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Joint Resolution of Supply Chain Risks: The Role of Risk Characteristics and Problem Solving Approach

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JOINT RESOLUTION OF SUPPLY CHAIN RISKS:
THE ROLE OF RISK CHARACTERISTICS AND PROBLEM SOLVING APPROACH

BY

LEAH BOVELL

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This dissertation was prepared under the direction of the *Leah Bovell* Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctoral of Philosophy in Business Administration in the J. Mack Robinson College of Business of Georgia State University.

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ABSTRACT

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THE ROLE OF RISK CHARACTERISTICS AND PROBLEM SOLVING APPROACH

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The purpose of this study is to examine the disruption risk resolution process in supply chains; specifically, to assess how risk attributes impact the approach firms select to resolve risks and the associated final outcomes.

We propose that high magnitude risks are positively associated with mutually beneficial problem resolution; on the other hand, low likelihood risks have the opposite effect, they are negatively associated with mutually beneficial resolution. Our conceptual contribution lies in our articulation of the mechanisms though which risk magnitude and risk likelihood impact mutual problem resolution. We posit that high magnitude risks and low likelihood (uncommon) risks mobilize the social network of actors, triggering vigilant monitoring for risks, communication among actors and across firm boundaries, and resource sharing and coordination which facilitate collaborative problem solving and mutual resolutions. These mobilization

mechanisms help supply chain partners to overcome the challenges of complexity and allow for information and resource flows among actors and between firms.

Our statistical analysis demonstrates that the impact of risk attributes on mutual problem solutions is fully mediated by timely problem identification and collaborative problem solving.

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CHAPTER 1: INTRODUCTION

The first flight of the Boeing 787 Dreamliner suffered a two year delay, from September 2007 to December 2009. Customer deliveries were delayed a total of six times, and, as of January 2010, deliveries were over thirty months behind the overall program schedule. These production delays cost Boeing; it is estimated that the impact on earnings is approximately eleven billion dollars to date. The Dreamliner's problems can be crystallized into one key issue: unidentified and unresolved supply chain disruption risks.

Severe supply chain disruptions are certainly not unique to Boeing. Scholars have highlighted and documented severe and costly disruptions at Toyota (Sheffi 2001); Nokia and Ericsson (Latour 2001); Sony and Nike (Hendricks and Singhal 2008); and Dole, Chiquita, Dell, and Apple (Griffy-Brown 2003, Tomlin 2006), among others. Supply chain disruptions may be defined as "unanticipated events that interfere with the normal flow of goods and/or materials in a supply chain" (Craighead et al 2007 pg 132). Similarly, Svensson (2009) offers the following definition, "an unplanned event that might affect the normal, expected flow of materials, information, and components." Scholars are increasingly paying attention to the study of the risk of supply chain disruptions, that is, the inability of a firm to match demand and supply (Hendricks and Singhal 2005), and this issue is receiving increased coverage and consideration in the business and academic literatures.

Motivation for the Study

The Significant Long- and Short-term Costs of Supply Chain Disruptions

As illustrated through the case of Boeing, supply chain disruptions have the potential to cause significant negative economic consequences. Using event study methodology, Hendricks and Singhal (2003) examined the economic impact of supply chain disruptions on shareholder wealth. They found that, after adjusting for normal market movements, shareholders lose an average of 10% of the value of their stock over the forty-eight hour period spanning the day of and the day before the announcement of a disruption. In follow-up work on the long-term stock price effects and equity risk effects of supply chain disruptions, Hendricks and Singhal (2005a) find that the average abnormal stock returns of firms that experienced disruptions is nearly -40%. Further, according to the researchers (Hendricks and Singhal 2005b), firms that experience disruption glitches report, on average, 6.92% lower sales growth, 10.66% higher growth in cost, and 13.88% higher growth in inventories. Knight and Pretty (1996) found that shareholder wealth suffered a dramatic 8% decrease and a fifty day recovery period following a disruption.

The causes of supply chain disruptions are myriad, ranging from operational risks - such as inaccurate forecasting, poor planning, part shortages, quality problems, capacity shortfalls, operational constraints, production and supply related problems experienced by suppliers (Hendricks and Singhal 2008, Fisher and Raman 1996, Fisher 1997, Raman 1997, Yu et al 2009) - to risks arising from natural hazards, terrorism and political instability (Kleindorfer and Saad 2005). According to Hendricks and Singhal (2005b, pg 695), "it does not matter who caused the glitch, what the reason was for the glitch, or what industry a firm belongs to – glitches are associated with negative operating performance across the board." Perhaps more importantly, firms do not quickly recover from the negative economic impact of supply chain disruptions.

"During the two-year time period after the glitch announcement, operating income, sales, total costs, and inventories do not improve" (Hendricks and Singhal 2005b, pg. 695).

Trends in Supply Chain Management Increase Firms' Susceptibility to Disruption Risks

Due to recent trends in the structuring and management of supply chains, susceptibility to disruption risk is greater than ever before. Supply chains now consist of increasingly complex, dynamic links with scores of independent, yet interconnected member entities. Yu, Zeng and Zhao (2009, pg. 788) observe that "relationships between suppliers and their immediate buyers have evolved from fragmented, scattered links to today's integrated, interdependent supply chain networks." Global sourcing adds layers of complexity as supply chain members must manage not only the flow of goods and services between partners, but must also successfully grapple with differing corporate and national cultures, differing tax and legal regulations, and differing political and economic environments. Further adding to complexity in supply chains are trends including: (1) increased reliance on outsourcing and partnering; and, (2) oversight and management of a large number of supply chain partners; (3) the need to coordinate many tiers of supply chain members; and, (4) long lead times (Hendricks and Singhal 2005a).

Supply chain strategies aimed at improving efficiency, productivity and cost also add to firms' susceptibility to disruption risks. For example, reducing inventory levels, excess capacity and slack, decentralization, and sole sourcing have been suggested as strategies which increase exposure to disruption risks (Stecke and Kumar 2009). Tang (2006) suggests that as firms implement various initiatives such as lean, agile, outsourcing, and global networks to gain cost advantage and market share, their supply chains become more vulnerable at the same time and any disruption can have dramatic impacts on the entire chain. The trends increase supply chain vulnerabilities by either (1) increasing the number of risk exposure points, (2) increasing the distance and/or time the material takes to travel between supply chain partners, (3) decreasing flexibility in the supply chain, or (4) reducing buffers or redundancies (Stecke and Kumar 2009).

Given the above discussed complexity and trends in supply chain management, companies will have to deal with disruption risk more often as “the potential for and the frequency of occurrence will increase” (Blackhurst et al 2005). Skipper and Hanna (2009 pg 405) note, “In reality, it is not a matter of a supply chain system encountering a problem, but rather a matter of when a problematic event will occur and the severity of the event.” Craighead et al (2007 pg 131) not only acknowledge the inevitability of supply chain disruptions, but also opine that disruptions and their associated operational and financial consequences are “the most pressing concern facing firms that compete in today’s global marketplace.” Blackhurst et al (2005 p. 4068) opine that global trends affecting supply chains will “likely propel the issue of supply chain disruptions into the forefront of key supply-chain issues.”

Firms’ Unprepared to Effectively Manage Disruption Risks

Despite the evidence that disruptions are inevitable and costly, Tomlin (2006) reports that firms’ default strategy for dealing with supply disruptions is passive acceptance. Only 33% of firms reported that they paid adequate attention to vulnerabilities in the supply chain and actions to resolve potential disruption problems or risks (Poirier and Quinn 2004). Blackhurst et al (2005) draws further attention to the lack of preparedness of most companies; according to Mitroff and Alpaslan (2003), only between 5% and 25% of Fortune 500 companies are prepared to handle crises or disruptions.

The Call for Research Addressing Disruption Risk Management

Notwithstanding firms' need to effectively manage supply chain risks and their evident unpreparedness to do so, quantitative studies on the management of disruption risks associated with suppliers and the supply network are still sparse (Yu, Zeng and Zhou 2009). Juttner et al (2003) opined that the concept of supply-chain vulnerability to risk was still in its infancy and called attention to the need for both practitioners and academics to pay more attention to this area of research.

Based on the above, it is very important for practitioners to pay greater attention to supply chain disruption risks and to developing the skills, expertise and systems necessary to develop greater capability to manage and prevent supply chain disruptions. Firms now have the challenge of simultaneously implementing strategies to improve the productivity and efficiency of their supply chains while protecting themselves against the increased risk of supply chain disruptions which often accompanies such strategies. Research aimed at understanding disruption risk management, especially within the context of global, complex supply networks, is necessary and timely. It is generally understood that prevention is better than cure and that it is better to engage in loss avoidance and pre-emptive risk resolution than to deal with the consequences of actual disruptions (Kleindorfer and Saad 2005). Understanding the risk management process and the conditions which facilitate effective resolution of disruption risks is vitally important.

In summary, this research endeavor is motivated by our recognition of the following points: (1) complexity and trends in supply chain management have increased the likelihood and frequency of supply chain disruption risks; (2) supply chain disruptions are associated with significant short-term and long-term costs; (3) firms are unprepared to effectively avoid and manage disruption risks; and, (4) there is a pressing need for firms to understand disruption risk management, its processes and the conditions which facilitate effective resolution of disruption risks.

Purpose of the Study

This research aims to add to the literature on supply chain disruption risks by examining the conditions which facilitate effective resolution of disruption risks in complex supply chain contexts. In particular, we study how disruption risk characteristics impact timely problem identification, the problem resolution process, and ultimately problem resolution outcomes. We demonstrate that certain risk characteristics trigger mobilizing mechanisms which motivate supply chain actors to achieve timely problem identification, collaborative problem solving and mutual resolution. In this paper, we focus on one particular potential cause of disruption - supply risk, that is, the distribution of outcomes related adverse events in inbound supply that affect the ability of the focal firm to meet customer demands (Manuj and Mentzer 2008, Christopher and Peck 2004). Further, we focus our efforts on pre-emptive resolution, that is, the ability of firms to mitigate supply chain risks before they are realized.

This study will offer important managerial insights on how supply chain partners manage their relationships and the disruption risk management process in order to avoid both short-term disruptions to operations as well as achieve risk resolution in mutually satisfactory ways.

Organization of the Study

This manuscript is organized as follows: Chapter 2 provides a literature review on the topics of supply chain risk management; the conceptual model and hypotheses are presented in Chapter 3; Chapter 4 discusses the research design and methodology, as well as how each construct is measured, and data collection procedures; Chapter 5 provides a report of the results; and finally, the major conclusions, the academic and managerial implications of our findings, as well as the contribution we make to the literature are discussed in Chapter 6.

CHAPTER 2: LITERATURE REVIEW

While supply chain issues have received considerable attention in the past two decades, the focus has largely been on improving the efficiency of supply chains, that is, on lowering the costs associated with supply chain operations (Khan and Burnes 2007). Strategies associated with supply chain efficiency and cost minimization have included outsourcing; lean manufacturing; reduction in inventories, supply chain slack and excess capacity through just-in-time production, etc. As noted in the Introduction, these strategies may improve efficiency and cost effectiveness; however, they expose supply chains to increasing levels of disruption risk. Hendricks and Singhal (2005a) argue that, in focusing on cost reduction, organizations have paid inadequate attention to risks of supply chain disruption.

In recent years, supply chain risk management has received increasing attention from researchers and practitioners (Juttner 2005), especially as supply chains become more complex and globally interconnected (Rao and Goldsby 2009, Manuj and Mentzer 2008) and as scholars and practitioners recognize the risks associated with cost minimization supply chain strategies.

WHAT IS RISK?

