This is to certify that the
dissertation entitled

BUSINESS CONTINUITY IN THE SUPPLY CHAIN:
PLANNING FOR DISRUPTIVE EVENTS

presented by

Andrea McGee Prud'homme

has been accepted towards fulfillment
of the requirements for the

Ph.D. degree in Marketing and Supply Chain Management

Kenneth K. Boyer David J. Closs

Major Professor's Signature

5/9/2008

Date

BUSINESS CONTINUITY IN THE SUPPLY CHAIN: PLANNING FOR DISRUPTIVE EVENTS

By

Andrea McGee Prud'homme

A DISSERTATION

Submitted to
Michigan State University
In partial fulfillment of the requirements
For a degree of

DOCTOR OF PHILOSOPHY

Department of Marketing and Supply Chain Management

2008

ABSTRACT

BUSINESS CONTINUITY IN THE SUPPLY CHAIN: PLANNING FOR DISRUPTIVE EVENTS

By

Andrea McGee Prud'homme

This study examines the planning firms engage in to manage supply chain risk to maintain or improve the stable flow of goods, services, information, and funds through the supply chain for enhanced firm performance. Two different theories are utilized to examine opposing premises related to the occurrence and management of disruptive events. Specifically, Normal Accident theory is used to examine the role of supply chain attributes of complexity, dependency and uncertainty on the use of supply chain risk management planning, the occurrence of disruptive events, and firm performance. High Reliability Theory is used to examine the role of both effective business practices and concern for disruptions on supply chain risk management planning, the occurrence of disruptive events, and firm performance.

The theories are tested using data obtained from supply chain management professionals associated with the American Purchasing Society. A survey instrument was used to obtain information on the perceptions of supply management professionals regarding their firms supply chain attributes, the use of supply chain continuity planning, the occurrence of supply chain disruptions and firm performance. The survey was administered via electronic and traditional paper mail, with an overall survey response rate of 9.5%.

The findings indicate that firms that engage in continuity planning activities are positively associated with higher levels of firm performance. Firms that perceive they have high levels of dependencies within the supply chain are more likely to engage in risk management activities, although firms with higher levels of complexity are more likely to experience supply chain disruptions. In additional, formal supply chain continuity planning, especially when shared with other supply chain partners, is more effective than informal planning.

DEDICATION

While there were many people that provided training, encouragement and support through my process of earning a Ph.D., there are a few people without whose support I would never have had the courage to even begin or to at times simply preserver. I dedicate my dissertation to my family: without their love, encouragement, advice and shoulders to sometimes cry on, I would not be in the position to write these words of dedication.

My mother is an amazing woman. Her life long and unfailing example of hard work, perseverance, and ability to rise to what ever the occasion demanded, coupled with her belief in my ability and her support and encouragement to pursue my goals, serves as my personal inspiration and benchmark. Without her as my rock, my guidepost, and my personal champion, I would not have had the strength and confidence to spread my wings. My mother has also given me the gift of wonderful sisters. Their support, encouragement and friendship have also provided me with the resources to continue to grow and achieve. I can not imagine how I could have come this far without the constant knowledge that my mother and sisters are there to help me up when I stumble, to hold my hand when I need someone to walk beside me, and to help me soar when I want to fly.

My grandparents, who passed on while I was in my Ph.D. program, had always been a source of support and encouragement. I was blessed to grow up with a second set of parents to help me to be the best person I could be. Their unconditional love, joy in my successes and influence is greatly missed, and I deeply regret that they are not able to share in this achievement.

ACKNOWLEDGMENTS

Obtaining a Ph.D. is a long journey that begins well before the first day of the first seminar course. I equate the journey to a series of doors opening and through which I was encouraged and allowed to pass. For me the journey began subtly and I did not recognize where the first open door would eventually lead. Dr. Billy M. Thornton supported and mentored me during my time as an adjunct faculty Colorado State University. He gently planted the idea that I should continue my education to make the transition from industrial professional to become a university professor. While at CSU, Dr. Madeline (Mellie) Pullman opened the next important door for me by advising me on Ph.D. programs and introducing me to the person that would be the gate keeper of the many subsequent doors through which I would travel. Dr. Kenneth K. Boyer served as my advisor, teacher, mentor, coach, champion and friend through my years of study at Michigan State University. He opened doors that would otherwise have remained closed, he helped me get through doors that I didn't think I could fit through, and pressed me through doors that I didn't want to pass through. I could not have done this work without his unfailing guidance and support. When I found myself at what I thought was a dead end, Dr. David J. Closs opened a door that I didn't know existed, allowing me the opportunity to continue on my journey, for which I am eternally grateful. Dr. Roger J. Calantone provided invaluable knowledge and guidance to help me with the technical aspects of my training and research. Dr. George A. Zsidisan's sharing of his knowledge in the area of risk management, his support as a friend and his introduction into CAPS are also most greatly appreciated. And finally, there were many times that I

didn't think I could pass through another door or I was ready to shut a door myself. At these points, my family, my closest friends, my fellow Ph.D. students, and Dr. Michael A. Gross helped to remind me that the journey is long, it is hard, there are points at which we stumble, and there are hills that seem insurmountable; but that it is achievable and that I can keep traveling by taking it one step at a time.

To all of these people I owe a great debt, for without them opening doors that need opened and by encouraging me to keep passing through them, I would not have been able to complete this first long stage in the ongoing journey to become a creator and disseminator of knowledge.

My heartfelt appreciation and deepest gratitude goes to all of these people for opening doors and for walking along parts of my journey with me. I could not have successfully made the trip without their support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 *Introduction*

This study examines the planning firms engage in to manage supply chain risk to maintain or improve the stable flow of goods, services, information, and funds through the supply chain for enhanced firm performance. There has been limited empirical research on the topic of continuity planning and risk management occurring specifically within the area of supply chain management. Previous research has been primarily conceptual with limited application of theory or contribution to theory building. The use of theory here, specifically Normal Accident Theory and High Reliability Theory, provides a more rigorous scientific assessment regarding the drivers of supply chain risk management planning and its impact on the reduction of disruptive events and levels of firm performance. The theories are tested by means of empirical examination of the role of perceptions of supply chain complexity, uncertainty and dependency, and the use of general effective business practices on the planning activities undertaken to manage disruptive events and improve firm performance. The findings provide managers insight into the creation and content of business continuity plans that are used to better manage supply chain disruptions for enhanced firm performance.

There is growing academic interest in supply chain risk management, as evidenced by the special issue of *Production and Operations Management* entitled "Risk Management in Operations" (Seshadri & Subrahmanyam, 2005) and a recent call for papers by *Journal of Operations Management* for the issue "Risk Issues in Supply Chain Management." In addition, there are several recent books targeted at practitioners to better understand the causes of, and guidance for, planning for disruptive events (Barnes, 2001; Bazerman & Watkins, 2004; Mittelstaedt, 2005; Regester & Larkin, 2005; Sheffi, 2005). Finally, there have been several highly publicized events that clearly demonstrate the need for firms to engage in better continuity planning. A sampling of recent events include incidents that have impacted the logistical flow of goods, such as the 1997 strike by workers at United Parcel Service (UPS) who at the time controlled 80 percent of package deliveries in the U.S. (Krause, 1997); and the 2002 closure of 29 U.S. Pacific coast ports for 10 days that left over 200 ships anchored off the coast unable to dock (Michels, 2002). Events can impact component materials used for production of other goods, such as the 1999 earthquake in Taiwan that damaged finished inventory and work in processes, as well as severely impacting production of silicon chips (TSMC, 1999). Materials already in consumer possession may be impacted, such as the 2006 recall of over six million Sony batteries used in the laptop computers of Dell, Hewlett-Packard, IBM, Apple, and Toshiba. An early estimate of the cost for Sony was in excess of $250 million just for the Dell and Apple negotiated recalls (Sony Corporation, 2006). In short, there are multiple events that can have a considerable negative impact on the flow of goods and services through a supply chain.

Clearly there is a need for both academics and practitioners to better understand the role risk management plays in business performance, which may be driven by the prevalence of a multitude of events that can disrupt the supply chain. Rigorous research is needed to better understand the role of supply chain continuity planning on firm performance and for theory building to provide more insight into this critical business area.

1.2 *Problem Motivation*

The focus of specific topics within the general area of supply chain management (SCM) research is constantly changing. The quality interest from a decade ago developed into extensive total quality management (TQM) research. The original focus on material price reduction evolved into a concern for the total cost of ownership (TCO). More recently, interest regarding the role of supply chain risk and business continuity management has increased (Hutchins, 2003).

Firms must plan to manage business interruptions, defined by the Business Continuity Institute as "any event, whether anticipated (i.e., public service strike) or unanticipated (i.e., blackout) which disrupts the normal course of business operations at an organization's location." Management of the unexpected is one of the greatest challenges that business must deal with (Weick & Sutcliffe, 2001), but the difficulty of anticipating unexpected events makes this an especially challenging business responsibility. It has also been argued that better understanding of disruptive events to reduce their frequency and impact is the ethical responsibility of managers (Chapman, Christopher, Juttner, Peck, & Wilding, 2002). Increased visibility and awareness of the vulnerability of supply chains has caught the attention of senior management, who are now more likely to recognize the strategic importance of managing disruptions (Kleindorfer & Van Wassenhove, 2004). Continuity plans must be developed not only for events that are likely to happen but in order to account for the ambiguity and complexity found in today's supply chains, for events that are speculative and in the realm of 'could be' (Hamel & Prahalad, 1994; Pich, Loch, & Meyer, 2002), as well as for those with potentially greater visibility. However, much of the supply chain improvement efforts undertaken by firms have been focused on reducing costs and increasing efficiency, rather than on specifically managing supply chain risk (Hendricks & Singhal, 2005b).

To secure supply chain performance, firms must plan to both mitigate and manage disruptive events that could result in potential losses. Losses include those that directly impact the firm's reputation, functionality or its financial performance. To better manage such disruptions, there is a need for enhanced understanding of how firms create plans to both protect the supply chain from the occurrence of events and to diminish the impact should events occur. This understanding should include the process firms follow in risk management planning and the content of the plans created for upstream, internal and downstream supply chain continuity management. The scope of continuity planning has widened from a more narrow focus on 'disaster recovery' and preserving tangible assets to include a more comprehensive and proactive 'business continuity' approach. This more holistic view includes processes, networks, flows, relationships and affiliations for ongoing business functionality (Rodetis, 1999). This broadening of scope also includes moving beyond supply disruption and price fluctuation to included less tangible issues of brand, reputation and ethical issues (Khemani, 2007).

The need for increased planning to reduce and manage disruptive events is driven by a few critical factors. As firms have moved to a supply chain model that includes sourcing and market diffusion on a more global scale, the result is a flow of goods that is often physically elongated entailing longer and more variable lead times, with business entities that are more geographically dispersed (Sheffi, 2001; Hillman, 2006); in short, supply chains have become more complex. This complexity may lead to a higher likelihood of a disruptive event that could seriously impact a single supply chain member or ripple through the supply chain to negatively impact additional nodes (Choi, Dooley, & Rungtusanatham, 2001). On the other hand, if a firm is able to recognize the hazards within its own organization and the supply chain within which it operates it may be possible to create effective plans to mitigate the probability and the resulting negative impact of disruptive incidents. It is the complexity of supply chain structure which may influence the occurrence of business interruptions and the potential for well laid plans to positively influence firm performance that serves as the basis for this research.

Given the large number of events that can occur in a supply chain either inside a firm or in conjunction with its upstream and downstream partners, it is nearly impossible to predict *all* possible types of interruptions that could be experienced (Lewis, 2003) or even to predict all possible sources of disruptions (Christopher & Lee, 2004). Varying supply chain configurations result in variable 'shapes' of supply chain risk (sources, nature, triggers, scale, speed of onset, and severity of impact) that increase the challenges of managing risk (Ritchie & Brindley, 2007a). It is therefore prudent for managers to take proactive measures in order to effectively 1) *extend* the time until an event of serious magnitude occurs, 2) to take steps to *mitigate* the effects of an event and finally, 3) to *recover* from the effects of such an event to increase the likelihood of ongoing profitability and survival of the organization.

The relatively nascent level of scholarly study of the topic of risk management as it specifically relates to the supply chain presents both opportunities and challenges. Much of the research to date in this area has been conceptual and practitioner focused with some theory testing (Smeltzer & Siferd, 1998; Svensson, 2000; Zsidisin & Ellram, 2003; Hellström, 2005; Zsidisin, Melnyk, & Ragatz, 2005) rather than on theory building. There is also a corresponding lack of research to define relevant constructs; some preliminary constructs have been created (Svensson, 2002b), but there is no consensus for generally accepted constructs that have undergone rigorous testing in multiple studies. Therefore further research should entail the creation, testing and possible modification of constructs and corresponding scale items to examine the area of risk and business continuity within the context of the supply chain.

There has been work examining the types of disruptive events that firms attempt to provide protection from (Zsidisin, 2003), and there are also practitioner focused publications that provide advice for what should be included in risk management or business continuity plans (Elkins, Handfield, Blackhurst, &

Craighead, 2005; Sheffi & Rice Jr., 2005). However there has been little work to methodically and rigorously examine the risk management planning process and its impact on the occurrence of disruptive events and firm performance. This study examines the application of Normal Accident Theory and High Reliability Theory to: 1) understand if and how firms are engaged in risk management planning to provide protection from disruptive events; 2) determine if the planning reduces the frequency or impact of disruptive events; 3) determine if the planning improves firm performance; and 4) identify theory and tools that can enhance supply chain continuity knowledge.

1.3 *Definitions*

Risk and disruption management requires the review of several streams of literature including operations management, supply chain management, risk management, organizational behavior, and others. These literature streams often use differing terminology or use the same terms with a slightly different nuance of meaning. Therefore, it is important to define the terms to be used here in discussing these concepts, and the specific constructs that are developed for model testing. The following is a brief discussion of the terms used for this study and their associated meanings, within this bounded context:

- *Incident, event, disruption, disturbance,* and *occurrence* are used interchangeably to refer to an experience that interrupts or completely stops the flow of goods, services, information, and funds through a supply chain or which results in other negative quantitative or qualitative consequences for a firm or supply chain.
- *Entity, associate, member,* and *partner* are used interchangeably to refer to parties doing business with each other and that comprise separate business nodes within a supply chain. Although the term

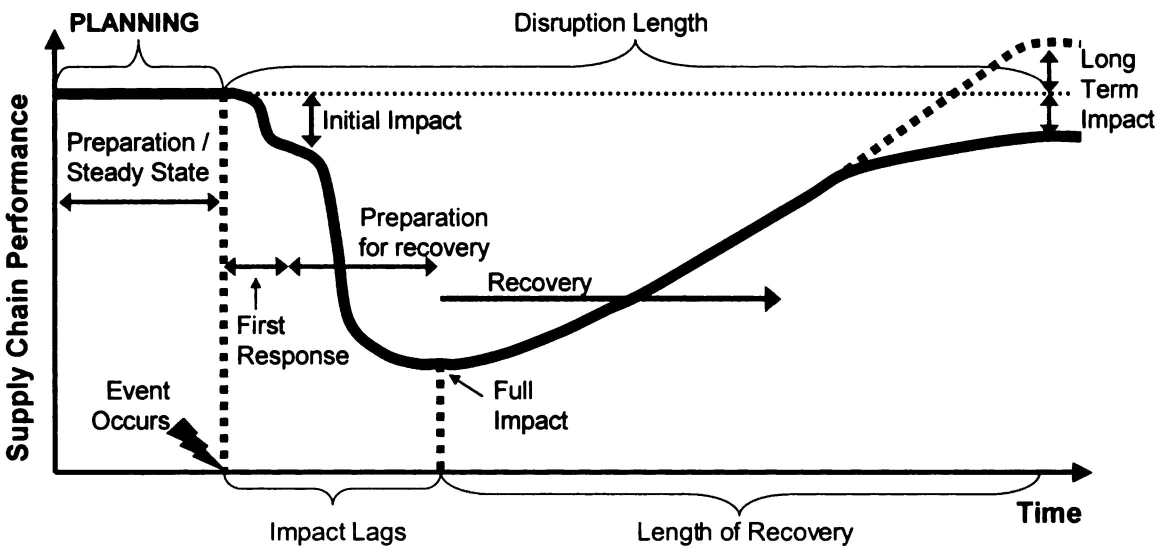
'partner' is often used to denote a specific type of long-term contractual and cooperative business relationship, within this study it does not imply any special type or configuration of interaction or link between business entities.

- *Chance, probability,* and *likelihood* are used interchangeably when discussing risk and the possibility of an unfavorable event occurring.
- *Risk* is used in general terms to indicate that there are various calculable probabilities surrounding a variety of possible events and their outcomes that could have a negative effect on the flow of goods, services, funds and information resulting in some level of quantitative or qualitative loss for the firm.

1.4 *Research Questions*

The disruption profile in Figure 1.1 illustrates the stages that occur when a firm experiences an event that inhibits normal business operations (Sheffi & Rice Jr., 2005). Planning has been identified as occurring in the preparation or steady state of the disruption profile. When an event is detected, a first response occurs to manage the initial impact. Preparation for recovery is meant to mitigate the event's full effect by limiting the depth and length of the performance decline. Finally, recovery efforts are implemented to return the firm to previous (or improved) performance levels.

Figure 1.1 The Disruption Profile



Modified from Sheffi and Rice (2005)

The purpose of this research is to better understand the processes and techniques firms utilize in the planning stage of supply chain continuity management, before an event occurs. In order to focus and bound this research project, *ex post* activities used to manage potentially negative consequences *after* an event has occurred to return to a steady state are excluded from explicit examination. Within this study there is no focus on any particular type of disruption. Although there has been work specifically focused on the prevention of events that are the result of malevolent human actions and are studied within the area of supply chain security (Closs & McGarrell, 2004), the intention here is to examine the general planning activities used by firms to improve the potential for business continuity regardless of the source of the disruptive event.

The focus on the supply chain risk management planning firms undertake within the study is built upon the alternative theories of Normal Accident (Perrow, 1984; Perrow, 2004) and High Reliability (Roberts, 1989). The literature review and interactions with industry experts suggest the following research questions:

1. What factors drive firms to engage in supply chain continuity planning?
2. How are firms undertaking the creation of supply chain continuity plans (process)? What are firms including in supply chain continuity plans (content)? What are the 'best practices'?
3. To what extent are firm's engaged in supply chain continuity planning upstream, internally, downstream or some combination of directions?
4. Does increased supply chain continuity planning result in a reduced frequency and impact of disruptive events and in improved firm performance?
5. Does supply chain complexity, uncertainty or dependency influence the processes and effectiveness of supply chain continuity planning processes or results?

These questions have not been definitively addressed in the extant supply chain management literature, yet represent important aspects of business planning within the complex and uncertain environment of contemporary supply chains.

1.5 *Research Methodology Overview*

This empirical study utilizes a survey to gather data from supply chain management practitioners. Members of a professional organization for supply management are utilized as the sample in this study. A survey instrument was created based upon constructs and scale items generated from current knowledge regarding risk management, supply chain management, complexity, and Normal Accident and High Reliability Theories. Structural equation modeling (SEM) is utilized to examine the proposed model.

1.6 *Research Contributions*

This study seeks to advance supply chain continuity planning and risk management by examining the process of planning for disruptive events which can mitigate the frequency and impact of occurrences negatively impacting a firm and its supply chain. A comprehensive literature review synthesizes findings and theory from several streams of literature to provide insights into this complex area. The literature review and the study findings can be used as the foundation for a stream of research examining the use of logistics, procurement, inventory management, etc., in supply chain risk management and continuity planning. The findings will be useful to firms with exposure to unplanned abrupt natural events (e.g.: floods, tornadoes, earthquakes), unplanned for but intentional human events (e.g.: terrorism or sabotage); or unplanned unintentional events (e.g.: fires or power outages). In addition, the application of alternative theories that have been used in management but have had limited application or testing in supply chain planning furthers theoretical development in the field.

2. LITERATURE REVIEW

Several streams of literature and research form the basis of this study. A general examination of risk in business is followed by a discussion of the specific role it plays within the context of a supply chain. Risk is a multidimensional concept, specific aspects of which have been extensively explored in areas such as insurance, finance, psychology, and organizational behavior. The intention here is not to fully explore risk as it relates to all business and behavioral areas, but to provide a general working definition of risk and the specific role of risk in supply chain continuity planning. After a discussion of the relevant risk literature, an examination of Normal Accident Theory and High Reliability Theory is conducted. Normal Accident Theory and High Reliability Theory represent a balance that businesses should consider when undertaking risk management in order to create appropriate continuity plans. Briefly, Normal Accident Theory states that all complex systems are subject to failure (Perrow, 1984; Perrow, 1999) while High Reliability Theory states that proper system structure and management can prevent failures (Roberts, 1989; Weick, Sutcliffe, & Obstfeld, 1999; Weick & Sutcliffe, 2001). The application of these two theories within the context of the supply chain as a system will be examined, and serves as the theoretical basis of the proposed model to be tested, along with the associated constructs.

2.1 *Risk*

The Merriam-Webster Dictionary defines risk as "the possibility of injury or loss". A common measurement of risk is based upon the probability or frequency of an event and upon the magnitude of the impact should the event occur. Quantitatively this can be represented as *Risk = Probability * Impact* (Weber & Milliman, 1997; Jia, Dyer, & Butler, 1999; Pich et al., 2002) where the assumption is that the impact is negative and involves some form of loss for the firm. The risk of loss is a result of the interactions of processes, people, systems, or external events that lead to failure or inadequate performance (Manning & Gurney, 2005). While there may be uncertainty about the actual *outcome*, the various *probabilities* of the potential outcomes are non-zero and may be known. An important element that is missing from this definition of risk is the ability to exert some control over the possibility and magnitude of loss exposure (Weber & Milliman, 1997). Therefore, it is worthwhile to explore ways in which firms can create plans to minimize or control risk for improved performance and ongoing business functionality.

2.1.1 Business Risk

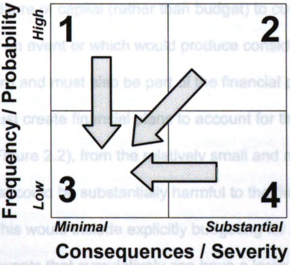
Risk management and business continuity have been examined in a number of business disciplines including facilities management (Hardy & Roberts, 2003; Castillo, 2004; Gill, 2006), information systems (Cerullo & Cerullo, 2004), banking (Bielski, 2003; Manning & Gurney, 2005), real estate (Temba & Jeff, 2002; Foster & Dye, 2005), accounting (Alonso & Boucher, 2001), project management (Pich et al., 2002), and insurance (Urrutia, Vu, Gronewoller, & Hoque, 2002). However, the specific discipline in which a research stream of risk management is grounded will influence the approach used and the particular aspects of risk being studied. Risk in these different streams has been examined as the consequence of an actual choice, as affecting the human or managerial decision making process, as dependent upon the context of the situation, and as the preferences or risk propensities of managers and other decision making individuals (Weber & Milliman, 1997; Conchar, Zinkhan, Peters, & Olavarrieta, 2004). It is beyond the scope of this study to provide an exhaustive review of the study of 'risk' in the business, psychology and organizational behavior literature. For the purposes of the current study and as indicated earlier, 'risk' is defined as:

> *the various calculable probabilities surrounding a variety of possible events, and their outcomes, that could have a negative effect on the flow of goods, services, funds and/or information at one of more supply chain nodes and that results in some level of loss for the firm*

It is important to note that for the purpose of this study, continuity planning is not to be limited the need to control or lessen the frequency or impact of very large scale, catastrophic events that seriously damage a firm. While these types of high-profile events can without doubt individually have a considerable impact on an organization and often receive a great deal of publicity, they are not the only type of event that firms should seek to provide protection from. Smaller events can also adversely impact a business, especially if they occur repeatedly resulting in a large cumulative effect. Included in this study are disruptions of any size or source which negatively impact the firm or the functionality of the supply chain.

The management of risk for business continuity should take into account events ranging from the potentially catastrophic (low or high frequency and substantial impact) events to the less disastrous (low frequency and minimal impact) events, as shown in the enterprise vulnerability map in Figure 2.1.

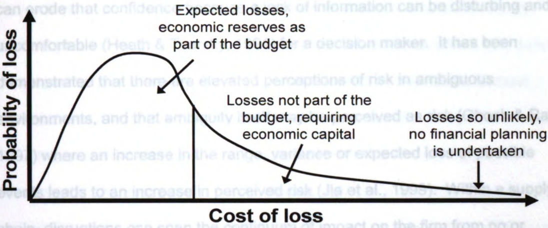
Figure 2.1 Enterprise Vulnerability Map



Research to date has tended to focus greater attention on risky events that have a higher likelihood and a larger negative effect (Zsidisin et al., 2005). While it is imperative that firms plan to protect against incidents that occur in area 2 (high frequency/substantial impact), if there are enough events in area 4 (low frequency/substantial impact) or area 1 (high frequency/minimal impact) the cumulative results can still be very detrimental (Hallikas, Karvonen, Pulkkinen, Virolainen, & Tuominen, 2004; Sheffi, 2005) and come to result in a major damaging effect on the firm. The primary goal of risk management is to try to move from areas 1, 2 and 4 into area 3 for a reduction in both the frequency and impact of events, while also considering the cost/benefit of the possible strategies and outcomes for making such shifts.

Because it is not possible to eliminate all possible sources of loss, firms will often include the financial impact of some negative events into their budget or even create and fund specific hazard accounts for identified risks based upon a cost/benefit analysis. 'Significant risk' represents a possible hazard that would require the expenditure of capital (rather than budget) to cushion against the resulting impact of an event or which would produce considerable damage to the firm (e.g. reputation) and must also be part of the financial planning process. Therefore firms must create financial plans to account for the variety of events that could occur (Figure 2.2), from the relatively small and mundane to much larger incidents that could be substantially harmful to the firm (Manning and Gurney, 2005). This would include explicitly budgeting for potential expected or higher frequency events that cumulatively can have a large negative impact, while also attempting to create plans to reduce their occurrence. In addition, it may be necessary to set aside funds for lower frequency events that individually can have a large, detrimental impact. Finally, there are events that are so unlikely that even though their occurrence would be catastrophic for the firm, little if any financial planning would occur, since current assets could be better used in other ways.

