MANAGEMENT OF TECHNOLOGY

# ANTICIPATION OF LEGACY SYSTEM SUPPLY CHAIN RISKS: A COMPARATIVE STUDY OF DECISION MAKER PERSPECTIVES

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Thesis under the direction of Professor David Dilts

As systems age and require new efforts for revitalization, the original supply chain faces risks that once were not an issue. The supply chain for a legacy system can diminish over time as factors such as new technologies, economic shifts and global considerations redirect suppliers. This study examines the potential level misalignment between engineers, who develop legacy system supply chain strategies, and managers who oversee the function of these systems. A two part survey, assessing the risk of a legacy supply chain, compares the responses of 331 engineers with 203 upper managers, all of who are associated with systems engineering. Despite the potential for functional misalignment among engineers and managers, we found few statistically significant differences of perceptions of supply chain risks. There were, however, notable differences in views concerning the necessary level of supplier assistance and ethical standards.

Keywords: Functional Misalignment, Supply Chain Management, Systems Engineering, Legacy Systems, Risk Mitigation

Approved_______________________________________________Date_________________

# ANTICIPATION OF LEGACY SYSTEM SUPPLY CHAIN RISKS: A COMPARATIVE STUDY OF DECISION MAKER PERSPECTIVES

By

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TABLE OF CONTENTS

LIST OF TABLES

# LIST OF FIGURES

# CHAPTER I

# INTRODUCTION

As systems age and require new efforts for revitalization, the original supply chain may no longer be able to perform as it once did (Gunasekaran, 2004). Supply chain disruptions and failures can delay and immobilize a project, losing valuable time and money. Given the increasingly complicated and volatile nature of today's legacy supply chains, organizations must anticipate risks in order to avoid costly disruptions (Chopra and Sodhi, 2004). If operating strategies are misaligned, the likelihood of poor performance increases (Joshi, Kathuria, and Porth, 2003). Additionally, if managers and engineers have different attitudes (Shaw and Shaw, 2003) then there lies the possibility for a misalignment within an organization (Berry, Hill, and Klompmaker, 1996). Although our study examines perception of supply chain risks, managers should also be able to identify and manage level misalignments so that they do not make the organization vulnerable to such risks (Sosa, Eppinger, and Rowles, 2004).

Short term threats such as war and terrorism, natural disasters, and labor issues can wreak havoc on supply chains (Hendricks and Singhal, 2005). During the 11 day work stoppage of 29 West Coast ports in 2002, the United States lost approximately $1 billion per day (Pai *et al.*, 2003). The global meat supply was disrupted by the spread of foot-and-mouth disease in England's cattle. These examples illustrate costly periods that eventually recover fully. Legacy systems face even more severe threats to the supply chain that can cause complete system failure. In addition to these short term problems, legacy systems must manage diminishing supplier base, the exponential growth rate of technology, outsourcing and globalization. Take for instance the concept of power line communications, or broadband over power line (BPL). It was introduced in the United Kingdom in 1997, and one year later DSL arrived providing a superior service. Since then, BPL has moved through the hands of Nortel, Siemans, Swiss based Ascom, and now the Spanish company DS2 is struggling to manage this obsolete system (Varley, 2005).

Today, it is primarily those building large-scale, long-term systems that face diminishing supply chain concerns (Kunesh, 2005), but the time is quickly approaching for other, smaller manufacturers to also address these possible problems.

Solomon, Sandborn and Pecht (2000) present a depiction of a system's lifecycle and indicate the zone of obsolescence towards the end of its lifecycle (see Figure 1).
The decline stage is marked by increased maintenance and part replacement (Solomon, Sandborn, and Pecht, 2000), thus beginning the challenge of sourcing new suppliers. Take for instance the B-52 bomber project which began in 1946 with an expected lifecycle of only one decade (Bowers, 1989). Thanks to technology insertion projects, the B-52 is expected to serve the US Air Force up to 2045, but like any old system it has needed constant maintenance. The designers of this system's updates have the growing challenge of finding products that will integrate into a sixty year old system. A broader global search of suppliers is one way to improve this process.

With the rapid expansion of today's global economy come new challenges in managing the supply chain (Pyster and Thayer, 2005). General Motors is currently facing a major crisis and has undergone an extensive restructuring (Welch, 2005). GM constantly gets pressured into more product outsourcing in order to reduce costs every year (Alkadi, Alkadi, and Totaro, 2003). Low-cost country sourcing (LCCS) is an increasingly popular practice that has shown remarkable supply chain cost savings, however mitigating the risks of this strategy can be complicated. Establishing secondary sources in less risky, but more expensive,  countries is the top method of handling these risks; but inevitably as competition increases manufactures will be forced to take more chances to keep costs down (Fitzgerald, 2005).

In addition to outsourcing, product/service complexity, globalization, and e-business all contribute to the new breed of supply chain (Harland, Brenchley, and Walker, 2003). It is management and systems engineering that will be responsible for dealing with these new challenges. Systems Engineering (SE) takes an interdisciplinary approach that encompasses the entire technical effort, and evolves into and verifies an integrated and life-cycle balanced set of system people, products, and process solutions that satisfy customer needs (*Systems Engineering Fundamentals, 2000)*. SE is most commonly used in long-term, large-scale projects where entire lifecycle considerations must be made such as the B-52 project.

Systems Engineering falls in an unusual place with regard to the changing supply chain. SE fundamentals include considerations for the supply chain during the design of a project as well as maintenance and support of legacy systems (Blancard and Fabrycky, 1998). SE takes a meticulous approach to organize complex systems. Conversely, the mentality of checking and rechecking, and then having further reviews could create a situation where the supply chain drawn up in the design phase looks completely different when the project is actually implemented. For example, Boeing could begin a project today using systems engineering practices to update the electronics in the B-52. If the design of the project takes two years, according to Moore's Law, which predicts a doubling of computing power every 18 months, Boeing will have problems sourcing outdated electronics when it is time to begin the project. Therefore, the designers would need to expand their supplier search. The sophisticated global supply chain that promises so many advantages in speed, quality and cost may be problematic in situations where it is not fully understood (Holweg, et.al, 2005). Eagerness to join the world-wide market is dangerous if the supply chain strategies are based on older processes. The time between designing an updated supply chain and successfully implementing changes is specific to the circumstances.

Whether the threat is obsolete technology or environmental factors, successfully managing the supply chain requires coordination. The focus of our study is on the interface between systems engineers and the more broadly thinking management (see Figure 2). Joshi, Kathuria and Porth (2003) conducted a similar study that measured performance in instances with and without alignment among managers. In order to measure the performance difference due to misalignment, one must first identify if such a misalignment actually exists.

This conceptual model, adapted from a study measuring manufacturing performance by Joshi, Kathuria and Porth (2003), illustrates how supply chain risk mitigation success depends on how well the environmental factors such as outsourcing and DMSMS are controlled. In order to do this well, strategies must be aligned (circled section). The perceptions of supply chain risk from both managers and engineers add to the strategy, yet these inputs come from different organizational levels. The dashed line indicates the influence that managers have on engineers. It should be noted that our study does not measure the success of supply chain risk mitigation strategy, as our main concern is understanding the relation between inputs that go into the strategy.

# CHAPTER II

## THEORETICAL FOUNDATION: FUNCTIONAL MISALIGNMENT

Allison and Zelikow (1999) write "To perform complex tasks, the behavior of large numbers of individuals must be coordinated". When such coordination does not exist it is known as functional misalignment. Literature suggests that different cultures, value systems and traditions, as well as divisions and level of corporate influence can be the cause of intra-organizational misalignments (Berry, Hill and Klompmaker, 1994). The commonly studied gap between manufacturing and marketing shows obvious potential for inefficiencies within a company (Menda and Dilts, 1997). Many would also argue that cultures and traditions also differ between engineers and their managers (Shaw and Shaw, 2003). In a similar fashion, this study observes the possible misalignment of perceived risks between these two distinct groups; considering the different cultures and levels on which managers and engineers operate. Between systems engineers and managers, there are different corporate influences resulting in differing responsibilities (Cleland, 1981). This problem goes beyond traditional functional misalignment to a more complex idea of level misalignment.