A thorough review of the literature on risk is beyond the scope of this paper. However, the meaning of the term has changed over time, and it can mean different things to different people depending on their field, their individual perceptions, and the particular context. It is, however, generally accepted that the term encompasses two elements: (1) a range of outcomes that may occur; and, (2) the likelihood or probability associated with those outcomes. While the first element may include both favorable and unfavorable outcomes, managerial focus has generally been on the unfavorable implications associated with an event (Hood and Young 2005). Wagner and Bode (2008) agree with this position and argue that it is only the downside that truly reflects the business reality. We similarly focus on the negative side of risk, and adopt the definition offered by Rowe (1980 pg. 23), "the potential for realizing unwanted negative consequences for causal events."

Several categorizations of supply chain risk exist in the literature. Juttner, Peck and Christopher (2003) propose three categories: (1) environmental risk, (2) organizational risk, and (3) network-related risk. Environmental risk sources include accidents, socio-political actions, or acts of God e.g. extreme weather or earthquakes. Organizational risk sources "lie within the boundaries of supply chain parties" (pg. 202) and include issues like machine failure or information technology problems. Finally, network-related risks arise from interactions between organizations in the supply chain and include problems like blurred boundaries between buying and supplying firms in the supply chain, and a lack of responsiveness to environmental or other changes.

Rao and Goldsby (2009) categorize risks as relating to (1) environmental factors (political, policy, macroeconomic, social, and natural uncertainties), (2) industry factors (input market, product market, competitive uncertainties), (3) organizational factors (operating, credit, liability, agency uncertainties), (4) problem-specific factors (risk interrelationships, task complexity), and (5) decision-maker factors (knowledge/skill/biases of decision makers, bounded rationality, etc).

Yet another schema (Christopher and Peck 2004, Manuj and Mentzer 2008) categorizes supply chain risks into one of four groups: (1) demand risk, that is, "adverse events in the outbound flows that affect the likelihood of customers placing orders with the focal firm, and/or variance in the volume and assortment desired by the customer" (pg. 199), (2) operations risk, that is, "adverse events within the firm that affect a firm's internal ability to produce goods and services, quality and timeliness of production, and/or profitability" (pg. 198) (3) security risk, that is, "adverse events that threaten human resources, operations integrity, and information systems; and may lead to outcomes such as freight breaches, stolen data or proprietary knowledge, vandalism, crime, and sabotage" (pg. 199) and, (4) supply risk, that is, the probability of adverse events in inbound supply that affect the ability of the focal firm to meet customer demands both in terms of quality and quality. Supply risk examples include inbound product quality problems, schedule delays, and cost increases (Manuj and Mentzer 2008).

This paper is primarily concerned with addressing supply risks, as defined above, which have the potential to result in disruptions to the short-term and long-term operations of a focal buying manufacturing company.

SUPPLY CHAIN RISK MANAGEMENT

Given the high costs associated with disruptions, passive acceptance of disruption risks is not a viable option for firms. An active disruption risk management strategy is a necessary component of a firm's overall supply chain strategy (Tomlin 2006).

Several definitions for supply chain risk management (SCRM) exist in the literature. An overview of these definitions is presented by Rao and Goldsby (2009). Christopher (2002) defines SCRM as follows, "SCRM is the management of external risks and supply chain risks through a coordinated approach among supply chain members to reduce supply chain vulnerability as a whole."

Manuj and Mentzer (2008) offer a more detailed outline of the activities involved in global supply chain management and define SCRM as "the identification and evaluation of risks and consequent losses in the global supply chain and implementation of appropriate strategies through a coordinated approach among supply chain members." A similar definition is offered by Juttner et al (2003) who note that "SCRM aims to identify potential sources of supply chain risk and implement appropriate actions to avoid or contain supply chain vulnerability."

Khan and Burnes (2007), drawing from the work of White (1995 pg. 36), posit that supply chain risk management involves: (1) risk identification, which involves the perception of hazards, identification of failures and recognition of adverse consequences; (2) risk estimation, which involves estimating the risk probabilities, describing the risk and quantifying the risk, and (3) risk evaluation, which involves estimation of the significance of the risk, judgment of the acceptability of the risk, and comparison of the risks against benefits.

We synthesize the definitions provided above and determine that there are three key activities involved in supply chain risk management: (1) identification of risks, (2) evaluation of risks, that is, assessment of the potential adverse consequences (magnitude) and determining risk probabilities (likelihood), and (3) mitigation/resolution of the risk. These three key risk management activities are the focus of this research endeavor.

RISK IDENTIFICATION

Successful recovery from disruption risks, whether pre-emptive elimination of the potential negative impacts or contingent reduction of the negative impact, depends on first becoming aware of the potential or actual disruption (Blackhurst et al 2005). A firm must, therefore, have in place an effective means of discovering potential supply-chain disruptions. It is disruption discovery, or identification, which leads to the ability to recover from the disruption and redesign the supply chain if necessary. Similarly, Juttner et al (2003) list assessing, defining and identifying risk drivers as activities which must precede risk mitigation.

Although there is a burgeoning literature on the management of risks, research associated with identifying risks is still in an early stage and some scholars believe that identification of risks in the supply chain is an under-investigated issue (Rao and Goldsby 2009). We investigate supply chain risk identification and the specific risk characteristics that impact effective and efficient early identification of risks by measuring the timeliness of risk identification (timely problem identification).

RISK EVALUATION

Choosing an appropriate mitigation approach to address an identified risk must be preceded by an assessment of the risk. Assessing the risk and evaluating its significance is important when deciding on the most appropriate response for mitigating the risk and when determining the most appropriate party or parties to manage the risk (White 1995). In our model, we examine risk evaluation through the constructs "Risk Magnitude" and "Risk Likelihood" and show how the significance/magnitude of risks as well as the probability of the risk occurring affect the associated mitigation activities.

RISK MITIGATION

Tomlin (2006) proposes a mitigation and contingency framework to categorize disruption management tactics. In this work, Tomlin (2006 p. 640) suggests that mitigation tactics are those "a firm can take in advance of a disruption (and so incur the cost of the action regardless of whether a disruption occurs). On the other hand, contingency tactics are those which a firm takes only if a disruption actually occurs. Contingency planning means "developing a plan to be resilient or being prepared to respond to, and to restore operations after an unexpected disruption occurs" (Skipper and Hanna 2009, Rice and Caniato 2003).

It should be here noted that a firm is not limited in terms of tactics it can employ, and, in many circumstances, "a combination of tactics might be the appropriate strategy for managing disruption risk" (Tomlin 2006 p. 640). Inventory (investment in buffer or safety stock) and sourcing (having dual or multiple sources) tactics are the two most common and widely discussed mitigation strategies examined in the literature. Contingency strategies include (1) re-routing, for example, temporarily increasing production at alternate locations or suppliers and rerouting ships or changing transportation arrangements (Tomlin 2006) and (2) demand management, for example, shifting consumer demand to easily supplied products.

Another scheme for organizing disruption management approaches has been developed by Stecke and Kumar (2009) who propose three categories of disruption management tactics: (1) proactive strategies which aim to reduce the probability of a disruption or reduce a supply chain's vulnerability to disruptions (for example, choosing robust, reliable suppliers and establishing strong and effective communication linkages among members of the supply chain); (2) advance warning strategies which allow an organization valuable preparation time to minimize disruption effects or mitigate disruption risks (for example, enhancing visibility and coordination among supply chain members); and (3) coping strategies which offer supply chains the ability to minimize the effects of a disruption (for example, carrying excess inventory, alternative sources and flexible transportation).

In summary, the work of Tomlin (2006) and Stecke and Kumar (2009) suggest two categories of risk recovery: a proactive, pre-emptive approach for resolving risks before disruptions occur, and a reactive approach to minimize disruptions after risks have been realized. While both approaches are important for organizations, we focus on pre-emptive risk resolution, that is, risk mitigation according to Tomlin (2006), and proactive and early warning strategies according to Stecke and Kumar (2009). We take the view espoused by Kleindorfer and Saad (2005) that prevention is better than cure, and that it is better to engage in loss avoidance and pre-emptive risk mitigation than to deal with the consequences of actual disruptions. A firm's development of strong risk mitigation capabilities would allow it to enjoy the benefits of supply chain strategies aimed at cost minimization while having the ability to quickly resolve risks before actual disruptions occur.

Several authors have suggested that supply chain risks must be mitigated through coordination or collaboration among supply chain partners (Christopher 2002, Tang 2006). For example, Zsidisin and Ellram (2003) and Zsidisin et al (2000) discuss closer working relationships with suppliers as a key supply chain risk management strategy. Min et al (2005) conclude that collaboration is viewed as the driving force behind effective supply chain management. Christopher and Peck (2004) write that "building resilience to supply chain risks requires a high degree of collaboration," and Krause (1999) finds that communication and early involvement of suppliers in strategic decision-making is an important element of SCRM. Thus, a key element in any successful supply chain risk management strategy is effective relationship management and a collaborative climate between supply chain partners. Collaboration then is clearly a specific form of relational exchange which requires a high level of cooperation (Viera et al 2009). Cao et al (2010 p. 6617) define supply chain collaboration as a "long-term partnership process where supply chain partners with common goals work closely together to achieve mutual advantages that are greater than the firms would achieve individually."

Collaboration has been referred to as "an intense process" (Nix et al 2008) which involves "two or more independent companies working jointly to plan and execute supply chain operations with greater success than when acting in isolation (Whipple and Russell 2007). Collaboration is the "process of working together among independent firms along a supply chain … for the basic purpose of optimizing long-range profit for all … and creating competitive advantage."

A collaborative approach to supply chain operations between two firms may be manifested in information sharing (Simatupang and Sridharan 2004, Whipple and Russell 2007), decision synchronization, sharing costs, risks and benefits (Simatupang and Sridharan 2004, 2008), and joint actions and joint planning (Viera et al 2009, Whipple and Russell 2007). Cao et al (2010) assert that the sub-components of supply chain collaboration include information sharing, goal congruence, decision synchronization, incentive alignment, resource sharing, collaboration communication and joint knowledge creation.

The literature is replete with studies documenting the benefits firms can derive from employing collaborative approaches to supply chain management. Kohli and Jensen (2010) summarize this stream of literature and highlight that collaboration enables cost reductions, improved service, improved end-customer satisfaction, shorter lead times, improved information visibility, increased competitiveness and a clearer division of responsibility among partners. Enhancements to efficiency, effectiveness and stronger market positions are other positive collaboration-related outcomes (Min et al 2005). In this study, we examine risk mitigation through the construct, Collaborative Problem-Solving.

Scholars have overwhelmingly focused on measurements to gauge the nature or degree of collaboration that exists (Kohli and Jensen 2010) and have neglected to simultaneously address the degree of effectiveness of collaboration among supply chain partners (Simatupang and Sridharan 2004). Sandburg (2007) opines that the literature is still unclear regarding what actually happens or is accomplished when companies collaborate. A similar criticism is discussed by Jap (1999, 2001) who clearly differentiates between collaboration and the outcomes of collaborative activity. As noted in the definitions offered earlier, collaboration in a supply chain is the process of "working together" (Nix et al 2008), "working jointly" (Whipple and

Russell 2007) or working "closely together" (Cao et al 2010). The desired outcome of collaboration is to achieve "greater success" (Whipple and Russell 2007) than when acting in isolation or, in other words to achieve, "mutual advantages that are greater than the firms would achieve individually (Cao et al 2010 p. 6617)." It is important to note, however, that while resolution of the risk, and creating mutual advantages in the process, are the goals of collaboration, it is important for scholars to demonstrate these outcomes empirically. Research on supply chain collaboration focuses heavily on the collaborative process and on the facilitating conditions or resources to collaboration. We address this shortcoming by measuring the construct, "Mutual Resolution" to capture whether or not the collaborative process resolves risk and achieves mutual advantage for the collaborating parties.