Figure 2.2 Financial Planning for Risk



Adapted from Manning and Gurney (2005)

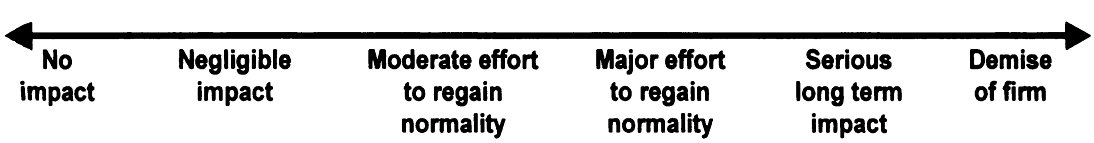
2.1.2 Risk in the Supply Chain

An established measurement of risk is based upon the probability or frequency of an event and upon the magnitude of the impact should the event occur (Weber & Milliman, 1997; Jia et al., 1999; Pich et al., 2002). An important element in the evaluation of risk is the ability to precisely determine the probability of an outcome (Conchar et al., 2004). When it is not possible to determine the probability distributions within given scenarios, the lack of information creates an ambiguous situation (Ghosh & Ray, 1997) for a decision maker. Given the extremely large number and variety of disruptive supply chain events that could occur (considering disruptions from the environment, upstream, internal, or downstream sources) combined with the number of entities that may experience events, it is evident that a supply chain operates in a highly ambiguous environment.

Risk taking requires confidence in decision choices. However, ambiguity can erode that confidence because a lack of information can be disturbing and uncomfortable (Heath & Tversky, 1991) for a decision maker. It has been demonstrated that there are elevated perceptions of risk in ambiguous environments, and that ambiguity itself may be perceived as risk (Ghosh & Ray, 1997) where an increase in the range, variance or expected loss of possible events leads to an increase in perceived risk (Jia et al., 1999). Within a supply chain, disruptions can span the continuum of impact on the firm from no or negligible impact through varying degrees of effort to restore normality to serious long-term damage or even the possible demise of the firm, as shown in

Figure **2.3**. It has been empirically demonstrated that poor previous experiences with risk reduces self-efficacy and increases a desire for risk avoidance; conversely high self-efficacy has been associated with an increase in risk taking (Krueger Jr. & Dickson, 1994). It has also been argued that risk is closely related to the potential for losses (Conchar et al., 2004). It seems reasonable that when organizations perceived that they are vulnerable to supply chain disturbances, especially if there is high variation in the possible type, source and impact, that a greater focus would be placed on planning to reduce the probability and impact of future events in an effort to reduce future negative impacts and losses.

Figure 2.3 Possbile Impact on the Frim



Supply chains are a complex collection of business entities involving multiple players performing a series of activities to supply, transform and deliver goods and services, including exchanges of information and funds, to meet market demand (Chen & Paulraj, 2004). While a comprehensive definition would include the reverse or backward flow of goods, only the forward flow is considered in the scope of this study. This supply chain definition can be further expanded to include their adaptive and complex nature as a collection of firms, entities or agents that seek to maximize profitability and increase firm longevity through the exchange of goods and services (Choi et al., 2001). Although it can be argued that most supply *chains* are really supply *networks*, the term supply chain will be utilized within this study, and the examination of a true supply network is not attempted.

As a large-scale system (due to the number of members), supply chains exist within a paradox of autonomy and dependence. Each individual supply chain entity is an autonomous enterprise, yet is also interdependent upon the other autonomous entities (suppliers and customers) with which it must do business (Grabowski & Roberts, 1997). This creates a substantial challenge in the management of a supply chain which stems from the need to control the boundary spanning activities that occur between a firm and the upstream and the downstream tiers that form the supply chain. The autonomy of firms and their decisions, combined with the fact that their actions (or lack thereof) also impact the other firms upon which they are mutually dependent through linked business processes, contributes to supply chain vulnerability to disruption when an event (or series of events) occurs at one point in the system that inhibits the normal business operations and flow of goods and services at that point, or possibly beyond. The impact of such events may ultimately propagate through the supply chain creating difficulty or an inability to continue to meet customers' needs as scheduled (Spekman & Davis, 2004; Wu, Blackhurst, & O'Grady, 2007). Although the likelihood that a serious incident would occur at any *particular* location is rather small, the number of firms that are part of a supply chain result in an increased collective probability of a disruptive occurring at *some point* in a given supply chain that would result in a negative impact on other members of the supply chain (Sheffi, 2005).

Recent changes in supply chains as a result of globalization and the outsourcing of multiple functions (manufacturing, logistics, IT services, warehousing, etc) have created longer, more complex and further dispersed networks (Cavinato, 2004; Christopher & Lee, 2004; Hillman, 2006). Globalization of supply chains means that firms have a greater flow of goods and services moving across national borders and need to respond to differing regulatory requirements (Closs & McGarrell, 2004). Growth in the outsourcing of business activities has resulted in firms having a greater dispersion of processes being performed outside of the firm's immediate control (Bowersox, Closs, & Stank, 2000). Deregulation in a number of industries and the increasingly rapid rate of technological change have also increased the environmental complexity of supply chains and the turbulence that firms face (Siggelkow & Rivkin, 2005).

As firms become more dependent upon the actions and activities of other members of the supply chain, the level of the organization's exposure to disruptive events becomes increasingly dependent upon those same external links (Pfeffer & Salancik, 1978; Zsidisin, Panelli, & Upton, 2000). These changing and increasing risks require new management responses and processes (Brindley & Ritchie, 2004; Christopher & Lee, 2004). Simultaneously, supply chains are also experiencing the prevalence of practices such as lean systems and JIT, which have led to a consolidation of firms' operations and supplier bases, leaner operational practices, and tighter inventory policies that remove the slack that serves as buffers between processes and firms. Both of these trends contribute to an increase in supply chain fragility and vulnerability to disruptions (Kleindorfer & Van Wassenhove, 2004; Zsidisin et al., 2005). The best efforts of business to make supply chains more efficient and to run with lower costs may have had the unintended consequence of increasing the risk of a disruption occurring or in the possible expansion of the impact magnitude when an event occurs (Sheffi, 2005).

As firms continue to try to 'do more with less' in efforts to reduce costs and increase efficiency, fewer resources are available for proactive environmental scanning. In general, employees need to have time available to identify and consider possible events to make proactive plans, with the implication that they are therefore freed from spending all of their working hours on direct, tactical daily tasks. Another problem is that investments for the improvement of a process (in this case improving supply chain continuity) often do not yield immediate, directly linked or easily visible results. It may not be possible to know and analyze the quantitative or qualitative impact of an event that *could* have happened, but *didn't*. This lack of a direct, easily traceable link between efforts and results, combined with an inability to capture the savings achieved by *avoiding* an event, may reduce the desire and likelihood of firms to make efforts or investments in supply chain risk management (Repenning & Sterman, 2001). A reduced level of available attention for, and investment in, managing non-recurring events and activities may reduce the costs of daily or routine transactions, but incurs a trade-off cost by leaving fewer resources available to plan for unexpected events. This may increase the potential for damage from surprise events that disrupt the supply chain (Lampel & Shapira, 2001; Weick & Sutcliffe, 2001).

The management of operational risk within the supply chain has growing practical concern yet is an under-researched area within operations and supply chain management literature (Killian, 2002; Peck, 2005), in spite of empirical evidence demonstrating the negative impact of supply chain disruptions on the firm. Even a relatively small, single disruption of short duration has been shown to have a detrimental effect on a firm's financial performance and stock price. An announcement of a product or shipment delay can have a swift impact, reducing stock prices by over 8% immediately after an event, and with a long term reduction of up to 20% over the following six months (Hicks, 2002). Hendricks and Singhal conducted a study resulting in empirical evidence of the substantial negative impact of supply chain 'glitches' or disruptions on firms. Their first findings relate to the profitability and cash flow of the firm (Hendricks & Singhal, 2005a) where they found that firms experience a mean 6.92% reduction in sales growth, a 10.66% increase in costs and a 13.88% increase in inventory levels following a supply chain glitch. Interestingly, the findings are consistent across multiple industries and are apparently unrelated to the cause or source of the disruption. In addition, there is a damaging impact on market perceptions of the equity risk of the firm (Hendricks & Singhal, 2005b). An increased perception of firm riskiness may cause investors to demand higher rates of return and increase the firm's cost of capital. Further, customers and suppliers may demand assurances and impose contractual guarantees for supply chain performance. Disruptions of all kinds and across industries appear to result in sizeable financial and potential relationship penalties for firms who do not manage supply chain continuity well.

Catastrophic events on a larger scale resulting in major losses (and often considerable negative publicity coverage), such as the Tylenol tampering in 1982 or the 1989 Exxon *Valdez* oil spill, have also been shown to have an immediate negative impact on stock prices of 5-11%, and long term impact of up to 15% for firms that are less effective in managing the recovery process (Knight & Pretty, 1998). Conversely, it has been shown that announcements of the implementation of supply chain management tools, technologies or processes that are viewed as effective or 'best' practices can have a positive impact on financial performance and stock values (Filbeck, Gorman, Greenlee, & Speh, 2005).

There is clearly strong evidence that effective supply chain management, specifically including the improvement of supply chain continuity, can help an organization to avoid unfavorable financial implications and market perceptions that may result from publicly known disturbances in the flow or timing of goods or service availability. This is especially important in light of the apparent perception of the market that it is irrelevant as to the cause, reason or industry in which the event occurs; *all* firms are expected to maintain a smooth and uninterrupted flow of goods and services through their supply chains (Hendricks & Singhal, 2005a).

In addition to adversely impacting shareholders, an operational disruption can have a detrimental impact on employees, customers, suppliers, and other stakeholders (Lewis, 2003; Hendricks & Singhal, 2005b; Ritchie & Brindley, 2007b). Poor management of a disruption can also adversely impact a firm's reputation, hurt brand image and equity, firm credibility, and damage customer relationships. In contrast, handling such events well can eventually lead to stronger branding in the long term (Rodetis, 1999; Chopra & Sodhi, 2004). Finally, there are regulatory requirements impacting fiduciary activities (e.g. Sarbanes-Oxley) or the movement of goods (e.g. Home Land Security) that require firms to more explicitly address risk planning and management (Hutchins, 2003; Manning & Gurney, 2005). Overall, firms have ample incentive to engage in effective planning to reduce the occurrence of disruptive events. Unfortunately, while there is strong evidence of a negative link between supply chain disruptions and firm performance, there has been little scientific examination of the planning that firms engage in to reduce the frequency and impact of their occurrence.

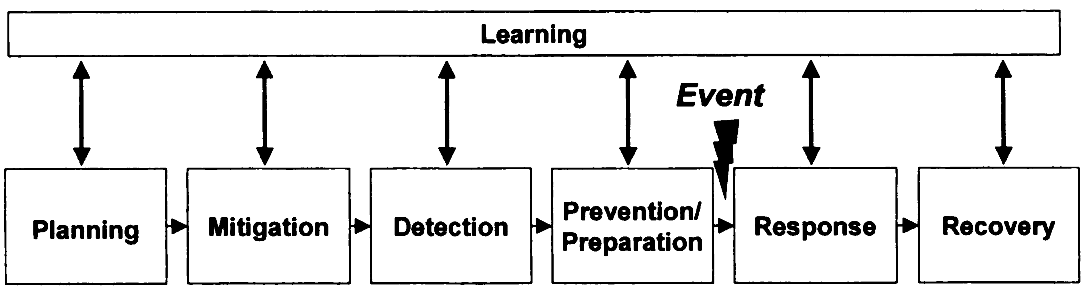
It is important to note that not all disruptions lead to long term or permanent damage to the firm. Take for example Nokia and Ericsson; both experienced a massive supply side disruption when the facility of a key supplier to both firms had a sizable fire in a manufacturing facility. Nokia, working closely with the supplier, was able it implement plans that allowed for a more rapid recovery than Ericsson. Within a year of the incident, Ericsson's market share had dropped to the point that it withdrew from the market and Nokia's market share grew substantially when Ericsson, its major competitor, left (Norrman & Jansson, 2004; Sheffi, 2005). Given the demonstrated impact of even a small disruption, the potential of a large unscheduled event such as a disruptive disaster that completely shuts down a facility, or which severs a link in the supply chain in which the firm is embedded, creates a strong motivation for firms to create plans to better deal with such events. Proper continuity planning may be able to help firms to avoid undesirable events that in turn may lead to financial repercussions. Planning well may even allow the firm to emerge stronger following an incident than it was before (Norrman & Jansson, 2004).

2.1.3 Risk Planning

The effective management of disruptions is a multi-step process that should begin long before an event actually occurs (Helferich & Cook, 2002). The common first step is mapping the supply chain to better understand the network of linkages in which the firm is imbedded. This is followed by the identification of the types of events that could occur and their possible ramifications (Chopra & Sodhi, 2004), which may vary with the business environment and structure of a specific supply chain. It is also important to identify the signals that may indicate a disastrous event is developing and that action is need to either prevent it or to mitigate its impact (Mitroff, 1988).

Once possible sources and impacts of events have been analyzed, the firm should create plans that allow for possible avoidance of events. When avoidance is not possible, plans must be put in place that reduces the impact when events do occur (Lewis, 2003; Kleindorfer & Saad, 2005). The project management literature (Pich et al., 2002) adds still further to this with a final element of learning for continuous improvement in all of the steps to mitigate and manage an event (Figure 2.4). The purpose of continuity planning for ongoing supply chain functionality is first to try to prevent events from happening with early detection and action, and secondly to reduce the severity of the event, allowing the firm to recover to a level of supply chain performance that is, at a minimum, no less than before the event occurred.

Figure 2.4 The Iterative Cycle of Learning in Disruption Management



The impact of disruptive events on a supply chain can manifest in multiple forms. The first and perhaps the most obvious form is a disturbance in the availability of physical goods or materials. This can be either a deficiency, as in a stock-out or shortage; or it can be an over abundance of inventory that is not immediately needed, is unwanted or is obsolete (Cavinato, 2004; Christopher & Lee, 2004; Spekman & Davis, 2004). The issues associated with a lack of material may lead to missing scheduled customer shipments, expedited processing and shipping, or the need to purchase materials from non-usual sources – often at a higher price. Having more inventory than desired leads to an increase in carrying costs, driven primarily by the opportunity cost of capital and the possibility of obsolescence which impacts the cash flow and investment capacity of the firm.

A second manifestation of supply chain risk deals with the flow of information (Spekman & Davis, 2004) including a lack of material or product visibility within the pipeline, especially when the supply chain is physically elongated due to off-shore sourcing and/or servicing a global customer market (Christopher & Lee, 2004). There could also be the distortion of demand information as it flows through the supply chain (Forrester, 1961; Lee, Padmanabhan, & Whang, 1997). Information on market intelligence of events that are occurring in the business environment (e.g. competitor actions, changes in regulatory requirements, etc.) is also important for effective management of the supply chain (Cavinato, 2004), and can be used to detect possible precursor signals that an event may be impending or beginning to unfold.

A third impact is financial, where a flow of funds is parallel to the flow of materials. Many times supply chain location decisions are based upon advantageous tax allowances, currency valuation or other financial incentives; when these change there may be an impact on the cost structure of the supply chain. Supply chain members can be susceptible to changing material pricing, currency fluctuations, effects of hedging, credit worthiness of supply chain associates, timeliness of payments, and the financial stability of suppliers and customers (Cavinato, 2004; Spekman & Davis, 2004; Sheffi, 2005).

A fourth manifestation is relational and includes the appropriateness of supplier and customer selection, the types of relationships firms engage in, the degree of interdependence, and the tendency of supply chain entities to engage in opportunism. An important aspect of the selection of supply chain business relationships is the ability to discover and bring to market advances in technology, products, services and processes, as well as the ability of supply chain entities to protect the image, brand equity, and reputation of the firm through appropriate behavior, business practices and corporate social responsibility. Appropriate supply chain partner firms should be selected based upon their ability to advance the goals of the firm in addition to their ability to provide protection from undesirable disruptions or negative business practices (Cavinato, 2004; Spekman & Davis, 2004; Sheffi, 2005).

The fifth dimension encompasses hazards to physical assets such as substantial damage or destruction of a facility from causes such as a flood, fire, or severe weather. It may also take the form of product or process failure that may cause harm to individuals or to the environment which creates significant liability and undesirable press for the firm (Sheffi, 2005).

Although disruptions can manifest in multiple forms, it is the dependencies between firms that may allow disruptions to propagate across entities, making them susceptible to disruptions in the flow of goods and services when an event occurs at some point in the supply chain. There are three types of dependencies within a supply chain. The first relates to time, where there are time lags between processes to move goods or funds, to provide services, or to share and utilize information. These time lags are further exacerbated by global supply chains which have longer physical paths for goods to travel, and conversely by the shortened 'clockspeed' of many product life cycles (Kleindorfer & Van Wassenhove, 2004). The second dependency relates to functionality. Firms perform unique activities which serve to complement other firms in the network. The third dependency is relationships, where business activities rely on the interaction of processes within the supply chain (Wilding, 1998; Svensson, 2004). These three dependencies put supply chain members at risk if an event occurs which impacts the ability of one member to continue to engage in normal business activities to maintain the flow of goods and services through the supply chain.

No organization is entirely immune from experiencing a disruptive event. There is a compounded probability that an event will occur at some individual node in a supply chain due to the increasing number of entities that each have their own distinctive vulnerabilities and corresponding chance of an incident.

Therefore, firm's must take steps to build a supply chain that is both *secure* (reduced likelihood or lower impact of events) and *resilient* (able to adapt, respond and recover when events do occur) to minimize the total impact of disruptive events on the supply chain (Rice Jr. & Caniato, 2003; Sheffi, 2005). However, recent research suggests that, surprisingly, only 5%-25% of firms listed on the Fortune 500 are formally prepared to handle a crisis event or major disruption (Mitroff & Alpaslan, 2003) and less than 20% of firms examine their supply network at least annually (Hillman, 2006). This lack of planning occurs despite industry statistics that reveal the number of natural and human induced disruptive incidents has been increasing (Rodetis, 1999). Recently, we have experienced events that have had substantial impact over wide geographic and economic areas. Examples include several highly visible natural disasters (e.g. the devastating 2004 Tsunami in the Indian Ocean and 2005 hurricanes Katrina and Rita in the U.S. Gulf region), economic and managerial disasters (e.g. 2001 Enron and 2002 WorldCom bankruptcies in the U.S., and 2007/8 sub-prime mortgage crisis), and infrastructure failures (e.g. 2003 power outages that lasted for several days in the northeastern U.S. and southeastern Canada). In addition, there are the large scale threats of future events, such as the potential pandemic of Avian Flu.

Not all disruptions have such widespread impact as those mentioned above. It is possible that the impact could be quite localized, such as the recent experience of General Motors when an exclusive supplier of stamped metal parts decided to terminate the business relationship (Chappell, 2006); or when a group of 33 employees, representing three quarters of the family owned printing company's workforce won a Powerball Lottery on a group ticket, resulting in a payout of over $2.6 million each (Delaware Lottery Games, 2004). It is therefore likely that a growing number of firms, from large to small, are now more aware of the need to create plans to prevent and mitigate the impact of disruptive events that would impede the continuity of flow of goods and services through the supply chain. Given the need for firms to engage in incident planning and continuity management, and the primary focus of research to date on supply chain disruptions from a very general or high-level view (Blackhurst, Craighead, Elkins, & Handfield, 2005), there is a need to more closely examine the ways in which firms manage exposure to disruptions and how plans are created to prevent and recover from possible events for ongoing performance.

2.2 *Normal Accident Theory*

This section will provide a brief overview of Normal Accident Theory (Perrow, 1984; Perrow, 1999). Although this theory has not had widespread direct application in operations or supply chain management literature, several of its underlying concepts, such as complexity, interdependencies, and coupling have been utilized. A review of the use of the key elements of Normal Accident Theory and an application within the context of a supply chain follows.

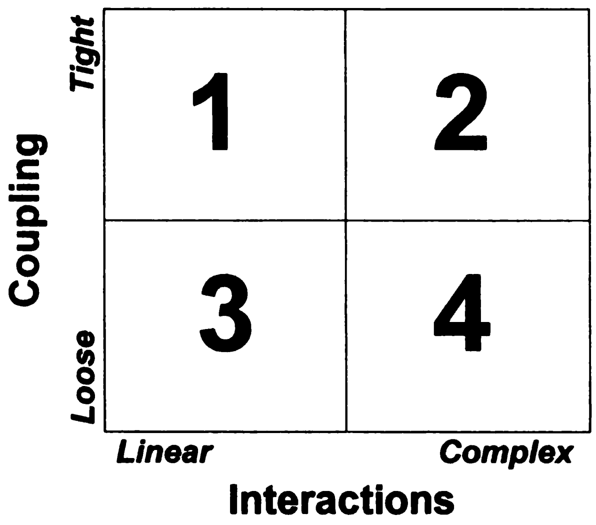
Normal Accident Theory as put forth by Perrow (1984; 1999) offers a pessimistic view of systems which states that any complex and interdependent system (e.g., a supply chain) will eventually fail, especially when combined with dangerous technologies. An important element of Normal Accident Theory (NAT) is that the focus is not on the choices of an individual decision maker or the activities (or lack of activity) of a single operator, but is instead based upon the structure and complexity of *interlinking* processes and organizations. The *interactiveness* of processes or entities and the degree to which they are *tightly coupled* to each other are the two factors that make a system more prone to experiencing negative events. Table 2.1 provides an overview of linear and complex interactiveness and of tight and loose coupling within the framework of NAT as shown in Figure 2.5. In general, the more complex the interactions, defined as sequences of actions and their results that may be unfamiliar, unplanned, unexpected, and are not easily visible or understood, the more vulnerable the system. The tighter the coupling, defined as little slack or buffer between entities or processes, the more vulnerable the system.

Table 2.1 Summary of Definitions in Interaction/Coupling Matrix

Linear System	**Complex System**
• Spatial segregation	• Proximity
• Dedicated connections	• Common-mode connections
• Segregated subsystems	• Interconnected subsystems
• Easy substitutions	• Limited substitutions
• Few feedback loops	• Feedback loops
• Singly purpose, segregated controls	• Multiple and interacting controls
• Direct information	• Indirect information
• Extensive understanding	• Limited understanding
Loose Coupling	**Tight Coupling**
• Processing delays possible	• Delays in processing not possible
• Order of sequences can be clanged	• Invariant sequences
• Alternative methods available	• Only one method to achieve goal
• Slack in resources possible	• Little slack possible in supplies, equipment or personnel
• Buffers and redundancies fortuitously applied	• Buffers and redundancies are designed in and deliberate
• Substitutions fortuitously available	• Substations of supplies, equipment, personnel are limited and designed in

Taken from Perrow, 1999, pages 88 and 96

Figure 2.5 Interaction/Coupling Matrix



(Perrow, 1999)

It is the dependencies within a complex system that increase vulnerability and the virtual inevitability of a 'normal accident.' A normal accident may occur quite rarely, the normality comes not from the frequency of occurrences, but from the view that a failure is a 'normal' or expected part of the system's existence. Within the framework of NAT, an accident is defined as reasonably substantial "damage to a defined system that disrupts the ongoing or future output of that system" (Perrow, 1999, pg. 64). Perrow further goes on to define 'incidents' as disruptions that impact a portion of the system, such as a *part* (the smallest component of the system, e.g. a valve) or a *unit* (a related collection of parts). Thus the specific term 'accident' is reserved for very serious events that impact major subsystems or the entire system, although incidents or disruptions on a smaller scale that may occur more frequently are also of concern; especially if there is a cumulative effect.

A major element of NAT is the requirement of complexity. Choi and Hong (2002) provide a concise definition where supply chain complexity is a function of the variety or structural differentiation of the system. Complexity contributes to vulnerability within a system in two ways. First, as the complexity of the system increases, so does the possibility that there will be a substantial weakness built into at least one part of the system. Second, as the system becomes more complex with a greater number of linkages or larger geographic dispersion between linked entities, the ambiguity within the system increases. Heightened ambiguity means that individuals operating in the system are less able to understand and be conscious and aware of events that are occurring in other parts of the system, including the possible ramifications of those events. In the most basic sense, complexity is a function of the structural variety and the degree of dispersion between entities, the linkages of system elements, and is impacted by the 'tightness' of those linkages (Chapman, 2005). The structural variety refers to the number of subsystems, departments, or divisions within the system (Daft, 1989). In a supply chain, this would be the number of suppliers, customers and channels of distribution (horizontal complexity), the number of the supply and demand tiers (vertical complexity), and the number of operating locations and their geographic dispersion (spatial complexity) (Choi & Hong, 2002; Daft, 1989). Complexity related to the coupling of the linkages within a system depends on how loose (high levels of uncertainty) or tight the relationships are. This also relates to the 'load' or amount of effort required to monitor or control the relationships (Dooley & Van de Ven, 1999). In a supply chain, this would be demonstrated by the number of relationships along the continuum of arms-length to full partnerships that require differing levels of attention and resource commitment.

A supply chain is more than a part of a complex system, it is a complex adaptive system (CAS) (Choi et al., 2001) and it is therefore undergoing frequent changes to physical structure and infrastructural linkages, further adding to its complexity. A CAS can be loosely described as a system that has a coherent form, changes over time, and is not dependent upon the deliberate actions of a single entity for management or control (Holland, 1995). Key elements of a CAS include the following:

- The system must consist of entities or agents that have purposeful and meaningful interactions based upon actions and events.
- The emergent actions of individual entities are a reaction to the simultaneous and parallel actions of other system entities.
- The actions of agents impact other agents due to the interconnectivities of entities in the system.
- The entities often do not have total freedom of action or autonomy due to negative feedback processes that regulate and control their actions (e.g. contractual obligations).
- Dynamism exists as agents enter or leave the system, and as they adapt and change, which then induces other entities to respond with adaptation and change.
- There are also dynamic environmental influences that impact specific entities and the system, but which exist external to the CAS (currency fluctuations, regulatory requirements, etc.).

These interacting changes, reactions and adjustments do not follow a linear pattern; large changes may lead to small impacts or small changes may lead to large impacts. Finally, although it would be logical to assume that the outcomes of a CAS would be chaotic and random, there are in fact patterns of behavior that do allow for some form of control and influence (Choi et al., 2001; Sterman, 2001). These characteristics tie into the view that a supply chain is an organized subset of firms within a much larger network of firms supplying and buying goods and services that is also influenced by the environment in which the individual firms and the supply chain operate. See Choi et al. (2001), pg 358, for a table that clearly links the general elements of a CAS specifically to a supply network (since a supply chain is a subset of a supply network, it is assumed that similar associations apply).

Within the framework of NAT, the tighter the coupling, defined as time dependency, path inflexibility and unavailability of slack resources (Perrow, 1999), the higher the interactive complexity of the system and therefore the more susceptible the *entire* system is to a negative event that occurs in any *part* of the system (Rice Jr. & Caniato, 2003). Serious failures can occur as a consequence of the interaction of diverse system elements, such as the environment, equipment, operators, processes and procedures, and supplies and materials (Jermier, 2004), all of which are active components of a supply chain. Due to the coupling of processes and entities, failure of the system is often the result of the interaction of many small failures rather than a single, large scale failure (Perrow, 1999).