**H1.** The perceptions of legacy system supply chain risks differ between managers and engineers.

Nath and Sudharshan (1994), when measuring alignment, considered three inputs: organizational structure, business strategy and environmental factors. The most extensively studied factor pertaining to supply chain management is the impact of the environment. Hill, Menda, and Dilts (1998) present a number of explanations for the inability to adapt to the changing environment. They note “the company may fail to notice gradual changes in market needs because it uses analysis that compares the current year only with the previous year”. This practice encourages incremental change, and restricts innovation that is necessary in today’s complex systems (Miller, et.al, 1995). The SE mentality embraces incremental changes because of its security and predictability; unfortunately the rate of change in the supply chain has increased (Chopra and Sodhi, 2004). In order to better understand the reasons for this change, one should become familiar with the current environment of complex systems and how it influences the supply chain.

### 2.1 Complex System Environment

Blanchard (2004) provides a depiction of the current environment in which a project must operate (see Figure 3). Of the ten trends presented that characterize the current environment, all affect the supply chain to some degree.

New factors such as increasing globalization, more outsourcing, greater international competition, and dwindling resources create not only system challenges but also risks to the supply chain. Harland, Brenchley and Walker (2003) identify the following as what contribute to the complexity of the supply chain: scale, technological novelty, quantity of sub-system components, degree of customization, quantity of alternative design and delivery path, number of feedback loops in the production and delivery system, variety of knowledge bases, number of actors in the network web of financial arrangements, and political and stakeholder intervention, among others. The emphasis being that as the complexity of the supply chain increases, so will the opportunity for problems to occur (Harland, Brenchley, and Walker, 2003). The following sections will discuss the specific risks to legacy system supply chains, and what can happen when these are realized. Of these complexity threats, one issue that is especially pertinent to legacy systems is the attrition of available suppliers known as Diminishing Manufacturing Sources.

### 2.2 Diminishing Manufacturing Sources (DMS)

DMS, often combined with Material Shortage (DMSMS) (Kunesh, 2005), is a term coined by the military that began drawing attention some forty years ago with the growth of electronics. Two main factors fuel the importance of DMS today: 1) increasingly shorter lifecycles between introduction and obsolescence of commercial off the shelf (COTS) electronic components and 2) reduced defense budgets for legacy systems (Kunesh, 2005). Ironically, high-technology can be expensive, but often old-technology ends up costing more (Glass, 2004). Current technology, such as processors and electronics, advance at a rate of one new generation every six to eighteen months (Wilson, 2001). In order to have the best technology, large-scale systems use technology that has been developed for commercial applications, and by the time they can implement it into a project, there is already something new and better in the market. Sometimes it can actually be less expensive to have the latest technology, especially from a maintainability perspective (Chabrow, 2004). Figure 4 presents a scale of the Department of the Navy's DMSMS hierarchy of cost avoidance.

As a system ages, there are fewer inexpensive maintenance fixes and the options fall on the hierarchy of cost avoidance. A current example of this catch-22 exists in the Joint Strike Fighter. It will become the first aircraft to use fiber optics in place of hydraulic lines; unfortunately Wi-Fi systems are already threatening to force fiber optics into obsolescence for this application (Ramsey, 2001).

### 2.3 Legacy Systems

Legacy systems are aging systems that are approaching obsolescence but are still critical to the operation of a larger system (Sellars, 2004). The most common use of the term legacy system comes from software systems. Bennett (1995) informally defines legacy systems as “large software systems that we don’t know how to cope with but that are vital to our organization”. However the formal definition of a legacy system includes all types of systems; software, hardware, electrical, processes, and business plans (Sellars, 2004). In order to have a broader view of a legacy system consider the current state of health care in the US. The concept of workers paying into a system to provide for the retired populations worked while these two groups were equivalent. Brooke and Rampage (2001) credit the changing surrounding environment to a legacy system no longer being able to satisfy core business requirements. Therefore as the baby boomer generation ages, combined with rising health care costs, the current social security process will become obsolete, but still will be critical to the overall healthcare system.

Ironically, many legacy systems and their problems are byproducts of the systems engineering discipline (Bisbal, et. al, 1999). The full lifecycle approach taken by systems engineers often leaves decades old technology in mission-critical systems (Bisbal, et al., 1999). Unfortunately most organizations do not have the luxury of eliminating their aging systems and starting anew. Therefore obsolescence of legacy systems must be managed using a combination of the following techniques: reengineering, reverse engineering, replacement with COTS and system assessment (Sellars, 2004; De Lucia, et al., 2001). These approaches to managing legacy systems share common themes with systems engineering and supply chain management.

The involvement of legacy systems in our study adds another dimension to the overall understanding of misalignment. Legacy system considerations add complexity to the management and design of supply chains. With added complexity comes more risk and vulnerabilities that require consensus strategies among organizational levels.

# CHAPTER III

# METHODOLOGY

## 3.1 Sample and data collection

Due to the correlation between systems engineering and legacy systems, managers and engineers who associated themselves with systems engineering fields were selected to participate in our study. Selecting respondents who were familiar with the concepts of supply chains and legacy systems helped ensure content validity (Fowler, 1993; Fink and Kosekoff, 1998). The questionnaire consisted of 27 items measured on a seven-point Likert scale with values ranging from 1 (Low) to 7 (High). For Items 1-22 respondents were asked to respond between Strongly Disagree (1) and Strongly Agree (7); items 23-25 were measured on a Likert 1-7 scale from Not Important (1) to Very Important (7); item 26 is measured on a Likert 1-7 scale from Very Little (1) to Very Much (7); item27 is measured on a Likert 1-7 scale from Not Concerned (1) to Very Concerned (7); Items 28-29 were open ended (see appendix A for the entire survey). The following three items were reverse coded to ensure validity (Trochim, 2001):

- Q3. Supplier reputation,
- Q8. High technology demands,
- Q21. Complexity inversely related to reliability.

The survey was approved by the Vanderbilt University Institutional Review Board, approval no. 050699, on August 8, 2005.

The majority of respondents came from across the United States, with others from Canada, South America, Europe and Asia. A pilot study of forty participants was conducted by first calling the respondent, then sending an email with an online link to the survey. As Zhang (1999) noted, correspondence through email provided a number of advantages including 1) the ability of each respondent to ask questions before completing the questionnaire, 2) individual emails assuaged fears of illegitimacy of the study and our intentions, 3) email communication allowed for the exchange of research ideas and information, and 4) feedback from respondents concerning their experiences was accessible. Once the questionnaire was deemed acceptable, 3,865 emails containing a letter of confidentiality and the link to the online survey were sent directly to the possible respondent. Of this number, 166 emails bounced as invalid email addresses leaving a target sample size of 3699. A total of 646 responses were collected over a two month period, yielding a response rate of 17.5%. Approximately 200 responses were discarded for incomplete data and duplication. Many others declined the offer to participate citing a lack of experience or knowledge of supply chains and/or legacy systems. See Table 1 for the sample and population breakdown of the survey.

In order to compare the responses of different groups, the respondents were divided into four categories depending on their professional position (see Table 1). The Manager group consisted of respondents who listed their position as: Director, President, Vice-President, Chief Executive Officer, Chairman, Project Manager, and equivalents. The Engineer group consisted of: Systems Engineer, Senior Engineer, PE, consultant, analyst, and equivalents. The Educator group was made up of primarily Professors. The Other group included retired respondents and positions that did not intuitively fit into another category.

### 3.2 Measurement of variables

For items 1-27, scales were built using a model developed from appropriate literature (see Appendix B). The model constructs and items were developed based on earlier studies and literature (see Appendix C). Data analysis using Cronbach's alpha reliability estimate test (Nunnally, 1967) and factor analysis also was used to develop scales.  This reliability and validity approach has been applied in other similarly structured studies (Kuei, et. al, 2002; Kuei and Madu, 2001).