In summary, supply chain risk refers to the potential for negative, unfavorable outcomes in the supply chain and supply chain risk management involves three key activities: identifying, evaluating, and mitigating supply chain risks. Key to any SCRM strategy is supply chain collaboration; that is, working together with supply chain partners to cooperatively and jointly resolve supply chain risks. In addition to the three key risk management activities, we also examine risk resolution outcomes, that is, whether or not mutual resolutions to disruption risks are achieved.

We demonstrate that risk evaluation or assessment (in particular firms' assessments of a risk's characteristics: risk magnitude and risk likelihood) affect mutual resolution through two mediating mechanisms: (1) timely problem identification and, (2) collaborative problem solving. To the best of our knowledge, this study is the first to hypothesize and examine differential effects of risk characteristics on the risk management process and to include a measure of risk resolution outcome. The supply chain risk literature presents overwhelming support for the positive impact of strong, good quality relationships on the risk management process. We therefore examine our proposed study controlling for supplier trustworthiness.

CHAPTER 3: CONCEPTUAL MODEL AND HYPOTHESES

In this chapter, a conceptual model is presented which relates risk attributes to the supply chain risk management process and mutual resolutions. We present the theoretical rationale for each of the six hypotheses.

Competitive Advantage through Collaborative Problem-Solving

The resource-based view of the firm asserts that firms can create competitive advantage by maximally using resources which exist within firms' boundaries. Resources are strengths that firms can use to develop and implement strategies; they include physical, human, and organizational capital (Barney 1991). Importantly, resources also include the capabilities, processes, information, knowledge, and know-how within the firm's control, as well as other intangibles, like time, effort, and attention (McEvily et al 2003). Not all resources are capable of generating competitive advantage; superior resources are those which are: (1) valuable; (2) rare among existing and potential competitors; (3) imperfectly imitable; and, (4) non-substitutable, i.e. there are no strategically equivalent substitutes for the resource that are valuable but not rare or imperfectly imitable (Barney 1991).

In many cases, such superior resources are not available within firm boundaries and organizations have three basic options for dealing with such deficiencies: (1) market acquisition of the resource; (2) intermediate governance (developing and managing contractual relationships with resource providers); or (3) developing the resource in-house (Barney 1999). Each of the above approaches has significant costs and disadvantages. For example, developing a resource in-house may require a long, difficult learning process involving socially complex and unknown phenomena; and acquisition of another firm with the resource can be costly to reverse if it turns out not to be valuable and/or if there is unwanted baggage inextricably bound with the desired capabilities (Barney 1999). To overcome these costs and risks, Dyer and Singh (1998) propose cooperative inter-firm strategies and discuss how they can be sources of competitive advantage.

The relational view of competitive advantage (Dyer and Singh 1998) simply posits that arm's length exchanges between firms cannot generate competitive advantage because these exchanges, typically characterized by minimal information and coordination devices and low interdependence, lack inimitability. Therefore, it is only when partners move their relationship away from market-type relationships and implement cooperative strategies (such as information and knowledge exchange, and use of complementary competencies) that competitive advantage is created. The ability to develop and maintain beneficial inter-firm relationships therefore becomes critical. In line with this thinking, Jap (1999 p. 462, 463) notes that "the process of collaboration across organizational boundaries represents a system resource of the firm – a complex socially created phenomenon that involves a complex web of direct and indirect links among the organization's capabilities, investments, and resources that are not specified easily in advance." The aim of collaboration is "expand the size of the joint benefit pie" (Jap 1999 p. 463), that is, to create mutually beneficial strategic outcomes between cooperating firms.

In recognition of the above, the literature emphasizes collaboration between supply chain partners and the advantages firms reap by maintaining close, cooperative partner relationships. The supply chain risk management literature stresses that a collaborative approach to resolving disruption risks allows firms to benefit from cost reductions, improved service, improved end-customer satisfaction, shorter lead times, improved information visibility, and ultimately, competitive advantage.

Collaboration Challenges in Modern Supply Chains

Collaborative disruption risk resolution is challenging because of the degree of complexity that now characterizes modern supply chains. A supply chain is a network of entities collectively responsible for procurement, manufacturing, and distribution activities, which create value for final customers (Christopher 1992, Min and Zhou 2002). Supply chains today are highly dynamic, complex social networks that comprise an overwhelming number of interactions and inter-dependencies among tiers of autonomous supply chain organizations, actors, processes and resources.

Several factors contributing to increasing levels of complexity were discussed in the Introduction section of this paper and include (1) increased reliance on outsourcing and partnering with firms across the globe; and, (2) oversight and management of a large number of supply chain partners across many tiers. Further, strategies such as reducing inventory levels, excess capacity and slack, and lean and agile approaches, improve supply chain efficiency, but also add layers of complexity, making collaboration and coordination a greater challenge. Some scholars (Surana et al 2005 p. 4235) suggest that "supply chains have acquired a complexity almost equivalent to that of biological systems."

Consider the Boeing 787 case once again. Boeing truly employed a complex, global supply network with many tiers of suppliers. One hundred and thirty-five major suppliers were to deliver twelve hundred subassemblies for final assembly in Everett, Washington. Each of those suppliers sourced materials and parts through hundreds of second and third tier suppliers in locations around the world. Boeing's supply network management capabilities at the time would allow a single supplier issue to escape detection and potentially create a serious disruption to the entire program. And it happened; Boeing's 135 major suppliers could not manage their upstream suppliers and the company suffered significant cost overruns, received bad quality parts, and experienced late deliveries of key subassemblies. Unfortunately, Boeing simply did not manage the complexity in the supply network well. The sobering reality is that, in today's business environment, the overwhelming complexity of Boeing's supply network is not uncommon.

Supply Chains as Complex Adaptive Systems

Several members of the academic community, most notably Choi et al (2001), are calling for supply chain researchers to recognize and study supply chains as complex adaptive systems (CAS) or complex adaptive supply networks (Li et al 2009). A complex adaptive system emerges over time (Choi et al 2001) into a coherent form, and adapts and organizes itself without any single entity deliberately managing or controlling it (Holland 1995). Pathak et al (2007) highlight the academic and managerial benefits of conceptualizing supply chains as complex adaptive networks: (1) it has the potential for integrating and structuring existing supply chain research by providing an overarching framework for validating and testing theories; and (2) it has proved successful when applied in managerial contexts at Southwest Airlines and Citibank. In fact, Boeing has effectively used CAS principles to redesign the 787 Dreamliner network (Global Logistics and Supply Chain Strategies 2007).

Theories of CAS focus on the interplay between a system and the environment and the co-evolution of both the system and the environment. Thus, Choi et al (2001) discuss three foci in CAS: (1) internal mechanisms; (2) the environment; and (3) co-evolution. In simple terms, internal mechanisms (e.g. supply chain agents/entities) sense and respond to environmental stimuli (e.g. risk); as a consequence, the CAS adapts and evolves over time (Surana et al 2005).

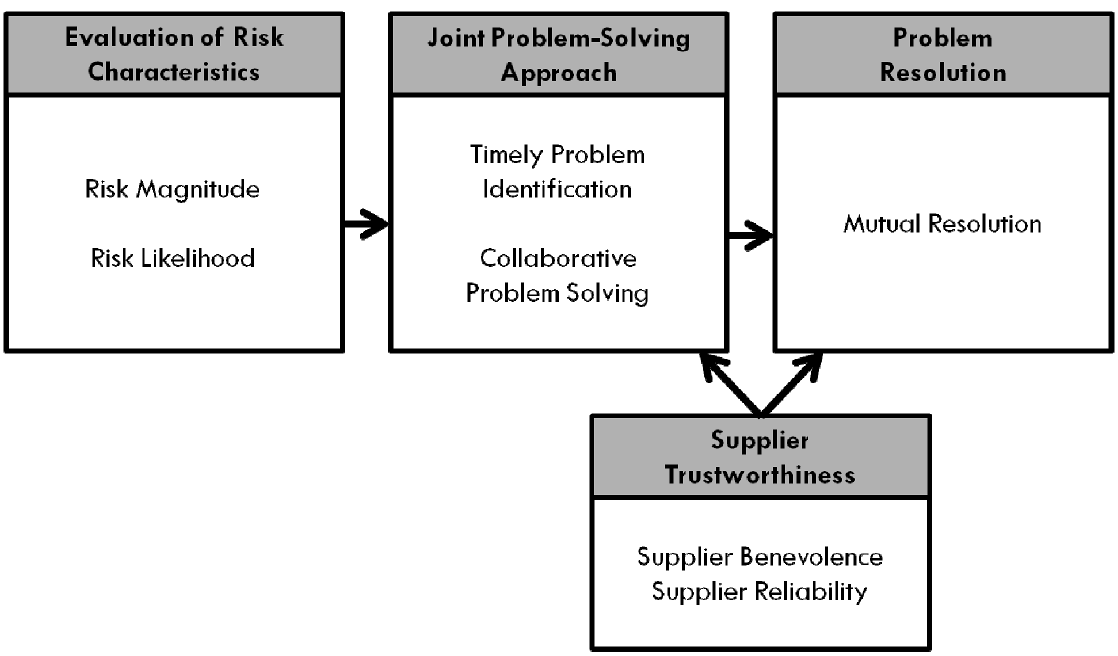
Conceptual Model

One of the major challenges for supply chain managers is to develop collaboration mechanisms that can facilitate adaptive, flexible and synchronized behavior in highly complex supply chains (Li et al 2009). Pathak et al (2007) stress the importance of examining how environmental constructs are related to phenomena of interest and suggest research related to environmental constructs like demand, dynamism, uncertainty, ecological factors and risk. In this study, we address these calls for research by examining the impact of disruption risk attributes on timely problem identification, collaborative problem-solving and ultimately the achievement of mutual resolutions (See Figure 1 below).

Our conceptual contribution lies in explaining how risk characteristics impact outcomes through social, internal mechanisms which overcome problems of complexity, and help partnering firms coordinate their resources across firm boundaries for maximal advantage.

The unit of analysis in this study is the dyadic relationship between a focal manufacturing firm and first tier suppliers. Although we do not employ a network approach in this study, it is important to stress that the challenge of complexity is observed in dyadic exchanges (Robson, Katsikeas and Bello 2008); for example, complexity in dyadic international strategic alliances has been identified as one of two major problems accounting for alliance failure (Park and Ungson 2001). Each organizational member in a dyadic exchange comprises multiple agents/employees who work in a variety of functional areas and who must coordinate resource and information flows with multiple agents/employees in the partner firm. Partnering firms may have very different corporate and national cultures and business processes, dissimilar organizational structures, and may be separated by great physical and psychic distance. Thus, studying dyadic relationships can provide significant insight into how risk characteristics impact risk identification and resolution outcomes through internal, social mechanisms that alleviate problems of complexity. A dyadic relationship between a manufacturer and its first tier supplier represents the first link in the wider global supply network which includes second, third and additional tiers of supply partners. The findings of this research endeavor are therefore related to the smallest building block in the global supply network; however, conclusions about these relationships are expected to be applicable to other dyads in the supply network.

Figure 1: Conceptual Model



RISK CHARACTERISTICS → JOINT PROBLEM SOLVING APPROACH

We hypothesize that firms' evaluation of risk attributes - risk magnitude and risk likelihood - have differing effects on mutual resolution and that these effects are mediated by timely problem identification and collaborative problem solving.

The resources necessary for successful supply chain risk management may be scattered across the actors/employees of partnering firms (Zaheer et al 1998). Layers of complexity separate and disconnect the actors who may therefore remain unaware of resource requirements and unmotivated to share resources across boundaries (Zaheer and Zaheer 2006). In this section of the paper, we discuss how risk characteristics can set mechanisms in place which mobilize actors to coordinate interfirm resource flows across the social network.