The coupling elements in NAT of time dependency and path inflexibility are specifically applied to a supply chain by Svensson (2004) as time lags and co-dependent process functionality and relationships. The lack of availability of slack resources and of changing (reduced) levels of inventories (Sterman, 2001) is manifestations of the current trends of lean and JIT practices. This creates a susceptibility to disruptions that in essence allows a domino effect where an event, even a small one, occurs in one part of the chain and potentially grows as it travels through the chain, leading to a larger failure at some other point (Roberts, Bea, & Bartles, 2001; Elsinger, Lehar, & Summer, 2006). The complex and cascading linkages that exist may make the system more sensitive to events and result in more disruptions or 'catastrophes' than might otherwise be intuited (Choi et al., 2001). This contagion of impact is especially true when there are large scale events that are exogenous to the system (Elsinger et al., 2006). In light of the trend over the past two decades for supply chains to become leaner and more tightly coupled, complex and dispersed, supply chains may now exhibit the unintended consequence of having become more fragile and more susceptible to disruptive events that may ultimately have larger negative impacts (Rice Jr. & Caniato, 2003; Sheffi, 2005).

2.3 *High Reliability Theory*

High Reliability Theory (HRT) is an optimistic counter to NAT in which Roberts (1989) posits that in high reliability organizations (HRO) the occurrence of 'accidents' is very rare and it is not implicitly clear that all systems are subject to failure. This view was further expanded by Weick, Sutcliffe and Obstfeld (1999) who put forth the basic tenet that with correct management organizations can stave off 'normal accidents' indefinitely. In general, HROs operate under difficult conditions but experience fewer accidents than might be expected, even when faced with the possibility of a propensity of unexpected events due to technologies, complexity and variable demand (Weick & Sutcliffe, 2001). The key point is that these organizations place a greater emphasis on the importance of system *reliability* rather than on *efficiency* (Weick & Roberts, 1993). The view is that if systems are better understood for more appropriate and effective management, potential hazards can be detected earlier and reigned in before a situation spirals out of control into a disaster (Chapman, 2005). It is important to note that both NAT and HRT do not focus on *individual* behaviors and choices, but on *systems*, *organizational structure*, and the *linkages* that bind them together (Rosa, 2005).

Organizations themselves have become leaner, with fewer employees doing more work and with their attention spread more thinly. The resulting reduced attention that can be given to non-tactical and non-recurring events may reduce the costs of routine transactions, but at the cost of increased damage that may result from an unexpected event (Lampel & Shapira, 2001) which is not detected early enough to prevent damage. Thus, there is a need to effectively plan to stave off disruptive events in almost all organizations. The specific plans used by business can be implemented to varying degrees at the discretion of management based upon a firm's business environment, strategy and goals. Firms in some industries are critical to the general infrastructure of a community or the country (e.g. hospitals, airports, utilities, financial services and public works) and may operate under strict regulatory mandates that require them to engage in effective business continuity planning (Rodetis, 1999; Bielski, 2003). However, most firms are not in industries that are under the same externally imposed requirements and are free to pursue varying levels of risk management and planning.

The majority of research on HROs has focused on organizations that are required to have exceptionally high levels of reliability, where even a small lapse in performance can have catastrophic results, such as a US Navy aircraft carrier (Rochlin, Porte, & Roberts, 1998), nuclear power plants and the United States Federal Aviation Agency Regional Air Traffic Control Center (Klein, Bigley, & Roberts, 1995) or Pacific Gas and Electric Company (Roberts, 1990). There is little research examining firms experiencing a multitude of low impact events over time which may still result in a major cumulative effect (Lewis, 2003) or that are not in such 'mission critical' environments as those operating in the industries previously mentioned. It stands to reason that organizations not engaged in such high risk activities or with such high need for near perfect continuity would still have a need for high reliability in a competitive business environment. There is evidence that firms with high risk products (e.g. chemicals) or with rapidly changing products (e.g. high-tech) examine their supply networks most often (Hillman, 2006), but this does not preclude firms from other industries or with other products from the need to find ways to provide some protection from disruptive events (Waller & Roberts, 2003).

While the study of HROs has been focused on single organizations or other types of single entities, HRT is also applicable to systems that span across organizational boundaries. Within the context of HRT, a supply chain represents a "large-scale system" composed of a network of humans utilizing technical systems to complete tasks that support the goals and missions of multiple entities (Grabowski & Roberts, 1997), as goods and services flow through the system. This also means that many of the processes that are used in HROs to mitigate risk for improved system reliability and business continuity are applicable to a larger, multi-entity supply chain. Grabowski and Roberts (1997; 1999) argue that most of the challenges within a large-scale system, such a supply chain, are driven by a paradox of autonomy and interdependence. Each member within a supply chain exists *autonomously* as a self-managed entity with unique objectives, assets, processes, and organizational culture; however, each individual supply chain member is simultaneously *interdependent* upon the actions, behaviors and goods and services of other entities operating within the supply chain. This paradox drives many of the issues that the supply chain faces, and the solutions that are implemented.

One issue that must be addressed is the need for effective communications. The challenge specifically in a supply chain is that the entities are most often distributed both spatially and organizationally, making face-to-face communications difficult. This puts an increased burden on understanding cultural needs and mental models to clarify goals, responsibilities, relationships, and to develop trust across organizations. It can also make it difficult to gather relevant data from all pertinent sources (Grabowski & Roberts, 1997; Roberts et al., 2001). Therefore, the entities within a supply chain must create methods for effectively communicating operating status and be able to recognize when an event or situation requires communication with other supply chain members.

A second issue is the impact of decisions that may generate unintended consequences. A single firm or a dyad in a supply chain may make a change that is perceived as beneficial, but that ends up impacting another member of the network in an unanticipated and possibly negative way. A third issue to overcome is that separate supply chain entities each have their own norms, processes, policies, goals, and reward structures that are used to reinforce their unique business strategy and culture; however, as members of a larger scale system, it is necessary to work across organizational boundaries to form an overall focus on system reliability beyond the specific needs of individual entities.

This would include the development of reward and incentive practices that span across firm boundaries to encourage multiple supply chain members to take into account the desirable benefits of reliability and the avoidance of the costs of failure not just for their own firm, but for other firms in the supply chain (Roberts et al., 2001). This requires oversight and the use of checks and balances for feedback to ensure the system is running appropriately, especially if there are long incubation periods for events to permeate into serious system disruptions. Finally, the structure of the system must be designed to allow for flexibility to adapt to a changing environment as well as having built in redundancy for system slack that serves to create buffers between processes and entities.

Five traits have been identified by Weick and Sutcliffe (2001) as the distinguishing characteristics of HROs. Collectively they call these five attributes 'mindfulness'. This definition includes the purposeful decision to create an organizational structure that allows for better visibility of unexpected events at an earlier stage so that the expansion of incidents can be halted or managed for reduced overall impact. It also includes a concerted effort to continuously update the understanding of the organization and its relationship with its environment for ongoing interpretations of its contexts, issues and potential problems, and possible solutions. The key advantage of mindfulness for HROs is the ability to recognize events while they are still in the earliest stages, even if they are providing only faint signals or signs of their existence, for improved prevention, mitigation and management of disruptions.

The five traits of mindfulness identified by Wieck and Sutcliffe (2001) are summarized as:

- *Preoccupation with failure*: HROs experience a lower than expected number of disasters due to an obsession with *failures* of all sizes, rather than a hubristic focus on *success*. This is accomplished through the timely reporting of errors and near misses, followed by an examination of root causes for continuous improvement.
- *Reluctance to simplify interpretations*: There is not an attempt to simplify all information because HROs acknowledge the complex, unstable, unknowable and unpredictable environment in which they operate.
- *Sensitivity to operations*: There is a focus on the operational, reporting and structural processes along with constant examination to uncover points of vulnerability *before* an event occurs.
- *Commitment to resilience*: HROs learn from previous events, where an examination of holistic information and sensitivity to operations are combined with a commitment to resilience, so that they can quickly recover from incidents. The key point is not that HROs are completely event free and that errors never occur, but that they are able to rapidly respond and recover, so that events are not disabling or recurring.
- *Deference to expertise*: HROs cultivate diversity in order to acquire greater breadth of knowledge; decision making is placed in the hands of those that have the greatest expertise to make decisions and manage processes.

HROs take a proactive approach to managing risk. They undertake continuous network analysis and monitoring in order to identify changes in the network and potential resulting changes in sources of risk. This allows for the reduction of exposure to possible disruptive events while also taking advantage of changes that may create potential opportunities (Hillman, 2006). A key element of network scanning is the identification of the early warning signals that many events have, long before the situation reaches the stage of eminent negative impact (Mitroff, 1988).

In general, HROs are acutely aware that they are open to the occurrence of unfavorable events, and they also actively seek ways to control, reduce or eliminate their sources of vulnerability. A focus on managing processes, or 'mindfulness', creates an environment in which individuals are aware of the possible events that should be monitored, they know their role in the process on a larger scale, and they understand the actions that should be taken when event signals are detected. In short, they plan for events so that they are better prepared to act when an incident occurs to ensure the highest possible level of ongoing business functionality.

2.4 *Synthesizing the Literature*

Supply chain risk literature has focused primarily on supplier management (Zsidisin, 2003; Zsidisin, Ellram, Carter, & Cavinato, 2004; Giunipero & Eltantawy, 2004; Hallikas & Virolainen, 2004; Hillman, 2006;) and on the demand or the downstream side of risk (Fisher, Hammond, Obermeyer, & Raman, 1994; Lee et al., 1997; Sodhi, 2005). There is a much more limited stream that examines internal disruptions (Castillo, 2004; Gill, 2006). An October 2003 examination of supply chain risk management literature found that since 1990, 74% of the articles focus on the upstream or supply side, 69% considered the downstream or demand side, and only 10% examined internal elements (some articles examined more than one direction of risk management) (Paulsson, 2004). There is however limited research that holistically examines risk and continuity planning from the perspective of a single firm and that explicitly and simultaneously considers upstream, internal, downstream, and environment sources of possible disruptions. In addition, while it is accepted that a supply chain is embedded within a larger and more complex network, there has been little research examining the impact of complexity on performance within a supply chain context (Milgate, 2001). Nor has there has been work that explicitly examines the relationship between supply chain complexity and continuity planning for disruptive events for the reduction of disruptive events and their impact on firm performance. A summary of the supply chain risk management literature is provided in Table 2.2

Table 2.2.

This study seeks to fill the current research gaps by specifically examining the following areas:

1. Explicit examination of the supply chain continuity planning processes that firms are engaged in.

2. Examination of three possible sources of motivation for supply chain continuity planning: perceptions of vulnerability, perceptions of supply chain complexity and the use of continuity planning as an effective strategic practice.

3. Examination of the impact of supply chain continuity planning on firm performance and the reduction of supply chain disruptions

Table 2.2 Summary of Supply Chain Risk Literature

Author(s)	Study Purpose	Key Findings	Supply Chain Direction	Theory	Focus
(Fisher, Hammond, Obermeyer, and Raman, 1997)	Case study of Sport Obermeyer and the use of supply and demand matching	With high complexity (product variety) and high demand uncertainty (long lead time, fashion products) it is key to find use 'accurate response', faster lead time and higher flexibility to better meet demand	Demand		Risk response/ reduction activities
(Lee, Padmanabhan, and Whang, 1997)	Conceptual discussion of demand uncertainty	'Bullwhip' effect consists of four sources: demand signal processing, rationing game, order batching, and price variations. Gives possible mitigation strategies	Demand		Risk response/ reduction activities
(Smeltzer and Siferd, 1998)	Examines proactive purchasing as risk mgt within the context of TCE and Resource Dependency model. Case studies of 24 firms	Linkage of purchasing administrative actions with their possible risk and consequences. Identification of the conditions necessary for the purchasing function to manage risk, which may involve activities beyond their normal scope	Supply	Transaction cost economics	Risk response/ reduction activities
(Zsidisin, Panelli and Upton, 2000)	Examines risk assessment, contingency plans and buffering as utilized by purchasing professionals, Case studies of nine firms	Risk assessment is relatively common, either formally or informally. The creation of contingency plans is not often used. Many firms reported little corporate investment of time or resources. Buffering is a common mitigation strategy	Supply		Risk assessment
(Svensson, 2000)	Conceptual examination of the construct of supply chain vulnerability, using single case studies from furniture, auto, retail, & pre-mfg house industries	Disturbances to supply chain have source, category and time dimensions. First of Svensson's vulnerability frameworks. Very high level of atomistic source of disturbances that is more frequently categorized as quantitative than qualitative. Reviews methods to reduce vulnerability and variation	Supply	Channel Theory	Sources and assessment of supply chain risk

Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Warren and Hutchinson, 2000)	Conceptual examination of security for e-commence	Provides examples of potential attacks on electronic systems and applicable counter measures	Supply chain		Risk response/ reduction activities
(Johnson, 2001)	Post hoc 'case' of toy industry	Lessons from managing risk in toy industry; presents techniques to manage demand and supply: product extensions; rolling mix; licensing; outsourcing; producing in multiple countries	Supply chain		Risk response/ reduction activities
(Sheffi, 2001)	Conceptual examination of security and terrorism issues in the supply chain	Advocates the use of operational redundancies and modified organizational structure, specifically the use of public-private partnerships	Supply chain		Risk response/ reduction activities
(Hallikas, Virolainen, and Tuominen, 2002)	Examines risk assessment process. Case study of two firms	Illustrates the use of internal audit and computer aided cause and effect analysis to analysis risk in a buyer supplier dyad	Supply		Risk assessmen t
(Chapman, Christopher, Juttner, Peck, and Wilding, 2002)	Conceptual examination of the process steps of risk mgt	Supply chain risk mgt consists of the fours steps of • risk identification • risk assessment • continuity mgt, coordination • learning from experiences.	Supply chain		Stages of continuity planning
(Hicks, 2002)	Examines stock price following an announcement of supply chain delay	Stock prices fell an average of 8% immediately after announcement of a product or shipment delay, and had a long term (6 month) impact of up to 20%.	Supply		Financial impact of disruptions
(Svensson, 2002a)	Conceptual examination of vulnerability of in/outbound logistics flows. Data from the Swedish auto industry.	Operationalization of a construct of vulnerability based upon service level (absence of disturbances), deviation (presence of disturbances), consequence, and trend.	Supply		Sources and assessmen t of supply chain risk

Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Svensson, 2002b)	Conceptual examination of supply chain vulnerability in terms of time & relationship dependencies. Based on data from the Swedish automobile industry.	Operationalization of the construct of supply chain vulnerability based on time, technology, knowledge, social, economic/judicial, market, & IT dependencies. Created typology scenario matrix and identified key up and down stream dependency relationships	Supply and Demand		Sources and assessment of supply chain risk
(Lewis, 2003)	Examines risk from an input → output model perspective, based on case studies of four firms.	Creation of a model of risk based upon the classic operations of input → transformation → output model, the dimensions of causal event and negative consequence. Lack of visibility hampers risk mgt; layers of loss impact operations, customer, and direct and generic stakeholders.	Supply and Demand		Sources and assessment of supply chain risk
(Rice and Caniato, 2003)	Conceptual discussion of actions firms should take to increase resiliency. Based upon anti-terrorism and security research.	Provides prescriptive basic and advanced responses to increase physical, info and freight security through the use of flexibility and redundancy. IDs possible actions based upon specific failure modes of production supply, HR, transportation and communications	Supply And Logistics		Risk response/ reduction activities
(Russell and Saldanha, 2003)	Conceptual discussion of logistics practices of security aware logistics	Lists five tenets of: partnering with freight moving firms, overseas partner knowledge, access to mode-shifting capabilities, using multiple communication channels, adoption of military concepts of agility, reservists and pre-positioning	Supply and Logistics		Risk response/ reduction activities

Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Zsidisin, 2003)	Identified the characteristics of inbound supply, implications of perceptions of risk; classified risks. Six case studies.	Literature summary of factors affecting supply risk perceptions and supply risk characteristics. Identification of significant market and supplier characteristics for supply management managers.	Supply		Sources and assessmen t of supply chain risk
(Zsidisin and Ellram, 2003)	Use of Agency Theory framework to manage supply risk	Examines the role of the purchasing function in controlling risk from the supply side through buffering and behavioral-based management techniques. Summary of literature on supply risk research.	Supply	Agency Theory	Risk response/ reduction activities
(Castillo, 2004)	Case study of business continuity planning at Boeing	Uses Boeing's model, details some issues to be examined in continuity planning, including infrastructure and personnel issues	Internal		Sources, assessmen t and reduction of risk
(Cavinato, 2004)	Conceptual examination of logistics risk, and call for broadening definition of risk	Supply chain consists of five internal chain/network constructs: physical, financial, informational, relational, and innovational. Four categorizations of relevant product/supply costs are presented as are four types of supply risks	Internal		Risk assessmen t
(Chopra and Sodhi, 2004)	Conceptual examination of importance of proactively managing SC risk	Identification of the drivers of supply chain risk, the implications for various mitigations strategies and the risk/reward trade-off curve for managing risk.	Supply chain		Sources and assessmen t of supply chain risk
(Sinha, Whitman, and Malzahn, 2004)	Conceptual examination of risk with consideration of multiple supply chains simultaneously	Presents a generic prescriptive methodology for mitigating risks in an aerospace supply chain and minimizes conflicting objectives using integrated definition (IDEFO) modeling	Supply chain		Risk response/ reduction activities

Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Finch, 2004)	Examines relationship between firm size and level of risk. Case studies and review of 'grey' literature.	Increased levels of risk are associated with increased inter-organizational networking, especially with small to medium sized enterprises.	Supplier and Customer		Sources and assessment of supply chain risk
(Giunipero and Eltantawy, 2004)	Conceptual examination of the level of investment in risk mgt that firms should undertake.	Investments in risk mgt are determined by level of product technology, need for security, criticality of supplier, and level of experience with the material and/or supplier (uncertainty).	Internal		Investment levels to reduce risk
(Hallikas, Karvonen, Pulkkinen, Virolainen, and Tuominen, 2004)	Conceptual examination of risk in supplier networks	When the dependency between companies increases, they become more exposed to the risks of other companies.	Supply		Risk response/ reduction activities
(Hallikas and Virolainen, 2004)	Conceptual examination of network and risk management	Examines use of supplier selection and relationship management as methods to manage/reduce risk.	Supply	Transaction cost economics	Risk response/ reduction activities
(Spekman and Davis, 2004)	Conceptual discussion of supply chain management risk.	Identifies six dimensions of supply chain risk as the flow of goods, information, funds, firm reputation, relationships, and security of information systems, Strong tie to partner selection.	Supply chain		Sources and assessment of supply chain risk
(Svensson, 2004)	Examination of horizontal and vertical corporate vulnerability. Based up data from the Swedish automobile industry.	Dependencies categorized into three areas of time, functional & relational. Each has internal or external focus, and is either atomistic or holistic. ID causes of up & down stream vulnerabilities. Degree of tier level visibility firms have is key component of vulnerability perceptions.	Supplier and Customer		Sources and assessment of supply chain risk

Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Zsidisin, Ellram, Carter and Cavinato, 2004)	Examination of the process of assessing supply risk. Case studies of seven firms.	Firms use a multitude of techniques to asses supply risk. Firms focus on supplier quality issues, supplier performance and preventing supply interruptions.	Supply	Agency Theory	Sources and assessment of supply chain risk
(Hellström, 2005)	Centralized & decentralized risk mgt based upon a contingency model of leadership	Creation of a normative model for employee involvement in risk reduction consisting of five styles (autonomous, modified autonomous, segmented, unitary & group decision)	Internal	Contingency Theory	Risk management decision making
(Hendricks & Singhal, 2005a)	Event study methodology to examination of firm stock prices after a supply chain problem	After supply chain 'glitch' there is 6.92% reduction in sales growth, 10.66% cost increase, and 13.88% inventory level increase. Consistent across industries, disruption sources.	Internal		Financial impact of disruptions
(Hendricks & Singhal, 2005b)	Event study methodology to examination of firm stock prices after a supply chain problem	Generally worse performance for firms before the announcement of supply chain problems compared to benchmark portfolios. After announcement, increase in firm's equity risk of 13.5%.	Internal		Financial impact of disruptions
(Kleindorfer and Saad, 2005)	Development of a conceptual framework based upon joint risk assessment and mitigation. Utilizes data from U.S. Chemical Industry.	Creation of 'SAM-SAC' framework: firms should engage in establishing security stds, classifying assets & processes, rank & prioritize assets, and iterate for CI to reduce frequency of disruptions and increase absorptive capacity. Necessary implementation conditions: environmental 'fit' and effective relationships	Supply chain		Sources and assessment of supply chain risk
(Peck, 2005)	Sources of risk affecting the supply chain, using a systems theory approach	Identified four levels of SC risk (product & process, infrastructure, environment, interorganizational, to explain risk scope and dynamism	Supply chain	Systems Theory	Sources and assessment of supply chain risk

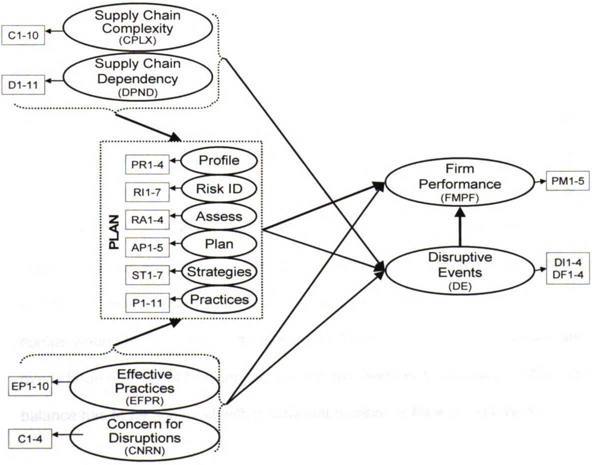
Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Sheffi and Rice, 2005)	Long term, comprehensive research into disruption management. Focus on conceptual identification of common traits of high/under performing firms	Graphic disruption profile and the stages of prep, event, first response, initial impact, full impact, recovery preparation, recovery, and long-tem impact. Illustrates vulnerability framework along axis of disruption probability & disruption consequences to identify a vulnerability profile. Input → transformation → output.	Supply chain		Sources and assessmen t of supply chain risk
(Sodhi, 2005)	Use of modeling to manage demand risk	Creation of a model to allow company to reallocate capacity among different products and thus manage demand/inventory risk	Demand		Risk response/ reduction activities
(Zsidisin and Smith, 2005)	Conceptual examination of the role of early supplier development in managing supply risk. Uses a case study of a single firm.	Early supplier involvement is proposed to reduce risk in new product development by •reducing uncertainty •improving info flow •creating goal congruency •limiting adverse selection •allowing buying firm to better monitor supplier firm activities	Supply	Agency Theory	Risk response/ reduction activities
(Zsidisin, Melnyk and Ragatz, 2005a)	Examination of how & why firms create business continuity plans, using case studies of three firms selected as having high continuity planning.	High degree of convergence of practices around principles of awareness, prevention, remediation, and knowledge management. Propose that business continuity planning will grow in prevalence, firms will benchmark high performers and it will evolve into a standard purchasing practice	Supply	Institution al Theory and Open Systems Theory	Business continuity plans
(Zsidisin, Ragatz, and Melnyk, 2005b)	Examination of the impact of supply chain management trends on risk.	Increased risk driven by shorter product life-cycles, 'leaning' of the supply chain, high customer expectations, more info linkages facilitated by IT. SC continuity planning framework.	Supply		Sources and assessment of supply chain risk

Table 2.2 (cont'd)					
Author(s)	**Study Purpose**	**Key Findings**	**Supply Chain Direction**	**Theory**	**Focus**
(Tomlin, 2006)	Single product, two suppliers model to examine the impact of disruptions	Supplier's percentage uptime and the nature of the disruptions (frequent but short versus rare but long) are key determinants of the optimal sourcing strategy	Supply		Risk response/ reduction activities
(Gill, 2006)	Conceptual discussion of decentralized workplaces	Decentralized workplaces can be advantageous for business continuity	Firm		Risk response/ reduction activities
(Hillman, 2006)	Conceptual discussion of areas & sources of risk in supply base	Results from larger research study that identifies the area of supply chain risk that are foremost in the minds of practitioners	Supply		Sources and assessment of supply chain risk
(Kiser and Cantrell, 2006)	Conceptual discussion of process of understanding and controlling supply risk	Identifies external & internal risks. Provides six steps for managing risk: profile supply base, assess vulnerability, evaluate implications, id mitigation actions, perform cost/benefit analysis & implement plans	Supply		Risk response/ reduction activities
(Swink and Zsidisin, 2006)	Survey of firms to examine risks/benefits of focused commitment strategy with suppliers.	Increasing focused commitment provides benefits when existing commitment is low. Over commitment can lead to risk that off-sets the transactional and scale-related benefits.	Supply	Transaction cost economics, Agency & Knowledge based view	Sources and assessment of supply chain risk
(Craighead, Blackhurst, Rungtusanatham, and Handfield, 2007)	Conceptual examination of linkages of SC density, node criticality and complexity with mitigation capabilities of recovery and warning	Calls into question practices of supply base reduction, global sourcing and use of supply clusters	Supply		Sources and assessment of supply chain risk & Risk response/ reduction activities

3. MODEL DEVELOPMENT

Research is an iterative process grounded in theory and existing knowledge that extends our understanding though the use of data to test and modify existing theories and to create new theories (Handfield & Melnyk, 1998; Meredith, 1993). The proposed conceptual model, as shown in Figure 3.1, served as the starting point of the iterative process undertaken in this study. It represents a recursive, cross-sectional model using reflective constructs. The original model was tentative and it was expected to undergo revision based upon findings from the data. A discussion of the literature reviewed and applied to create the specific constructs in the proposed model follows.

Figure 3.1 Proposed Model



3.1 *Construct Development*

Good empirical research requires good measurement as its foundation, where multi-item constructs are developed with a sound conceptual and strong theoretical base. A two-step normative process for construct development, as outlined in Stratman and Roth (2002) serves as the basis for the construction of construct scales in this research. The exploratory nature of this study and the absence of scales which have been tested in other studies makes it especially important that a rigorous and scientific process of construct development and scale creation occurs as a necessary predecessor to empirical research of this topic (Sethi & King, 1991).

The constructs (or latent variables) consist of a set of reflective scale items (or manifest variables) meant to capture a specific concept represented by the construct. The manifest variables (MV) are captured through an extensive literature search and from practitioner input as the representative scale items meant to capture the latent variable (LV) construct to be tested. Since structural equation modeling (SEM) will be used to test the model, at least three MVs are needed for each LV to ensure the model has statistical identification (Bentler & Chou, 1987; Marsh, Balla, & McDonald, 1988); there are no single indicator constructs which may hamper measurement reliability (Bentler & Chou, 1987) and model identification. A larger ratio of MVs to LVs will also aid in compensating for a potentially small sample (Marsh et al., 1988). However, an overly large number of MVs inhibits parsimony (Gerbing & Anderson, 1984), so a balance has to be achieved with a sufficient number of MVs to capture the LV without the ratio becoming unnecessarily large. The constructs developed for use in this study are grounded in previous theoretical and empirical studies. The literature used for the creation of each LV and the associated measurement MVs are detailed in the following sections.

