Red Grapefruit with and without Copper, 2003-04 through 2014-15.

			Model With Copper		
Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2003-04	25,000.00	25,000.00	$ 3.76	6221.40	$ 93,912.31
2004-05	28,080.96	28,080.96	$ 0.76	6195.31	$ 21,421.40
2005-06	27,690.22	27,690.22	$ 1.11	6155.74	$ 30,604.38
2006-07	27,343.10	27,343.10	$ 1.37	6082.66	$ 37,340.90
2007-08	27,018.96	27,018.96	$ 1.65	5954.43	$ 44,568.51
2008-09	26,650.79	26,650.79	$ 2.02	5803.89	$ 53,717.10
2009-10	26,224.60	26,224.60	$ 2.39	5655.88	$ 62,641.11
2010-11	25,699.84	25,699.84	$ 2.95	5527.18	$ 75,746.09
2011-12	25,170.88	25,170.88	$ 3.57	5430.00	$ 89,750.25
2012-13	24,643.10	24,643.10	$ 4.18	5376.19	$ 103,060.19
2013-14	24,133.67	24,133.67	$ 4.79	5374.17	$ 115,613.32
2014-15	23,665.09	23,665.09	$ 5.37	5430.08	$ 127,012.28
			Model Without Copper		
Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2003-04	25,000.00	25,000.00	$ 4.66	6221.40	$ 116,372.75
2004-05	26,111.05	26,111.05	$ 4.11	6210.90	$ 107,197.55
2005-06	25,748.13	25,748.13	$ 4.14	6247.45	$ 106,610.44
2006-07	25,439.97	25,439.97	$ 4.17	6332.15	$ 106,032.25
2007-08	25,229.69	25,229.69	$ 4.19	6437.50	$ 105,596.49

2008-09	25,121.52	25,121.52	$ 4.19	6550.67	$ 105,359.49
2009-10	25,139.80	25,139.80	$ 4.15	6668.58	$ 104,400.25
2010-11	25,225.81	25,225.81	$ 4.18	6788.66	$ 105,387.85
2011-12	25,418.08	25,418.08	$ 4.16	6907.85	$ 105,787.49
2012-13	25,683.83	25,683.83	$ 4.14	7024.06	$ 106,293.94
2013-14	26,004.29	26,004.29	$ 4.11	7136.66	$ 106,832.70
2014-15	26,362.56	26,362.56	$ 4.07	7244.16	$ 107,339.99

Table 3. Estimated Production, Utilization, On-tree Price, Total trees and Revenue for White Grapefruit with and without Copper, 2003-04 through 2014-15.

Model With Copper

Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2003-04	15,900.00	15,900.00	$ 2.28	3526.90	$ 36,237.26
2004-05	17,238.53	16,110.94	$ 0.59	3500.74	$ 9,453.40
2005-06	17,142.01	16,186.98	$ 0.68	3470.72	$ 10,926.50
2006-07	17,035.73	16,316.23	$ 0.70	3430.88	$ 11,456.82
2007-08	16,920.77	16,379.30	$ 0.78	3377.30	$ 12,692.85
2008-09	16,768.01	16,389.25	$ 0.91	3314.52	$ 14,845.13
2009-10	16,566.55	16,472.19	$ 1.00	3246.35	$ 16,451.82
2010-11	16,302.30	16,302.30	$ 1.46	3174.50	$ 23,724.85
2011-12	15,979.94	15,979.94	$ 2.10	3103.19	$ 33,578.41
2012-13	15,659.09	15,659.09	$ 2.74	3039.12	$ 42,888.06
2013-14	15,312.38	15,312.38	$ 3.39	2988.42	$ 51,940.40
2014-15	14,946.92	14,946.92	$ 4.04	2958.62	$ 60,375.05

Model Without Copper

Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2003-04	15,900.00	15,604.13	-$ 0.03	3526.90	-$ 397.78
2004-05	16,034.23	12,804.13	$ 0.52	3489.78	$ 6,619.02
2005-06	15,943.92	12,804.13	$ 0.52	3440.02	$ 6,619.02
2006-07	15,833.65	12,804.13	$ 0.52	3372.89	$ 6,619.02
2007-08	15,698.51	12,804.13	$ 0.52	3297.05	$ 6,619.02
2008-09	15,506.97	12,804.13	$ 0.52	3215.10	$ 6,619.02
2009-10	15,257.92	12,801.48	$ 0.52	3129.13	$ 6,638.39
2010-11	14,944.76	12,791.49	$ 0.53	3039.12	$ 6,711.39
2011-12	14,575.96	12,791.49	$ 0.53	2946.03	$ 6,711.39
2012-13	14,210.20	12,791.49	$ 0.53	2854.42	$ 6,711.39
2013-14	13,818.24	12,791.49	$ 0.53	2760.10	$ 6,711.39
2014-15	13,399.31	12,791.49	$ 0.53	2664.72	$ 6,711.39

The distribution of utilized red grapefruit between fresh and processed categories shows that right after the base year both increase (Table 4), and then both decline through 2014-15. Both fresh and processed utilization of red grapefruit have inverse relationships with their prices.