#### 3.2.1 Open ended item measurements

The open ended question (item 28: *What are the 3 main reasons your company would discontinue business with any given supplier?*) was coded into the following eleven bins:

1. High cost
2. Poor quality and performance
3. Schedule and reliability problems
4. Ethics
5. Communication problems
6. Better options
7. Contract breech and expiration
8. Changing Needs
9. Supplier finance issues
10. Relationship Issues (such as confidence and trust)
11. Others (such as security, safety, disruptions

(See Appendix D. for item 28 Outline and references)

Bins one through five accounted for 75% of the responses and bins one through ten accounted for 96% of the responses, leaving 4% falling in the "others" bin. These responses were grouped in the same way as the structured questions (by respondent position) and analyzed using analysis of variance. One-way ANOVA was conducted to test whether there is a meaningful difference between responses given by managers, engineers and educators. LSD, Bonferroni and Tamhane post-hoc tests were done to find the source of meaningful differences among groups.

CHAPTER IV

RESULTS

### 4.1 Items one through twenty-seven

Cronbach's alpha showed no scales were reliable at the 0.7 level and confirmatory factor analysis showed little relevant item groupings due to poor statistical indices, therefore each question was analyzed individually.

The individual analysis of each item was completed using analysis of variance (ANOVA) (see Table 2), as well as LSD, Bonferroni, and Tamhane post-hoc tests. The analysis of variance as seen in Table 2 shows no statistically significant difference on 22 of the 27 items (81.5%) of the items. Consequently, the primary hypothesis H1 is not supported.

However there were cases of statistically significant differences among groups. Items one (sharing similar corporate cultures), four (supplier must protect sensitive information), six (being taken advantage of during negotiations), twelve (willingness to assist in design), and thirteen (willingness to help) showed interesting differences among positions (see Table 3). Generally managers and engineers answered consistently while educators showed different perspectives. Item 6 (*We worry about being taken advantage of during negotiations*; p=.014) revealed a consensus among managers and engineers, but educators showed significant differences. The significant positive mean difference between educators and managers (.602) as well as educators and managers (.594) suggests that educators have a higher degree of concern and skepticism during negotiations. Another such case can be seen in the analysis of question 13 (*The supplier's willingness to help us in difficult situations is important*; p=.001). Both managers and engineers felt it was more important for suppliers to help in difficult situations than did educators.

Further examination of the results reveals an interesting finding in item 12 (*This supplier should be willing to assist in the design of a product to specifically meet our needs*; p=.054). The mean difference between managers and engineers (-0.229) showed a statistically significant difference. This result suggests that engineers place a higher value on a suppliers' willingness to help with design. Managers and engineers also disagree on the degree in which sensitive information should be protected (-0.191). Behavioral explanations for these differences will be given in the discussion section.

**4.2 Open ended question twenty-eight**

*What are the 3 main reasons your company would discontinue business with any given supplier?*

The ANOVA of this question indicates three of the eleven possible responses for this question show statistically significant differences among groups (see Table 4).

Managers indicated a greater concern for ethical behavior from their suppliers (p=.041) than did engineers. Importantly, managers and engineers also differed on their concern for changing needs and the role of the supplier. The mean difference of -0.68 between managers and engineers suggests that engineers have a higher concern for this issue (see Table 5).

Finally, the emphasis on supplier relationships shows a statistically significant difference between educators and the other groups.

# CHAPTER V

# DISCUSSION

Short-term supply chain disruptions garner immediate attention due to the obvious visible threat (Blackhurst, J., et al., 2005). On the other end of the spectrum lies the slowly degrading supplier pool for legacy systems. Like a cancer that goes untreated, this issue will become increasingly serious until it also visibly threatens the supply chain. Our study began the process of looking at alignment issues as a potential weak point in legacy supply chain management. Despite having difficulty with scales, our findings present interesting insight and basis for further research.

The aim of the study was to examine particular situations where managers and engineers may have different perceptions of risks. In most aspects, managers and engineers differed little. Bertua, Anderson and Salgado (2005) tested the general mental ability (GMA) of both engineers and managers and found that their job performance was almost identical, helping to confirm our finding.

There were, however, instances where managers and engineers did not share views. Engineers responded that suppliers should be more willing to help with the design of a product. This may be a reflection of the benefits of supplier/buyer collaboration (Jap, 1999) as experienced by the engineers, or it could be an indication that managers prefer to keep design in-house due to security, financial, or other concerns. Mangers and engineers also disagreed on the supplier's need to protect sensitive information, and managers expressed heightened concern about unethical suppliers. These disconnects could prove critical considering the globalization movement of supply chain management and the trend of doing business with little known suppliers. Another significant finding from the open ended response was the engineers' elevated concern for supplier capabilities. If managers do not recognize the changing needs of a system then the supply chain will become vulnerable to the diminishing supplier pool.

Intuitively, managers and engineers were expected to perceive supply chain risks more similarly than educators. Because educators completed the questionnaire from a purely hypothetical perspective it is understandable that differences existed. More specifically, educators exhibited a different perception about the threat of being taken advantage of during contract negotiations. This is a logical result because contract negotiations are not an everyday part of an educator's life.

The majority of respondents would not consider this to be a study about a crisis situation. However, if and when environmental factors become too difficult to manage and DMSMS faces smaller manufacturers, diminishing supply chain management will be a more serious concern. Allison and Zelikow (1999) explain that "where you stand depends on where you sit". Managing a crisis situation tends to isolate positions and polarize perceptions. Unfortunately this is when collaboration is essential, yet most difficult (Allison and Zelikow, 1999). Pyster and Thayer (2005) warn that human customs and practices react at a much slower rate than the changing environment, suggesting that managers and engineers should not wait until crisis mode to make strategy changes. Further studies will be essential in anticipating and forecasting future issues.

The differing perceptions found in our study could depend on the different behavioral or managerial characteristics of each group. Other demographic criteria such as age, experience, location and specific industry could also help to explain perceptions gaps. Perhaps it is the influence that managers have on engineers due to their supervisory role that helps keep strategies aligned. What should be taken from this study is that few differences in perceptions exist between managers and engineers but there is always the potential for differences and this question should be revisited in the future.

# CHAPTER VI

# CONCLUSION

Like all problems, the earlier the detection the less costly the remedy and this holds true for legacy supply chain risks. We have only begun to speculate the extent of problems stemming from the complex environment in today’s market. Jack Welch, former CEO of GE, took this philosophy one step further and sought out potential problem areas and made changes before they could arise. Many questioned why he would revamp a seemingly well structured organization, until it was clear that his changes produced even better results (Byrne, 1998). Although our study does not show misalignment issues between managers and engineers to be a current critical threat, not enough is known about how this relationship will function in the future.

Ultimately it is the manager’s responsibility to make strategic decisions during difficult times. But often, even the best reaction to a problem cannot solve it. Using the findings of this study, managers should adopt the attitude of Vijaya Lakshmi Pandit when she said, “the more we sweat in peace, the less we bleed in war” (Grover and Arora, 1993).

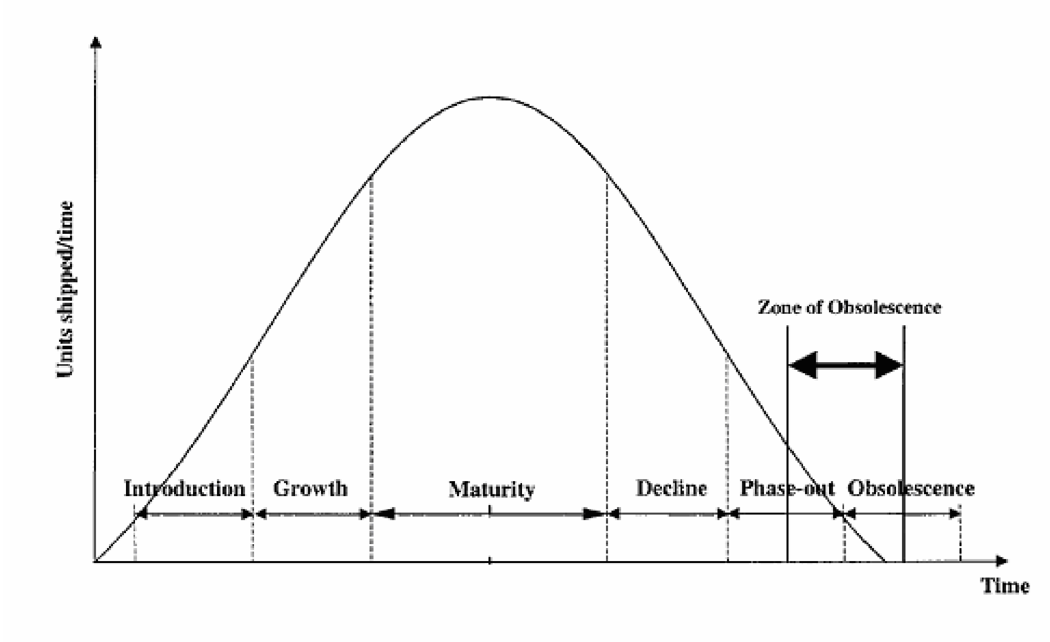


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Figure 1. Life cycle of a System (Solomon, Sandborn, and Pecht, 2000, p.708)