Mobilizing is "the process of converting resources into finalized activities performed by interdependent actors" (McEvily et al 2003 p. 97). Mobilization activates the social network and stimulates actors to be proactive in resource exchange, thereby creating organizational and interorganizational action. As discussed earlier in this paper, resources may be tangible, or intangible, like knowledge, information, attention, time and effort. Mobilized actors are willing and motivated to share their resources and to coordinate and combine them for use in joint activities, and to direct them toward the achievement of organizational goals (McEvily et al 2003). Mobilized actors are therefore able to overcome the challenges of interfirm coordination in highly complex situations because they are especially motivated or driven to do so.

Specifically, we discuss how high magnitude and low likelihood risks activate mobilizing mechanisms that facilitate resource flows and exchange across the social network of employees/actors.

Risk Magnitude

High magnitude risks are severe and are potentially very disruptive to supply chains. We propose that high magnitude risks are positively associated with mutual resolution by positively impacting timely problem identification and collaborative problem solving. High magnitude risks trigger mobilizing mechanisms which help firms overcome the problems associated with complexity to quickly identify risks and collaboratively resolve them. Because of their disruptive potential, high magnitude risks trigger monitoring and communication among actors within a firm and across organizational boundaries. Additionally, high magnitude risks are more likely to require know-how, information and knowledge from actors in partnering firms and therefore, actors are activated to share and combine resources in a collaborative problem solving effort.

Risk Magnitude → Timely Risk Identification

Risks with potentially detrimental effects on the supply chain are hypothesized to have a positive impact on timely risk identification because these risks mobilize the network of agents in partnering firms to devote the time, attention and effort to vigilantly monitor the environment in order to quickly identify them. Actors in both firms are more sensitive to these types of risks and do more environmental scanning to detect these problems early. It is also likely that high magnitude risks affect more functional areas within firms; therefore, more agents are stakeholders in having the problem solved. Therefore, these risks mobilize actors across functions and levels of management to join in the screening process.

Additionally, high magnitude risks facilitate greater disclosure and knowledge sharing among actors in supply chain relationships. When facing disruptive problems, actors are mobilized to put aside fears of opportunism and openly share confidential information (Dyer and Chu 2003) with partners who may be impacted by the risk or have the skills and resources to help manage the risk. Thus, the greater the degree of severity associated with a risk, the more information about the risk will be shared among actors within a firm and then across organizational boundaries to actors in partnering firms.

H1: High magnitude risks are positively associated with timely problem identification.

Risk Magnitude → Collaborative Problem Solving

Nix et al (2008) highlight that collaboration is most useful when problems are complex and the solution is dependent on knowledge and insights from another firm. Thus, we propose that there is a positive association between risk magnitude and collaborative problem solving.

As compared to low magnitude risks, successful resolution of high magnitude risks is more likely to require resources which span partner boundaries and require the know-how or technical capability of both supply chain partners. Supply chain actors are therefore more motivated to contribute their resources for use in joint activities when risks have great disruptive potential. Disruptive risks mobilize actors to coordinate and combine resources, thereby facilitating collaboration.

By implication, we suggest that risks with low magnitude offer less motivation for actors to share resources and skills for joint problem solving. Although the supply chain literature seems to unequivocally advocate collaborative approaches for supply chain management and risk mitigation, we suggest that actors are not as mobilized to do so when risks have low disruptive potential.

H2: High magnitude risks are positively associated with collaborative problem solving.

Risk Likelihood

We propose that high likelihood risks (frequently reoccurring, common risks) are negatively associated with mutual resolution and that the effect of high likelihood risks on mutual resolution is mediated by timely problem identification and collaborative problem-solving. On the other hand, low likelihood risks (uncommon risks) are positively associated with mutual resolution because they trigger mobilizing mechanisms which help firms overcome the problems associated with complexity to quickly identify risks and collaboratively solve them.

Risks with high degrees of likelihood are common and have high probabilities of reoccurrence. It is therefore very reasonable to presume that supply chain partners have either: (1) anticipated these types of problems in advance; or (2) experienced these types of problems in the past. Thus, partnering firms are likely to have a negotiated plan for handling the risk which includes prescribed procedures for resolving the problem and pre-established role specifications. On the other hand, risks with low degrees of likelihood are uncommon and have low probabilities of reoccurrence. These types of risks, when encountered in the supply chain, are surprises for which scripted problem solving routines may not exist.

We posit that uncommon risks set off mobilizing mechanisms through which (1) the system as a whole becomes more quickly aware of the problem, and (2) actors are motivated to combine resources in an effort to jointly determine and implement the best approach for resolving the problem.

Risk Likelihood → Timely Problem Identification

We propose that common, expected problems do not create or generate much attention because they do not stand out enough to trigger detection and alarm. Supply chain actors likely assume that these routine, reoccurring problems can be easily handled in pre-determined ways, and therefore these risks are less actively monitored and measured, and information about these risks are less actively shared through the social network.

Detailed, specific plans regarding roles and the actors responsible for implementing the prescribed problem solving routine are likely already established for high likelihood risks. Common risks are not the responsibility of most actors and hence: (1) most actors would be indifferent to these common problems, and (2) fewer actors would be involved in scanning the environment for these risks. If identified by an actor with no responsibility for the risk, information is not likely to spread quickly though the social network because that actor is not highly motivated to do so. Thus, even if identified by an actor, information about these risks does not spread as quickly to reach the all actors responsible for problem solving.

On the other hand, detailed contingency plans are not likely to exist for uncommon or surprise problems. Because low likelihood risks are no one's responsibility, more actors monitor and screen the environment for them. Further, these types of problems mobilize and activate supply chain actors to communicate with other actors in the system to determine: (1) role responsibilities, that is, which actors should be involved; and, (2) problem solving routines, that is, how the risk should be resolved. Actors are more motivated to spread knowledge of uncommon risks across organizational boundaries because the partner firm may have the knowledge and skill to participate in the resolution effort.

Task uncertainty, defined as a lack of information or know-how concerning the work people are supposed to do (Galbraith 1973), is related to uncommon problems. Equivocality, a more fundamental form of uncertainty, refers to situations in which actors have difficulty making sense of and analyzing the situation (Perrow 1967). High levels of task uncertainty and equivocality mobilize partners to engage in continuous communicative and observational interactions (Kumar et al 2005); this communication allows firm to overcome the challenges of complexity to identify risks in a timely manner. Thus, the more uncommon the problem (low likelihood), the more actors are mobilized to quickly identify the problem and communicate the problem to their partners.

H3: Common risks are negatively associated with Timely Problem Identification

Risk Likelihood → Collaborative Problem Solving

Kumar et al (2005) propose that task uncertainty is positively associated with intense collaboration. High levels of task uncertainty mobilize partners to calibrate and coordinate their individual actions (Kumar et al 2005), thus overcoming the challenges of complexity and facilitating collaborative problem solving.

Therefore, we propose that risk likelihood has a similar effect on collaborative problem solving; common risks are negatively associated with collaborative problem solving. Common risks are anticipated, and it is probable that detailed contingency plans were developed in advance. It is also probable that firms have learned from frequently reoccurring risks and actors have likely gained some experience in implementing a problem solving routine. Therefore, we expect that partnering firms in a supply chain rely less on a bilateral, collaborative approach for resolving common risks.

Surprise risks, on the other hand, are not anticipated and detailed contingency plans or scripted problem solving routines are not likely in existence. These risks require improvisation and the social network of actors are activated to work together for their resolution. Because both parties are likely unfamiliar with the risk, actors are motivated to combine their knowledge, skills and expertise to determine and implement a suitable problem solving routine. Thus, uncommon problems are more likely to require joint activities and a collaborative problem solving approach.

H4: Common risks are negatively associated with Collaborative Problem Solving.

JOINT PROBLEM SOLVING APPROACH → MUTUAL PROBLEM SOLUTIONS

Timely Problem Identification → Mutual Problem Solutions

As discussed previously, successful risk resolution depends on first becoming aware of the potential or actual disruption risk. It is disruption risk discovery/identification which leads to the ability to recover from the disruption. Rao and Goldsby (2009) opine that research on the identification of supply chain risks is still in its early stages. There is, however, a burgeoning literature on a very closely related concept: supply chain visibility. Visibility is the degree to which supply chain partners have access to information related to supply chain operations and management considered to benefit each other (Wei and Wang 2010). It is "the identity, location and status of entities transiting the supply chain, captured in timely messages about events (Francis 2008 p. 182)." There is general consensus that supply chain visibility must go far beyond simple information sharing to accurate and timely information sharing (Wei and Wang 2007). Firms with superior supply chain visibility are able to identify problems in a timely manner.

Using the dynamic capabilities view, Wei and Wang (2010) discuss visibility as enabling sustainable competitive advantage in supply chains by permitting firms to quickly recognize changes in the environment and to "sense and adapt" (pg. 240) to key supply chain events. Therefore, supply chain partners with superior visibility are more likely to become quickly cognizant of potential supply chain disruption risks and to be able to effectively adapt to the risk situation.

The advantages of early risk detection and visibility are significant. Timely detection and visibility of supply chain events and risks enable supply chain partners to access complete information to: (1) support coordinated decision-making and, (2) quickly arrive at a consensus regarding collaborative goals (Wei and Wang 2010). Further, timely risk detection can lead to improved coordination and enhanced customer satisfaction (Barua et al 2004, Wei and Wang 2010). By sharing timely supply information, "firms at downstream stages can alert a disruption at an upstream stage" and "make proper decisions to offset the impact of the disruption", (Li and Lin 2006), therefore information sharing enhances the agility of firms in the face of disruption risks. Based on the above, timely detection of disruption risks is a pressing need in SCRM (Blackhurst et al 2005) and "a key element in any strategy to mitigate supply chain risk" (Christopher and Lee 2004), hence

H5: Timely Risk Identification is positively associated with Mutual Resolution.

Collaborative Problem Solving → Mutual Resolution

The necessity and benefits of a collaborative approach in relationships are well documented in the literature on interorganizational relationships. Few organizations are internally self-sufficient with respect to their critical resources, thus firms are motivated to establish and maintain interorganizational relationships. Dyer and Singh (1998) highlight that "a firm's critical resources may span firm boundaries and may be embedded in interfirm resources and routines" (p. 660). Therefore, firms willing and able to combine resources in unique ways have access to a relational rents and competitive advantage which is not attained in arm's length exchanges characterized by inimitability (Barney 1991, Jap 1999).

Collaborative problem solving is therefore posited to enable firms to achieve more benefits and greater risk resolution success since collaborating partners can have greater access to information and resources than when acting alone. Collaborating firms can employ shared know-how (Dyer and Singh 1998), complementary assets (Park et al 2004), and technological capabilities (Powell et al 1996); and may reduce logistical (Stank et al 2001) and transaction costs and enhance productivity (Kalwani and Narayandas (1995).

Jap (1999) describes the collaborative process as one which is intended to "enlarge the size of the joint benefit pie and give each party a share of an incrementally greater pie that could not be generated by either party in isolation." Collaboration is not a cost-free activity, however, firms are willing to invest time and other resources to work jointly with their supply chain partners because there is empirical evidence that higher levels of collaboration tend to provide competitive advantages to firms (Simatupang and Sridharan 2005, Kohli and Jensen 2010). Supply chain collaboration goes beyond simple coordination; it entails organizations working together to achieve mutual benefits. According to McClellan (2002), supply chain collaborations are "win-win" arrangements in which both parties derive improved business success. Therefore, we posit that a collaborative approach to risk mitigation is positively associated with mutually beneficial risk resolutions.

H6: Collaborative problem solving is positively associated with Mutual Resolution.