For white grapefruit, the base model shows that fresh utilization increases after the base year through 2009-10 and then decreases through 2014-15 (Table 5). Fresh white utilization is inversely related to price. Processed utilization of white grapefruit increases through 2007-08, remains

approximately the same for 2007-08, 2008-09, and 2009-10 and then decreases through 2014-15. With the increase in processed quantity, price declines and remains negative for six years after the base year and then again with the decrease in processed quantity, price turns positive through the end of the period. The nature of low and negative prices found by the model for processed fruit is more a matter of accounting than economics. Citrus that does not meet fresh quality standards is eliminated from the packing line and sent to a processing plant. This citrus bears an "elimination charge" which accounts for the money already spent in the packinghouse before the fruit is eliminated and the cost of hauling the fruit to the processing plant. Upon arrival at the processing plant, this fruit bears the picking and hauling cost from the grove to the packinghouse and from the packinghouse to the processor plus the elimination charge. If the processor offers a positive price for the fruit, it is viable for the packinghouse to dispose of the fruit via the processor versus dumping the fruit. If the processed price is low, the net on-tree price will likely be negative because of the pick and haul costs and the elimination charge which are subtracted from the processed price.

Alternative Results

The alternative model (without copper) shows a lot less price volatility than the base model (with copper) and consequently, less variance in production as well as in utilization. Production and utilization of red grapefruit increase for one year after the base year and then decrease from 2004-05 through 2008-09 and increase from 2008-09 through 2014-15 (Table 2). Accordingly, on-tree prices are more or less stable over the period, maintaining an inverse relationship with utilized quantities except from 2009-10 to 2010-11 where price and quantity both increase. After initially decreasing from the base year to the next year, new tree plantings occur from 2004-05 through 2014-15 because of relatively high on-tree prices. Total revenue from red grapefruit decreases from 2003-04 through 2009-10 and then increases through 2014-15. Total revenue never returns to its former high which occurred during the base year (Table 2).

For the white grapefruit, production increases for the first year after the base year and then it declines through 2014-15 (Table 3). On the other hand, utilization drops initially and then remains relatively stable but lower than the base year. On-tree prices show the theoretically expected inverse relationship with utilized quantities. Due to stable and low on-tree prices, the total tree numbers decline through 2014-15. Total revenue from white grapefruit increases through 2014-15 as a consequence of the return to positive prices that remain fairly stable.

Fresh utilization of red grapefruit shows that fresh utilization decreases from 2004-05 through 2008-09 after an increase from the base year and then increases from 2008-09 through 2014-15 (Table 4). Fresh prices maintain an inverse relationship with quantities through 2014-15. Processed utilization increases right after the base year, only to settle down on that higher level through 2014-15. The processed price remains the same for the entire period. This is because the processed quantity has reached its maximum beyond which it will not be profitable to process the fruit. For the white grapefruit, fresh utilization is constant over the analyzed period with a constant price (Table 5). The processed utilization shows a similar pattern with a sharp drop right after the base year.

Table 4. Estimated Fresh and Processed Quantity and On-Tree Price for Red Grapefruit with and without Copper, 2003-04 through 2014-15.

	Model With Copper			
Year	Fresh Qty. (*1000 boxes*)	Price (Fresh) (*$/ box*)	Processed Qty. (*1000 boxes*)	Price (Processed) (*$/box*)
2003-04	13,262.54	$ 6.94	11,737.46	$ 0.16
2004-05	14,805.45	$ 3.02	13,275.51	-$ 1.76
2005-06	14,610.81	$ 3.52	13,079.41	-$ 1.59
2006-07	14,439.12	$ 3.95	12,903.99	-$ 1.52
2007-08	14,277.65	$ 4.36	12,741.31	-$ 1.38
2008-09	14,093.05	$ 4.83	12,557.74	-$ 1.14
2009-10	13,880.76	$ 5.36	12,343.85	-$ 0.95
2010-11	13,616.61	$ 6.03	12,083.24	-$ 0.53
2011-12	13,348.81	$ 6.72	11,822.08	$ 0.00
2012-13	13,081.62	$ 7.41	11,561.48	$ 0.53
2013-14	12,823.34	$ 8.07	11,310.33	$ 1.07
2014-15	12,585.30	$ 8.68	11,079.79	$ 1.60