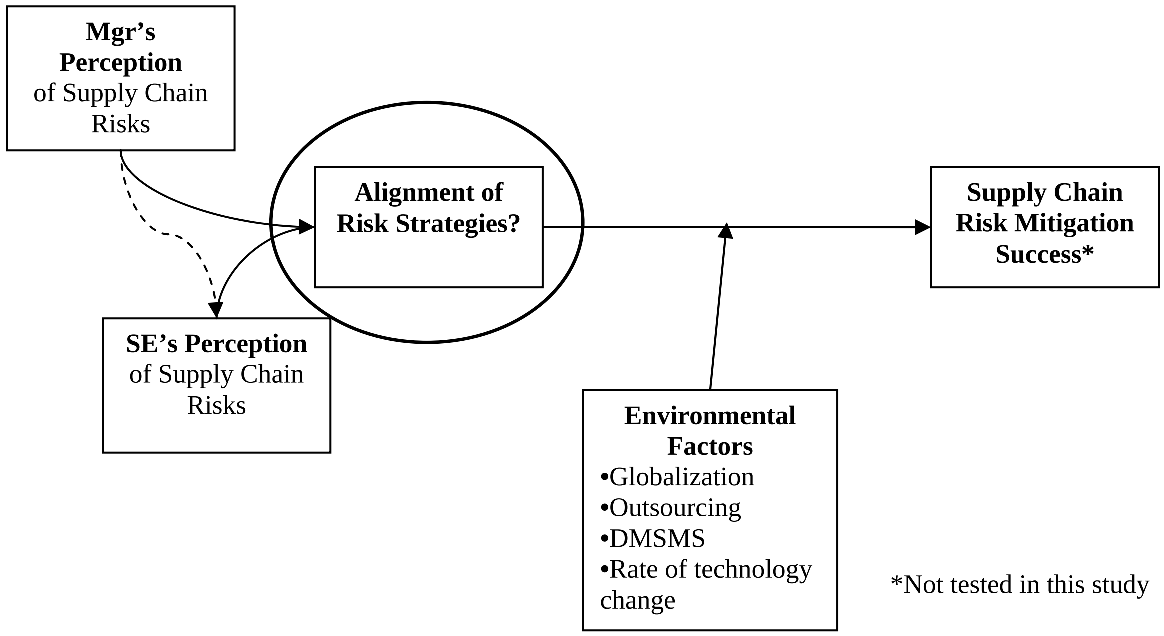


Figure 2. A conceptual model depicting the relationship between alignment, risk mitigation and environmental factors.

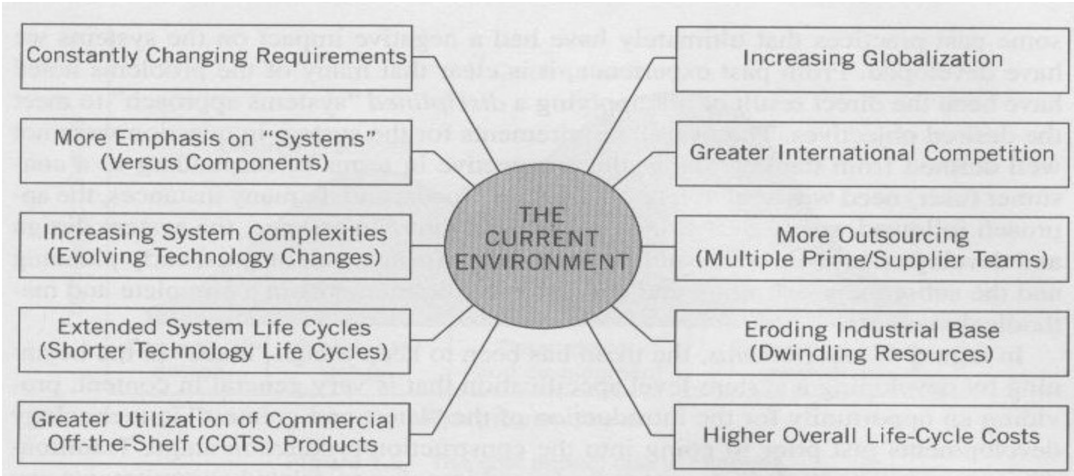


Figure 3. The current environment of large-scale projects (Blanchard, 2004, p.3)

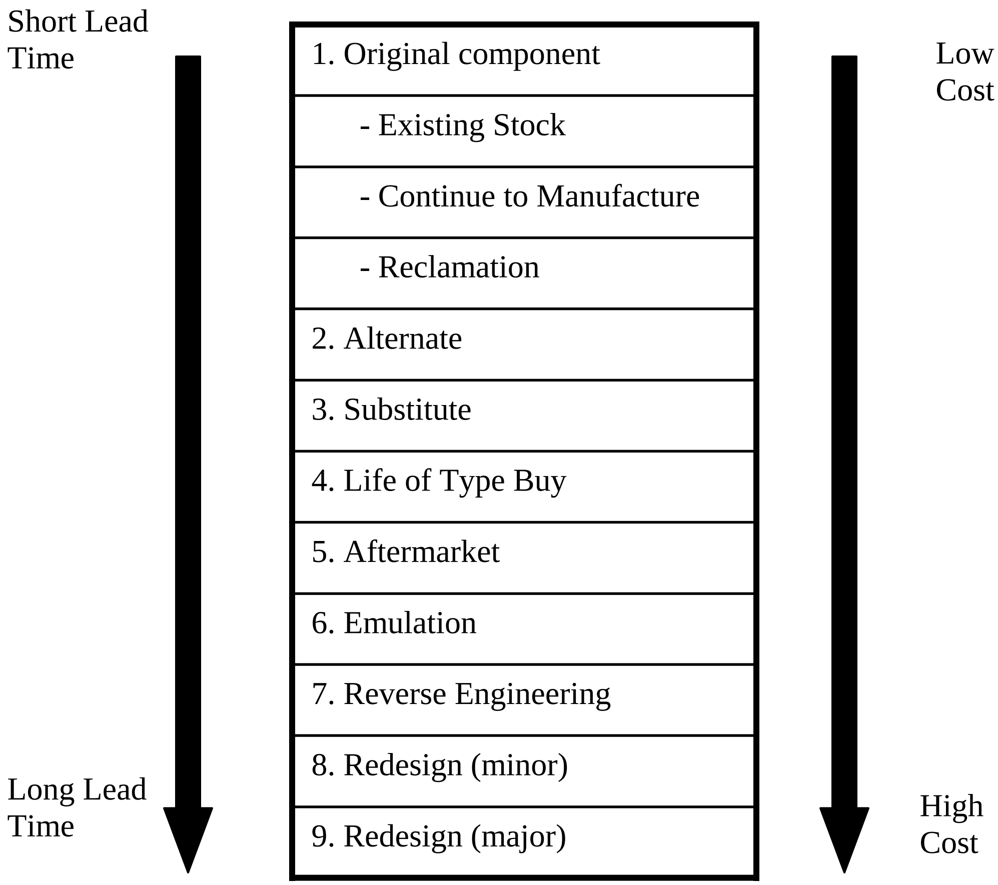


Figure 4. DMSMS Hierarchy of Cost Avoidance (Kunesh, 2005, p. 2)

| Table 1. Questionnaire Statistics | |
|---|---|
| Start Date | 12/6/2005 |
| End Date | 2/1/2006 |
| | |
| Total emails sent | 3865 |
| No. Bounced emails | 166 |
| Target sample size | 3699 |
| Total responses (N) | 646 |
| **Respondent Breakdown** | **(Type and Number)** |
| Managers | 203 |
| Engineers | 331 |
| Educators | 55 |
| Other | 32 |
| No Position | 25 |