3.1.1 Supply Chain Complexity

Complexity can be loosely defined as the variety and uncertainty contained within a system (Flynn & Flynn, 1999; Frizelle, 1998). The complexity of the system is a key element of its susceptibility to disruptive events (Choi et al., 2001). Operationally, the complexity of a supply chain is a function of the individual attributes of *uncertainty*, *technological intricacy*, and *system structure* and their influence on each other.

Specifically, research has been done on the uncertainly of demand due to information distortion as data flows upstream through supply chain entities, often referred to as the 'bullwhip effect' (Davis, 1993; Fisher et al., 1994; Forrester, 1961; Lee & Billington, 1995; Lee et al., 1997). There is also general uncertainty of expected demand that is inherent in the process of forecasting (Chase, Jacobs, & Aquilano, 2004; Sheffi, 2005). There can be uncertainty about the supply of material into the firm due to long physical paths along which goods must travel that increases lead times with greater variation in delivery times (Hallikas & Virolainen, 2004).

Technological intricacy of the products and processes used can drive greater complexity within a supply chain. The complexity of the technology and processes used to make a product contribute to difficulty in gathering relevant information and in controlling the processes (Flynn & Flynn, 1999; Khurana, 1999; Tatikonda & Montoya-Weiss, 2001). The complexity of the products relates not only to the processes used in manufacturing, but to the depth of the bill of material used to make the product. A large bill of material can serve as a proxy measure of both the complexity of the products the firm provides and the number of possible suppliers required to supply many different types of materials (Choi & Hong, 2002).

Finally, the number (forward, backward and within-tier) and dispersion of players in the system (Daft, 1995; Beamon, 1999; Choi & Hong, 2002; Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007) influences the structural complexity of the supply chain. The greater the number and the more geographically dispersed supply chain entities are, the more difficult it is to know the status of each supply chain node and to manage the flow of information, goods and services to ensure supply chain continuity. The scale items and literature source for the construct are summarized in Table 3.1.

Table 3.1 Summary of Supply Chain Complexity Scale Items

Scale Items	Source
Products and processes	(Khurana, 1999; Randall and Ulrich, 2001; Tatikonda and Montoya-Weiss, 2001; Choi and Hong, 2002)
Market	(Zsidisin, 2003; Chen and Paulraj, 2004; Hallikas and Virolainen, 2004)
Supply chain structure	(Daft, 1995; Beamon, 1999; Flynn and Flynn, 1999; Choi and Hong, 2002; Craighead et al., 2007)
Uncertainty	(Wilding, 1998; Flynn and Flynn, 1999)

3.1.2 Supply Chain Dependency

Vulnerability is defined by the Merriam-Webster Dictionary as "capable of being…wounded or open to attack or damage". A supply chain is vulnerable when it is possible that events could occur which would be detrimental to the firm, including potential disruption in normal business activities, an interruption in the flow of goods and services, a negative financial impact of increased costs or reduced revenue, or harm to the firm's reputation. Vulnerability exists when disturbance in the flow of goods and services occurs and the impact can not be completely absorbed (Svensson, 2002a).

Dependencies within the supply chain can also result in 'parallel interactions' that occur within the system between different supply chain entities within the same supply chain tier. There is a ripple effect where the poor performance of one supply chain member impacts another seemingly unrelated member. For example the late delivery of material from one supplier may result in a different material originally requested from another supplier to not be needed or consumed as originally scheduled (Wilding, 1998). Or the late material may need to be expedited from an alternative source.

Sources of disturbances in the flow of goods can be generally grouped as atomistic or holistic. An atomistic disturbance is one that has a direct impact on the firm driven by the performance of a first-tier partner or the logistics link between the firm and a fist-tier partner. A holistic disturbance has an impact beyond the first-tier relationship as a disturbance ripples through the supply chain. Additionally, disturbances can be categorized as quantitative or qualitative. A quantitative source includes a lack of needed volume or availability of goods, possibly resulting in a stock-out. A qualitative source includes incorrect or poor quality materials (Svensson, 2000). Due to the obscurity of events that occur upstream and downstream within the supply chain beyond the first tier, most firms are only explicitly aware of events that transpire atomistically (Svensson, 2004). Therefore, firms may have difficulty in gauging their vulnerability beyond their internal operations and their dependency upon first-tier upstream and downstream partners.

In an effort to operationalize the construct of supply chain vulnerability due to supply chain linkages, Svensson (2002b) built upon earlier work to identify the following dependency dimensions:

- *Technical*: adaptation to align business practices and the use of compatible equipment and technology
- *Time*: use of time-based need or the synchronization of business activities
- *Knowledge*: mutual sharing and learning from each other to create knowledge of problem solving
- *Social:* interaction between firms is based upon personal relationships and the strength of the social atmosphere and personal chemistry of executives
- *Economic/judicial*: formal, often written, agreements between firms
- *Market*: image and status of a firm which may impact the image and status of other firms, including general goodwill
- *Information Technology*: the investment in and use of compatible hardware and software for communication, including common IT standard protocol

Ambiguity can also contribute to perceptions of vulnerability. Ambiguity is exacerbated by uncertainty about possible changes in demand patterns and supply availability, and the non-linear and parallel interactions that occur as the impact of events ripple through the supply chain (Wilding, 1998; Peck, 2005). It is therefore appropriate to include both ambiguity and the multiple dimensions of dependence in a construct to measure perceived supply chain vulnerability. The scale item topic and literature source are summarized in Table 3.2.

Table 3.2 Summary of Perceived Supply Chain Dependency Scale Items

Scale Items	Source
Alignment of business activities	(Svensson, 2002b)
Time-based synchronization	(Svensson, 2002b)
Knowledge exchange	(Svensson, 2002b)
Close personal relationship	(Svensson, 2002b)
Economically dependent	(Svensson, 2002b)
Reputation influence	(Svensson, 2002b)
Adaptation of IT investments	(Svensson, 2002b)
Knowledge of first tier partner activities	(Ghosh and Ray, 1997; Svensson, 2004; Peck, 2005)
Knowledge of partner activities beyond the first tier	(Svensson, 2004)
Awareness of partner strengths and weaknesses	(Ghosh and Ray, 1997; Peck, 2005)

3.1.3 Effective Practices

Firm performance can not be attributable to planning for business continuity alone; therefore a construct to capture the use of business practices that have been linked to improved business performance must also be included. There have been numerous studies attempting to identify the effective or 'best' operation management and supply chain practices that lead to higher business performance (Vickery, Dröge, & Markland, 1993; Flynn, Schroeder, & Sakakibara, 1995; Sakakibara, Flynn, Schroeder, & Morris, 1997; D'Avanzio, von

Lewinski, & Van Wassenhove, 2003). It has further been found that many 'best practices' are dependent upon the environment, firm goals, and interaction effects between those practices and supply chain members (Ketokivi & Schroeder, 2004a). Firms must engage in effective practices that improve internal processes as well as crossing organizational boundaries to engage other supply chain firms in the improvement of external and shared processes (Stank, Keller, & Closs, 2001; Spekman & Davis, 2004; Filbeck et al., 2005). There is a plethora of research examining specific practices in operations and the supply chain that are related to firm performance (Davies & Kochhar, 2002). A complete review of effective practices is beyond the scope of this research, so those practices which have been identified in studies as representing effective or 'best' practices, with consideration of the timeliness of the study, are utilized here (e.g. TQM has become so ubiquitous, it is a standard rather than 'best' practice) The effective practices used in this study consist of both internally and externally focused methods that have shown to have a positive relationship with performance (Stank et al., 2001; Davies & Kochhar, 2000; Wisner, 2003; Griffis, Cooper, Goldsby, & Closs, 2004; Ketokivi & Schroeder, 2004a; Spekman & Davis, 2004; Laugen, Acur, Boer, & Frick, 2005; Li, Rao, Ragu-Nathan, & Ragu-Nathan, 2005). The scale item topic and literature source are summarized in Table 3.3.

Table 3.3 Summary of Effective Practices Scale Items

Scale Items	Source
New Product Development	(Salvador, Forza, Rungtusanatham, and Choi, 2001; Ketokivi and Schroeder, 2004a; Laugen et al., 2005)
Productivity and waste elimination	(Ketokivi and Schroeder, 2004a; Laugen et al., 2005)
Outsourcing non-core competencies	(Laugen et al., 2005)
Cross-functional orientation	(Ketokivi and Schroeder, 2004b)
Acquisition of proprietary assets	(Ketokivi and Schroeder, 2004a)
Strategic partnerships	(Salvador et al., 2001; Ketokivi and Schroeder, 2004a; Laugen et al., 2005; Li et al., 2005)
Information sharing	(Davies and Kochhar, 2000; Wisner, 2003; Li et al., 2005)
Supplier certification	(Davies and Kochhar, 2000; Salvador et al., 2001)
Customer relationship management	(Wisner, 2003; Li et al., 2005)

3.1.4 Concern for Disruptions

There is ample evidence of the direct costs and of other direct negative impacts on firm financial performance due to a supply chain disruption (Hendricks & Singhal, 2005a, 2005b). There is also evidence that handling disruptions well can lead to improved firm performance over the long run (Norrman & Jansson, 2004; Sheffi, 2005). However, investing in supply chain resiliency to reduce the likelihood and impact of disruptive events requires a concern for supply chain disruptions. Because supply chain disruptions can come for a variety of directions, firms should be concerned about disruptions from upstream and internal sources (supply), customer sources (demand) and business environment sources.

3.1.5 Continuity Planning

The stages of the disruption profile, as defined by Sheffi and Rice (2005) include preparation, first response, management of the initial impact, preparation for recovery, and the recovery process. The creation of a continuity plan should include securing the people in the organization, core assets (systems, facilities, processes, equipment, and infrastructure), and business relationships within the supply chain (Foster & Dye, 2005). This research focuses on the planning that firms undertake when evaluating sources of risk and creating plans that will reduce the likelihood and impact of events that may interrupt normal business functionality. The Disaster Recovery Institute defines business continuity and business continuity management as follows:

> *business continuity*: the ability of an organization to provide service and support for its customers and to maintain its viability before, during, and after a business continuity event
>
> *business continuity management*: a holistic management process that identifies potential impacts that threaten an organization and provides a framework for building resilience with the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities. The management of the overall program through training, rehearsals, and reviews, to ensure the plan stays current and up to date

Continuity planning is a multifaceted process that in its entirety consists of six distinct elements. Therefore, the construct used here must also include the specific elements of a comprehensive supply chain continuity plan. They are summarized as (Chopra & Sodhi, 2004; Clark & Harman, 2004; Hallikas & Virolainen, 2004; Kiser & Cantrell, 2006; Sheffi & Rice Jr., 2005):

- *Profile the supply chain*: examine the existing supply chain to determine the number and location of suppliers, production and warehouse facilities, transit lanes, customers and their associated linkages
- *Risk identification*: investigate possible sources of risk in the supply chain that could impede the flow of goods and services, or normal business operations
- *Risk assessment*: determine the probability and impact of identified potential disruptions
- *Risk management strategies*: general strategies of acceptance, management, reduction, pooling, sharing, transferring and elimination of supply chain risk should be examined for fit with the firm and the supply chain, along with cost/benefit analysis of various strategies
- *Implementation of risk management plans*: specific techniques and practices selected as most appropriate are implemented based upon the selected risk management strategies
- *Audit of risk management plans*: plans should be examined for effectiveness, including sharing plans with appropriate supply chain partners.

The construct of planning for events is formed by the six specific elements of risk management planning outlined above. Each has a unique scale meant to assess the degree to which the firm is engaged in a particular element of overall supply chain continuity planning, and will be discussed at greater length in the following sections.

3.1.5.1 Profile the Supply Chain

The first stage is to profile the supply chain, or create a 'map' of the existing system. This includes the identification of suppliers, production and service points, warehouses, logistics lanes, and customers that are crucial for ongoing business functionality in terms of their locations, linkages and volumes (Gardner & Cooper, 2003). Understanding the locations and criticality of suppliers, logistics providers, internal operations, and customers is the first step of the creation of viable continuity plan (Barnes, 2001; Bazerman & Watkins, 2004; Elkins et al., 2005; Hillman, 2006; Sheffi, 2005). The scale item topic and literature source are summarized in Table 3.4.

Table 3.4 Summary of Profile the Supply Chain Scale Items

Scale Items	Source
Identify supply chain partners and transit lanes	(Gardner and Cooper, 2003; Elkins et al., 2005; Sheffi and Rice, 2005a; Hillman, 2006)
Create a supply chain 'map'	(Gardner and Cooper, 2003; Hillman, 2006)

3.1.5.2 Risk Identification

Supply chain susceptibilities exist due to time, functional and relationship dependencies (Kleindorfer & Van Wassenhove, 2004). It is therefore necessary for firm's to explicitly consider possible susceptibilities when selecting *new* suppliers and customers as well as in the evaluation of *existing* business relationships (Hillman, 2006). Although the uninterrupted flow of goods and services is often the most obvious concern, there are qualitative issues that should also be considered. The reputation or brand equity of the firm can be impacted by the poor selection of a supply chain associate who may be engaged in questionable or undesirable business practices (Finch, 2004; Spekman & Davis, 2004). The selection and evaluation of potential supply chain partners should consider not only the physical sources of risk, but the behavioral as well. An important part of evaluating the risk of a supplier or customer involves understanding the sources of potential fragility and defining the types of events that could transpire. Zsidisin (2003) provides a summary of event types from the supply side, many of which the firm may also experience in its role as a supplier to its own customers. The scale item topic and literature source are summarized in Table 3.5.

Table 3.5 Summary of Risk Identification Scale Items

Scale Items	Source
Risk as part of selection and evaluation of supply chain partners	(Finch, 2004; Spekman and Davis, 2004; Hillman, 2006)
Identification of partner vulnerabilities	(Zsidisin, 2003; Finch, 2004)
Information from multiple sources	(Zsidisin, 2003; Finch, 2004)

3.1.5.3 Risk Assessment

A common measurement of risk is based upon the probability or frequency of an event and upon the magnitude of the impact should the event occur (Jia et al., 1999; Pich et al., 2002; Weber & Milliman, 1997; Zsidisin et al., 2004). The process of a comprehensive appraisal of risk exposure should identify potential losses, including the likelihood and the quantitative (financial) and qualitative (non-financial) impact that might be the result from a disruptive event, for a comprehensive appraisal of risk exposure (Yates & Stone, 1992). The scale item topic and literature source are summarized in Table 3.6.

Table 3.6 Summary of Risk Assessment Scale Items

Scale Items	Source
Probability	(Weber and Milliman, 1997; Pich et al., 2002; Zsidisin et al., 2004)
Impact	(Yates and Stone, 1992; Weber and Milliman, 1997; Zsidisin et al., 2004)

3.1.5.4 Risk Management Strategies

There are a number of general strategies firm's can use to try to cope with supply chain risk, including accept, manage, share, transfer, reduce, pool or eliminate it altogether (Allaire & Firsirotu, 1989; Chopra & Sodhi, 2004; Hillman, 2006; Johnson, 2001; Rudi, 2001; Sheffi, 2001; Sheffi, 2005). The strategies can be briefly summarized as:

- *Accept*: Determine that there is little to be done to change or manage the frequency or impact of events, and simply carry on with business.
- *Manage*: Firms can manage demand variability with active price adjustments, and collaborative planning, forecasting and replenishment (CPFR); or supply variability with continuous replenishment programs (CRP). Both demand and supply management can be done via activities such as information sharing and collaboration.
- *Share*: Risk sharing can take the form of agreements, often explicitly contained in contracts that include buy-back agreements, revenue sharing, automatic price adjustments, and other such activities.
- *Transfer*: Require other supply chain partners to take on the risk, such as supplier owned inventory, volume or price guarantees, and penalties for lack of performance. It may also include activities such as sub-contracting for additional capacity.
- *Reduce*: Working with supply chain partners to determine sources of vulnerabilities and eliminating those that can be. Those that can't be require the identification of early detection mechanisms so that action can be taken early to mitigate the impact of the impending event.
- *Pool*: On the demand side this may include reduction of product mix, the use of postponement, or use of aggregated and centralized inventory management. On the supply side this may include buyer consortiums or *keiretsu* type structures.
- *Eliminate*: The source of risk has been completely removed to have a zero probability of occurrence or zero impact.

Because it is not feasible to make efforts to reduce or eliminate *all* possible sources of risk, it is important for firms to undertake cost/benefit analysis to determine which types of risk management efforts are most appropriate (Elkins et al., 2005). The scale item topic and literature source are summarized in Table 3.7.

Table 3.7 Summary of Risk Management Strategies Scale Items

Scale Items	Source
Accept	(Sheffi, 2005)
Manage	(Allaire and Firsirotu, 1989; Sheffi, 2005)
Share	(Sheffi, 2005; Hillman, 2006)
Transfer	(Allaire and Firsirotu, 1989; Sheffi, 2005; Hillman, 2006)
Reduce	(Johnson, 2001; Chopra and Sodhi, 2004; Sheffi, 2005; Hillman, 2006)
Pool	(Johnson, 2001; Rudi, 2001; Chopra and Sodhi, 2004; Hillman, 2006)
Eliminate	(Sheffi, 2005; Hillman, 2006)

3.1.5.5 Risk Management Practices

The two primary techniques that firm's can implement to better control risk are redundancy and flexibility (Pich et al., 2002). Redundancy is a form of buffering (Sheffi, 2005), and can take the form of utilizing multiple suppliers for key materials or by holding safety stock of materials (Christopher & Lee, 2004; Zsidisin & Ellram, 2003) and/or of finished goods in order to de-couple supply chain tiers (Hillman, 2006). Redundancy is often used to maintain the capability of normal business functionality, even if a portion of the process fails (Elkins et al., 2005; Rochlin et al., 1998). Flexibility can take the form of having the ability to adjust to changing conditions or the form of standardization (Chopra & Sodhi, 2004; Li et al., 2005; Rice Jr. & Caniato, 2003; Rochlin et al., 1998; Zsidisin & Ellram, 2003). This could consist of specific contractual relationships that include the ability to adjust product mix, timing and volumes of material. It may also include standardization of processes and facility layout so that multiple facilities can meet firm needs, or through cross training of employees (Sheffi, 2005). The implementation of continuity management plans must address both directions from which disruptions can originate: disruptions in the availability of supply from upstream and internal sources, and disruption in the desired demand for goods from downstream sources (Johnson, 2001). The scale item topic and literature source are summarized in Table 3.8.

Table 3.8 Summary of Risk Management Practices Scale Items

Scale Items	Source
Holding safety stock	(Zsidisin and Ellram, 2003; Chopra and Sodhi, 2004; Christopher and Lee, 2004; Hillman, 2006)
Have multiple suppliers	(Zsidisin and Ellram, 2003; Chopra and Sodhi, 2004; Christopher and Lee, 2004; Elkins et al., 2005)
Have multiple facilities	(Elkins et al., 2005; Sheffi, 2005)
Employee cross-training	(Ketokivi and Schroeder, 2004a; Sheffi, 2005)
Standardization	(Chopra and Sodhi, 2004; Sheffi, 2005)
Postponement	(Chopra and Sodhi, 2004; Li et al., 2005)
Flexibility	(Chopra and Sodhi, 2004; Sheffi, 2005)

3.1.5.6 Audit of Risk Management Plans

Once plans are in place, the final step is to test the plans to ensure that they function as expected and that everyone involved in the process has a clear understanding of the activities that must be completed when an events begins to manifest, and what steps must be taken to prevent further damage (Mitroff, 1988). Because a supply chain involves links between autonomous business entities, it is important that the plan is shared with, and reviewed by, key partners both upstream and downstream, as well as within the firm (Grabowski & Roberts, 1997). This includes understanding the signs that would trigger activation of the risk response plan, 'fire drills' to test plans, and modification of plans as the supply chain and environment changes (Elkins et al., 2005; Elsinger et al., 2006; Hillman, 2006). Testing of the plan should take place *before* an event occurs to ensure that critical information is included and appropriate responses and activities are well understood (Rodetis, 1999). Because the network in which a supply chain is imbedded is subject to nearly constant change, it is important to reexamine the entire process, beginning with periodically updating the supply chain profile and map. This is necessary as suppliers, customers, and competitors enter or leave the market and as the market environment is altered due to changing currency exchange rates, government regulation, consumer preferences, technological changes, and material availability, firms must regularly re-examine their supply chain to identify changes that may require adjustments to previous plans (Bielski, 2003; Sheffi, 2005). The scale item topic and literature source are summarized in Table 3.9.

Table 3.9 Summary of Audit Risk Management Plans Scale Items

Scale Items	Source
Review plans with key players	(Mitroff, 1988; Grabowski and Roberts, 1997)
Test plans ('fire drills')	(Elkins et al., 2005; Elsinger et al., 2006; Hillman, 2006)
Periodic plan review	(Bielski, 2003; Sheffi, 2005)

3.1.6 Disruptive Events

Events that could disrupt the supply chain can come from two generic directions; from either outside or inside the supply chain. Events from inside the supply chain can be further broken down into three directions, for a total of 4 directions from which a firm can experience a disruption. Events that are generated from outside the supply chain, can be called 1) '*environment events*' (economic or technological changes, competitor actions, etc.); or events can be generated by actions that occur within the supply chain from 2) *upstream events* (late deliveries, lack of material or service availability, etc.); 3) *internal events* (lack of adequate capacity, poor processes performance or output, etc.); and 4) from *downstream events* (changes in demand mix, timing or volume requested) (Chen & Paulraj, 2004; Davis, 1993; Sheffi, 2005; Sodhi, 2005; Zsidisin, 2003).

Environment events represent those incidents that originate from actions or incidents outside of the supply chain in the larger business environment and over which supply chain members may have little or no control (Christopher & Lee, 2004). These can include governmental regulation, competitor actions, changes in the economic environment (Zsidisin, Ragatz, & Melnyk, 2005; Zsidisin et al., 2005b), the number of qualified suppliers, technological changes (Chen & Paulraj, 2004), copyright or patent infringement, and counterfeiting

Upstream events are disruptions that impact the flow of goods and services *into* the organization. They can be either an inability of suppliers to meet the firm's needs or due to a logistical problem where in-bound materials may be lost, damaged or delayed (Chopra & Sodhi, 2004). These incidents may be due to the actions of a firm's direct supplier, or may be the result of an event that occurs further upstream and that impacts the chain of supply that feeds the firm (Sheffi, 2005). The inability of the supplier to meet the needs of the firm could be caused by capacity issues related to volume, mix or timing of demand or to technological changes (Zsidisin, 2003). Firms may be impacted by global shortages of some material as demand increases from developing countries, such as India or China (Hillman, 2006) or due to the time lag needed to build plants to increase capacity (Sheffi, 2005). Although there is a tendency to consider the inbound supply chain as consisting of materials, it does include important services such as the continuous supply of utilities such as power and water; an interruption in the flow of these services can also have a serious impact on supply chain performance.

Disruptive events that are internal to the firm may occur when there is a problem with output volume or quality levels that inhibits the ability to meet demand (Chopra & Sodhi, 2004), due to situations such as a capacity shortage, equipment or process failure, or poor quality performance. It is also possible for a firm to experience a disruption in internal processes due to personnel events such as a labor strike, widespread illness, or a number of employees leaving the company simultaneously (Sheffi, 2005). It may be possible for the firm to resolve the situation before the customer becomes aware of a problem. However, a more serious case is when the customer also is impacted by the issue the firm is experiencing.

Downstream, or demand side, events are generated by customers, such as dramatic changes in requested product mix, volume or timing (Chopra & Sodhi, 2004) that the firm may have difficulty responding to. Customer needs are often dynamic, requiring supply chains to adjust to meet changes in demand (Chen & Paulraj, 2004). Both large increases and decreases in volume, as well as changes in timing or the mix of demand, can have a detrimental impact on the firm. The scale item topic and literature source are summarized in Table 3.10.

Table 3.10 Summary of Disruptive Events Scale Items

Scale Items	Source
Environment Events	(Zsidisin, 2003; Chen and Paulraj, 2004; Zsidisin et al., 2005b)
Upstream Events	(Zsidisin, 2003; Chopra and Sodhi, 2004; Sheffi, 2005)
Internal Events	(Chopra and Sodhi, 2004; Sheffi, 2005)
Downstream Events	(Chen and Paulraj, 2004; Chopra and Sodhi, 2004; Sheffi, 2005)

3.1.7 Firm Performance

Asking direct questions about firm performance may lead to high non-response bias (Boyer & Verma, 2000), especially when the queried individual either does not know the answer or is not comfortable sharing potentially sensitive information. Therefore, researchers often ask performance related questions in an indirect way. These are termed quasi-perceptual measures, where the content is exactly defined (e.g. market share or sales in units) but a relative unit of measurement (e.g. a 1-7 'compared to industry performance' scale) allows the informant to use their discretion in comparing their firm to their competitors (Dröge, Jayaram, & Vickery, 2004; Ketokivi & Schroeder, 2004b; Vickery et al., 1993) and does not involve revealing possibly proprietary information. The performance measures used here are built upon quasi-perceptual measures as used in other relevant studies (Anand & Ward, 2004; Beamon, 1999; Boyer, 1999; Randall & Ulrich, 2001; Ward & Duray, 2000; Wisner, 2003). While detailed performance measures specific to supply chain performance, such as on-time delivery or fill rates, have been used quite often (Griffis et al., 2004), the measures used here are meant to capture the general performance of the firm. The assumption is that the ability to effectively plan for supply chain disruptions will have a positive impact on the firm. The scale item topic and literature source are summarized in Table 3.11.

Table 3.11 Summary of Firm Performance Scale Items

Scale Items	Source
Sales	(Beamon, 1999; Anand and Ward, 2004)
Profitability	(Boyer et al., 1997; Beamon, 1999)
Overall competitive position	(Wisner, 2003)
Return on assets (ROA)	(Randall and Ulrich, 2001)
Return on sales (ROS)	(Randall and Ulrich, 2001)

3.1.8 Demographic Information

Respondents are asked general demographic questions about their functional job responsibility and level with in the firm, the industry the company operates in, and the size of the company in terms of revenue and number of employees. These questions will be used to examine the response constituency for possible group comparison. Demographic specifics are not part of the model or the specific hypotheses to be tested, but may be useful for examination of response by group, such as large and small firms.

3.2 *Hypotheses*

The following section discusses the hypotheses to be tested, based upon the initial research questions, a review of the literature and the proposed model. The influence of supply chain complexity and dependency on risk management planning and the occurrence of disruptions are grounded in Normal Accident Theory. The influence of the use of effective business practices and a concern for supply chain disruptions on risk management planning, the occurrence of disruptions and firm performance are grounded in High Reliability Theory. The relationships between risk management planning, the occurrence of disruption, and firm performance are based on the review of operations and supply chain management literature.