CONTROL VARIABLES

The supply chain management literature has certainly addressed the 'hard' factors important to the risk management process; for example, there has been ample discussion on inventory management and the maintenance of buffer stock, second sourcing, and the technological systems which facilitate the identification and mitigation of supply chain risks. It is important to note, however, that the readiness and ability of an organization to engage in collaborative problem solving also depends on 'soft' factors such as the organization's character, its willingness to collaborate, and the affective/empathetic relationships it has cultivated with key partners (Rosas and Camarinha-Matos 2009).

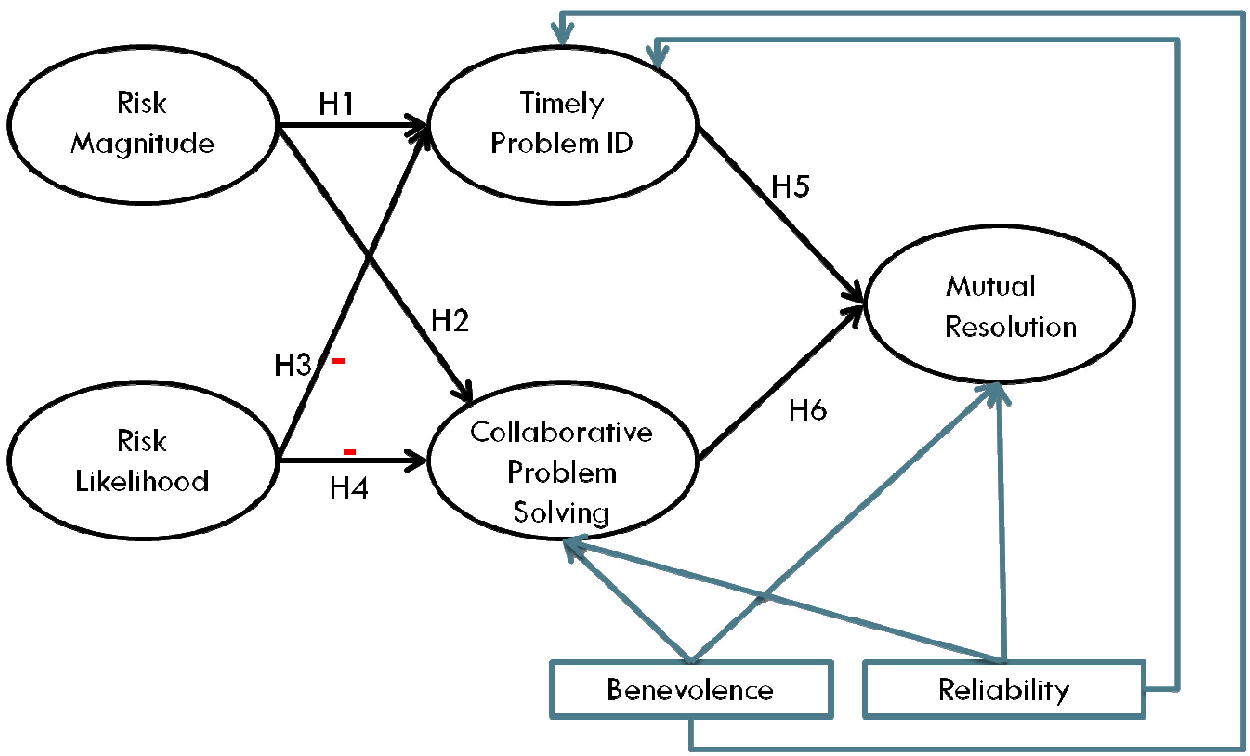
McEvily et al (2003) define trust as the willingness to accept vulnerability based on positive expectations about another's intentions or behavior. There is abundant evidence in the literature that trust is important for long-term relational exchanges. Robson et al (2008) model the belief component as including (a) affective trust (based on an expectation of the partner's benevolence) and (b) calculative trust (based on an expectation of the partner's technical competence and qualifications). We control for these two components of trust, the focal firm's confidence in their supplier's (1) benevolence and (2) reliability.

Trust is also a mobilizer which "motivates actors to contribute their resources, and to combine, coordinate, and use them in joint activities, and to direct them toward the achievement of organizational goals" (McEvily et al 2003, p. 97). Mobilization results in organizational action as trusted actors are willing to share confidential information necessary to work together jointly to resolve problems (Dyer and Chu 2003). Robson, Katsikeas and Bello (2008) demonstrate how trust in an alliance partner impacts alliance performance through social mechanisms that alleviate the problems of organizational complexity.

Trust mobilizes actors in a supply network to share resources and skills to identify and jointly resolve problems by encouraging knowledge-sharing and increasing the disclosure of knowledge to others (McEvily et al 2003). Trust also strengthens identity, which in turn leads to commitment. As identification intensifies, the strength of attachment or commitment increases as well" (McEvily et al 2003). Similarly, Narayandas and Rangan (2004) also find that interpersonal trust across dyads leads to increased levels of interorganizational commitment. A commitment to a long-term relationship will lead supply chain partners to work together collaboratively to resolve relationship problems and to generate mutual benefit in order to preserve the relationship. Finally, trust mobilizes actors by encouraging them to suspend judgment of each other thereby reducing the need for firms to devote resources to non-productive activities such monitoring and safeguarding.

Based on the above, we expect that trust overcomes problems of complexity since it mobilizes actors in a supply network to share information, skills and other resources to quickly identify problems, collaboratively resolve them and derive mutually beneficial solutions.

Figure 2: Path Model Depicting Hypotheses



CHAPTER 4: METHODOLOGY

In this chapter, we present the research design and methodology used to test the conceptual model. We begin with a description of how the constructs used in this study are operationalized. Then, sampling and data collection procedures will be presented. Questionnaire development and the pre-test will be discussed and a description of the sample will be provided. Finally, we identify the analytical procedures used to test the conceptual model.

OPERATIONALIZATION OF EXOGENOUS CONSTRUCTS

Exogenous constructs are those that have an effect on one or more endogenous constructs in the model, but are not a function of any other constructs in the model. The levels of the exogenous constructs are used as given and their antecedents are not relevant in the proposed model. Exogenous constructs in this study relate to the characteristics of disruption risks encountered in supply chains.

As discussed earlier, it is generally accepted that the term risk encompasses two elements: (1) a range of outcomes that may occur; and, (2) the likelihood or probability associated with the outcomes. We measure these two attributes of supply chain disruption risk through the use of two constructs: (1) Risk Magnitude, and (2) Risk Likelihood.

Risk Magnitude. This construct captures the degree of severity or disruptive potential of the identified supply chain disruption risk. Since respondents reported on a scenario which occurred sometime in the past, buyers were asked to report on the assessment they made of the risk at the time they first became aware of it. In particular, they were asked to report on "the impact the risk could have had if it was not resolved in a timely manner."

Risk Likelihood. This construct captures the probabilities associated with the supply chain disruption risks. Since respondents reported on a risk which was already realized in the past, respondents were asked to report on the degree of likelihood of the risk reoccurrence.

OPERATIONALIZATION OF ENDOGENOUS CONSTRUCTS

By definition, any construct that is influenced by another construct in the model is endogenous. As depicted in the conceptual model (Figure 1), the endogenous constructs capture: (1) the characteristics of the problem solving approach used to resolve the disruption risk (measured by two constructs: Timely Problem Identification and Collaborative Problem Solving) and; (2) the nature of solution found to the disruption risk, (measured by the construct, Mutual Problem Solution).

Timely Problem Identification. This construct measures how early disruption risks were identified by the actors responsible and involved in its resolution. In particular, the measures assess whether or not the risks were identified early enough to enable the firms to find a solution without causing disruptions in the focal manufacturing firm.

Collaborative Problem Solving. We aim to measure the manner in which the risk was resolved, in particular, to assess whether or not a collaborative approach, involving joint action between firms, was employed to resolve the risk.

Mutual Resolution. This construct measures the degree to which both parties derive mutual benefit from the risk resolution.

OPERATIONALIZATION OF CONTROL VARIABLES

Trust is the willingness to accept vulnerability (or risk) based on positive expectations about another's intentions or behaviors (McEvily et al 2003). A party's willingness to trust a partner is based on their assessment of the partner's attributes. The literature suggests two key attributes necessary to assess a partner's trustworthiness and these two attributes are captured in the following constructs. Measures were adapted from Robson, Katsikeas and Bello (2009), Lui et al (2009) and Doney and Cannon (2007).

Benevolence. The benevolence construct captures the buyer's degree of expectation that the other party has integrity and will not engage in actions which may have a negative impact on the firm.

Reliability. The reliability construct captures the degree of the buyer's expectation that the other party is technically competent.

SAMPLING AND DATA COLLECTION PROCEDURES

The aerospace defense industry was selected as an appropriate setting to test the conceptual model. This study focuses on the relationship between a focal manufacturing organization and its first tier suppliers.

The sampling frame is a list of 524 buyers and their email addresses provided by the focal manufacturing organization. The study required respondents to provide information on the relationship between the manufacturing firm and a focal first tier supplier, attributes of a supply chain disruption risk encountered with that supplier during the past year and particulars regarding how the risk was identified and resolved. Therefore, the major eligibility criteria used to determine suitability for participation in the study was detailed familiarity with the relationship between the focal manufacturing firm and the supplier firm. All 524 buyers met the major eligibility criteria for participation in the study because they each had responsibility for complete management of all interactions and affairs with at least one supplier firm. All buyers on the list were therefore invited to participate in the study.

Buyers managed a wide variety of relationships ranging from those with suppliers producing major sub-assemblies which are sole-sourced to those with suppliers of basic commodity parts which are widely available through a large number of potential suppliers. This array allowed us to obtain variation in the relationships studied and variation in the types of risks encountered.

The following procedure was used to contact each respondent for final data collection. An initial email was sent by a key employee of the company (1) informing buyers of the research endeavor to be conducted by researchers from Georgia State University and, (2) assuring them of complete confidentiality should they decide to participate in the study. The researchers subsequently sent another email to the buyers inviting them to participate in the study; this email included a link to the survey. After one week, the researchers sent a final reminder email to those buyers who had not yet participated in the study.

QUESTIONNAIRE DEVELOPMENT

Field Study

Fieldwork was conducted over a period of one year and included two visits to the focal manufacturing organization and twelve interviews with key employees. Interviews lasted approximately thirty minutes each, and were carried out with a wide variety of employees (including two buyers) who interacted with or had responsibility for managing supplier relations.

The fieldwork produced several important results. It enabled the researchers to gain a thorough background on the challenges experienced by the company, the roles and responsibilities of respondents, and the type of interactions respondents have with suppliers. The fieldwork informed the design of the research and the survey instrument.

Most importantly, the fieldwork validated that our key informant approach was viable. Even though multiple departments interacted with supplier firms, interviews revealed that oversight of all aspects of the relationships was the buyers' responsibility. Buyers would therefore be knowledgeable and familiar with the nature of the relationships and the types of problems encountered in each relationship and were therefore the best source of this type of information.

The basic outline of the questionnaire developed was as follows:

1. Identification of Buyer and Supplier: The respondent (1) identified himself and (2) identified his major supplier, on whom all the survey questions were based.
2. Attributes of the Supplier: The respondent answered questions regarding the general climate of the relationship between his company and the supplier firm. In particular,

respondents provided their assessment of the partner's technical competence and the partner's benevolence toward the focal manufacturing firm.

3. Risk Description: The respondent was asked to recall and report on a specific problem/risk that recently arose (and which was resolved) in the course of the relationship with the previously identified supplier. All subsequent questions in the survey were based on the single particular risk identified by the buyer in this section of the survey.
4. Risk Identification: This section assessed the manner in which the previously described risk was first identified, in particular, how early the risk was identified.
5. Risk Attributes: This section required respondents to report on the potential magnitude of the risk and the associated risk probability or likelihood.
6. Risk Resolution: The respondent was asked to indicate the manner in which the risk was resolved, in particular, whether or not a collaborative problem solving approach was employed.