**Table 2. ANOVA results**

| Question # | Expected Construct | Item | F-value | p-value |
|---|---|---|---|---|
| | C1. Positive Collaboration | | | |
| 1 | C1.1 Culture | *Similar corporate cultures* | 3.153 | **0.043** |
| 2 | C1.1 Culture | *Quality goals* | 2.068 | 0.127 |
| 3 | C1.2 Trust | *Supplier reputation* | 0.265 | 0.767 |
| 4 | C1.2 Trust | *Protection of sensitive information* | 3.178 | **0.042** |
| 5 | C1.2 Trust | *Work before finalized contract* | 1.87 | 0.155 |
| 6 | C1.2 Trust | *Being taken advantage of during negotiations* | 4.278 | **0.014** |
| 7 | C1.2 Trust | *Sharing confidential information* | 0.758 | 0.469 |
| 8 | C1.3 Infrastructure | *High technology needs* | 0.815 | 0.443 |
| 9 | C1.3 Infrastructure | *Communication* | 0.259 | 0.772 |
| 10 | C1.3 Infrastructure | *Geographical distance* | 1.635 | 0.196 |
| 11 | C1.3 Infrastructure | *Information free flow* | 0.06 | 0.942 |
| 12 | C1.4 Assistance | *Assist in design* | 2.929 | **0.054** |
| 13 | C1.4 Assistance | *Help in difficult situations* | 7.219 | **0.001** |
| 14 | C1.4 Assistance | *Supplier production problems* | 2.851 | 0.059 |
| | C2. Power | | | |
| 15 | C2.1 Leverage | *Prefer smaller suppliers* | 2.542 | 0.08 |
| 16 | C2.1 Leverage | *Willingness to replace suppliers* | 0.189 | 0.827 |
| 25 | C2.1 Leverage | *Bargaining leverage* | 0.934 | 0.394 |
| 26 | C2.1 Leverage | *Stress on suppliers* | 1.525 | 0.219 |
| 17 | C2.2 Profit | *Supplier choice because of cost savings* | 0.037 | 0.964 |
| 18 | C2.2 Profit | *New relationship expense* | 1.179 | 0.308 |
| 19 | C2.2 Profit | *Supply chain savings* | 1.55 | 0.213 |
| 20 | C3 Reliability | *Long term supplier relationships* | 0.774 | 0.462 |
| 21 | C3 Reliability | *Complexity inversely related to reliability* | 0.233 | 0.792 |
| 22 | C3 Reliability | *Supplier experience* | 0.139 | 0.87 |
| 23 | C3 Reliability | *Necessity of supplier support in five years* | 1.87 | 0.155 |
| 24 | C3 Reliability | *On-time shipment* | 0.573 | 0.564 |
| 27 | C3 Reliability | *Supplier financial problems* | 2.963 | 0.052 |

| Table 3. Multiple Comparisons | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Mean Difference | | | 95% Confidence Interval | |
| **Dependent Variable** | | **(I) Position** | **(J) Position** | **(I-J)** | **Std. Error** | **Sig.** | Lower Bound | Upper Bound |
| Question 1 | LSD | Manager | Engineer | 0.179 | 0.179 | 0.178 | -0.082 | 0.44 |
| | | | Educator | -0.338 | -0.338 | 0.137 | -0.783 | 0.108 |
| *Sharing similar corporate cultures with this supplier is important* | | Engineer | Manager | -0.179* | -0.179* | 0.178 | -0.44 | 0.082 |
| | | | Educator | -0.517* | -0.517* | 0.018 | -0.944 | -0.09 |
| | | Educator | Manager | 0.338 | 0.338 | 0.137 | -0.108 | 0.783 |
| | | | Engineer | 0.517* | 0.517* | 0.018 | 0.09 | 0.944 |
| | Bonferroni | Manager | Engineer | 0.179 | 0.179 | 0.535 | -0.14 | 0.498 |
| | | | Educator | -0.338 | -0.338 | 0.411 | -0.882 | 0.207 |
| | | Engineer | Manager | -0.179 | -0.179 | 0.535 | -0.498 | 0.14 |
| | | | Educator | -0.517 | -0.517 | 0.053 | -1.039 | 0.005 |
| | | Educator | Manager | 0.338 | 0.338 | 0.411 | -0.207 | 0.882 |
| | | | Engineer | 0.517 | 0.517 | 0.053 | -0.005 | 1.039 |
| | Tamhane | Manager | Engineer | 0.179 | 0.179 | 0.454 | -0.143 | 0.501 |
| | | | Educator | -0.338 | -0.338 | 0.267 | -0.829 | 0.154 |
| | | Engineer | Manager | -0.179 | -0.179 | 0.454 | -0.501 | 0.143 |
| | | | Educator | -0.517* | -0.517* | 0.026 | -0.986 | -0.048 |
| | | Educator | Manager | 0.338 | 0.338 | 0.267 | -0.154 | 0.829 |
| | | | Engineer | 0.517* | 0.517* | 0.026 | 0.048 | 0.986 |
| Question 4 | LSD | Manager | Engineer | -0.191* | -0.191* | 0.047 | -0.38 | -0.002 |
| | | | Educator | 0.118 | 0.118 | 0.470 | -0.203 | 0.44 |
| *This supplier must protect sensitive information if necessary* | | Engineer | Manager | 0.191* | 0.191* | 0.047 | 0.002 | 0.38 |
| | | | Educator | 0.309* | 0.309* | 0.049 | 0.001 | 0.617 |
| | | Educator | Manager | -0.118 | -0.118 | 0.470 | -0.44 | 0.203 |
| | | | Engineer | -0.309* | -0.309* | 0.049 | -0.617 | -0.001 |
| | Bonferroni | Manager | Engineer | -0.191 | -0.191 | 0.142 | -0.422 | 0.04 |
| | | | Educator | 0.118 | 0.118 | 1.000 | -0.275 | 0.511 |
| | | Engineer | Manager | 0.191 | 0.191 | 0.142 | -0.04 | 0.422 |
| | | | Educator | 0.309 | 0.309 | 0.147 | -0.067 | 0.685 |
| | | Educator | Manager | -0.118 | -0.118 | 1.000 | -0.511 | 0.275 |
| | | | Engineer | -0.309 | 0.157 | 0.147 | -0.685 | 0.067 |
| | Tamhane | Manager | Engineer | -0.191 | 0.103 | 0.179 | -0.437 | 0.055 |
| | | | Educator | 0.118 | 0.19 | 0.9 | -0.344 | 0.58 |
| | | Engineer | Manager | 0.191 | 0.103 | 0.179 | -0.055 | 0.437 |
| | | | Educator | 0.309 | 0.174 | 0.224 | -0.118 | 0.736 |
| | | Educator | Manager | -0.118 | 0.19 | 0.9 | -0.58 | 0.344 |
| | | | Engineer | -0.309 | 0.174 | 0.224 | -0.736 | 0.118 |