	Model Without Copper			
Year	Fresh Qty. (*1000 boxes*)	Price (Fresh) (*$/ box*)	Processed Qty. (*1000 boxes*)	Price (Processed) (*$/box*)
2003-04	7,795.83	$ 21.47	15,754.58	-$ 3.67
2004-05	8,116.66	$ 20.48	17,106.06	-$ 3.67
2005-06	8,011.86	$ 20.81	17,106.06	-$ 3.67
2006-07	7,922.88	$ 21.08	17,106.06	-$ 3.67
2007-08	7,862.16	$ 21.27	17,106.06	-$ 3.67
2008-09	7,830.92	$ 21.36	17,106.06	-$ 3.67
2009-10	7,836.20	$ 21.35	17,232.94	-$ 3.67
2010-11	7,861.03	$ 21.27	17,131.33	-$ 3.67
2011-12	7,916.56	$ 21.10	17,131.33	-$ 3.67
2012-13	7,993.29	$ 20.87	17,131.33	-$ 3.67
2013-14	8,085.83	$ 20.58	17,131.33	-$ 3.67
2014-15	8,189.29	$ 20.26	17,131.33	-$ 3.67

Table 5. Estimated Fresh and Processed Quantity and On-tree Price for White Grapefruit with and without Copper, 2003-04 through 2014-15.

	Model With Copper			
Year	Fresh Qty. (*1000 boxes*)	Price (Fresh) (*$/ box*)	Processed Qty. (*1000 boxes*)	Price (Processed) (*$/box*)
2003-04	3,228.88	$ 7.81	12,671.12	$ 0.87
2004-05	3,311.10	$ 6.91	12,799.84	-$ 1.05
2005-06	3,338.49	$ 6.67	12,848.49	-$ 0.88
2006-07	3,349.03	$ 6.58	12,967.20	-$ 0.82
2007-08	3,371.75	$ 6.38	13,007.55	-$ 0.68
2008-09	3,411.36	$ 6.03	12,977.90	-$ 0.44
2009-10	3,441.23	$ 5.76	13,030.95	-$ 0.26
2010-11	3,377.94	$ 6.38	12,924.36	$ 0.17
2011-12	3,258.55	$ 7.52	12,721.40	$ 0.71
2012-13	3,139.71	$ 8.65	12,519.39	$ 1.26
2013-14	3,011.38	$ 9.87	12,301.00	$ 1.81
2014-15	2,876.22	$ 11.13	12,070.70	$ 2.35
	Model Without Copper			
Year	Fresh Qty. (*1000 boxes*)	Price (Fresh) (*$/ box*)	Processed Qty. (*1000 boxes*)	Price (Processed) (*$/box*)
2003-04	2,171.25	$ 18.33	13,432.88	-$ 2.99
2004-05	2,171.25	$ 18.33	10,632.88	-$ 3.12
2005-06	2,171.25	$ 18.33	10,632.88	-$ 3.12
2006-07	2,171.25	$ 18.33	10,632.88	-$ 3.12
2007-08	2,171.25	$ 18.33	10,632.88	-$ 3.12
2008-09	2,171.25	$ 18.33	10,632.88	-$ 3.12
2009-10	2,171.25	$ 18.33	10,627.58	-$ 3.12
2010-11	2,171.25	$ 18.33	10,607.61	-$ 3.12
2011-12	2,171.25	$ 18.33	10,607.61	-$ 3.12
2012-13	2,171.25	$ 18.33	10,607.61	-$ 3.12
2013-14	2,171.25	$ 18.33	10,607.61	-$ 3.12
2014-15	2,171.25	$ 18.33	10,607.61	-$ 3.12

Comparison of Results

It is interesting to note how the model reacts differently for each variety of fruit. As noted before, in general and on average, on-tree prices for red grapefruit tend to increase while those for white variety tend to decrease when copper is withdrawn (Tables 2 and 3). The same occurs with overall production, with red increasing and white decreasing. This result happens to be the optimal response of our model while trying to maximize profits. As the price of white grapefruit relative to red falls, production of red grapefruit relative to white increases as a natural supply response.

Comparing the results of the two models in more detail we observe that without copper,

production and utilization decline four years for red and 10 years for the white seedless varieties, and then begin to increase for the last six years for red grapefruit only. On-tree prices and total revenues are stable for red and white seedless grapefruit (Tables 2 and 3). Utilization of red grapefruit increases by 4.4 percent immediately after the copper withdrawal, while utilization of white grapefruit declines more than 17.9 percent. On-tree prices for red and white grapefruit remain steady after an initial decline from the base year when copper is removed (Tables 2 and 3).