After the fieldwork, the first version of the questionnaire was constructed. Items were developed as discussed below. Before the questionnaire was formally pre-tested, it was evaluated by colleagues and several field study participants for face validity.

THE PRE-TEST

The objective of the pre-test was to purify measures for use in the final test. Data collection procedures for the pre-test were the same as for primary data collection. Email invitations were sent to fifty buyers from the list of 574 buyers provided by the focal manufacturing firm. Eleven buyers fully completed the survey, resulting in a response rate of 22%. This low response rate indicated the need for the focal manufacturing firm to send an introductory email assuring buyers that their participation in the study was sanctioned by the firm and that all participants were guaranteed anonymity. Follow-up conversations with key company employees guided the refinement of the survey instrument.

THE SAMPLE

For the final study, the remaining 524 buyers were contacted using the procedures previously discussed. Responses were submitted by 234 buyers for a response rate of 44.66%. This dramatic improvement in response rate indicated that the introductory email from the focal manufacturing firm eased respondents' anxiety regarding their participation in the study and the confidentiality of their responses.

As an additional check on the eligibility of respondents, buyers were asked to identify one major supplier with whom they worked and to base all subsequent answers on the relationship with that specific supplier. Eleven cases were dropped because of unsatisfactory answers to this question. Eight cases were dropped after an examination of the survey completion times and twelve cases were dropped because of pattern responses. A total of 203 cases were retained and used in the analysis.

ANALYTICAL PROCEDURES

Once the scales were validated in the pre-test, the final data was collected. The hypotheses were tested via the structural equation modeling method which has assumed a very prominent place in the marketing academic literature. Structural equation modeling allows researchers to answer a set of inter-related questions in a single, systematic and comprehensive analysis by representing and testing linear relationships among multiple independent and dependent constructs in a single theoretical network (Gerbing and Anderson 1988). Structural equation modeling also offers major advantages as it relates to managing measurement error.

We employed the use of the maximum likelihood technique, which is the most widely used method in practice. The maximum likelihood (ML) estimation technique was used due to its robustness to potential violations of the strict assumptions of structural equation modeling (Chou and Bentler 1995). In particular, it has been observed that the maximum likelihood (ML) estimation method is reasonably robust to moderate departures from normality (Rigdon 1998).

Data analysis follows Anderson and Gerbing's (1988) two-step process. First, a measurement model of all constructs was tested; once acceptable fit statistics were achieved the hypothesized structural model was tested. The measurement model specifies how observed indicators are linked to underlying variables or constructs; the structural model, on the other hand, indicates the causal relationships among the latent variables.

Confirmatory Factor Analysis was used to determine the unidimensionality of the constructs. This was done by specifying the observed item to latent variable relationships and allowing the latent variables to correlate with one another (Anderson and Gerbing 1988). Decisions to drop or retain items were based on Anderson and Gerbing's (1988) recommendations. A separate test of the measurement model is conducted for two primary reasons: (1) any respecification in measurement models should be done "independently of considerations of the substantive, structural model" (Anderson and Narus 1990, p. 48); and, (2) this approach prevents the interpretational confounding which can occur when the measurement model and the structural model are tested at the same time (Anderson 1987).

Following the test of the measurement model, the construct structural model of the proposed conceptual framework is tested. In this step, the hypothesized relationships among the theoretical constructs are specified and examined for goodness of fit characteristics. We assess model fit in two ways: (1) absolute fit; (2) incremental fit; and (2) the significance of individual parameter estimates. Absolute fit indices assess how well an a priori model reproduces the sample data while incremental fit indices measure the proportionate improvement in fit by comparing a target model with a more restricted, nested baseline model.

In order to assess absolute fit we report on the chi-square statistic (Jöresgog 1969), the room mean square error of approximation or RMSEA (Browne and Cudeck 1993) and the standardized root mean square residual or SRMR.

The overall chi-square statistic provides a test of whether the sample covariance matrix is equivalent to the model-implied covariance matrix, within sampling error. As noted by Rigdon (1998), well-known problems with the chi-square statistic have led researchers to interpret it with caution. Jöresgog and Sörbom (2001) highlight that chi-square is highly sensitive to departures from multivariate normality of the observed variables. Further, chi-square has been demonstrated to be a function of sample size when the proposed model is not perfectly correct in the statistical population. Proposed structural models are typically gross simplifications of reality rather than exact representations; therefore, a strong sample size influence on the chi-square is the rule rather than the exception (MacCallum and Tucker 1991). In light of the above reasons, many structural equation modeling users believe that with a reasonable sample size (over 200 cases) and good approximate fit as indicated by other fit tests, the significance of the chi-square may be discounted and that a significant chi-square is not a reason by itself to modify a model. Bryne (1989) posits that a chi-square to degrees of freedom ratio greater than two is suggestive of inadequate fit.

The RMSEA minimizes the impact of sample size and shifts the focus from exact fit to approximate fit (Rigdon 1998). RMSEA values between 0 and 0.5 are viewed as indicating good approximate overall fit and values above 0.10 indicate significant fit problems (Browne and Cudeck 1993). The SRMR examines the standardized differences between observed correlations and predicted correlations. A value less than 0.08 is generally considered a good fit (Hu and Bentler 1999).

In order to implement incremental fit, we assess and report on the comparative fit index (CFI) as developed by Bentler (1990) and the Tucker Lewis Index (TLI).

The CFI provides the means for researchers to compare the fit of their proposed models to a worst-case scenario, but under the same conditions of sample size and data distribution (Bentler 1990). CFI values range from 0 to 1 and values near 1 imply that the model is a good fit. In the past, CFI values of 0.90 or above indicated adequate fit, however there has been some criticism of this heuristic (Hu and Bentler 1995). Rigdon (1998) highlights that some members of the academic community have called for raising the minimal acceptable value to 0.95.

The TLI is sometimes called the NNFI (Non-Normed Fit Index). According to Marsh, Balla and McDonald (1988), the TLI is relatively independent of sample size. Values over 0.90 or 0.95 are considered acceptable (Hu and Bentler 1999).

We also reference Hu and Bentler's (1999) combinatorial rule (SRMR $\leq$ 0.8 and CFI $\geq$ 0.95 or SRMR $\leq$ 0.8 and RMSEA $\leq$ 0.6). This rule was demonstrated to minimizing type I and type II error rates.

Finally, we assess and interpret parameter estimates. We determine whether all signs and magnitudes of estimates are reasonable then we examine t-values for the hypothesized paths to determine the specific reject/accept decision for each hypothesis. Significant t-values for a hypothesized path indicates acceptance of the hypothesis.

Responses to the independent and dependent variables were both obtained through the same source. When cross-sectional data is gathered from a single source there may be artifactual covariance between the predictor and criterion variable produced by the simple fact that the respondent providing the measure of these variables is the same. To address this concern, we follow the recommendations of Podsakoff et al (2003) for limiting and assessing the effects of common method variance. Scale items were carefully constructed and included reverse-coded items, predictor and criterion variables were separated within the survey instrument, and all respondents were guaranteed anonymity and encouraged to answer questions as honestly as possible.

Finally, we conducted Harmon's single-factor test to address the issue of common method variance. Traditionally, researchers using this technique load all of the variables of their study into an exploratory factor analysis and determine the number of factors that are necessary to account for all the variance in the model. If common methods bias is a significant issue, then it is expected that all variables would load unto one factor or that one general factor would account for the majority of covariance among the measures (Podsakoff 2003). Researchers have begun to use confirmatory factor analysis as a more sophisticated test of the hypothesis that a single factor can account for all the variance in their data (Iverson and Maguire 2000, Korsgaard and Roberston 1995). We also employ the use of confirmatory factor analysis and report on our findings in the Results section.

CHAPTER 5: RESULTS

The purpose of this chapter is to describe the empirical results of the test of the conceptual model. As an important first step, a valid and reliable measurement model must be developed. This chapter firstly describes the measurement model, its items and its overall fit statistics. Secondly, the structural model is specified and tested for overall fit. The individual hypotheses in the conceptual model are then discussed as the parameter estimates are analyzed.

THE MEASUREMENT MODEL

As noted by Peter (1981), using reliable and valid measures is an important prerequisite for trustworthy theory testing. A measurement model, that is, one used to measure latent constructs, is valid and reliable as determined by a confirmatory factor analysis which confirms that the proposed observable items accurately measure the latent construct and not other variables. Unidimensionality is determined by specifying the proposed relations of the observed items to their underlying latent construct and allowing the constructs to intercorrelate (Anderson and Gerbing 1988).

The CFA led to the adjustment of several items and this phase of analysis led the researchers to drop several items because statistics indicated they did not measure the construct as indicated. None of the dropped items were used to measure different constructs than those originally anticipated. In all cases except one, at least three items were used to indicate each construct. Although there is some debate regarding the number of measures that should be used in studies, Marsh, Hau and Balla (1996) argued that having more measures is always better, all other things equal. Although it can be acceptable to use fewer items to indicate a construct, it is generally recommended to use three items per construct in order to avoid problems with identification, non-convergence and negative variance estimates (Bollen 1989).

Table 1 shows the final items used in the measurement model and their descriptive statistics (means and standard deviations). The final model consists of seven constructs and twenty indicators for these constructs. Table 1 also provides scale reliabilities as measured by Chronbach's Alpha. The reliability scores for scales range from .82 to .92, suggesting very good reliability. Table 2 shows the item measures correlation matrix. Table 3 shows the final results of the measurement model, that is, the standardized loadings and t-values of each item as well as their squared multiple correlations.

Convergent validity refers to the degree to which items measure the construct they are supposed to measure (Peter 1981). All items in the model demonstrate good convergent validity. In Structural Equation Modeling, convergent validity is established when each measure's estimated pattern coefficient loads significantly on its intended construct (that is, when parameter estimates are approximately two times the standard errors) (Anderson and Gerbing 1988). As can be seen in Table 3, all items load on their respective constructs, and all t-values are significant.

The measurement model performed well and fit statistics indicate that the model is a good fit for the data. The chi-square statistic is significant ($\chi^2_{(150)} = 207.163$, $p = 0.0014$), however, other absolute and incremental fit statistics indicate a very good fit of the measurement model (SRMR = 0.037, RMSEA 0.043, CFI=0.98, TLI=0.97) (Hu and Bentler 1999).