3.2.1 Grounded in Normal Accident Theory

The complexity of the system and environment in which a supply chain operates may influence planning, as firms try to control their supply chain risk for improved business continuity and firm performance. Practices such as outsourcing and globalization have created supply chains that are more complex and posses higher levels of interaction uncertainty, creating more complex and therefore more risky systems (Sheffi & Rice Jr., 2005). This is especially true as supply chains become longer and more dispersed with increased reliance on other supply chain members (Bowersox et al., 2000; Cavinato, 2004; Zsidisin et al., 2000).

Using Normal Accident Theory as a foundation, the greater the complexity of the system, the greater the likelihood of a system disruption. As the number of individual entities that make up a specific supply chain increases, the greater the cumulative probability that an event will occur in any single part of the chain that will impact other supply chain members. Yet firms have difficulty knowing the activities that occur beyond their first-tier partners (Svensson, 2004). It is therefore expected that when firms are participants in supply chains that are more complex, there will be a greater need to engage in continuity planning to better mitigate the occurrence of disruptive events on both a large scale ('normal accidents') and on a smaller scale (Craighead et al., 2007).

Supply chain vulnerability is related to the multiple forms of dependency that firms have with other supply chain members (Svensson, 2002a) and the ambiguity of the system due to a lack of visibility (Peck, 2005; Svensson, 2004) that may allow disruptions to business operations and the flow of goods and services. Organizations that are more tightly linked to other members of the supply chain network are more susceptible when a problem occurs with another supply chain node (Hallikas et al., 2004). There is strong empirical evidence that such disturbances can have substantial negative short and long term quantitative and qualitative effects that firms want to avoid (Hendricks & Singhal, 2005a; Lewis, 2003). In addition, there is evidence that handling disruptions well can contribute to a reduction in negative results and that there are also positive impacts that allow the firm to become more competitive after a disruption (Chopra & Sodhi, 2004; Norrman & Jansson, 2004). The effective management of supply chain disruptions represent a significant business challenge, and one that senior management is increasing recognizing as being of strategic importance (Kleindorfer & Van Wassenhove, 2004; Weick & Sutcliffe, 2001). Therefore, it is expected that perceptions of dependency will be positively related to higher levels of comprehensive planning for business continuity.

H1a: *Higher levels of perceived supply chain complexity are positively associated with higher levels of continuity planning*

H1b: *Higher levels of perceived supply chain dependency are positively associated with higher levels of continuity planning*

H2a: *Higher levels of perceived supply chain complexity are positively associated with greater frequency and impact of disruptive events*

H2b: *Higher levels of perceived supply chain dependency are positively associated with greater frequency and impact of disruptive events*

3.2.2 Grounded in High Reliability Theory

In a competitive business environment, firms must successfully implement effective practices for improved firm performance, and there is ample empirical evidence of this linkage. Using a cumulative capabilities view, as firms engage in practices that improve firm performance, there are likely to be multiple positive outcomes from the effective practices (Dostaler, 2001). It has also been argued that business continuity planning is a subset of effective practices (Hendricks & Singhal, 2005b). Using High Reliability Theory as a foundation, firms that are more 'mindful' of the need to improve reliability place a greater emphasis on the proactive management of supply chain risk (Weick & Sutcliffe, 2001). As part of mindful practices, there is ongoing environmental scanning and engagement in continuous improvement efforts. In addition, there is some evidence that the market responds favorably to implementation of supply chain management practices that are considered to be effective or 'best' (Filbeck et al., 2005). Therefore, the following hypotheses will be tested:

H3a: *Higher levels of the use of effective practices is positively associated with higher levels of continuity planning*

H3b: *Higher levels of concern for disruptions is positively associated with higher levels of continuity planning*

H4a: *Higher levels of the use of effective practices is positively associated with firm performance*

H4b: *Higher levels of concern for disruptions is positively associated with firm performance*

H5a: *Higher levels of the use of effective practices is negatively associated with disruptive events*

H5b: *Higher levels of concern for disruptions is negatively associated with disruptive events*

3.2.3 Impact of Risk Management Planning

There is evidence of the negative financial impact of supply chain disruptions, as well as possible negative qualitative impacts (Chopra & Sodhi, 2004; Hendricks & Singhal, 2005a; Hendricks & Singhal, 2005b; Hicks, 2002; Knight & Pretty, 1998). There can be increased costs from expediting, excess material, idle capacity, and rework (Zsidisin et al., 2004). If it is accepted that disruptive events contribute to poor firm performance, it is possible that the avoidance of such disturbances would result in better firm performance. It can therefore be expected that firms that are engaged in supply chain continuity planning may experience a reduced level of frequency and impact of disruptive events and exhibit higher firm performance (Craighead et al., 2007).

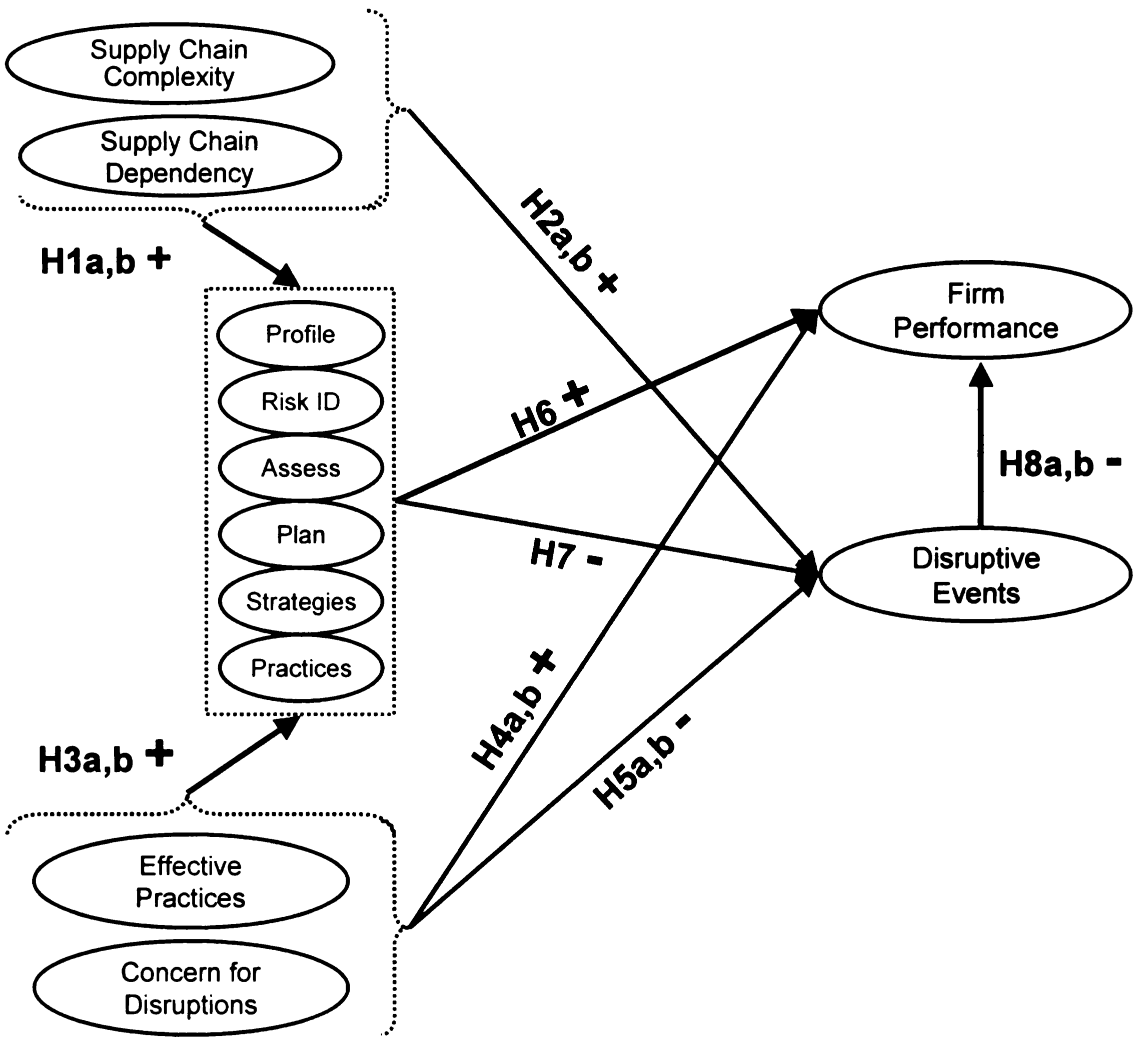
H6: *Higher levels of continuity planning are positively associated with higher levels of firm performance*

H7: *Higher levels of continuity planning are negatively associated with disruptive events*

H8: *More frequent and larger magnitude disruptions are negatively associated with firm performance*

A summary of the hypotheses in the proposed model are shown in Figure 3.2.

Figure 3.2 Model with Hypotheses



3.3 *Scale Development and Validation*

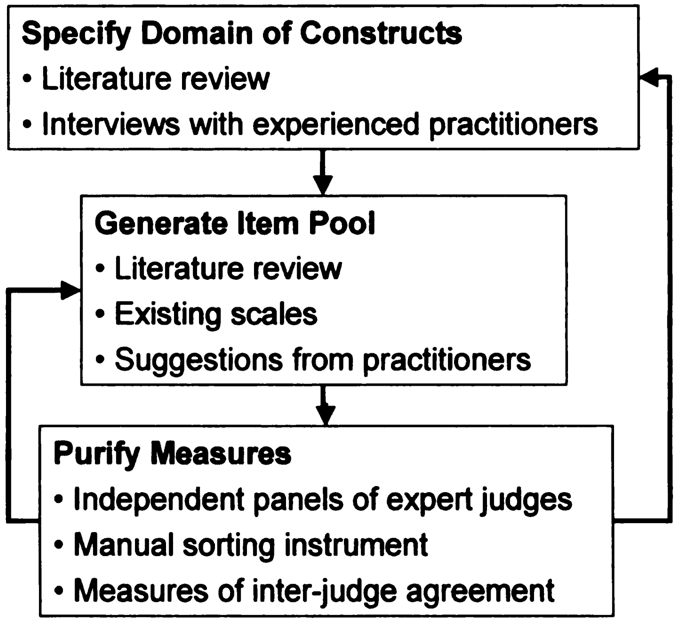
The determination of constructs, the creation of their respective scale items and their validation should be a rigorous, multi-step process. The selection and development of constructs should be based upon the theory utilized and the hypotheses to be tested (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990) as well as on existing literature (Menor & Roth, 2007). Statistical validation occurs during the data analysis stage; however it is helpful to pre-examine the constructs, the scales, and the survey instrument *before* data collection to eliminate as many barriers to validation as possible. A three step process for the examination of validity is outlined by O'Leary-Kelly and Vokurka (1998). First, before data collection occurs, assessment of *content validity* is undertaken to demonstrate that the scale items are linked to their parent constructs both logically and theoretically. The second validity test involves examining the data to determine *construct validity* or the empirical assessment of the indicators for unidimensionality, reliability, and validity. Finally, the *nomological validity* is used to determine the structural relationships between constructs. The process to be used before data collection is discussed in the following sections, and the process utilized after data collection will be discussed in the Data Analysis chapter.

Although assessment of content validity is a single step in the overall validity testing process, scale development for content validity is itself a three-stage process. The three-stage scale development process is based upon Churchill (1979) as utilized by Stratman and Roth (2002) who provide a compressed overview (see Figure 3.3) and must occur before data collection. Both of these works provide guidelines for rigorous and systematic construction of scales for scientific investigation. During the first stage, multi-item scales consisting of at least three items are used to asses the constructs. Multi-item scales are necessary to adequately capture each of the constructs which measure multifaceted business processes. Because supply chain research occurs in organizations of different sizes and in different industries, it is possible that there may be differences in the applied definitions of constructs or in terminology need in scale development (Hensley, 1999). In addition, because the scale items are based upon the judgment of the respondent, multiple measures are needed to improve convergence (Perreault & Leigh, 1989).

However, it has also been shown that there are costs associated with asking respondents to answer items that appear to be redundant or when the construct appears to have too many questions; respondents tend to become aggravated and may not read and respond to each question resulting in responses that may not be accurate reflections of the survey respondent. Therefore, researchers must carefully balance the need for multiple items to appropriately measure complex concepts while also considering the small incremental information obtained with each additional question when weighed against the possibility of discouraging respondents and compromising measurement reliability (Drolet & Morrison, 2001).

The specific constructs utilized in this study are based upon theory, a review of the literature and input of industry expert practitioners (Menor & Roth, 2007). With this input, scale items were created to support the defined constructs (Hensley, 1999).

Figure 3.3 Scale Development Process



Adapted from Churchill (1979) and Stratman and Roth (2002)

Initial pre-testing of the scale items requires that they be purified in order to eliminate any obvious sources of measurement error and to achieve substantive ('face') validity. An approach that is especially appropriate for new scale development (Hensley, 1999) uses a manual sorting technique to pre-establish tentative unidimensionality of the constructs and scale reliability and validity (Hinkin, 1995; Li et al., 2005; Moore & Benbasat, 1991; Stratman & Roth, 2002). This in an iterative process where independent judges are given short descriptions of the constructs and a randomized list of all of the scale items as generated from the literature and modified from the previous sorting round. In each round, the judges are asked to assign each of the scale items to what they believe to be the appropriate construct. Modification of scale items occurs based upon the success or failure of the assignment of individual items to the intended parent construct. As part of this process, the judges will also be asked to suggest additional items that may better capture the construct than those already created, or to eliminate items that appear to be redundant or inappropriate.

It is expected that when appropriate scales are developed that proper sorting of the items into the intended constructs would occur at a greater rate than would occur due to chance. Pre-test scale reliability based upon the judgments from the manual sorting of the instrument can be done utilizing different methods. One method, as outlined by Moore and Benbasat (1991) simply examines the number of correct scale item to construct placements. The higher the percentage of correctly placed items, the higher the degree of inter-judge agreement, although there is no established guideline of an 'acceptable' ratio of placements (Li et al., 2005). Perreault and Leigh (1989) advocate a method that measures the observed proportion of agreement between judges. An advantage of this method is that the number of defined categories is included in the calculations, eliminating the conservative results found in earlier measures (Rust & Cooil, 1994).

Another issue that can impact the validity of survey responses is the problem of 'yea-saying', where respondents like to answer 'yes' or 'agree' with all responses. This issue can be reduced by rewording questions so that the direction of some questions varies. Questions that are positive or negative in nature should be interspersed in a random nature throughout the questionnaire. Reversing some questions requires respondents to answer some questions with a 'yes' or to 'agree', and to answer others with a 'no' or to 'disagree', helping to reduce yea-saying bias (Rosenthal & Rosnow, 1991).

Yea-saying is different from social desirability. Social desirability is a phenomenon where self-reporting respondents prefer to answer questions in a way that allows them to present themselves in a favorable light. One way that researchers attempt to circumvent this type of response is to offer the respondents anonymity and to keep responses confidential. However, in situations where respondents were not initially concerned with confidentiality, explicitly mentioning it may sensitize them to this issue and raise their suspicions regarding the survey and how it could be used (Rosenthal & Rosnow, 1991). Therefore, in this research, there will be an explicit statement that explains how the findings will be used and that individual responses will not be shared, with the results reported only in aggregate.

Most of the scale items will require the respondents to answer based upon a 7-point attitude scale. These items are primarily anchored by “strongly agree” and “strongly disagree” with a neutral mid-point. There are also some questions that ask respondents to estimate the frequency and impact of disruptive events that have occurred in the previous 12 months. A list of the scale items and the associated construct is contained in Appendix A. Although the concepts embedded within the constructs and the resulting scale items are based upon existing literature and theory, the format and wording of the questions as placed within the questionnaire are based upon the guidelines for question writing and survey construction as outlined by Dillman (2007) and elucidated in the following chapter.

4. RESEARCH METHODOLOGY

This chapter outlines the scientific research design and methodology used in this study. Research that is conducted in a rigorous and scientific manner provides a strong foundation for study replication and generalizability of findings. The remainder of this chapter outlines the use of grounded theory methodology and the research design employed. Description is provided of the organizational sponsorship, the target sample, the process used to gather data from survey respondents, and the data analysis techniques utilized.

4.1 *Grounded Theory Method*

The systematic approach for empirical research in operations management as detailed by of Flynn, Sakakibara, Schroeder, Bates and Flynn (1990) and Handfield and Melnyk (1998) serves as the basis for the process followed here. These studies represent key works that provide thorough and methodical guidelines for conducting scientific research in supply chain management. The prescribed steps include:

1) Establishment of a theoretical foundation
2) Selection of an appropriate research design in keeping with the research questions
3) Use of an appropriate data collection method with careful consideration of the advantages and drawbacks of possible choices
4) Implementation including sample selection, instrument design and testing, and data gathering
5) Data analysis using predetermined methodologies
6) Summarization of the results for eventual publication for knowledge sharing and building.

This study utilizes a grounded theory approach (Glaser & Strauss, 1967), which is the general view that research begins with a strong theoretical foundation to examine data gathered from the field for the refinement of theoretical views based on rigorous analysis of the data leading to the support, enhancement or modification of existing theory. This approach is well suited to situations that rely on a social system where human behavior is a major component of the business environment under study, and thus of the research questions. It is also appropriate when qualitative research techniques are employed.

The grounded theory approach is utilized here for three reasons. First, the constructs in the proposed model have limited, or no, specific usage in previously published research, have not previously been well defined, and do not have generally accepted measurement constructs. Second, given the lack of prior examination of the constructs, there is a corresponding lack of knowledge of the relationships among the constructs, as well as a lack of specific scale items to capture the constructs. Third, there is a need for empirical data gathering to begin to understand this area in order to formulate observation into higher-level generalizations and theory development (Meredith, 1998; Wacker, 1998; Forza, 2002;; Rungtusanatham, Choi, Hollingworth, Wu, & Forza, 2003).

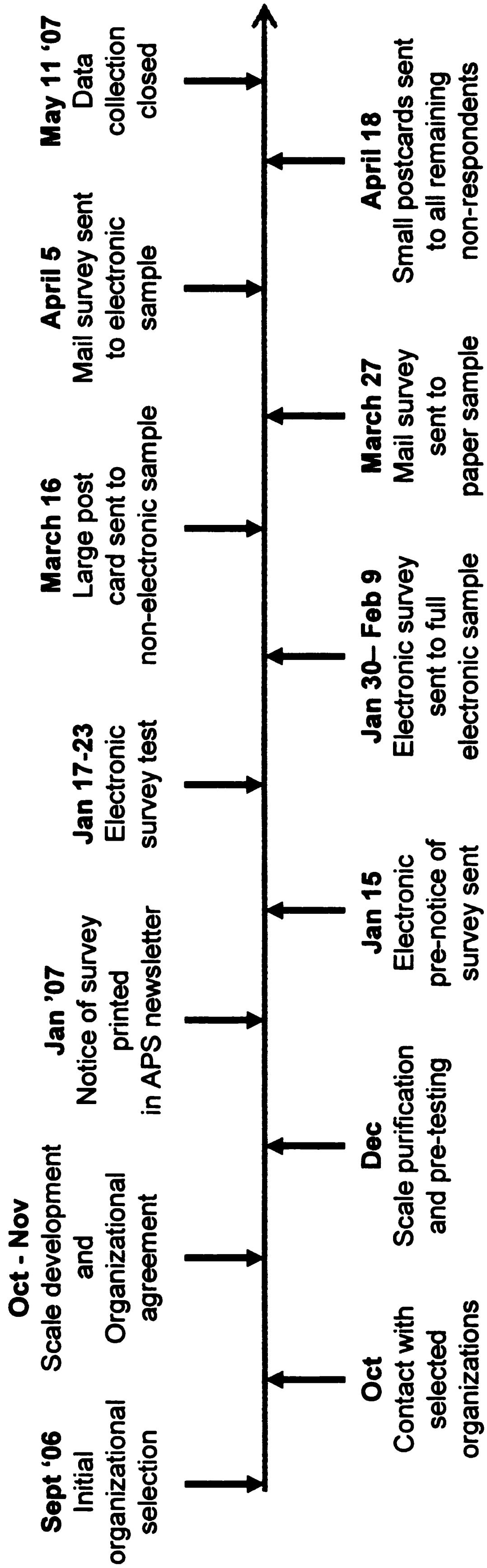
4.2 *Research Design*

Following the grounded theory method, the first step is to establish a theoretical foundation described in Chapter 2 Literature Review and Chapter 3 Model Development. Next, an appropriate research methodology should be selected based on theory and the research questions. Flynn et al. (1990) and Handfield and Melnyk (1998) provide guidelines for a systematic process to conduct empirical research in operations management. The theoretical foundation of this study is grounded in Normal Accident Theory and High Reliability Theory. Use of these theories from the management literature supports the need, and call, to utilize and incorporate theory from other disciplines to more accurately reflect the cross-functional nature of operations and supply chain management (Meredith, Rauri, Amoako-Gyampah, & Kaplan, 1989), as well as the more recent call to incorporate more behavioral theory in operations management research (Bendoly, 2006). These theories have not been well researched within a supply chain, and therefore provide an opportunity to expand our understanding of these theories and their application in more diverse contexts.

Given the exploratory nature of the research, a survey is an appropriate method for gathering data from a broad range of individuals for increased generalizability. The use of data from actual practitioners in a supply chain reflects the applied nature of operations and supply chain management and can help to close the gap between theory and practice (Flynn et al., 1990). The survey used here gathered data from a broad range of individuals, since there was no *a priori* intention to specifically examine particular types of disruptions, risk management planning practices, or firm responses to disruptions. Therefore, study participants did not consist of a pre-selected group of firms or individuals, but from a heterogeneous sample that has likely experienced a wide range of disruptive events and that engage in varying levels of supply chain risk management planning. The intention is to formalize research in the area of supply chain risk management with a strong theoretical base, and to better understand the current state of planning that firms are engaged in to reduce the likelihood and impact of disruptive events. Individuals will be asked relevant questions about the activities and performance of their own firm, and about activities between their firm and their customers and suppliers; therefore, the unit of analysis in this study is the corporation as it manages risk both within its supply chain consisting of its own operations and between its suppliers and customers, and from sources external to the supply chain.

The next steps, identification of appropriate data sources and the actual data collection, proved to be the most time consuming portion of this study. The timeline for all of the activities from initial identification of potential organizations for sampling through the closure of the survey are detailed in Figure 4.1. The process of selecting and obtaining a data source is detailed in section *4.3 Organizational Sponsorship*; sample selection and the survey implementation process are detailed in section *4.4 Data Collection*. The final steps in the Flynn et al. (1990) process, the analysis of the data for reliability and validity, are discussed in *Chapter 5 Reliability and Validity*.

Figure 4.1 Data Collection timeline



4.3 *Organizational sponsorship*

Data collection from appropriate data sources is necessary to obtain information to adequately test hypotheses and increase generalizability of the findings. The data source identified for this study was individuals involved in the management of a portion of the supply chain of their organization. This is an appropriate choice because professionals involved in the management of a firm's supply chain are quickly impacted by disruptions to supply and demand when they must adjust operational plans to accommodate changes to supply and demand plans. Because of their immediate and important role in responding to disruptions, they may frequently be involved in supply chain risk management and continuity planning.

One approach for contacting such individuals is through the use of one of the professional organizations that serve a variety of individuals working in different functional fields. Under the umbrella of supply chain management, such organizations include those serving individuals in supply management (purchasing or procurement), logistics (transportation or warehousing), or operations management (production planning, manufacturing engineering, etc.) There are multiple organizations of varying sizes and specializations that target each of these general supply chain areas. A list of ten organizations was initially selected based on two criteria: 1) each needed to have a large enough membership base to provide an adequate sample size and 2) having members that would likely have the appropriate knowledge and experience in the management and performance of a supply chain to be able to suitably responded to the survey questionnaire. The ten identified organizations were:

- American Management Association (AMA)
- American Purchasing Society (APS)
- Business Continuity Planners Association (BCPA)
- Business Continuity Institute (BCI)
- Council of Supply Chain Management Professionals (CSCMP)
- International Customer Service Association (ICSA)
- Project Management Institute (PMI)
- Society of Manufacturing Engineers (SME)
- SOLE - The International Society of Logistics
- Warehouse Education and Research Council (WERC)

This list was reviewed by academicians with knowledge and expertise regarding the specific and differing characteristics of these groups. Several were removed because of particular limitations - either it was unlikely that the organization would wish to participate in this study or that the membership was not as appropriate a target sample as originally anticipated. Contacting the short list of organizations required a great deal of time and effort. It was sometimes difficult to get into direct touch with the appropriate individual responsible for coordinating research projects within the organization. This often required multiple electronic and telephone communiqués to reach the correct person and discuss the study. After much explanation of the study and several rejections for participation, two organizations agreed to participate in the study. However, as the time for the survey approached, one of the organizations (BCI) pulled out of the study, leaving the American Purchasing Society as the single organizational sponsor willing to participate that possessed an appropriate membership base.

The American Purchasing Society (APS) serves a large member base of over 1,600 individuals; as well other professionals who are not members but still utilize its services. The description of the APS from their website is:

> "The American Purchasing Society is an organization of buyers, purchasing managers, executives, and others interested in the purchasing profession. We were founded in 1969 and have members from every state and 28 countries worldwide. Our objective is to improve the business purchasing function through education and our certification program. We were the first organization to establish a certification program for professional buyers and purchasing managers and our Certified Purchasing Professional (CPP) program is unique because we not only measure the competence of the applicants through a written examination, but we conduct reference checks to evaluate the applicant's business reputation. The American Purchasing Society's educational objectives are achieved through training programs and our own educational publications of interest to business and the purchasing community." (American Purchasing Society)

In addition to its certification program, it offers numerous courses covering topics such as negotiation skills, purchasing law, cost and price analysis, supplier selection, and other professional skill and knowledge enhancement classes. They also conduct surveys of their membership to obtain current information on professional trends and best practices. The APS is an organization committed to the continuing education of its members and to industry, and therefore an appropriate partner for the data needed for this study.

The American Purchasing Society agreed in late 2006 to participate in and champion the study. Their support was important beyond simply providing contact information was important because by endorsing and supporting the study, survey recipients may perceive greater relevance, which lends additional encouragement to participate and therefore increase the response rate (Aaker, Day, & Kumar, 1998; Frohlich, 2002). APS management expressed enthusiasm for the study, providing evidence that the topic is seen as relevant and of intrinsic interest to their membership. In addition, APS allowed use of their logo and the name and signature of the APS president on all correspondence with the target sample. In exchange for providing their support, the sponsoring organization was promised a summary report of findings.

Although the American Purchasing Society initially agreed to participate in the study, a great deal of trust building had to occur before full access was granted to all of the data needed for this study. Unfortunately, the APS has participated in studies in the past where promises made by the researchers were not kept. Thus, there were several weeks of negotiation needed to obtain their agreement. As part of this process, coupled with a desire to protect their members' privacy, the initial contact information for APS individuals did not include company name or job title information. However, after a large number of people responded quickly to the survey, combined with the encouraging comments written by respondents on the survey, the APS became more enthusiastic and agreed to provide all the desired contact information.