| Table 3. Multiple Comparisons cont'd | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | **Mean Difference** | | | **95% Confidence Interval** | |
| **Dependent Variable** | | **(I) Position** | **(J) Position** | **(I-J)** | **Std. Error** | **Sig.** | Lower Bound | Upper Bound |
| Question 6 | LSD | Manager | Engineer | -0.009 | 0.129 | 0.946 | -0.262 | 0.245 |
| | | | Educator | -0.602* | 0.219 | 0.006 | -1.032 | -0.172 |
| *We worry about* | | Engineer | Manager | 0.009 | 0.129 | 0.946 | -0.245 | 0.262 |
| *being taken* | | | Educator | -0.594* | 0.21 | 0.005 | -1.006 | -0.181 |
| *advantage of during* | | Educator | Manager | 0.602* | 0.219 | 0.006 | 0.172 | 1.032 |
| *negotiations* | | | Engineer | 0.594* | 0.21 | 0.005 | 0.181 | 1.006 |
| | Bonferroni | Manager | Engineer | -0.009 | 0.129 | 1.000 | -0.319 | 0.301 |
| | | | Educator | -0.602* | 0.219 | 0.018 | -1.128 | -0.077 |
| | | Engineer | Manager | 0.009 | 0.129 | 1.000 | -0.301 | 0.319 |
| | | | Educator | -0.594* | 0.21 | 0.015 | -1.098 | -0.089 |
| | | Educator | Manager | 0.602* | 0.219 | 0.018 | 0.077 | 1.128 |
| | | | Engineer | 0.594* | 0.21 | 0.015 | 0.089 | 1.098 |
| | Tamhane | Manager | Engineer | -0.009 | 0.13 | 1.000 | -0.321 | 0.303 |
| | | | Educator | -0.602* | 0.219 | 0.021 | -1.135 | -0.07 |
| | | Engineer | Manager | 0.009 | 0.13 | 1.000 | -0.303 | 0.321 |
| | | | Educator | -0.594* | 0.209 | 0.017 | -1.103 | -0.084 |
| | | Educator | Manager | 0.602* | 0.219 | 0.021 | 0.07 | 1.135 |
| | | | Engineer | 0.594* | 0.209 | 0.017 | 0.084 | 1.103 |
| Question 12 | LSD | Manager | Engineer | -0.229* | 0.102 | 0.025 | -0.43 | -0.028 |
| *This supplier should* | | | Educator | 0.001 | 0.171 | 0.997 | -0.336 | 0.337 |
| *be willing to assist* | | Engineer | Manager | 0.229* | 0.102 | 0.025 | 0.028 | 0.43 |
| *in the design of a* | | | Educator | 0.23 | 0.163 | 0.159 | -0.09 | 0.55 |
| *product to* | | Educator | Manager | -0.001 | 0.171 | 0.997 | -0.337 | 0.336 |
| *specifically meet* | | | Engineer | -0.23 | 0.163 | 0.159 | -0.55 | 0.09 |
| | Bonferroni | Manager | Engineer | -0.229 | 0.102 | 0.076 | -0.475 | 0.016 |
| | | | Educator | 0.001 | 0.171 | 1.000 | -0.41 | 0.411 |
| | | Engineer | Manager | 0.229 | 0.102 | 0.076 | -0.016 | 0.475 |
| | | | Educator | 0.23 | 0.163 | 0.477 | -0.162 | 0.621 |
| | | Educator | Manager | -0.001 | 0.171 | 1.000 | -0.411 | 0.41 |
| | | | Engineer | -0.23 | 0.163 | 0.477 | -0.621 | 0.162 |
| | Tamhane | Manager | Engineer | -0.229 | 0.105 | 0.088 | -0.482 | 0.023 |
| | | | Educator | 0.001 | 0.2 | 1 | -0.486 | 0.487 |
| | | Engineer | Manager | 0.229 | 0.105 | 0.088 | -0.023 | 0.482 |
| | | | Educator | 0.23 | 0.187 | 0.533 | -0.229 | 0.689 |
| | | Educator | Manager | -0.001 | 0.2 | 1 | -0.487 | 0.486 |
| | | | Engineer | -0.23 | 0.187 | 0.533 | -0.689 | 0.229 |

| Table 3. Multiple Comparisons cont'd | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | 95% Confidence Interval | |
| **Dependent Variable** | | **(I) Position** | **(J) Position** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** | Lower Bound | Upper Bound |
| Question 13 | LSD | Manager | Engineer | -0.088 | 0.069 | 0.202 | -0.225 | 0.048 |
| *The supplier's* | | | Educator | 0.332* | 0.117 | 0.005 | 0.103 | 0.56 |
| *willingness to help* | | Engineer | Manager | 0.088 | 0.069 | 0.202 | -0.048 | 0.225 |
| *us in difficult* | | | Educator | 0.420* | 0.111 | 0.000 | 0.202 | 0.638 |
| *situations is* | | Educator | Manager | -0.332* | 0.117 | 0.005 | -0.56 | -0.103 |
| *important* | | | Engineer | -0.420* | 0.111 | 0.000 | -0.638 | -0.202 |
| | Bonferroni | Manager | Engineer | -0.088 | 0.069 | 0.606 | -0.255 | 0.078 |
| | | | Educator | 0.332* | 0.117 | 0.014 | 0.052 | 0.611 |
| | | Engineer | Manager | 0.088 | 0.069 | 0.606 | -0.078 | 0.255 |
| | | | Educator | 0.420* | 0.111 | 0.001 | 0.153 | 0.687 |
| | | Educator | Manager | -0.332* | 0.117 | 0.014 | -0.611 | -0.052 |
| | | | Engineer | -0.420* | 0.111 | 0.001 | -0.687 | -0.153 |
| | Tamhane | Manager | Engineer | -0.088 | 0.071 | 0.512 | -0.258 | 0.082 |
| | | | Educator | 0.332 | 0.148 | 0.081 | -0.029 | 0.692 |
| | | Engineer | Manager | 0.088 | 0.071 | 0.512 | -0.082 | 0.258 |
| | | | Educator | 0.420* | 0.14 | 0.011 | 0.077 | 0.763 |
| | | Educator | Manager | -0.332 | 0.148 | 0.081 | -0.692 | 0.029 |
| | | | Engineer | -0.420* | 0.14 | 0.011 | -0.763 | -0.077 |

*The mean difference is significant at the .05 level.

**Table 4. ANOVA Open Ended Item**

**Question 28:** *What are 3 main reasons your company would discontinue business with any given supplier?*

| Bin category | F-value | Sig. |
|---|---|---|
| Cost | .424 | .654 |
| Quality | .010 | .990 |
| Schedule | .683 | .506 |
| Ethics | 3.212 | **.041** |
| Communication | .466 | .628 |
| BetterOption | .630 | .533 |
| Contract | 1.452 | .235 |
| Needs | 4.060 | **.018** |
| Finance | .076 | .927 |
| Relationship | 6.487 | **.002** |
| Other | 1.476 | .230 |

| Table 5. Multiple Comparisons of Open Ended Item | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variable | | (I) Position | (J) Position | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
| | | | | | | | Lower Bound | Upper Bound |
| ethics | LSD | Managers | Engineers | 0.091* | 0.044 | 0.042 | 0.00 | 0.18 |
| | | | Educators | 0.173* | 0.083 | 0.036 | 0.01 | 0.34 |
| | | Engineers | Managers | -0.091* | 0.044 | 0.042 | -0.18 | 0.00 |
| | | | Educators | 0.083 | 0.080 | 0.300 | -0.07 | 0.24 |
| | | Educators | Managers | -0.173* | 0.083 | 0.036 | -0.34 | -0.01 |
| | | | Engineers | -0.083 | 0.080 | 0.300 | -0.24 | 0.07 |
| | Bonferroni | Managers | Engineers | 0.091 | 0.044 | 0.127 | -0.02 | 0.20 |
| | | | Educators | 0.173 | 0.083 | 0.109 | -0.03 | 0.37 |
| | | Engineers | Managers | -0.091 | 0.044 | 0.127 | -0.20 | 0.02 |
| | | | Educators | 0.083 | 0.080 | 0.900 | -0.11 | 0.27 |
| | | Educators | Managers | -0.173 | 0.083 | 0.109 | -0.37 | 0.03 |
| | | | Engineers | -0.083 | 0.080 | 0.900 | -0.27 | 0.11 |
| | Tamhane | Managers | Engineers | 0.091 | 0.046 | 0.139 | -0.02 | 0.20 |
| | | | Educators | 0.173 | 0.075 | 0.071 | -0.01 | 0.36 |
| | | Engineers | Managers | -0.091 | 0.046 | 0.139 | -0.20 | 0.02 |
| | | | Educators | 0.083 | 0.071 | 0.572 | -0.09 | 0.26 |
| | | Educators | Managers | -0.173 | 0.075 | 0.071 | -0.36 | 0.01 |
| | | | Engineers | -0.083 | 0.071 | 0.572 | -0.26 | 0.09 |
| Needs | LSD | Managers | Engineers | -0.068* | 0.027 | 0.011 | -0.12 | -0.02 |
| | | | Educators | -0.100* | 0.049 | 0.043 | -0.20 | 0.00 |
| | | Engineers | Managers | 0.068* | 0.027 | 0.011 | 0.02 | 0.12 |
| | | | Educators | -0.032 | 0.048 | 0.499 | -0.13 | 0.06 |
| | | Educators | Managers | 0.100* | 0.049 | 0.043 | 0.00 | 0.20 |
| | | | Engineers | 0.032 | 0.048 | 0.499 | -0.06 | 0.13 |