Table 1: Item Descriptive Statistics

Construct and Item	Mean	Standard Deviation
<u>**Benevolence (α=.92)**</u>		
• This supplier seems genuinely concerned about LM's needs and not just its own interests [BEN1]	5.31	1.49
• This supplier can be expected to have favorable motives toward LM and to be helpful in difficult situations [BEN2]	5.48	1.40
• When making important decisions, this supplier is always concerned about LM's welfare and interests [BEN3]	4.81	1.49
<u>**Reliability (α=.88)**</u>		
• LM is confident that this supplier has the technical ability to deliver on its promises [REL1]	5.87	1.16
• This supplier has the necessary expertise to perform reliably [REL2]	5.87	1.21
• Compared to other suppliers, this supplier has above average technical skills and capabilities [REL3]	5.44	1.30
<u>**Risk Magnitude (Seven-Point Semantic Differential Scale) (α=.92)**</u>		
• Not Harmful – Very Harmful [RM1]	5.28	1.41
• Not Severe – Severe [RM2]	5.20	1.62
• Very Disruptive – Disruptive [RM3]	5.52	1.56
<u>**Risk Likelihood**</u>	3.43	2.74
• What is the probability of this same risk event reoccurring next year?		
<u>**Timely Problem Identification (Seven-Point Semantic Differential Scale) (α=.845)**</u>		
• The detection of the risk was early enough that there was sufficient time to resolve the issue before other aspects of the program were affected [IDT1]	4.40	1.82
• The discovery of the risk was too late to permit its resolution before disruptions occurred [IDT2]	4.23	1.911
• The risk became evident before it posed an immediate threat to production schedules [IDT3]	4.38	1.86
• The risk was identified before it impacted the functioning of the program [IDT4]	4.70	1.75
<u>**Collaborative Problem Solving (α=0.87)**</u>		
• The issue was addressed by both parties working together collaboratively [COLL1]	5.62	1.20
• LM and the supplier engaged in joint problem solving and shared responsibility [COLL2]	5.38	1.37

• Rather than working collaboratively, LM solely determined and specified the supplier's approach for resolving the risk [COLL3]	5.37	1.39
Mutual Resolution (α=0.803)		
• A suitable solution was developed that mitigated risk for both parties [MS1]	5.32	1.20
• The situation was resolved to the mutual satisfaction of LM and the supplier [MS2]	5.34	1.30
• The ultimate solution to the situation was cost effective to both parties [MS3]	4.80	1.45

Table 2: Item Measures Correlation Matrix

	REL2	REL1	REL3	BEN1	BEN2	BEN3	COLL2	COLL1	COLL3
REL2	1								
REL1	0.879	1							
REL3	0.623	0.681	1						
BEN1	0.48	0.525	0.372	1					
BEN2	0.474	0.518	0.368	0.865	1				
BEN3	0.425	0.464	0.329	0.774	0.765	1			
COLL2	0.202	0.221	0.156	0.34	0.336	0.3	1		
COLL1	0.229	0.25	0.178	0.386	0.381	0.341	0.751	1	
COLL3	0.192	0.21	0.149	0.323	0.319	0.286	0.629	0.714	1
RM2	-0.035	-0.04	-0.027	-0.101	-0.1	-0.089	0.201	0.229	0.192
RM1	-0.036	-0.04	-0.028	-0.102	-0.1	-0.09	0.202	0.23	0.193
RM3	-0.031	-0.03	-0.024	-0.089	-0.088	-0.079	0.178	0.203	0.17
RL	-0.187	-0.2	-0.145	-0.155	-0.153	-0.137	-0.143	-0.16	-0.14
IDT2	0.162	0.177	0.125	0.179	0.177	0.158	0.119	0.135	0.113
IDT1	0.195	0.213	0.151	0.215	0.213	0.19	0.143	0.162	0.136
IDT3	0.149	0.163	0.116	0.165	0.163	0.146	0.11	0.124	0.104
IDT4	0.174	0.19	0.135	0.192	0.19	0.17	0.128	0.145	0.122
MS2	0.245	0.268	0.19	0.346	0.342	0.306	0.357	0.405	0.339
MS1	0.268	0.293	0.208	0.378	0.374	0.335	0.39	0.442	0.371
MS3	0.18	0.197	0.14	0.255	0.252	0.225	0.262	0.298	0.249

	RM2	RM1	RM3	RL	IDT2	IDT1	IDT3	IDT4	MS2	MS1	MS3
RM2	1										
RM1	0.866	1									
RM3	0.763	0.767	1								
RL	0.092	0.092	0.081	1							
IDT2	-0.048	-0.048	-0.042	-0.14	1						
IDT1	-0.057	-0.058	-0.051	-0.17	0.636	1					
IDT3	-0.044	-0.044	-0.039	-0.13	0.487	0.587	1				
IDT4	-0.051	-0.051	-0.045	-0.15	0.568	0.685	0.525	1			

MS2	0.093	0.093	0.082	-0.18	0.283	0.341	0.261	0.305	1		
MS1	0.101	0.102	0.09	-0.2	0.309	0.372	0.285	0.333	0.754	1	
MS3	0.068	0.069	0.06	-0.13	0.208	0.251	0.192	0.224	0.507	0.554	1

Table 3: Results of Measurement Model

Construct and Item	SMC	Standardized Loading	t-value
Benevolence			
• BEN1	0.88	0.94	63.63
• BEN2	0.85	0.92	59.36
• BEN3	0.69	0.83	33.15
Reliability			
• REL1	0.96	0.98	63.84
• REL2	0.80	0.90	46.63
• REL3	0.48	0.70	17.78
Risk Magnitude			
• RM1	0.86	0.93	58.61
• RM2	0.87	0.93	57.47
• RM3	0.68	0.82	31.98
Risk Likelihood	-	1.00	-
Timeliness of Problem Identification			
• IDT1	0.53	0.88	28.68
• IDT2	0.77	0.73	17.90
• IDT3	0.45	0.67	13.99
• IDT4	0.61	0.78	20.42
Collaborative Problem Solving			
• COLL1	0.66	0.92	40.69
• COLL2	0.85	0.81	26.83
• COLL3	0.60	0.77	23.10

Mutual Resolution			
• MS1	0.69	0.91	32.26
• MS2	0.82	0.83	26.21
• MS3	0.37	0.61	12.45

Once measurement models demonstrate adequate fit, structural models may then be specified and tested. This approach (Anderson and Gerbing 1988) prevents confounding between measurement issues and structural issues which may occur when these models are estimated simultaneously. This two-step approach therefore allows for a more rigorous test of the specific hypotheses proposed in the previous chapters. The section below discusses and evaluates the structural model specification and interpretation.

THE STRUCTURAL MODEL

Structural models are specified as a series of linkages (or causal relationships) among latent constructs as hypothesized in the conceptual framework. Specifically, the exogenous or predictor variables (Risk Magnitude, Risk Likelihood) and control variables (Benevolence and Reliability) are specified to relate to the endogenous constructs (Timely Risk Identification, Collaborative Problem Solving, and Mutual Resolutions).

Like the measurement model, the structural model is tested using the covariance matrix and the method of estimation is also maximum likelihood (ML).

In terms of overall fit, the model appears to fit the data well. The chi-square test is significant (($\chi^2_{(153)} = 210.739$, p = 0.0014), however the ratio of χ^2 to degrees of freedom is less than two. Other fit statistics suggest good fit (CFI = 0.98, TLI = 0.97, SRMR = 0.041, RMSEA

0.043) (Hu and Bentler 1999). Table 4 shows the path coefficients along with their significance levels.

Table 4: Structural Model Results

Model Parameters	Hypothesis	Estimate	T-value	Sig
Risk Magnitude → Timely Problem Identification	H1	-0.023	-0.31	ns
Risk Magnitude → Collaborative Problem Solving	H2	0.337	5.31	***
Risk Likelihood → Timely Problem Identification	H3	-0.141	-1.91	*
Risk Likelihood → Collaborative Problem Solving	H4	-0.135	-2.09	**
Timely Risk Identification → Mutual Resolution	H5	0.346	5.21	***
Collaborative Problem Solving → Mutual Resolution	H6	0.387	5.60	***
Benevolence → Timely Problem Identification	Control	0.171	1.85	*
Benevolence → Collaborative Problem Solving	Control	0.466	6.02	***
Benevolence → Mutual Resolution	Control	0.155	1.83	*
Reliability → Timely Problem Identification	Control	0.119	1.30	ns
Reliability → Collaborative Problem Solving	Control	-0.004	-0.05	ns
Reliability → Mutual Resolution	Control	0.051	0.65	ns

*** $p < 0.001$, ** $p < 0.05$, * $p < 0.10$

Since the sample covariance matrix estimated by the data is a reasonable representation of the constrained model, individual hypotheses may now be examined.

MAIN EFFECTS

All estimated t-values greater than an1.96 indicate the relationship is significant and the hypothesis should therefore be accepted. In all, four of the six hypotheses are accepted at the 0.05 level and one is accepted at the 0.10 level. One hypothesis was not supported.

The first hypothesis (H1) suggested a positive association between risk magnitude and timely problem identification. The findings do not provide support for H1 ($\beta = -0.03$, $p > 0.05$). All other hypotheses relating risk characteristics to problem identification and mitigation are supported; there is support for H2 ($\beta = 0.337$, $p < 0.001$), H3 ($\beta = -0.141$, $p < 0.10$), and H4 ($\beta = -0.141$, $p < 0.05$). Thus, the findings partially support the logic that high magnitude findings mobilize supply network actors to share resources across interorganizational boundaries thereby overcoming complexity challenges. The findings also support the view that risk likelihood has the opposite effect, that is, that high likelihood risks are not as mobilizing as low likelihood risks because they are less common and expected.

We find support for the positive effect of benevolence on timely problem identification ($\beta = 0.171$, $p < 0.10$), collaborative problem solving ($\beta = 0.466$, $p < 0.001$), and mutual resolution ($\beta = 0.155$, $p < 0.010$), but no support for reliability. These findings suggest that it may only be expectation of goodwill between partners, and not their technical reliabilities that drives firms to jointly resolve supply chain risks.

MEDIATION EFFECTS

Our conceptual model posits a mediating role for timely problem identification and collaborative problem solving. We tested this assertion by estimating two alternative models. Full mediation is supported if: (1) risk magnitude and risk likelihood significantly affect mutual problem solutions in a non-mediated model; and (2) these effects decline to insignificance when indirect paths between these variables and mutual problem solution via timely problem identification and collaborative problem solving are added in a mediated model (Kraimer et al

2001). In both the non-mediated and mediated models, we include the trust control constructs for a more robust test of mediation.

In the non-mediated model, risk magnitude exhibited a positive significant effect on Mutual Resolution ($\beta = 0.187$, $p < 0.05$), while risk likelihood exhibited a significant negative effect ($\beta = -0.147$, $p < 0.05$). Benevolence was also a significant predictor of Mutual Resolution ($\beta = 0.392$, $p < 0.001$), while Reliability proved insignificant ($\beta = 0.062$, $p > 0.05$).

When timely problem identification and collaborative problem solving are added as mediators, the direct paths from risk magnitude ($\beta = 0.083$, $p = 0.225$), and risk likelihood ($\beta = -0.063$, $p = 0.316$) to mutual problem solutions are no longer significant. These findings suggest that the effects of risk characteristics on mutual problem solutions are fully mediated by timely problem identification and collaborative problem solving.

To test for common method variance, we conducted Harmon’s single-factor test using a confirmatory factory analysis approach. Results do not suggest that a single factor accounts for the majority of variation in the data.

CHAPTER 6: DISCUSSION AND CONCLUSIONS

A review of the literature on supply chain disruption risk management reveals that firms are unprepared to effectively avoid and manage disruption risks. This finding is particularly troublesome since trends in supply chain design and management will continue to make firms increasingly susceptible to disruption risk and the significant associated short- and long-term financial losses. Hence, there is an urgent need for firms to understand disruption risk management, its processes, and the conditions which facilitate effective resolution of disruption risks. This study is a response to calls for research which address these issues.

This research aims to add to the literature on supply chain disruption risks by examining the conditions under which supply chain partners are able to achieve risk resolutions which are of mutual benefit to the parties.

We find strong support for the hypothesis that a positive link exists between the use of a collaborative approach to problem solving and the achievement of mutual resolution. This finding is consistent with the literature which stresses collaboration as a critical supply chain management strategy which yields superior outcomes for participating firms.

Very few organizations are equipped with all the knowledge, skills, and other resources needed to resolve risks independently. As noted earlier, "a firm's critical resources may span firm boundaries, and may be embedded in interfirm resources and routines" (Dyer and Singh 1998, p. 660). By combining resources in unique, idiosyncratic ways, firms are able to achieve superior outcomes or competitive advantages (Jap 1999). Collaboration therefore allows firms greater access to technological capabilities, information, know-how and other resources to aid in the risk resolution process. Therefore, as expected, collaborative problem solving is positively associated with the achievement of mutually beneficial risk resolution for the collaborating parties.