The APS originally provided contact information, including both e-mail and traditional addresses, when available for their 1,674 members and several weeks later for an additional 3,764 individuals who had recently contacted APS but who were not members (for a total of 5,438). Contact information for some individuals was limited to only name and e-mail information. After the survey process had begun with responses that indicated the respondents were very interested in the study APS agreed to provide additional information, including job title, organization name and addresses. A willingness to provide more information is a function of both the evidence of interest by the membership in the study, and the continued trust building occurring between the APS and the researcher. The additional contact information would have been useful to have *a priori* so that individuals with explicit characteristics that made them unsuitable for this study (e.g. inappropriate industry or job title) could have been eliminated from the contact data base. The use of this additional *post hoc* data will be discussed in greater detail later.

The large data base of individuals provided by APS provides a sufficient and appropriate target sample to adequately gather information on the constructs to be examined and to provide adequate power for data analysis. Comparable empirical studies have used similar target groups (Krause & Ellram, 1997; Melnyk, Sroufe, Calantone, & Montabon, 2003; Zsidisin & Ellram, 2003). A contact sample of supply management professionals is considered appropriate because these managers are often involved in supply chain risk management and continuity planning. In addition, supply chain disruptions impact the flow of goods through the firm, and procurement professionals are in a position to quickly see evidence of either a shortage or a build up of material that would be the result of disrupted flows.

4.4 *Data Collection*

4.4.1 Target Sample

The sample selected for data collection represents supply chain professionals who match the *a priori* objective of querying individuals working in heterogeneous supply chains. As such, there was a concerted effort to eliminate members from the full database that identified themselves as consultants or academics, individuals from organizations categorized as service, consultancy, educational, and other potential respondents that are undesirable for inclusion in this study. The careful qualification of participants provides a more appropriate sample for the study, and ensures that the general topic of the research is of interest to the survey participants (Aaker et al., 1998). Of the original 5,438 individuals for which the APS provided contact information, 2,239 where identified as inappropriate for this study, after the additional contact information was provided. Because this data was not available in the initial database supplied by the APS, elimination of some individuals deemed as inappropriate for the study occurred *post hoc* (Fredendall, Hopkins, & Bhonsle, 2005). This *post hoc* approach is less than ideal because of the effort wasted in obtaining responses that were unusable for this specific study (although still of use for the APS), but rigorous in the sense that while reducing the sample size, it provides much greater reliability of the final response data, findings and conclusions.

In examining the information contained in the full-data contact list, several criteria were developed to identify individuals that were not appropriate for inclusion in this study, such as job title or organization name. Individuals were removed based upon a job title that indicates a potential for limited knowledge of the supply chain, their firm's supply chain strategy or of firm performance (e.g. purchasing coordinator, administrator, expediter, consultant, etc.) (Huber & Power, 1985). Individuals were also removed based upon the name of the organization they were affiliated with (e.g. City of XXX, other government organizations, educational institutions, etc.). The remaining individuals made up the qualified sample consisting of 3,199 (58.8% of original list) individuals. Because the initial survey contact was made before it was possible to screen out unqualified individuals, any response from this category of respondent was also removed, resulting in the elimination of 22 responses from the early stages of data collection. The use of *post hoc* elimination of responses trades some statistical power for greater reliability and validity.

Required sample size is a function of the power needed to detect and reject a poor model (MacCallum, Browne, & Sugawara, 1996; McQuitty, 2004). A sample size that is too small may result in estimates of parameters that are too low, bias in some model goodness of fit statistics, and increased uncertainty in replication and statistical power (Shah & Goldstein, 2006). A larger number of sample respondents provide more flexibility in the types of analysis that can be done, including the ability to potentially compare groups of respondents. Therefore, an *a priori* design consideration was obtaining a suitable sample which provides an adequate number of responses. This is a function of the size of the contact sample and the anticipated response rate. It is important to also recognize that some responses received may be unusable for a number of reasons, including having the respondent fail to complete the entire questionnaire, missing data within the response, or outliers. The possibility of the occurrence of any or all of these issues requires some buffer to be designed into the target sample so that the elimination of unusable cases would still leave an adequate response sample size.

However, there can be difficulty in obtaining a large percentage of responses from those requested to participate. There is a perception that many potential respondents have reached a saturation point, where individuals are asked so often to participate in a study or take a survey that they are simply no longer interested (Bickart & Schmittlein, 1999). The reduction in response rates is especially applicable to samples that are drawn from frequently utilized sources, such as the major professional organizations like the Council of Supply Chain Management Professional (formerly Council of Logistics Management) (Griffis, Goldsby, & Cooper, 2003) or the Institute for Supply Management (ISM). In this light the relative lack of use of the APS is one of its major positive attributes within the context of this study. These managers have been contacted less frequently through their organization contact information to participate in studies, thus are likely to be more responsive to this study. In addition, there is evidence that response rates in published supply chain research has been decreasing to levels as low as 4.23%, especially for surveys which use contact information from frequently targeted organizations (Griffis et al., 2003; Faught, W., & Whitten, 2004). Concerns with low response rates can be mitigated with careful selection of survey respondents, rigorous methodology and diligent follow-up (Boyer & Verma, 2000; Frohlich, 2002; Dillman, 2007). The qualified sample used in this study is large enough to provide the variety of potential respondents needed and even with a relatively lower response rate will still allow for adequate power to carry out the desired statistical analysis.

4.4.2 Questionnaire Design

The guidelines of Dillman (2007) serve as the template for the 1) construction of the questionnaire, 2) pre-testing and 3) data collection implementation. Careful design of the physical survey instrument has a significant impact on the ability to adequately capture the constructs being studied, as well as on response rates. Pre-testing is an important part of survey research, and when the constructs have had little direct previous usage, it becomes even more important. Pretesting is done to eliminate problems associated with potential confusion in question wording and format, errors in spelling or other typos, and in the general understandability of the questionnaire. Pilot testing will assist in exposing possible flaws in question wording, terminology or meaning before full survey implementation (Flynn et al., 1990;Dillman, 2007).

Having a sufficient portion of the targeted sample respond to the survey instrument is critical for increased validity and generalizability of the findings (Flynn et al., 1990). The process of designing the survey is multifaceted and must be carefully managed to adequately capture the concepts under study and to encourage a high response rate. There are several elements that have been found to have the greatest influence on actual survey participation (Aaker et al., 1998; Frohlich, 2002; Dillman, 2007). The specific items and a brief comment on how they were addressed *a priori* to survey implementation are shown in Table 4.1 with a detailed discussion following in the next sections.

Table 4.1 Summary of Survey Response Rate Issues

Issue	How addressed
Perceived amount of work required (related to survey length) and ease of response	Survey questions limited to 92 items, six demographic questions, and three optional open-ended questions. Survey available on line via a custom web site link, or paper survey sent with pre-addressed and postage paid return envelope.
Intrinsic interest in the topic	The sponsoring organization expressed interest and support for the study, including 'championing' the research.
Credibility of the sponsoring organization	APS is highly respected in supply chain management and possesses members with appropriate skills and knowledge.
Level of induced motivation (the incentives used)	Incentives were 1) a summary copy of the study results; 2) a copy of a relevant supply chain risk management article; and 3) entry into a drawing for a small monetary reward.
Multiple contacts using mixed media	At least four and up to six contacts via electronic and paper mediums. Posting in APS newsletter and direct contact sent electronically and paper via traditional mail, including post cards with the survey web-link address and a paper copy of the survey.
Personalization	All messages addressed with personal salutation consisting of both first and last name and electronic copies of both APS president and researcher signatures.

4.4.2.1 Construction of the Survey

There are several key elements for increasing response rate outlined by Aaker (1998) and Dillman (2007) that should be undertaken in the construction of the survey. First, the questionnaire should be respondent-friendly to decrease the time and effort required for respondents to complete the survey. This would include an attractive and easy to follow layout of the survey with questions that are clear and easily comprehensible, as well as easy to respond to (a copy of the survey, including the format as sent to the target sample is included in Appendix A. The number of questions asked will also influence respondent's perceptions of the ease of completing the survey. The questionnaire used here consists of 92 questions (plus six for demographics and three optional open ended) meant to gather information about perceptions of supply chain complexity, uncertainty and dependency; effective practices and concern for disruptions; aspects of supply chain continuity planning; firm performance; and disruptive events. Gathering demographic information will help to ensure the most accurate information regarding the individual's status with in the firm and about the firm. There are also three optional, open-ended questions which allow respondents to provide information on 'best' practices and to share their opinions on supply chain risk management issues.

The length of the survey seeks to strike a balance between parsimony and comprehensively gathering information by containing a sufficient number of questions to adequately capture the constructs being examined while not becoming so long that participants are unwilling to complete (or even begin) the full questionnaire. Longer questionnaires often result in a reduced response rate, with each additional question potentially reducing the number of responses by 0.05% (Heberlein & Baumgartner, 1978). However, if the survey is too short, response rates may also be reduced because respondents do not perceive that the survey is a serious attempt to gather information (Adams & Gale, 1982). Insufficient information may also impede the ability to adequately examine the concepts under study, reducing the validity and reliability of the findings.

4.4.2.2 Survey Pre-testing

As part of the initial pre-testing process, several individuals were asked to complete the survey and time themselves to determine the average length of time need to respond to the questionnaire. Individuals were selected primarily from other doctoral students and several supply chain professionals who were not included in the APS contact database. Because the survey was to be distributed both electronically and in paper form, the survey was pre-tested using both forms. Ten individuals completed the survey, and reported a mean time of 14.5 minutes to complete the survey, although none responded to the optional open-ended questions. No significant difference between the times to complete the electronic and paper survey was found. In addition, the pre-testers made several recommendations regarding minor changes in wording to improve readability and flow.

4.4.2.3 Survey Implementation

The letter asking the survey contacts to complete the survey contained instructions for completing the survey, including information that completing the survey should take no longer than 20 minutes. It is important to note that in the section of the survey that allowed respondents to provide open-ended feedback on the survey, a very small number of individuals (six, representing only 1.6%) commented that the survey was long or had too many questions. The survey length may have deterred some individuals from undertaking or completing the survey, especially for the paper survey when it was possible to see the length of the entire questionnaire (the electronic survey only displayed a single page or grouping of questions as a time). However, it is very important to note that nine (2.9%) commented that they liked the survey and thought the topic important and 10 (3.3%) individuals specifically asked to receive a summary copy of the study even though such a report was promised to the respondents as an incentive for completing the study; this enthusiasm would seem to indicate that the topic is of interest to supply management professionals. This supports other empirical research which found that two of the most important factors positively influencing survey response was the saliency of the topic to the target sample members and the sponsoring organization (Larson, 2005), both of which are achieved in this survey.

The frequency and type of contact (e-mail, phone, traditional mail, etc.) with the target sample is a second area of interest in designing a sampling plan. Dillman (2007) recommends multiple points of contact using mixed methods.

There is not a specific recommendation of the types of contact to be used, therefore, the contact methods utilized in this study were slightly modified as the actual data collection occurred and in response to the specific requests of the participating organization. The first contact with the target sample occurred electronically. This method has several advantages. A primary advantage of using electronic surveys is a reduction in the expected effort required for the respondents to complete the questionnaire, a key element in improving response rates (Aaker et al., 1998; Frohlich, 2002). Another important advantage is the ability to avoid data transcription errors that can occur when the responses from a completed paper survey are later entered into an electronic form for data analysis. In addition to ease of implementation and speed of receiving responses, there is evidence that data utilizing paper and electronic collection processes does not generate problematic differences in results and can be used to support the same conclusions (Griffis et al., 2003), making it an attractive data collection method (Klassen & Jacobs, 2001).

Multiple electronic and paper mailings were sent to further aid in increasing the response rate, thereby reducing non-response bias. Multiple mailings allow for non-response bias testing by comparing the results from early and late respondents where late respondents serve as a proxy for non-responders (Armstrong & Overton, 1977; Dillman, 2007). It is important to know if non-respondents are significantly or systematically different from respondents, as this will compromise the generalizability of the findings (Flynn et al., 1990). In general, an increased number and variety of contacts, and a greater ratio of contacts that are made using paper methods (letter, postcards, etc.) will result in higher data collection costs. It is therefore important to carefully consider the expense per collected response when determining the number and mode of communications to be sent out (Kaplowitz, Hadlock, & Levine, 2004).

The first contact with the targeted sample was indirect when the APS posted a notice in their monthly newsletter that a research project was being undertaken to study risk management. This notice also encouraged readers to respond when they received the survey invitation, in effect 'priming' them for the survey to come. The first direct communication with the target sample for which e-mail contact information was available was an electronic pre-notice message sent to the identified sample respondents a short time before the survey was conducted, to provide a brief explanation of the importance of the study, the value of the individual's response, and indicating the support of the APS. The use of pre-notification has been found to be even more important when e-mail is being used, due the to amount of 'junk mail' and 'spam' that many people receive (Porter & Whitcomb, 2003; Kaplowitz et al., 2004). The concern regarding spam was addressed by having the pre-notice sent using the APS and university logo, and the name and signature of the organization president and lead researcher on the electronic communication to alert individuals to expect the survey. APS sponsorship helped impress upon recipients the support of the parent organization and the importance of their response.

The pre-notice was followed electronically a few days later by an electronic form of cover letter. This letter more fully outlined the purpose of the study, provided a web-link to access an electronic version of the questionnaire, described important information on the voluntary nature of participation (in accordance with Michigan State University's UCRIHS human subjects research protocol), and expressed appreciation for completing the survey and information about the response incentive.

In addition, all electronic messages were sent using 'mass mailing' software that provides a couple of key features meant to address the issues of e-mail 'spam filtering' and the possibility of invalid electronic addresses. The software utilized sends a pre-signal to the address to confirm that it is valid. In addition, each message is sent individually so that they are not received as part of a mass distribution on the host system and they are sent with an individual return e-mail account. In this case, a new secured e-mail account (msurisk@bus.msu.edu) was established specifically to be used for sending these messages and to allow for the receipt of any queries that individuals might have about the survey. This proved to be quite useful, as some of the target sample had e-mail systems that upon receipt of a message from an unknown source sent an automatic reply to the sender address to request that the sender undertake some form of identification or process to establish the message as actually coming from an individual. The use of an e-mail address that is survey specific also allowed for the receipt of automatic messages that indicated if an individual was no longer part of the organization, allowing for maintenance of the qualified contact list. Unfortunately, it was not possible to determine if any messages were stopped and excluded by the recipients' e-mail filtering software.

Therefore, the number of successful contacts made is less than or equal to that reported. As a result, the response rate reported is a conservative estimate.

The timing of electronic communications is also important. The initial invitation to participate in the study was sent mid-week and the messages were sent in the early morning hours (U.S. Eastern Time) so that the messages would be available when the recipients opened their e-mail in the morning. Both the daily and weekly timing of survey invitations have been shown to increase response rates (Faught et al., 2004). In addition, the use of a web-link for survey response has been shown to increase response rates (Klassen & Jacobs, 2001).

Several days later, a second electronic message with a similar cover letter and web-link to the survey was sent, followed by a third message after several more days. Those individuals with electronic contact information were therefore contacted up to four times: first with the pre-notice and subsequently with the invitation to participate in the survey and the link to the actual survey. If an individual provided their contact information when responding to the survey, their name was removed from subsequent mailings [by the end of the data collection, 255 individuals (84%) provided their complete contact information]. This reduced the intrusion of multiple contacts for participants, with the intent of curtailing the perceived imposition on their time.

Personalization of all correspondence sent is another important aspect to improving response rates. This would include using the individual's name in the salutation and hand written or electronic signatures (rather than simply typed names) in the closing. It is important to note that personalization now has a reduced impact, especially in electronic communications (Porter & Whitcomb, 2003) due to the ease of using 'mail-merge' and other programs to easily insert predetermined personal data into what is otherwise a form letter. An alternative method for making the individual feel important could be by telling them that they are part of a select group asked to participate in this survey and utilizing a closing time of the survey to create a sense of urgency. This is another point where the support of the sponsoring organizations can be used to improve response rates. All contact with the target sample, electronic and paper, included a personal salutation to the recipient.

Finally, some sort of incentive can be used to further encourage individuals to respond to a questionnaire. Three incentives were used to encourage respondents to complete the survey. One of the incentives utilized here was the promise of a summary copy of the findings. Copies of the summary report were sent to the individuals that provided contact information, and to the APS. The APS can then decide if the report should be sent directly to all members or simply posted on their web-site for access by all those who are interested. Due to the low initial response rate, a second incentive was included. Access to a copy of the paper "18 Ways to Guard Against Disruption" (Elkins et al., 2005) was promised and provided. Permission to utilize this paper as an incentive was granted by the authors and by the publisher. The final incentive utilized was financial. Respondents were given the opportunity to enter into a drawing for an individual reward of a $50 Visa gift card. If an individual chose to respond anonymously to the survey, there was no way to enter them into the drawing, and no automatic or predetermined identifying information was attached to any survey sent or to any response.

After it was decided that no further responses would be generated by electronic contact (the pre-notice and three invitations to complete the survey), a paper invitation and questionnaire was sent to the non-responders. The paper invitation was printed on Michigan State University letter head, with a copy of the APS logo and with the names and signatures of both the APS president and lead researcher. This letter contained the same information as the electronic letter (instructions for completing the survey, web-link information, UCRIHS disclosure and voluntary nature of participation, etc.). Also included was a pre-addressed business reply envelope. Given the large number of survey packages sent, and the number of electronic contact already undertaken, only a single set of paper surveys were sent out.

4.4.3 Response Rate

A variety of techniques were used to increase the response rate, in keeping with the guidelines of Dillman (2007). As previously mentioned, all contact with the individuals included the logos of both the APS and Broad Graduate School of Management at Michigan State University as well as the signatures of both the APS president and MSU lead researcher (copies of survey contact material is in Appendix A.). A pre-survey notice was sent to individuals, and both electronic and paper surveys were used. Incentives for participation included the ability to request a copy of the survey results, access to a practitioner article on the subject of supply chain risk management and the ability to register for a chance to win a gift card worth $50.

Overall, the final response rate was 9.5% (303 responses from a qualified sample of 3,199). Response rates of approximately 10% are considered acceptable when using similar professional organizations as the target sample (Melnyk et al., 2003), although lower response rates are often used in supply chain research (Griffis et al., 2003). Of these, 246 (81%) responded electronically and 57 (19%) responded by returning the paper survey. The paper survey sent out also included information for accessing the electronic survey, which some respondents chose to utilize, resulting in a lower paper survey response rate. The order and wording of the questions was identical, so this is not a concern. A summary of the response rates is shown in Table 4.2.

Table 4.2 Responses Rates

	APS Members	Non-APS Members
Complete Database	1,674	3,764
Qualified Sample	1,199	2,000
Qualified Responses	188	115
Qualified Response Rate	15.7%	5.8%
Total Qualified	3,199	
Total Qualified Responses	303	
Total Qualified Response Rate	9.5%	

As can be seen, the response rate for the APS members is much higher than for non-members. This result is not surprising, since there is evidence that response rates are higher when there is high saliency of the research topic and identification with the sponsoring organization (Larson, 2005). As previously mentioned, APS regularly conducts surveys of their membership, and they have an organizational mission of education and service which includes providing members with current research in the field of supply management.

Another issue that is important to discuss is the use of actual APS members and non-members. During initial contact with APS regarding participation in the study, the membership number originally provided by APS was in fact a combination of both members and non-members. This inflation of membership is partially a result of the desire to appear as a more substantial alternative to more well-known organizations, such as the Institute for Supply Management (ISM, formerly NAPM). The quote of the combined contact sources was an unwelcome surprise for the researcher. The use of members and non-members in this study has both drawbacks and advantages. The most obvious is the higher response rate from APS members. The contact sample of all qualified individuals if they were members, and using the same response rate a members, would have provided a much larger response sample (extrapolated to be ~500) which in turn would allow for a greater range of data analysis techniques and increased possibility of sub-group analysis. Conversely, the inclusion of both organizational members and non-members provides a more heterogeneous supply professional sample which increases support for the generalizability of the findings.

In summary, the data collection was carried out utilizing contact information of supply management professional provided by the American Purchasing Society. Initial contact with the APS began in September 2006. Because of the approaching holiday season and a perception that many business professionals would be exceptionally busy at the end of the calendar year, the start of the actual data collection was held until the beginning of 2007. APS provided a notification of the impending survey in their January 2007 newsletter. An e-mail pre-notice of the survey was sent to all the individuals for whom the APS had provided contact information. The mass e-mail software program used is able to identify undeliverable e-mail addresses prior to sending out the messages inviting the individuals to participate in the study and providing a link to the survey website. The high initial response rate encouraged the APS to provide more detailed information on the contact list already supplied. This increased visibility raised questions regarding the appropriateness of some of the sample, resulting in 2,239 people being removed from the original sample of 5,438 for a remaining qualified sample size of 3,199. Through the month of March and April several e-mail invitations and post card reminders where sent to illicit a higher response rate. In addition, a full paper copy of the survey was sent to the APS non-responders in late March. In total 246 people responded electronically via the survey website and 57 people responded to the traditional paper survey, for a total of 303 responses (9.5% response rate). This response rate is in keeping with similar studies (Griffis et al., 2003; Melnyk et al., 2005). , and as detailed in the analysis of the collected data that follows in the next chapters is large enough to provide adequate statistical power (McQuitty, 2004).

5. RELIABILITY AND VALIDITY

Before advanced methods of data analysis can begin, it is necessary to examine the data utilizing fundamental statistical techniques to 1) determine the degree to which the data adheres to the basic assumptions underlying multivariate methods; 2) evaluate and adjust for missing data; and 3) identify outliers (Hair Jr., Black, Babin, Anderson, & Tatham, 2006). In addition, it is important to assess the demographics of the respondents to determine if the response sample adequately represents the target population. The following sections discuss steps undertaken to ascertain the appropriateness of the sample data for use. All statistical information reported in the following sections was developed using SPSS 15.0, unless otherwise noted.

5.1 *Demographics*

The target sample for this study is a broad cross-section of supply chain professionals. Therefore, individuals with differing levels of responsibility within their firm and representing varying sizes and a range of industries are included. Possession of current demographic information about the respondents allows for comparison of clusters of responses along dimensions such as level of responsibility/influence within the firm, firm size, or industry (Flynn et al., 1990). The following summarizes the demographics provided by the survey respondents.

The contact information provided by the APS did not include data on each individual's industry. There were also no *a priori* assumptions regarding linkages between supply chain disruptions and specific industries. Therefore, there was no need, nor useful way, to eliminate individuals from participating in the survey based on industrial sector, other than obvious elimination based upon the individual's firm affiliation as reported to APS. As can be seen from Table 5.1, the respondents represent a wide range of industries, although the majority identified themselves as working in manufacturing. Surveys from individuals in industries such as communications or finance indicated that their area of responsibility included supply chain activities and are therefore appropriate for inclusion in this study.

Table 5.1 Industry Sector of Survey Respondents

Industry Sector	n	Percent
Agriculture	1	0.3
Communications	4	1.3
Construction	10	3.3
Finance, Insurance, Real Estate	9	2.9
Government	11	3.6
Health Services	12	4.0
Hospitality & Food Service	8	2.6
Manufacturing	171	56.4
Retail or Wholesale	29	9.6
Transportation & Warehousing	6	2.0
Utilities	3	1.0
Other	38	12.5
Missing	1	0.3
Total	303	

Firm representation spans across a wide spectrum of sizes, as measured by both firm revenue and number of employees, as seen in Table 5.2. There are several respondents that indicated they were not authorized to provide revenue information, resulting in this specific item having the largest number of missing responses. There are no respondents that omitted *both* revenue and employment information.

Table 5.2 Indicators of Firm Size

Annual Revenue	n	Percent
Less than $10 million	33	10.8
$10 to 249 million	84	27.7
$250 to 499 million	57	18.8
$500 to 749 million	28	9.2
$750 million to 1 billion	83	27.4
Over $1 billion	4	1.3
Missing	14	4.6
Total	303	

Employees	n	Percent
Less than 100	65	21.5
100 to 249	48	15.8
250 to 999	73	24.1
1,000 to 4,999	54	17.8
5,000 to 9,999	17	5.6
Over 10,000	43	14.2
Missing	3	1.0
Total	303	

Most of the individuals report that they have functional responsibility for supply management (purchasing, procurement, buying, etc.) as Table 5.3 indicates. There are however 36 individuals that report different functional responsibilities other than supply management. However, the functional area of responsibility reported is closely enough related to still remain relevant to this study. In addition, as can be seen in Table 5.4, survey respondents are primarily in a managerial and supervisory level of responsibility, with several individuals at the Director or Vice president level. Finally, Table 5.5 illustrates that respondent organizational level is almost equally split between corporate level and strategic business unit along with plant levels. The diversity of respondents provides support for the generalizability of the findings.

Table 5.3 Respondents' Functional Responsibility

Function Responsibility	n	Percent
Engineering	3	1.0
IT/IS	4	1.3
Logistics	10	3.3
Production Control/Planning	13	4.3
Supply Management	265	87.5
Warehousing	5	1.7
Missing	2	0.6
Total	303	

Table 5.4 Respondents' Level of Responsibility

Level of Responsibility	n	Percent
Vice President	10	3.3
Director	46	15.2
Manager	142	45.6
Supervisor	26	8.6
Individual Contributor	72	23.8
Other	7	2.3
Missing	3	1.0
Total	303	

Table 5.5 Respondents' Organizational Level

Organizational Level	n	Percent
Corporate	144	47.5
Strategic Business Unit	88	29.0
Plant	59	19.5
Other	8	2.6
Missing	4	1.3
Total	303	

5.2 *Missing Data*

Missing data can present a problem for data analysis. This is particularly true with surveys where data gathering issues such as response fatigue may result in more blank responses toward the end of the questionnaire or if individuals do not feel comfortable or lack the knowledge to respond to specific items or a set of items. The issue of missing data is similar to non-response bias. In non-response bias, the researcher is concerned with patterns and causes for not participating in a study and with missing data the concern is also for patterns and causes of non-response within the collected data. From a practical standpoint when cases with incomplete responses are removed from the data, a reduction in usable sample size may limit the ability to robustly conduct data analysis, or require the gathering of additional data to reach an appropriate sample size for adequate power. From a substantive standpoint, missing data may occur non-randomly, indicating bias and affecting the validity and generalizability of the findings (Hair Jr. et al., 2006; Tsikriktsis, 2005).

A four-step process to identify and handle missing data is outlined in Hair, Black, Babin, Anderson, and Tatham (2006) and serves as the guide for the missing data analysis process utilized in this study. The first step involves determining the type of missing data. Second is examining the extent of missing data by case and by item, and searching for patterns. Third is determining the level of randomness of the missing data. The final step is the selection of an appropriate imputation method to estimate the missing data, if needed. The findings and outcomes of applying these steps are detailed in the following sections.