| Table 5. cont'd | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Bonferroni | Managers | Engineers | -0.068* | 0.027 | 0.032 | -0.13 | 0.00 |
| | | | Educators | -0.100 | 0.049 | 0.129 | -0.22 | 0.02 |
| | | Engineers | Managers | 0.068* | 0.027 | 0.032 | 0.00 | 0.13 |
| | | | Educators | -0.032 | 0.048 | 1.000 | -0.15 | 0.08 |
| | | Educators | Managers | 0.100 | 0.049 | 0.129 | -0.02 | 0.22 |
| | | | Engineers | 0.032 | 0.048 | 1.000 | -0.08 | 0.15 |
| | Tamhane | Managers | Engineers | -0.068* | 0.023 | 0.011 | -0.12 | -0.01 |
| | | | Educators | -0.100 | 0.059 | 0.261 | -0.25 | 0.05 |
| | | Engineers | Managers | 0.068* | 0.023 | 0.011 | 0.01 | 0.12 |
| | | | Educators | -0.032 | 0.060 | 0.933 | -0.18 | 0.12 |
| | | Educators | Managers | 0.100 | 0.059 | 0.261 | -0.05 | 0.25 |
| | | | Engineers | 0.032 | 0.060 | 0.933 | -0.12 | 0.18 |
| Relationship | LSD | Managers | Engineers | 0.023 | 0.021 | 0.261 | -0.02 | 0.06 |
| | | | Educators | -0.110* | 0.038 | 0.004 | -0.18 | -0.03 |
| | | Engineers | Managers | -0.023 | 0.021 | 0.261 | -0.06 | 0.02 |
| | | | Educators | -0.133* | 0.037 | 0.000 | -0.21 | -0.06 |
| | | Educators | Managers | 0.110* | 0.038 | 0.004 | 0.03 | 0.18 |
| | | | Engineers | 0.133* | 0.037 | 0.000 | 0.06 | 0.21 |
| | Bonferroni | Managers | Engineers | 0.023 | 0.021 | 0.783 | -0.03 | 0.07 |
| | | | Educators | -0.110* | 0.038 | 0.013 | -0.20 | -0.02 |
| | | Engineers | Managers | -0.023 | 0.021 | 0.783 | -0.07 | 0.03 |
| | | | Educators | -0.133* | 0.037 | 0.001 | -0.22 | -0.04 |
| | | Educators | Managers | 0.110* | 0.038 | 0.013 | 0.02 | 0.20 |
| | | | Engineers | 0.133* | 0.037 | 0.001 | 0.04 | 0.22 |
| | Tamhane | Managers | Engineers | 0.023 | 0.020 | 0.571 | -0.02 | 0.07 |
| | | | Educators | -0.110 | 0.064 | 0.255 | -0.27 | 0.05 |
| | | Engineers | Managers | -0.023 | 0.020 | 0.571 | -0.07 | 0.02 |
| | | | Educators | -0.133 | 0.062 | 0.114 | -0.29 | 0.02 |
| | | Educators | Managers | 0.110 | 0.064 | 0.255 | -0.05 | 0.27 |
| | | | Engineers | 0.133 | 0.062 | 0.114 | -0.02 | 0.29 |

*The mean difference is significant at the .05 level.

## Appendix A. Legacy System Supply Chain Survey*

INSTRUCTIONS:
In answering this survey, we would like you to look at the following statements and questions as if you were being approached by a new, potentially important supplier for your legacy system. Responses may reflect what you look for in a new supplier as well as what has happened in the past with similar business agreements.

There are 29 brief questions on 7 slides and should take less than five minutes to complete. Also, all responses are kept confidential. Thank you for your time.

Name:
Position:

(Items 1-22 are measured on a Likert 1-7 scale from Strongly Disagree (1) to Strongly Agree (7))

1. Sharing similar corporate cultures with this supplier is important
2. Sharing the same quality goals with this new supplier is important
3. The reputation of this supplier is not important to us
4. This supplier must protect sensitive information if necessary
5. We would agree to start working with this supplier before all paperwork is finalized
6. We worry about being taken advantage of during negotiations
7. We will share confidential information with this supplier
8. This supplier does not need a high level of technology to meet our demands
9. Communication with this supplier is expected to be easy
10. We can operate effectively with this supplier even if it is located far away from us
11. Information needs to flow freely between us and the supplier
12. This supplier should be willing to assist in the design of a product to specifically meet our needs
13. The supplier's willingness to help us in difficult situations is important
14. The supplier’s production problems are also our problems
15. We prefer to do business with a supplier whose company is smaller than ours
16. We are willing to replace a valued long-term supplier with a new supplier
17. Cost savings is the primary basis of our relationship with this supplier
18. We would be willing to pay more money in order to build a new relationship
19. Saving money in the supply chain is vital to our overall success as a company
20. We expect our relationship with this new supplier to last a long time
21. As the complexity of our requests increase, we understand that reliability will diminish
22. The more experienced the supplier the better

## Appendix A. Legacy System Supply Chain Survey* cont'd

(Items 23-25 are measured on a Likert 1-7 scale from Not Important (1) to Very Important (7))

23. If we add this new supplier, how important is it that they still provide the same parts and service in 5 years?
24. How important is on time shipment from the supplier?
25. How important is having leverage over the supplier in the relationship?

(Item26 is measured on a Likert 1-7 scale from Very Little (1) to Very Much (7))

26. How much stress do you place on your suppliers?

(Item27 is measured on a Likert 1-7 scale from Not Concerned (1) to Very Concerned (7))

27. How concerned do you become when suppliers have financial problems?

(Items 28-29 are open ended)

28. What are the 3 main reasons your company would discontinue business with any given supplier?
29. List the most common types of contracts your firm usually enters into. (fixed-price, cost plus, cost-reimbursement, incentive, indefinite-delivery, time-and-materials, etc.)

*Vanderbilt University Institutional Review Board approval no. 050699, August 8, 2005