Without copper, fresh utilization of red and white grapefruit remains fairly stable; however, processed utilization of red grapefruit increases by 8.7 percent while that of white grapefruit decreases by 21.0 percent (Tables 4 and 5). The nature of low and negative prices found by the model for processed fruit, both red and white, is more a matter of accounting than economics. As pack out rates decline when copper is withdrawn, a larger proportion of the fruit is sent to the processor. This fruit bears an "elimination charge" which accounts for the money already spent in the packinghouse before the fruit is eliminated. Upon arrival at the processing plant, this fruit bears the picking and hauling cost from the grove to the packinghouse and from the packinghouse to the processor plus the elimination charge. If the processor offers a positive price for the fruit, it is viable for the packinghouse to dispose of the fruit via the processor versus dumping the fruit. If the processed price is low, the net on-tree price will likely be negative because of the pick and haul costs and the elimination charge which are subtracted from the processed price. In our case, mean fresh on-tree prices for the entire period for red grapefruit increased by 265.7 percent while fresh on-tree prices for white grapefruit increased by 145.4 percent without copper (Table 4 and 5). As an average for the entire period, the processed price for red grapefruit decreased by 597.8 percent while the average processed price for white grapefruit decreased by 1144 percent.

Conclusions

Banning copper from grapefruit production will yield different price responses depending on which variety of grapefruit is considered. On one hand, on-tree prices will increase for the red grapefruit variety, which is the one that has more stringent quality requirements. The reverse occurs for the least quality demanding white grapefruit. This change favoring an increase in the relative production of red grapefruit leads to an increase in grower revenue for red grapefruit and a decrease in white grapefruit revenue. At the same time, fresh marketing decreases for red and white grapefruit, FOB packinghouse prices for domestic and international markets increase whereby the consumer prices increase at the same time. And even though the cost of production increases, net revenue to grove owners using no copper is greater than when copper is used. The main conclusion of the study is that a ban on copper in grapefruit production has a negative impact on consumers in terms of higher prices and lower grapefruit consumption, but a positive impact for producers in terms of the overall increase in net revenue.

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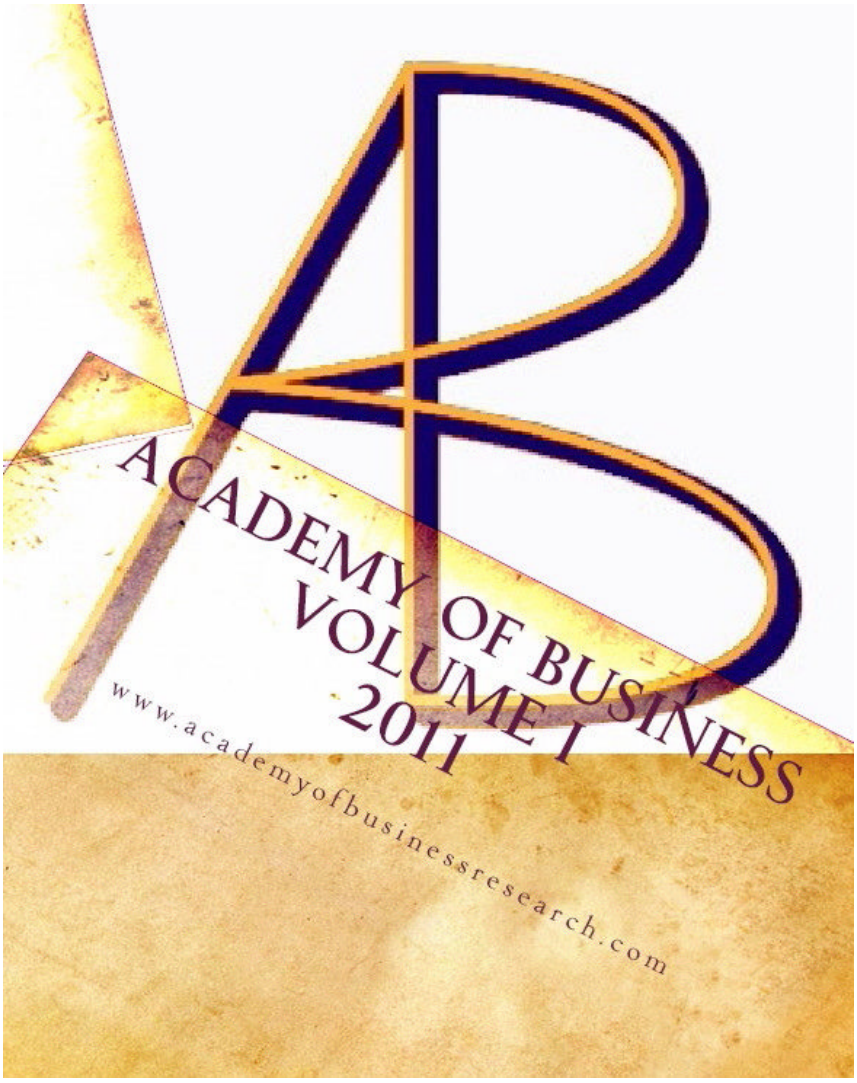

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