Some missing data is to be expected in almost all empirical data collection undertakings. Data that can be considered 'ignorable missing data' occurs at random and does not require specific remedies. This type of missing data is a result of imperfect representation in the sample of the complete target population, 'skip patterns' where respondents skip over sections or questions they are unable to answer or are not applicable in a survey instrument and data that is censored because it is inconsistent across the sample or not applicable to the current study. Of greater concern is missing data that is not ignorable and can be caused by either known or unknown processes. Identifiable processes that can explicitly cause missing data are often related to the survey instrument or data collection procedures. They may include a failure of respondents to complete the entire questionnaire or an identified data entry error. Unidentifiable processes, by definition, are more difficult to detect and to remedy and frequently are related to the respondents' actions. These may include respondents' unwillingness to answer sensitive questions or inability to provide the requested information. Care taken in the development of the survey instrument and the data collection methods may reduce the likelihood of substantial levels of non-ignorable missing data.

When non-ignorable missing data is found, it is necessary to determine the extent of the missing data. If the level of missing data is low enough, even if it occurs non-randomly, there may be no affect on the data analysis results. The assessment of missing data should be conducted to find both individual *items* and *cases* with larger than desirable levels of missing data. It is assumed that some data will be missing; however, when data is missing at low levels or in a random pattern, it is often possible to retain the items and the cases in the study; however high levels or non-randomly missing data presents a problem and must be addressed before further data analysis can proceed.

The level of missing data can be determined by assessing the percentage of *items* (representing survey questions) with missing data and the number of *cases* (representing respondents) with missing data above a pre-determined threshold. The goal is to determine if there are any cases or items with levels of missing data that are high enough to cause concern, or that indicate an obvious omission pattern. The survey sample was examined using the 'Missing Value Analysis' module in SPSS 15.0 (excluding demographic and open ended questions) to determine the extent and pattern of missing data for both items and cases. Of the 92 *items* examined, nine (10%) had no missing data and the remaining 83 items had missing data in less than 5 percent of the *cases*. No specific patterns of missing data at the item level were observed. Given the low levels of data missing per item (survey question), the fitl within general guidelines and the lack of a discernable pattern (Hair Jr. et al., 2006), no items were removed due to missing data.

Of the 303 *cases* included, 182 (60%) had no missing data, 65 (21%) cases were identified as missing data on a single item, 51 (17%) cases were missing data for two to eight items, and five (2%) cases had data missing for nine or more items. Individual cases which have less than 10 percent of the items missing data are considered usable, as long as the data is missing randomly (Hair Jr. et al., 2006). In order to protect against possible bias the five cases missing more than 10 percent of items were eliminated, bringing the sample size to 298 cases.

The number of cases with missing data here is somewhat higher than the average found in a recent study of missing data from articles published in the *Journal of Operations Management* between 1993 and 2001 (Tsikriktsis, 2005). Interestingly, 67 percent of the articles examined did not report any information regarding missing data in their samples. It is therefore difficult to determine if missing data occurs frequently but is simply rarely explicitly addressed, if the issue is simply ignored as surmised in (Tsikriktsis, 2005), or if authors are reluctant to report high levels of missing data. Based upon the high number of items on the survey, it was determined that further examination of the missing data was warranted to determine the usability of the remaining sample data.

The third step in diagnosing missing data is to determine the randomness of the missing data. The test for missing completely at random (MCAR) requires comparing the observed pattern to determine that it does not differ from a random pattern. Little's MCAR test has a significance value of 0.67, indicating that the missing data here is MCAR (Hair Jr. et al., 2006).

The identification of missing data as MCAR allows for the broadest choice from possible imputation methods to determine the value of missing data points based upon the values of other items and cases in the sample. There are several methods of imputation that are dependent upon the amount of data that is missing, the sample size and the level of conservativeness of the researcher (a summary of multiple methods can be found in Hair, Jr. et al, page 63). For example, the most conservative method would be to eliminate all items and cases with missing data. Other methods would include substitute missing data based upon similar cases or calculating missing data using regression analysis. The simplest calculation method is to utilize mean substitution, but the disadvantages of this method are a reduction in the variance of the distributions and in the observed correlations, as well as some distortion of the data distributions. Imputation by regression has the advantage of utilizing the actual relationships among variables, but may generate replacement values that fall outside of the bounded Likert scale range utilized here.

After careful consideration of the benefits and disadvantages of data imputation methods, a model-based method was selected to impute the missing data in this study. The advantage of this method in this situation is that it allows for the least bias by providing the best representation of the original distribution of the item values. The lack of bias is important for the generalizability of the findings. In addition, this method can accommodate both random and non-randomly missing data (Hair Jr. et al., 2006). The imputed data values were created using the EM (expectation-maximization) algorithm to estimate the means, the covariances, and the Pearson correlations of the missing data. This is a two step iterative process, where the first step ("E") computes expected values using maximum likelihood based upon on the observed data and the current estimates of the parameters. The second step ("M") step uses the new parameter estimates from step 'E' to re-estimate the missing data, and continues until convergence of parameter estimates is achieved (Tsikriktsis, 2005; SPSS 15.0, 2007). The remainder of the data analysis is conducted using the data set with the missing data imputed using the EM process.

5.3 *Data Normality*

Both univariate and multivariate statistical analysis is based on fundamental assumptions of the data characteristics. When these assumptions are found not to hold true for the data, it is often necessary to utilize various data transformation methods or to alter the types of data analysis that can be conducted. Normality refers to the distribution shape of the data. Meeting this assumption is important, since a large degree of non-normality inhibits the use of many basic statistical analysis tools (Hair Jr. et al., 2006). Two measures used to examine the shape of the data distribution are kurtosis (the tendency to a 'peaked' or 'flat' distribution) and skewness (the tendency to have a disproportionate amount of data in the left or right 'tail' of the data). High levels of kurtosis, usually bounded by cut-off value of +/- 3, indicate that the variance observed in the data is due to extreme, but infrequent observations; *both* tails of the distribution are elongated with a 'flatter' probability distribution. High levels of skewness, usually bounded by +/-1, indicate a tendency of the data to have *either* an elongated right or left tail. Observed together, kurtosis and skewness test the centered symmetry of the data distribution. In examining the kurtosis of the data, only one item falls beyond the cut-off value of +/- 3; no items fall beyond the skewness cut-off value of +/- 1 (Bollen, 1989; Hair Jr. et al., 2006). Use of the Kolmogorov-Smirnov and Shapiro-Wilk tests, both of which test the goodness of fit of the sample distribution with a normal and uniform distribution, indicate normality at a significance level of $p < .01$ for all of the items (a subsequent multivariate test of kurtosis with the confirmatory factor analysis achieved a Mardia-Based Kappa of 0.10). In summary, there is no strong evidence that the data collected is non-normal.

5.4 *Response Bias*

5.4.1 Non-response Bias

In order to assess potential non-response bias, an ANOVA comparison of early responders and later responders was conducted. This method assumes that late responders are similar to non-responders (Armstrong & Overton, 1977). In this case, late responders are individuals who received multiple invitations to participate, thus they likely would have been non-responders if not contacted multiple times, providing support for the assertion that they are likely to be similar to non-responders. The response sample was segmented into early, mid and late responder groups, each consisting of approximately 1/3 of the response sample. This was done to clearly separate early and late responders.

The exact time and order is known for the electronic responses due to the date and time stamp assigned as the data is recorded into the electronic file that received the data. The exact timing and order of response for paper surveys is less precise, since there are varying delivery lead times (determined by outbound and inbound travel distance, and by internal mail processing routines on both the respondent and research team mail handling systems); however, paper responses were entered into the data base in the order received for a close approximation of order and timing of actual response. In examining the response timing stratification, 104 (34%) of responses were categorized as 'early' and 112 (37%) as 'late'. An ANOVA of the item responses revealed that only 2 (2%) of the items had statistically different means and standard deviations at a $p < .05$ significance level. Given the large number of items (92) in the questionnaire and the low number of items that exhibit statistical difference, there is no substantial indication that non-response bias is present.

5.4.2 Common Method Bias

Common methods bias is the difference between the observed and the actual construct relationships, resulting in possible inflation or deflation of the true relationship between constructs. The resulting discrepancy between observed and actual constructs occurs as an artifact of the instrument used to gather the data, which inadvertently impacts or influences the respondents' reported measures or scores. The method used to gather data allows systematic variance that confounds the variance associated with the traits being measured (Doty & Glick, 1998). Although the respondents were given the option to respond electronically or by paper, the questions asked were identical and presented to the respondent in the same order. Therefore, although the data collection technologies are different, the respondents are utilizing a single instrument. Data used in this sample was collected from single respondents within a firm, examination of the contact information revealed that no individuals with the same organizational name/identification are included in the sample. Given the focus of the survey and the use of single respondents, there is the possibility of the results gathered to potentially exhibit common method bias.

Podsakoff, MacKenzie, Lee, and Podsakoff (2003) offer several techniques for controlling common method bias *a priori* as part of the survey instrument creation and data collection design. Suggestions used in this research include the protection of respondent anonymity, which reduces evaluation apprehension and aids in increasing answer honesty and reducing the occurrence of social desirability, leniency and acquiescence in responses. Another precaution taken was the careful construction and multiple rounds of testing undertaken on the scale items for improved comprehension, avoidance of 'double-barreled' questions, decomposition of complicated questions into simpler and more focused questions, and the avoidance of specific syntax that may lead to question ambiguity. Careful construction of scale items and survey questions was undertaken as an *a priori* precaution to mitigate common method bias, but it is still important to test for the presence of bias in the survey results.

Examination of the data for common method bias was conducted using a confirmatory factor analytic approach of Harmon's one factor test. The test operates on the assumption that if common method bias is present, a model containing a single latent factor would account for all manifest variables with fit equal to a multifactor model. Thus, a single factor model with worse model fit than the hypothesized measurement model would indicate an absence of common method bias. The model fit values for a one factor model yielded a χ^2 = 9065.67 with *df* = 2410 compared to χ^2 = 4294.78 with *df* = 2319 for the measurement model. Given the considerably worse fit for the unidimensional model, there is no indication that common method bias is a concern. A second point is that the model contains full mediation, which also serves to reduce the impact of common method bias (Podsakoff, MacKenzie, Lee, and Podsakoff, 2003).

5.5 *Confirmatory Factor Analysis*

The data analysis undertaken here follows the two-step approach advocated by Anderson and Gerbing (1988). The first step is to perform a confirmatory factor analysis (CFA) on the measurement model to examine the data for convergent and discriminate validity. CFA is used when there is *a priori* assignment of variables to their associated constructs. Confirmatory measurement models specify the relationships between the observed variables (measurements) and the underlying constructs (factors) with the constructs allowed to freely correlate. A properly specified, converging measurement model is a necessary precursor to examination of the relationships between constructs (Anderson & Gerbing, 1982; Bagozzi & Heatherton, 1981). Once a proper measurement model is achieved, the second step is to examine the structural relationships of the factors in the path model (this will be further discussed in the Chapter 6: Data Analysis). A summary of the CFA model fit is found in table 5.6 and discussed in detail in the following sections.

5.5.1 Measurement of Constructs

Before a CFA can be conducted, it is necessary to determine if the sample size is adequate to achieve a desired level of statistical power. Adequate power is needed to detect close model fit. Using McQuitty's (2004) guidelines, the degrees of freedom (*df* = 1363) and sample size (n=303) the data set are adequate to achieve power of at least 0.80. Another consideration is the ratio of manifest variables (MV) to associated latent variable (LV) (Shah & Goldstein, 2006). A MV is an observed variable (the items from the survey) which are intended to measure specific unobserved LVs. Latent variables are conceptual constructs that cannot be directly measured, and therefore require the use of multiple MVs to adequately capture the underlying LV. It is generally accepted that single indicator LVs are undesirable, and that a minimum of three MVs per LV should be used. A larger ratio of MVs to LV can compensate for a smaller sample size (Marsh et al., 1988), but requires a larger sample size when there are more parameters to estimate to achieve adequate power and also reduces model parsimony (Anderson & Gerbing, 1984). The model used here has 92 MVs for 13 LV constructs, for a MV to LV ratio of 7.08 All initial LVs have three or more MVs, with no single indicator LVs.

The ratio of sample size to the number of estimated parameters is also an important consideration in CFA. When the sample size to estimated parameters ratio is too low, there is a higher level of susceptibility to overestimated model fit and lower reliability. The use of model fit estimates that are less biased by smaller sample size can alleviate this issue (Hu & Bentler, 1998). While the general guideline is have a sample size to parameter estimate of 5:1, a recent study of operations management research found that 35.7% of the models had a lower ratio (Shah & Goldstein, 2006). The ratio of sample size to estimated parameters here is slightly below the 5:1 guideline at 3.3:1, but in keeping with other operations management research.

5.5.2 CFA Model Fit

After determination of adequate conditions as described above including 1) a minimum of three MVs per LV with no single indicator LVs, and 2) evidence of an acceptable sample size for the number of estimated parameters, the next step is to conduct a CFA analysis. The first step of Anderson and Gerbing's (1988) two step process is to assess the psychometric properties of the measurement models via CFA. Using CFA, the overall fit of the measurement model can be assessed using a variety of fit indices. In general, fit indices can be categorized as *absolute* (the degree to which the sample data is reproduced by the measurement model) and *incremental* (the improvement when the hypothesized model is compared to a restricted baseline model) (Bollen, 1989; Hu & Bentler, 1998). A summary of the most commonly used fit indices is shown in Table 5.6. The specific types of fit indices within these two categories are identified in the order of most common usage in operations management research according to the findings of Shah and Goldstein (2006).

There are several absolute fit measures, the most basic and frequently used of which is the χ^2 statistic, which quantifies the difference between the observed and estimated covariance matrices. Within the context of SEM, lower

χ^2 values indicate support of the model as representative of the data. The goodness of fit index (GFI) was developed to address issues of large sample size influencing model fit results and adjusted GFI (AGFI) increase as fit improves, up to a limit of one; generally accepted minimum levels range from 0.90-0.95 (N. W. Browne & Cudeck, 1989). AGFI takes into account model complexity by adjusting the GFI by a ratio of the total degrees of freedom to those used in the model. Used less frequently is root mean squares of approximation (RMSEA), which attempts to correct the tendency of rejecting models with either large sample sizes or a large number of observed variables. Both the Root mean square residual (RMSR) and Standardized Root Mean Residual (SRMR) rely upon standardized results and may make model comparisons more difficult. RMSR and SRMR decrease as the measurement model fit improves, and are bounded by zero with acceptable values in the area of 0.08. These metrics are sometimes called 'badness of fit' measurements where high values indicate poor model fit. RMSR tests the accuracy of the prediction of the variance for individual items; SRMR uses standardized RMSR values and is useful when comparing fit across models (Hair Jr. et al., 2006).

Table 5.6 Summary of Model Fit Indices

	Purpose	Advantages	Disadvantages	Cut-off values
Absolute Fit Measures: Assesses how well the implied model reproduces the sample data; comparing implied and observed covariance matrices				
χ^2	Used to quantify the difference between the observed and estimated covariance matrices	Only statistically based SEM fit measure	Sensitive to larger sample size , more estimated parameters, multivariate non-normality	Lower values indicate better fit, no specific cut-off
Goodness of Fit (GFI)	Attempt to address the effect of larger sample size	Reduces inappropriate results driven by larger sample size	Still sensitive to sample size indirectly due to effect of N on sampling distribution	Range of 0 to 1; higher values indicate better fit 0.90 ≤
Root Means Square Residual (RMSR)	Average of the residuals between observed and estimated co/variance terms	Examines residual error	Difficult to compare models unless results are standardized	Lower is better ≤ 0.10
Standardized Root Mean Residual (SRMR)	Standardized RMSR	Standardization allows for model comparison		"badness of fit" with large values indicating poor fit; closer to 0, within +/-.40
Root Mean Square Error of Approximation (RMSEA)	Reflects average lack of fit per degree of freedom	Less affected by sample size, model misspecification and non-normality. Ability to determine confidence interval		Lower is better ≤ 0.08
Incremental Fit Indices: Compares fit of a specified model to alternative baseline or null model				
Adjusted Goodness of Fit (AGI)	Addresses model complexity. Adjusts GFI by ratio of model *df* to total *df* available.	Penalizes less parsimonious models		Usually lower than GFI , in proportion to model complexity
Normed Fit Index (NFI)	Ratio of difference between χ^2 values for fitted and null model		Underestimates fit for small samples, sensitive to model complexity	Higher values indicate better fit 0.90 ≤
Comparative Fit Index (CFI)	Improves upon NFI by accounting for model complexity	Penalizes less parsimonious models	Sensitive to model misspecification	Normed range of 0 to1; higher values indicate better fit.
Tucker Lewis Index (TLI)	Conceptually similar to CFI	Penalizes less parsimonious models; less impact of sample size		Not normed, but higher positive values indicate better fit 0.95 ≤

Incremental fit indices are used to compare the research model to a reference model of either the worst case (null) model or to an ideal model that perfectly represents the modeled phenomena under study. The most commonly used incremental fit indices are comparative fit index (CFI) and normed fit index (NFI). CFI is an improvement over the NFI and is less sensitive to model complexity, with minimum acceptable fit value of approximately 0.90 (Hair et al., 2006). Less commonly used in operations management research are non-normed fit index (NNFI or TLI), and incremental fit index (IFI or BL86) (Shah & Goldstein, 2006).

The acceptable cut-off values for each specific fit measurement are an issue of continuing discussion in research methodology literature within a variety of social science disciplines (Bentler & Chou, 1987; Bollen & Lennox, 1991; Hu & Bentler, 1998). Compounding this debate are numerous other factors, including sample size, the number of latent factors and the number of their corresponding manifest variables, the degree to which a study is more or less exploratory as opposed to confirmatory, and researcher sensitivity to Type I or Type II errors. In addition, it is also often necessary to examine two or more fit measurement values simultaneously since each has its own unique strengths and weaknesses, and it often occurs that a marginal fit value with one measurement may be off-set by an acceptable value on another measurement (Hu & Bentler, 1998; Yuan, 2005).

The choice of appropriate fit measures is also a function of sample size, as many indices are sensitive to issues inherent to the examination of data from smaller samples. Hu and Bentler (1998) suggest that researchers use one of two sets of indices to assess model fit depending on the sample size. The sample size of 298 cases in this study is above the 250 cases cut-off that is often used to determine which fit indices would be most appropriate. Given the lack of definitive guidelines for the use of specific fit indices, it is best to report the results of multiple fit measures to allow for the most comprehensive understanding of model fit. At a minimum, it is suggested that researchers report χ^2 with the degrees of freedom, and RMR and RMSEA which reflect the residual differences between the input and implied (model) matrices. These measures denote the ability of the tested model to predict the matrix covariance (Shah & Goldstein, 2006).

Initial CFA examination of the proposed model resulted in poor model fit, so item purification was undertaken. The initial CFA yielded model fit statistics of χ^2 = 8111.02, *df* = 3990, CFI = 0.714, SRMR = .072, and RMSEA = .059; none of these results are within acceptable ranges for model goodness of fit values. In addition, a number of items failed to achieve acceptable factor loadings (λ values). Items that exhibited the worst fit within the model were eliminated one by one, based upon the Lagrange Multiplier (LM) evaluation and the standardized factor loadings. Of the original 92 items, 17 were eliminated. The resulting measurement model achieved fit statistics of χ^2 = 2602.20, *df* = 1363, CFI = 0.87, SRMR = .052, and RMSEA = .055 (CI: 0.52, 0.58). The difference between original CFA model and modified CFA model are $\Delta\chi^2$ = 5508.82 and Δ

df = 2627, demonstrating a substantial improvement in overall fit of the modified model over the original proposed model.

Because the scales used here have had limited or no testing in previous empirical research, it was expected *a priori* that there would be attrition of scale items within constructs. This is part of the iterative nature of ongoing improvement of construct validity and scale refinement (Menor & Roth, 2007). After scale reduction, all but two of the constructs still maintain the needed MV to LV ratio of not less than 3:1; which is discussed in detail below. The items removed from their associated constructs are indicated in Table 5.7 and explained in detail below.

Another important outcome of the examination of the proposed constructs is the finding that two constructs appear to capture more than a single concept and should each be split to better represent their intended concept. The construct related to the occurrence of disruptions, *Disruptive Events*, required modification. It was determined that measuring all directions of disruptions within a single construct was not appropriate. It appears that disruptions in supply (incoming material and firm output) should be separated from demand disruptions (from customers). Thus, the more discriminate constructs of *Disruptive Events – Supply* and *Disruptive Events – Demand* are utilized. The use of two separate supply chain constructs that discriminate between up-stream (supply) and down-stream (demand) differences is supported in other supply chain research (Frohlich & Westbrock, 2001). The distinction between the directionality of the disruption could be because the sample consists primarily of individuals focused on the supply side of their firm's supply chain; or it may be that there is indeed a difference in supply and demand disruptions that can not be precisely determined from the current data and warrants further study. This results in a demand disruption scale which contains two items.

The second construct that requires amendment is *Supply Chain Complexity*. Upon analysis, it appears that the concept of uncertainty which was thought to be imbedded within complexity is better represented by a separate construct of *Supply Chain Uncertainty*. Each modified construct still meets the minimum criteria for no less than three scales items.

Table 5.7 Items Removed from Associated Constructs

Supply Chain Complexity • Complexity of the products sold to customers (e.g. uses new or frequently changing technology) • Complexity in the business environment (e.g. number of competitors
Supply Chain Dependency • Our employees have close personal relationships with their supply chain partner counterparts • We are economically dependent on our supply chain partners • Our reputation in the market place is affected by our supply chain relationships
Concern For Disruptions • Level of concern for market/business environment caused disruptions (e.g. regulatory issues, currency fluctuations, material cost instability, economic change, competitor's actions, etc.) • In your opinion, how would you rate the vulnerability of your supply chain • You hear about your competitors experiencing supply chain disruptions
Effective Practices • We concentrate on core competencies and outsource some activities (e.g. IS/IT, facility maintenance, warehousing, etc.)
Profile the Supply Chain • We have a profile (or map) of our supply chain
Risk Identification • We know the particular vulnerabilities of our customers • We use multiple sources of information to identify supply chain risk
Audit of Risk Management Plans • We have informal supply chain continuity plans for our supply chain • We have identified signals that we should watch for that would indicate a disruption may be starting or about to occur
Risk Management Strategies
Risk Management Practices
Change in Disruption • FREQUENCY: Change in disruptions from upstream/supplier sources (material shortages • IMPACT: Change in disruptions from upstream/supplier sources (material shortages • FREQUENCY: Change in disruptions from business environment sources (changes in technology • IMPACT: Change in disruptions from business environment sources (changes in technology

Modifications to the original hypotheses are appropriate, as the basic underlying relationships between supply chain complexity, uncertainty, planning, the occurrence of supply chain disruptive events, and firm performance are maintained, although they are now examined with a greater degree of specificity through the use of the modified and added constructs. All further analysis of the constructs, model fit and path strength reflect the alteration of the original constructs and hypotheses. Specifically, the hypotheses incorporate the following changes:

H2a: *Higher levels of perceived supply chain complexity are positively associated with greater frequency and impact of disruptive events*

H2b: *Higher levels of perceived supply chain dependency are positively associated with greater frequency and impact of disruptive events*

Both now reflect the truncated construct of supply chain complexity and the relationship to both disruptive events from supply and demand sources so that,

H2a$_S$: *Higher levels of perceived supply chain complexity are positively associated with greater frequency and impact of disruptive events - supply*

H2a$_D$: *Higher levels of perceived supply chain complexity are positively associated with greater frequency and impact of disruptive events – demand*

H2b$_S$: *Higher levels of perceived supply chain dependency are positively associated with greater frequency and impact of disruptive events - supply*

H2b$_D$: *Higher levels of perceived supply chain dependency are positively associated with greater frequency and impact of disruptive events – demand*

The separation of disruptive events into supply and demand constructs also requires the following alterations of their relationships with other constructs of the use of effective practices, concern for disruptions, the use of planning, and firm performance.

H5a$_S$: *Higher levels of the use of effective practices are negatively associated more frequent and larger impact disruptive events - supply*

H5a$_D$: *Higher levels of the use of effective practices are negatively associated more frequent and larger impact disruptive events - demand*

H5b$_S$: *Higher levels of concern for disruptions are negatively associated more frequent and larger impact disruptive events – supply*

H5b$_D$: *Higher levels of concern for disruptions are negatively associated more frequent and larger impact disruptive events - demand*

H7$_S$: *Higher levels of continuity planning are negatively associated with more frequent and larger impact disruptive events – supply*

H7$_D$: *Higher levels of continuity planning are negatively associated with more frequent and larger impact disruptive events - demand*

H8$_S$: *More frequent and larger impact disruptions – supply are negatively associated with firm performance*

H8$_D$: *More frequent and larger impact disruptions – demand are negatively associated with firm performance*

In addition, the construct of *Supply Chain Uncertainty* which was extracted for the *Supply Chain Complexity* construct also requires the addition of the hypotheses

H1c: *Higher levels of perceived supply chain uncertainty are positively associated with higher levels of continuity planning*

H2c$_S$: *Higher levels of perceived supply chain uncertainty are positively associated with greater frequency and impact of disruptive events - supply*

H2c$_D$: *Higher levels of perceived supply chain uncertainty are positively associated with greater frequency and impact of disruptive events – demand*

The full list of hypotheses as modified and tested is contained in Appendix D: Summary of Final Revised Hypotheses.

Before statistical analysis of construct validity is undertaken, a basic examination of nomological and face validity should be conducted, especially given the number of manifest items that have been removed from the data set. Nomological validity is assessed by investigating the correlations between the measurement constructs. Constructs that are thought to be related to each other should have higher correlations than constructs thought to have less of a relationship. This is important specifically in this model that is both highly complex and that has several constructs that measure different concepts that are theorized to be highly related to each other. An examination of the matrix of the correlations of the constructs reveals that those constructs that are thought to be related also exhibit higher correlations than those that are thought to be less closely related (Table 5.8).

The establishment of face validity is a fundamental part of the survey instrument design, so should occur well before data collection and analysis, as it did in this study. However, given the number of items removed, it is advisable to revisit the face validity of the constructs and scales. As items were removed, careful attention was given to the possibility of changing the underlying conceptual meaning of the constructs or in the potential for omission of a key element of the construct. In reviewing the remaining scale items and constructs, with several risk management researchers, it was determined that face validity was maintained within the more parsimonious measurement model.