## Appendix B. Survey Model

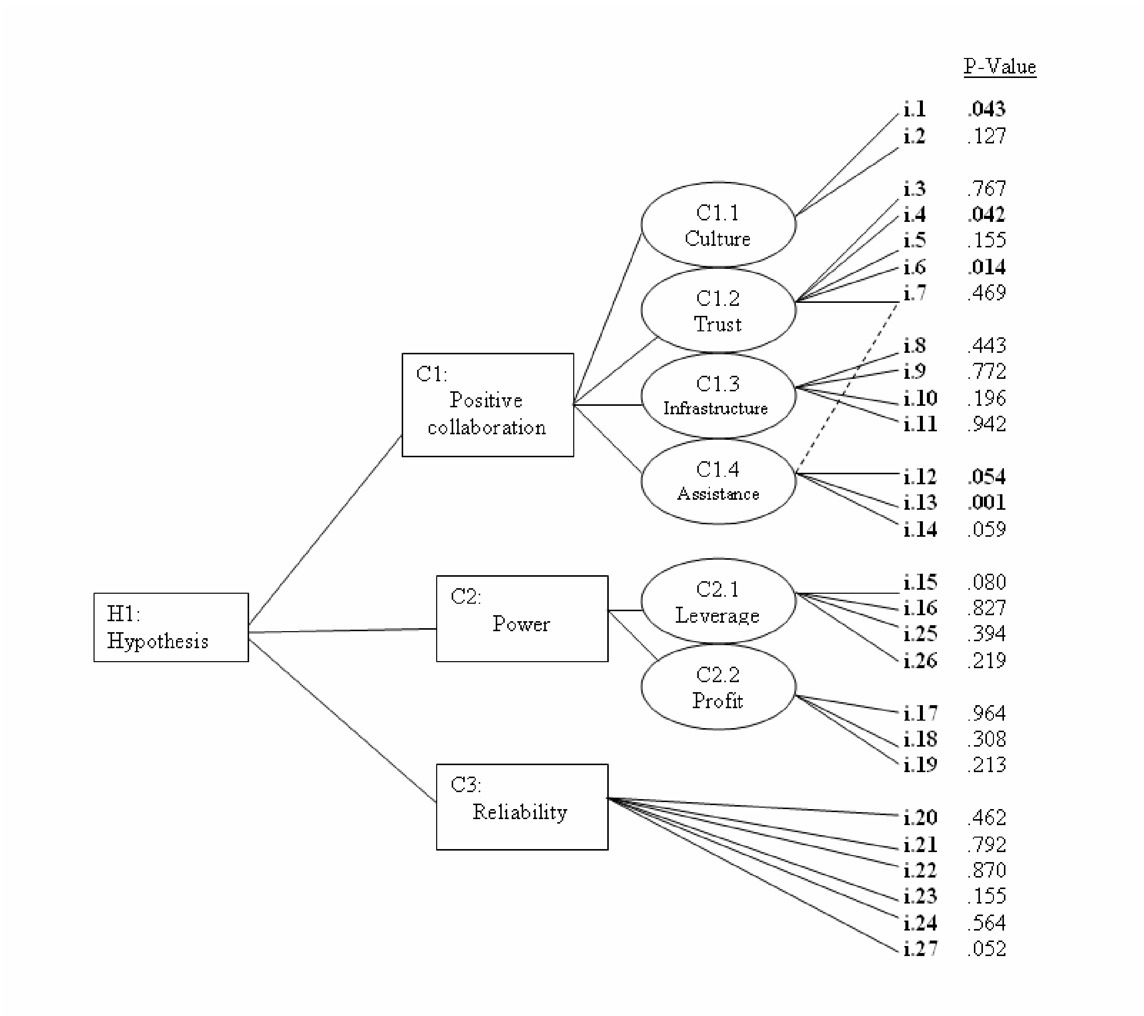


Figure 5. Survey Model Diagram

**H1.** The perceptions of legacy system supply chain risks differ between managers and engineers within their organization.

**H1a.** Managers and engineers perceive the importance of supplier/buyer positive collaboration differently.

**H1b.** Managers and engineers perceive the importance of having power in the buyer/supplier relationship differently

**H1c.** Managers and engineers perceive the importance of supplier reliability differently.

## Appendix C. Construct Outline and References

### C1.1 Culture

| | |
|---|---|
| 1. Sharing similar corporate cultures with this supplier is important<br>2. Sharing the same quality goals with this new supplier is important | Gunasekaran, A. (2001)<br><br>Harland, C., Brenchley, R. and Walker, H. (2003)<br><br>Spekman, R., Kamauff, J. and Myhr, N. (1998) |

### C1.2 Trust

| | |
|---|---|
| 3. The reputation of this supplier is not important to us<br>4. This supplier must protect sensitive information if necessary<br>5. We would agree to start working with this supplier before all paperwork is finalized<br>6. We worry about being taken advantage of during negotiations<br>7. We will share confidential information with this supplier | Harland, C., Brenchley, R. and Walker, H. (2003)<br><br>Spekman, R., Kamauff, J. and Myhr, N. (1998)<br><br>Stuart, I. (1997) |

### C1.3 Infrastructure

| | |
|---|---|
| 8. This supplier does not need a high level of technology to meet our demands<br>9. Communication with this supplier is expected to be easy<br>10. We can operate effectively with this supplier even if it is located far away from us<br>11. Information needs to flow freely between us and the supplier | Fitzgerald, K.R. (2005)<br><br>Harland, C., Brenchley, R. and Walker, H. (2003)<br><br>Stuart, I. (1997) |

## Appendix C. cont'd

**C1.4 Assistance**

| | |
|---|---|
| 12. This supplier should be willing to assist in the design of a product to specifically meet our needs<br>13. The supplier's willingness to help us in difficult situations is important<br>14. The supplier's production problems are also our problems | Gunasekaran, A. (2001)<br><br>Stuart, I. (1997) |

**C2.1 Leverage**

| | |
|---|---|
| 15. We prefer to do business with a supplier whose company is smaller than ours<br>16. We are willing to replace a valued long-term supplier with a new supplier<br>25. How important is having leverage over the supplier in the relationship?<br>26. How much stress do you place on your suppliers? | Spekman, R., Kamauff, J. and Myhr, N. (1998) |

**C2.2 Profit**

| | |
|---|---|
| 17. Cost savings is the primary basis of our relationship with this supplier<br>18. We would be willing to pay more money in order to build a new relationship<br>19. Saving money in the supply chain is vital to our overall success as a company | Beamon, B. (1999)<br><br>Chopra, S. and Sodhi, M. (2004)<br><br>Gunasekaran, A. (2001)<br><br>Holweg, M., Disney, S., Holmström, J., Småros, J. (2005)<br><br>Spekman, R., Kamauff, J. and Myhr, N. (1998)<br><br>Thomas, D.J. and Griffin, P.M. (1996) |

## Appendix C. cont'd

**C3. Reliability**

| | |
|---|---|
| 20. We expect our relationship with this new supplier to last a long time<br>21. As the complexity of our requests increase, we understand that reliability will diminish<br>22. The more experienced the supplier the better<br>23. If we add this new supplier, how important is it that they still provide the same parts and service in 5 years?<br>24. How important is on time shipment from the supplier?<br>27. How concerned do you become when suppliers have financial problems? | Chopra, S. and Sodhi, M. (2004)<br><br>Gunasekaran, A. (2001)<br><br>Krauss, D., Scannell, T. and Calatone, R. (2000)<br><br>Spekman, R., Kamauff, J. and Myhr, N. (1998) |

## Appendix D. Question 28 Outline and References

| *What are the 3 main reasons your company would discontinue business with any given supplier?* | |
|---|---|
| 1. High cost | Chopra, S. and Sodhi, M. (2004)<br><br>Gunasekaran, A. (2001)<br><br>Thomas, D.J. and Griffin, P.M. (1996) |
| 2. Poor quality and performance | Gunasekaran, A. (2001) |
| 3. Schedule and reliability problems | Chopra, S. and Sodhi, M. (2004)<br><br>Gunasekaran, A. (2001) |
| 4. Ethics | Kidd, J., Richter, F. and Stumm, M. (2003) |
| 5. Communication problems | Chopra, S. and Sodhi, M. (2004) |
| 6. Better options | Gunasekaran, A. (2001). |
| 7. Contract breech or expiration | Blanchard, B. & Fabrycky, W. (1998) |
| 8. Changing needs | Harland, C., Brenchley, R. and Walker, H. (2003) |
| 9. Supplier financial issues | Krauss, D., Scannell, T. and Calatone, R. (2000) |
| 10. Relationship issues (such as confidence and trust) | Harland, C., Brenchley, R. and Walker, H. (2003)<br><br>Kidd, J., Richter, F. and Stumm, M. (2003) |
| 11. Others (including security, safety and disruptions) | Chopra, S. and Sodhi, M. (2004)<br><br>Lee, H., Whang, S. (2005) |

**Appendix E. Letter of Confidentiality**

Stephen P. Maggart
Graduate Student
Management of Technology Program
Vanderbilt University
Tel: 615-497-2015
Fax: 615-322-7996

Dear Participant,

I am a graduate student in the Management of Technology program at Vanderbilt University in Nashville, Tennessee. The objective of my research is to attempt to identify any disconnect within an organization regarding perceived supply chain risks.

Your responses to the survey will only be used for the purpose of this study and the results will be presented in aggregate form to ensure individual confidentiality. Completing the survey is entirely voluntary, and by doing so you consent to having the survey information used in the study.

If desired, all participants may receive a complete copy of the results for their records.

The survey only takes about 5 minutes.

You may refuse to answer any question at any time and, again, all individual responses will be entirely confidential and anonymous.

This survey has been reviewed and received approval from the Institutional Review Board at Vanderbilt University. For questions concerning this study or survey, please contact the Management of Technology office in Featheringill Hall, or Stephen Maggart at (615) 497-2015, or the Institutional Review Board at (615) 322-2918 or 866-224-8273 (toll free).

Thank you in advance for your participation. Your input will help us to anticipate and avoid supply chain problems in the future. .

Stephen Maggart
Management of Technology Program
Vanderbilt University

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