The supply chain risk management literature also stresses visibility as an important goal for supply networks. Successful risk resolution depends on first becoming aware of potential or actual disruption risks. Supply chains with good visibility allow firms to quickly identify potential problems. Early detection: (1) enables firms to effectively adapt to the risk situation; (2) facilitates coordinated decision-making and (3) allows for consensus regarding collaborative goals. Therefore, as expected, there is a strong positive link between timely problem identification and mutual resolution. Firms are more likely to effectively resolve risks, and to do so in a mutually beneficial manner, when risks are identified earlier. We do not specify a path between timely problem identification and collaborative problem solving because we conceive that collaboration can be just as likely when risks are identified later.

Our findings on the positive effect of early problem detection and collaborative problem solving on mutual resolution adds further support to similar findings reported in the literature. The main contribution of this research lies in our findings relating risk characteristics to these desirable processes and outcomes.

Resource and information flows between supply chain partners are desirable both for problem identification and collaborative problem solving, however, these flows are difficult in complex situations. The literature makes it clear that alliances underperform under conditions of high organizational complexity. Today's supply chain is incredibly complex, comprising of multitudes of links and dependencies between autonomous firms across the globe. The main contribution of this study lies in our specification of the underlying mechanisms which relate specific risk characteristics to mutual resolution.

We propose that certain risk characteristics mobilize actors, and mobilize resource and information flows between actors and across organizational boundaries, thereby overcoming the hurdles of complexity and enabling mutual problem solutions. To the best of our knowledge, this is the first study to posit differing effects for the two elements of risk: risk magnitude and risk likelihood.

To lend greater support to our findings, we include measures of partner trustworthiness as controls. Trust has been widely studied as an important construct in interorganizational relationships and studies have found that trust plays an important role in overcoming complexity in alliances (Robson, Katsikeas and Bello 2008) by mobilizing actors to share resources and information. We measure the affective and calculative aspects of trust by including measures of benevolence and reliability and find benevolence, but not reliability, to be positively linked to timely problem identification, collaborative problem solving and mutual resolution.

The data supports our proposal that high magnitude risks are positively associated with mutual resolution. This assertion is counterintuitive as one would expect that risks with lower magnitudes are easier to resolve, less troublesome in supply chains, and more likely to be resolved to the mutual benefit of parties. However, we posit that risks with high disruptive potential mobilize actors to share resources and information amongst each other and across firm boundaries, thereby facilitating mutual resolution via timely problem identification and collaborative problem solving. We find support for the positive impact of risk magnitude on mutual resolution and on collaborative problem solving, but no support for risk magnitude's positive association with timely problem identification. Further, we find that the impact of risk magnitude on mutual resolution is fully mediated by collaborative problem solving. Thus, higher magnitude risks are more likely to be resolved to the mutual satisfaction of the parties, because these risks mobilize supply chain partners to collaborate.

Our hypotheses regarding risk likelihood are also counterintuitive. We found support for our proposal that risks with high degrees of likelihood (common, reoccurring risks) are negatively associated with mutual resolution, timely problem identification and collaborative problem solving. High likelihood risks do not mobilize actors to share information and resources with each other and across firm boundaries because these risks may have become mundane and do not generate as much attention as low likelihood (uncommon) risks. Further, we find that the negative effect of risk likelihood on mutual resolution is fully mediated by timely problem identification and collaborative problem solving. Thus, common risks are less likely to be successfully resolved to the partners' mutual satisfaction as are uncommon risks because they do not mobilize actors to share information and resources.

By implication, this study suggests that low magnitude risks, and common risks are not as likely to be resolved to the mutual satisfaction of the parties because collaboration and timely problem identification are less likely for these types of risks.

Risk is considered to be a high magnitude, high probability event. In line with this understanding of risk, our findings indicate that supply chain actors are more responsive in high magnitude risk scenarios; but contrary to expectation, we found that actors are less responsive in high likelihood scenarios. Low probability events are more concerning, and collaboration and early detection are of greater priority for uncommon risks. Thus low magnitude risks and high likelihood risks are less successfully resolved.

In light of the above, several questions need to be addressed. How do firms handle low magnitude and high likelihood risks? How should firms manage low magnitude and high likelihood risks? Should collaborative problem solving be employed for all types of risks? How can firms ensure early problem detection for recurring and low magnitude risks?

The literature on interfirm governance demonstrates that firms can manage a single relationship in different ways depending on the circumstances. For example, Heide and Wathne (2006) discuss two very different governance and relationship management strategies available to firms: (1) governance mechanisms of selection and socialization in which firms operate as "friends" under a logic of appropriateness, and, (2) governance mechanisms of incentives and monitoring in which firms operate as "businesspeople" under a logic of consequences. Although these governance strategies are very different, Heide and Wathne (2006) highlight that relationship parties should be viewed as collections of roles in which parties may assume multiple identities over time, even within the context of an individual relationship.

Collaboration is not a cost free activity, and it is apparent that supply chain firms decide against collaboration for low magnitude risks and risks which frequently reoccur. Heide (1994 p. 81) notes that "within a given relationship, processes from different governance forms can be combined in different fashions" and that "many actual channel relationships can be viewed most appropriately as hybrid organizational forms like clan-assisted markets or clan-assisted bureaucracies" (Barney and Ouchi 1986). Thus, even though an interfirm relationship is governed through non-market governance, both unilateral and bilateral processes may be used under different scenarios. Therefore, even when supply chain partners maintain a collaborative working relationship in general, and are willing to collaborate on risk resolution, a bilateral, collaborative approach to resolving every supply chain risk may not be necessary or indicated.

There is a strong, positive advocacy tone for collaboration in the supply chain risk management literature, and a prescriptive bias toward collaboration as good for relationships. However, this study suggests that a collaborative problem solving approach may not always the logical choice for supply chain partners. This study shows that a firm's assessment of disruption risk characteristics is expected to be an important factor when deciding on the most appropriate response for mitigating the risk and when determining the most appropriate party or parties to manage the mitigation effort (White 1995).

In frequently recurring risk scenarios, firms may have a clearly specified plan with detailed role specifications (Heide 1994) outlining the manner in which the firms should handle the risk. Thus, supply chain partners may only be mobilized to collaborate in ad hoc, undefined situations. Similarly, low magnitude risks may be easily resolved by pre-determined processes and therefore do not mobilize actors to collaborate.

The approach being employed for low magnitude and high likelihood risks is not effective in facilitating mutual resolutions. This suggests that firms need to pay greater attention to risk resolution processes for these types of risks to ensure mutually beneficial risk resolutions. We suggest that low magnitude and high likelihood risks have scripted problem solving routines which were developed through a negotiation process between the parties. Further, the partner with the power advantage in the relationship has greater leverage in negotiation and likely derives the greater benefit while the weaker party bears the greater cost. On the other hand, when uncommon (low likelihood) and high magnitude risks improvisation, demand joint attention and work, power asymmetry does not drive the risk resolution process and both parties derive mutual benefit.

CONTRIBUTIONS OF THE STUDY

Scholars recognize that (1) disruptions pose significant short- and long-term costs and other lingering negative financial consequences; (2) susceptibility to disruptions in supply chains will likely increase given the complexity of modern supply chains; (3) firms are evidently ill prepared to effectively handle disruption risks; and (4) understanding effective risk management should be an important area of focus for both academics and managers. This study is in response to the call for research in understanding how firms identify and manage supply chain disruption risks. We add to the literature by outlining the risk resolution process, and showing how risk management is handled under differing risk scenarios.

As far as we are aware, this is the first study to separately examine the effects of risk attributes (magnitude and likelihood), and to posit that these risk attributes have differing effects on the supply chain risk management process. We empirically demonstrate that while high magnitude risks are positively associated with mutual resolution, high likelihood (common) risks are negatively associated with mutual resolution. The main conceptual contribution of this study lies in the theoretical rationale offered for the hypotheses. We propose that high magnitude risks and low likelihood risks activate the social network of actors to: (1) vigilantly scan the environment in order to quickly identify the risk; (2) communicate knowledge of the risk to all parties responsible for problem resolution; and, (3) coordinate and share resources in a joint problem solving effort. Our statistical analysis shows that the impact of risk characteristics on mutual resolution is fully mediated by timely problem identification and collaborative problem solving.

High magnitude risks mobilize actors because they present significant disruptive potential, while low likelihood risks mobilize actors because role responsibilities and the appropriate risk resolution approach are unknown. Thus, this study should draw managers' attention to risks which do not seem to mobilize actors in a supply chain: low magnitude risks, and frequently reoccurring risks.

The findings therefore present some challenge to the way risk is typically considered in supply chains. Concerning risks are usually those considered to have high magnitude and high likelihood; this study suggests that firms are able to manage these risks to the mutual benefit of the parties because these risks mobilize actors and resource flows. Low magnitude risks (that is, those with low disruptive potential) and high likelihood (common, reoccurring) risks do not lead to mutual resolution because firms do not rely on collaborative approaches to resolve them.

The results of this study therefore lead us to question the positive advocacy tone in the literature for collaboration. It is apparent that firms' use of a collaborative approach depends on the risk scenario. This finding is consistent with the governance literature which highlights that differing forms of governance can be applied within the context of a single relationship.

Our study also provides some preliminary indication that it is the affective, and not the calculative aspect of trust that drives partners to share information and resources for early problem detection and collaborative problem resolution.

LIMITATIONS OF THE STUDY

This study uses cross-sectional data, therefore claims of causality cannot be made as easily as when rigidly controlled experiments are employed, or when time series data is used (Bollen 1989). Although we refrain from asserting causation, there is strong conceptual support for causal associations among the constructs in this study.

Another limitation of the study is that we employed single informant data, gathered from only one side of the dyad. Although multiple informants are preferred, it was not possible in this study. It was also not possible to gather data from both sides of the dyad.

While we discuss the complexity in supply networks, and the call in the literature to conceptualize supply chains as complex adaptive systems or complex adaptive networks, this is a dyadic study. However, as we discussed earlier, there is much complexity in a dyadic relationship between two supply chain partners who are separated by physical and psychic distance, differing corporate and national cultures, and inconsistent business processes.

There are some concerns regarding construct measurement. Several constructs were developed specifically for this study and thus were not validated across multiple studies.

Although we have a sufficient number of cases to test our hypotheses in structural equation modeling, there is insufficient power to declare no relationship where we found insignificant paths. Therefore, we cannot definitively declare that risk magnitude has no effect on timely problem identification or that calculative aspects of trust (reliability) do not drive the information and resource sharing which is necessary for timely problem identification, collaborative problem solving and mutual resolution.

FUTURE RESEARCH

Future research should be aimed at addressing the limitations addressed above. This study employs a variety of new measures and re-operationalization of existing measures. For complete confidence in the measures, replication of scale items in other studies is necessary. Dyadic data collection or a network approach, as well longitudinal data collection would strengthen the claims of this study and address the limitations highlighted earlier.

As with all SEM studies, the possibility exists that the findings are artifacts of the data set. Although care was taken in the conceptualization and operationalization of the measures, the proposed structural model should be tested in other contexts. The setting for this study was the defense industry; similar studies could be conducted in other industries, e.g. the retail industry, thereby establishing greater confidence in the generalizability of the findings.

Future research should investigate the interplay between risk magnitude and risk likelihood. Based on the findings of this study, the management of high magnitude, low likelihood risks and low magnitude, high likelihood risks seems clear. But, how do firms handle high magnitude, high likelihood risks? Or low magnitude, low likelihood risks? Comparison of risk resolution approaches employed in this way will require a much larger sample to ensure adequate power. A larger sample will also ensure adequate power for testing for zero paths where insignificant results were found.

Further, research should address the long-term implications of the non-collaborative approach firms employ in high likelihood, low magnitude risk scenarios. These types of risks are negatively associated with mutual problem solutions because they do not mobilize actors to share information and other resources across firm boundaries. Rather, firms depend on pre-specified problem solving approaches which seem to favor the powerful party in the relationship. Investigation into the long-term relationship impact of this approach should prove interesting.

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