Table 5.8 Summary of Fit Metrics of Final CFA Measurement Model

Scale Statistics, Covariances and Overall Model Fit from the Confirmatory Factor Analysis

Variable	Mean	SD	α	ICR	AVE	1	2	3	4	5	6	7	8	9	10	11	12
1. Concern for Disruptions	4.90	1.23	0.70	0.56	0.32	**0.57**											
2. Supply Chain Complexity	4.17	1.12	0.82	0.77	0.41	0.60*	**0.64**										
3. Supply Chain Uncertainty	4.46	1.30	0.78	0.71	0.46	0.70*	0.49*	**0.68**									
4. Supply Chain Profile	5.63	0.96	0.77	0.72	0.40	0.04	0.05	0.00	**0.63**								
5. Risk Identification	5.09	1.07	0.88	0.83	0.45	0.04	0.16*	0.05	0.64*	**0.67**							
6. Risk Assessment	4.03	1.51	0.90	0.84	0.56	0.10	0.19*	0.06	0.29*	0.58*	**0.75**						
7. Audit Plan	3.48	1.39	0.86	0.81	0.47	0.16*	0.25*	0.08	0.25*	0.51*	0.77*	**0.69**					
8. Effective Practices	4.95	1.20	0.86	0.83	0.38	-0.09	0.05	-0.13	0.28*	0.44*	0.54	0.57	**0.61**				
9. Dependency	4.77	1.10	0.87	0.83	0.39	-0.04	0.10	-0.08	0.30*	0.46*	0.68*	0.62	0.57	**0.62**			
10. Disruptions - Supply	4.19	1.22	0.88	0.77	0.62	0.21*	0.21*	0.26*	-0.04	0.00	-0.12*	-0.14	-0.30	-0.11	**0.79**		
11. Disruptions - Demand	3.93	1.53	0.92	0.83	0.71	0.38	0.28*	0.25*	-0.17*	-0.01	-0.14*	-0.17	-0.20	-0.19*	0.55*	**0.84**	
12. Firm Performance	4.86	1.15	0.92	0.86	0.56	-0.07	0.06	-0.03	0.24*	0.23*	0.28*	0.26	0.38	0.35*	-0.12*	-0.15*	**0.75**

Model Fit: χ^2 = 2602.202 *df* = 1363; CFI =0.868; SRMR = 0.052; RMSEA = 0.055 (CI: 0.052, 0.058)

Notes: SD = Standard Deviation; α = Cronbach's alpha; ICR = Internal Construct Reliability; AVE = Average Variance Extracted
The square root of the AVE for each construct is presents in **bold** along the diagonal
* significant at $p < 0.05$

5.5.3 Construct Validity

Construct validity is the degree to which the proposed theoretical latent constructs are adequately measured by a set of measurement items. To evaluate convergent and discriminant validity, the approach outlined by Fornell and Larcker (1981) is adopted. Convergent validity is determined by examination of factor loadings, construct reliability and variance extracted. Discriminant validity is determined through examination of correlations and comparison of the variance extracted with the squared correlation between constructs (Hair Jr. et al., 2006).

5.5.3.1 Convergent Validity

Factor loadings (λ values) that are high indicate that the items being measured converge onto a singly construct. In addition, they should also achieve statistical significance. Both conditions are necessary, because a statistically significant factor loading may only achieve relatively low strength. It is therefore recommended that factor loading be statistically significant and have a standardized factor loading of 0.50 or higher, with an ideal bottom cut-off of 0.70 (Hair Jr. et al., 2006). Standard factor loadings were used to identify scale items that did not demonstrate acceptable levels of convergent validity, with all but two exhibiting loadings above 0.50. The two items that were retained with values below 0.50 have λ values of 0.46 (change in frequency of upstream disruptions) and 0.47 (change in impact of upstream disruptions) quite close to the cut-off value and both statistically significant. They remain in the *Change in*

Supply Disruptions construct for the purposes of this study, but warrant further refinement in subsequent research.

Following the framework of Fornell and Larcker (1981), the construct reliability (CR), another indicator of convergent validity, is calculated based on the following equation. Here λ is equal to the standardized loading between an observed variable and the latent construct of interest and ε represents the standardized error of the estimate.

$$CR = \frac{(\Sigma\lambda)^2}{(\Sigma\lambda)^2 + \Sigma \text{ Var } \varepsilon}$$

Construct reliability is considered a better measure than Cronbach's coefficient alpha, which is highly sensitive to sample size and number of items in the construct. Reliability estimates greater than .70 are considered to be acceptable (Nunnally, 1978), although lower estimates are acceptable, provided other indicators of construct validity are good (Hair Jr. et al., 2006). Cronbach's alpha is shown for all factors, but we rely on CR. All of the constructs in this study achieve a CR ≥ 0.70, with the exception of *Level of Concern for Disruptions* which has a CR = 0.65 and *Change in Disruptions - Supply* with has a CR = .55. While these do not strictly meet the lower bound cut-off value, given the nature of the research, these values are generally considered acceptable.

A third test of the construct validity for each latent construct is assessed by calculating the average variance extracted (AVE) for each construct. AVE is calculated with the following equation:

$$AVE = \frac{\Sigma(\lambda^2)}{\Sigma(\lambda^2) + \Sigma \text{ Var } \varepsilon}$$

AVE values greater than 0.50 indicate that the variance captured by the construct is greater than the variance due to measurement error, providing evidence of convergent validity (Fornell & Larcker, 1981).

5.5.3.2 Discriminant Validity

In order to provide evidence of discriminant validity the shared variance between any given pair of constructs must fall below the average variance extracted for the constructs (Fornell & Larcker, 1981). This would indicate that the item measures better explain the latent construct with which it is associated than it does another latent construct (Hair Jr. et al., 2006). The test for this is to compare the squared correlation estimate between two constructs with the variance extracted. In order to more easily fit the information into a single summary table of the CFA test statistics, the square root of the variance extracted is included along the diagonal of **Error! Reference source not found.**Table 5.8.

5.6 *Reliability and Validity Summary*

Examination of the sample data is necessary to confirm that the basic underlying assumptions required for multivariate statistical testing are met before more advanced data analysis can begin. These include assessing the demographics of the respondents is an appropriate representation of the target sample and allows for generalizability of the results. Some missing data is to be expected, but the levels of missing data by item and case should be low and with a random pattern. In addition, the collection process should not introduce non-response bias and should control for common method bias. The data should exhibit a normal distribution, or data transformation may be necessary to carry out required analysis.

The data collected was obtained from a qualified target sample of 3,199 supply chain professionals. Of these, 303 responded to the survey, for a response rate of 9.5%. Examination of the demographics of the respondents indicates that they are all involved in supply chain management from a wide variety of industries and from a range of firm sizes, as shown in Table 5.1 and Table 5.2. This supports the generalizability of the results, since no particular industry or size of firm is disproportionally represented in the data.

Although the sample size obtained is adequate to undertake the data analysis techniques to be used, it is still important to ensure completeness of the data examination investigation of missing data. There are low levels of data missing by item and by case, although five cases were found to have more than 10 percent of the responses to items missing and were therefore eliminated. The remaining sample was tested and determined to have data missing completely at random (MCAR) with no underlying bias in the data. This allowed for imputation of the missing data using an expectation-maximization (EM) algorithm which allows for the best representation of the original distribution with the least bias (Hair Jr. et al., 2006). With a complete data set, it was determined that there were no outliers, and that the data should be inspected for normality. Levels of both kurtosis and skewness were found to be below the acceptable cut-off levels, indicating the data has a normal probability distribution. It was determined via an ANOVA test of early and late responders that there was no evidence of non-response bias. Finally, the study and the data collection instrument were carefully designed to take into account the risk of common method bias. An inspection of the data using Harmon's one factor test indicates that common method bias is not of concern within the data.

The testing undertaken on the sample data indicates that it is possible to proceed with further data analysis. This first analysis undertaken was a two-step confirmatory factor analysis as prescribed by Anderson and Gerbing (1988). The results of the CFA indicated that modification of several constructs. Specifically, the construct of *Supply Chain Complexity*, which contained elements of uncertainty, should have these items removed to form a new construct of *Supply Chain Uncertainty*. In addition, the construct of *Disruptive Events* which originally combined both supply and demand disruptions should be separated into two distinct constructs of *Disruptive Events – Supply* and *Disruptive Events – Demand.* The separation of these constructs into more discriminant and refined concepts reduces the risk of common method bias (Podsakoff, MacKenzie, Lee, and Podsakoff, 2003).

After the required changes to the constructs and their individual items, the data was examined for convergent and discriminate validity as prescribed by Fornell and Larcker (1981). Although Cronbach's alpha (α) is often used, more robust tests are available and were used in this study. Specifically, the λ of individual items, calculation of construct reliability and AVE indicate that the data does posses convergent validity. Further testing demonstrated the presence of discriminant validity. The results of these tests can be found in Table 5.8

6. DATA ANALYSIS

Structural equation modeling (SEM) is the method selected for model testing. SEM represents a special case of covariance structure modeling that is used to evaluate an *a priori* set of linear relationships (the 'path model') between variables that may be observed (manifest variables) or unobserved (latent variables). It is used here to examine both the construct measurement and structural relationship components of the research. There have been several recent guidelines in focused literature on the application of this powerful technique, such as strategic management (Shook, Jr., Hult, & Kacmar, 2004), logistics (Garver & Mentzer, 1999) and international business (Hult et al., 2006). The recently published guidelines for operations management by Shah and Goldstein (2006) serve as the skeleton for this study of the steps that should be completed and the data to be reported.

6.1 *Results of Path Model Testing*

The results of hypothesis testing for the Full model are provided in Table 6.1, which includes the parameter estimates, level of significance and model fit statistics (details for the NAT and HRT model are available from the author). In addition, the graphical presentation of the models and the significant paths are shown in Figure 6.1, in Figure 6.2 for the NAT Model and in Figure 6.3 for the HRO model, all of which will be discussed in detail. It is worth reiterating that the results of the CFA analysis indicated that it some of the originally designed constructs required modification. Most notably, the separation of two compound constructs into four focused constructs, and the consolidation of a second order construct. The original *Supply Chain Complexity* construct was divided into *Supply Chain Complexity* (of products, processes, market and supply chain structure) and *Supply Chain Uncertainty* (in supply and demand); the occurrence of *Disruptive Events* was divided based upon the source of the disruption into *Disruptive Events – Supply* and *Disruptive Events – Demand*. The second order construct of *Continuity Planning* was reduced from six elements to four.

The resulting full model consists of three constructs based upon NAT: *Supply Chain Complexity* (CMPLX), *Supply Chain Uncertainty* (UNCT) and *Supply Chain Dependency* (DPND); two constructs based upon HRT: *Effective Practices* (EFPR) and *Concern for Disruptions* (CNRN); a reduced second order construct of *Continuity Planning* (PLAN); separate constructs to represent *Disruptive Events – Supply* (DE_S) and *Disruptive Events – Demand* (DE_D); and lastly, *Firm Performance* (FMPR).

The primary purpose of hypothesis testing is to determine the efficacy of the use of risk management planning in a supply chain to reduce the frequency and severity of supply chain disruptions, a reduction that is hypothesized to positively relate to firm performance. Antecedents to continuity planning may be influenced by a firm's perceptions that it is vulnerable to disruptions based upon the supply chain structure in which it operates, or conversely that diligent management may be able to reduce vulnerability. These concepts are grounded in NAT and HRT theory, and tested within a full model and individually as separate models. Based upon the theoretical foundation of NAT, it may be inferred that when a supply chain is complex with high uncertainty and dependency between supply chain entities, there is little that a firm can do to prevent the occurrence of disruptions within the supply chain (the occurrence of 'normal accidents'). Conversely, HRT suggests that with proper concern for disruptions and the use of effective business practices and continuity planning, firms may be able to reduce their susceptibility to supply chain disruptions to move toward higher supply chain reliability.

Overall fits for all three models are marginal, but do provide consistent insights worth noting. First all three models indicate strong support for the mediating role of continuity planning, and the positive relationship of *Continuity Planning* with *Firm Performance* (H6). The second notable consistent finding is the lack of support for the expected relationship between *Concern for Disruptions* and the occurrence of *Disruptive Events – Supply* and *– Demand*; $H5b_{S,D}$ hypothesized that the relationship would be *negative* (higher levels of concern are associated with lower levels of disruptive events) however, in both the Full and HRT models, there is a significant *positive* relationship between these constructs. An important third result was also unexpected, specifically the lack of a significant relationship between *Disruptive Events –Supply* and *–Demand*, and *Firm Performance* ($H8_{S,D}$). All results for the three models are further discussed in the following sections, including a summary of hypothesis support, path λ values, significance levels and overall model fit in Table 6.1.

Table 6.1 Results of H1 to H8 and Model Fit Statistics

	Hypothesis	Full Model		NAT Model		HRT Model	
	H1a: (CPLX →PLAN) +	.12*	support	.13**	support		
	H1b: (DPND→PLAN) +	.50**	support	.64**	support		
+	H1c: (UNCT→PLAN) +	.07		.07			
+	H2a$_S$: (CPLX→DE$_S$) +	.19**	support	.28***	support		
+	H2a$_D$: (CPLX→DE$_D$) +	.16*	support	.20***	support		
+	H2b$_S$: (DPND→DE$_S$) +	-.04		-.12			
+	H2b$_D$: (DPND→DE$_D$) +	.03		-.02			
+	H2c$_S$: (UNCT→ DE$_S$) +	.04		.26***	support		
+	H2c$_D$: (UNCT→ DE$_D$) +	.13*	support	.20***	support		
	H3a: (EFPR→PLAN) +	.29**	support			.58***	support
	H3b: (CNRN→PLAN) +	.06				.16***	support
	H4a: (EFPR→FMPF) +	.23***	support			.25***	support
	H4b: (CNRN→FMPF) +	-.03				-.03	
+	H5a$_S$: (EFPR→DE$_S$) -	-.11				.03	
+	H5a$_D$: (EFPR→DE$_D$) -	-.04				-.03	
+	H5b$_S$: (CNRN→DE$_S$) -	.33***	reverse			.46***	reverse
+	H5b$_D$: (CNRN→DE$_D$) -	.13*	reverse			.30***	reverse
	H6: (PLAN→FMPF) +	.16***	support	.29***	support	.16**	support
+	H7$_S$: (PLAN→DE$_S$) -	-.14		-.03		-.07	
+	H7$_D$: (PLAN→DE$_D$) -	-.13*	support	-.14*	support	-.11	
+	H8$_S$: (DE$_S$→FMPF) -	-.06		-.08		-.06	
+	H8$_D$: (DE$_D$→FMPF) -	-.03		-.06		-.04	
		$\chi^2_{(715)}$ = 2068.6 CFI = .783, RMSEA =.080		$\chi^2_{(364)}$ = 1274.9 CFI = .807; RMSEA =.092		$\chi^2_{(217)}$ = 801.0 CFI = .839; RMSEA =.095	

Notes: + indicates hypothesis has been modified to reflect changes in constructs

*** p<.01, ** p<.05, * p<.10 $\chi^2_{(df)}$

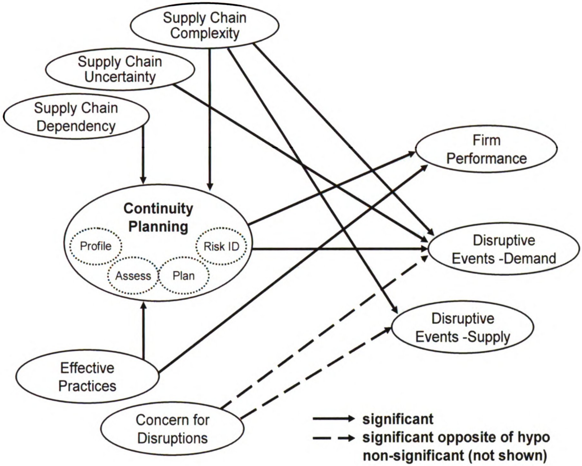
CPLX = Supply Chain Complexity, PLAN = Supply Chain Risk Planning,
UNCT = Supply Chain Uncertainty, DE$_S$ = Disruptive Event – Supply,
DE$_D$ = Disruptive Event – Demand, DPND = Supply Chain Dependency,
EFPR = Effective Practices, CNRN = Concern for Disruptions, FMPF = Firm Performance

Within the Full Model shown in Figure 6.1, which includes both NAT and HRT, statistically significant associations with the use of *Continuity Planning* are *Supply Chain Complexity* (H1a) and *Supply Chain Dependency* (H1b), and the use of *Effective Practices* (H3a). This would indicate that when there are higher perceptions of complexity and entity dependency within the supply chain, firms are more likely to engage in planning activities meant to manage supply chain risk. In addition, firms that are engaged in higher levels of a variety of generally accepted effective practices are also more likely to engage in planning activities. Interestingly, there is no significant relationship between *Supply Chain Uncertainty* (H1c) or *Concern for Disruptions* (H3b) and *Continuity Planning*. These findings provide some support for the efficacy of both NAT and HRT theory within this context. It would seem that firms can, through effective continuity management, positively impact disruptive events (support for HRT) although they will not be able to completely eliminate all disruptive events (support for NAT).

It is important to note that $H5b_{S,D}$ predicted a negative relationship between the *Concern for Disruptions* and *Disruptive Events - Supply* or *- Demand*. Using HRT as a basis, the expectation was that firms with greater concern for disruptions would experience disruptions at a lower rate or with lower magnitude. However, the significant positive relationship between the two constructs indicates that the potential cause and effect relationship may be that the occurrence of disruptive events leads to higher levels of concern for disruptions. This would seem to indicate that managers should in fact be concerned about disruptive events, since they seem to be experiencing them. In addition, given the market intolerance for disruptions to the supply chain, it is imperative that managers learn to better manage their supply chain risk for increased supply chain continuity. Although correlation can be determined, causality can't with the cross-sectional data used here. Future research utilizing longitudinal data may allow for more definitive conclusions regarding the relationship between the occurrence of, and concern for, disruptive events.

Continuity Planning is significantly related to lower levels of *Disruptive Events -Demand* ($H7_D$) but not *Disruptive Events -Supply* ($H7_S$). There is also strong support for the relationship between engagement in *Continuity Planning* and higher levels of *Firm Performance* (H6). Surprisingly, there is no support that *Disruptive Events – Supply* or - *Demand* are associated with lower levels of *Firm Performance* ($H8_{S,D}$).

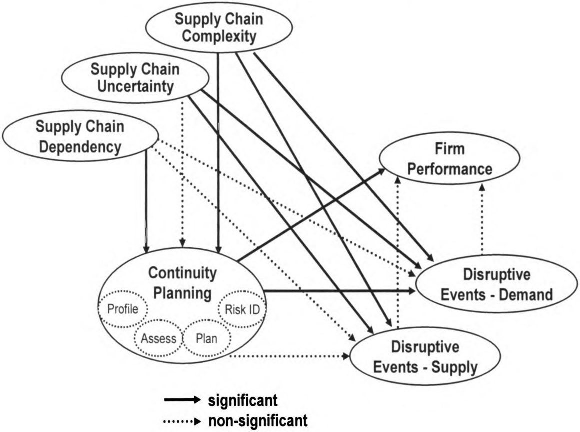
Figure 6.1 Full Model Significant Paths



Within the NAT Model shown in Figure 6.2, there is support for several of the hypotheses grounded in NAT. Consistent with the Full model, both *Supply Chain Complexity* (H1a) and *Supply Chain Dependency* (H1b) are significantly positively associated with *Continuity Planning* while *Supply Chain Uncertainty* (H1c) does not have a significant relationship. Also consistent with the Full model, *Supply Chain Dependen*cy does not have a significant relationship with *Disruptive Events - Supply* or *- Demand* (H2b$_S$ and H2b$_D$). In a slight difference from the Full model are the findings that higher perceptions of *Supply Chain Complexity* (H2a$_{S,D}$) and *Supply Chain Uncertainty* (H2c$_{S,D}$) which exhibit a stronger positive associated with higher levels of both *Disruptive Events - Supply* and - *Demand* disruptions. This is an interesting finding because a key element of NAT is the importance of dependency, which does not exhibit a significant association in the hypothesized models.

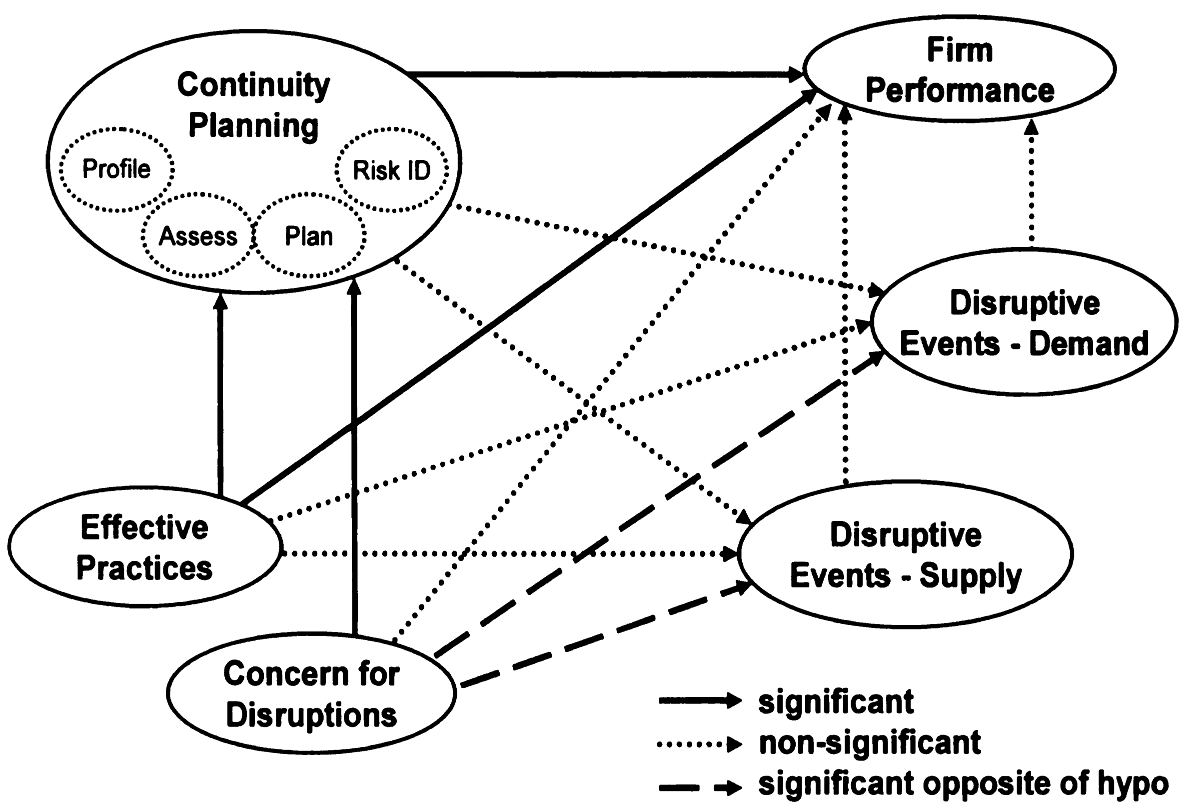
The relationships between other constructs in the Full model and NAT model are also similar. *Continuity Planning* (H6) has a significant positive relationship with *Firm Performance,* a weak significant negative relationship with *Disruptive Events – Demand* ($H7_D$) and no significance with *Disruptive Events - Supply* ($H7_S$). In addition, there is no significant relationship between *Disruptive Events - Supply* or – *Demand* ($H8_{S,D}$) and *Firm Performance.*

Figure 6.2 Normal Accident Theory Model Significant Paths



A comparison of the Full model with the High Reliability Model in Figure 6.3 highlights consistent findings for most of the hypothesized paths, with a few notable exceptions. *Effective Practices* (H3a) has a stronger positive association with *Continuity Planning* than in the Full model, and *Concern for Disruptions* (H3b) has a strong positive association not seen in the Full model. Confirmation of these hypotheses provides support for the efficacy of HRT in this context. Also similar to the Full Model, the HRT Model achieved significant positive associations between *Concern for Disruptions* and *Disruptive Events – Supply* and *–Demand*, a finding contradicting the hypothesized negative relationship ($H5b_{S,D}$).

Figure 6.3 High Reliability Model Significant Paths



In discussing the results of model testing, there are a few salient points worth mentioning. The most important finding is that across models, there is a significant positive relationship between *Continuity Planning* and *Firm Performance.* This relationship is strongest in the NAT model that does not include any other constructs that could positively impact firm performance. However, in the HRT model, the relationship between *Effective Practices* and *Continuity Planning* is stronger. This may indicate that activities undertaken to reduce and manage supply chain risk are part of a set of effective business practices.

Another important finding, that clearly supports NAT, is the strength of the relationship of *Supply Chain Dependency* and *Continuity Planning*. In fact, this is the strongest relationship in the models. Although *Supply Chain Complexity* is also important, it appears to be clear that firms understand the basic premise of NAT, which is that it is not the action (or inaction) of a single operator in the chain, but the interactions between entities when an event occurs that cause 'accidents' to happen and move through a system.

6.2 *Research Implications*

The proposed models used in this study achieve marginal fit statistics, but are still useful given the nascent level of research on risk management planning within a supply chain setting. In addition, the use of NAT and HRT has rarely been undertaken in supply chain research, so constructs that have been rigorously examined in multiple studies and contexts were not available. Therefore, this research makes several contributions to the field: 1) starting the process of construct creation and validation, 2) providing insights that could be used to examine and refine the role of complexity, uncertainty and dependency, and 3) examining the role of continuity planning and other effective practices in reducing events that disrupt supply chain functionality and that likely impact overall firm performance.

The findings here provide support for the utility of both NAT and HRT in explaining factors that influence firms to undertake planning efforts to reduce supply chain risk. In addition, the data provide insight on the impact of planning efforts on the occurrence of disruptions and firm performance. Consistent with NAT, firms with higher perceptions of supply chain complexity and dependency engage in higher levels of continuity planning. Within this study, supply chain complexity includes structural elements (number of internal divisions and facilities, production facilities and warehouse, and external links of suppliers and customers), geographic dispersion and multiple tiers of nodes. Supply chain dependency includes elements of time-based synchronization, knowledge of partner activities, awareness of partner strengths and weaknesses, alignment of activities, the exchange of knowledge and investment in information exchange. Interestingly, uncertainty of supply availability and demand variation does not have a significant impact on planning. It is possible that uncertainty is accepted as a 'normal' state with a perception that supply chain managers have little ability to take action to influence a reduction in uncertainty.

There is also support for HRT through the strong positive relationship of both concern for disruptions and the use of effective business practices on engagement in supply chain risk management planning activities. Within this study, effective business practices were limited to those that have been used in multiple recent studies and that are less ubiquitous than TQM, Lean or JIT. Those practices identified for inclusion here incorporate activities related to new product development, sharing high quality information, utilization of customer relationship management, interdepartmental cooperation and strategic supply chain management. While it can be argued that risk management may be an effective business practice, the analysis here indicates that there is reason to measure these constructs separately.

As expected, the use of a wide variety of effective business practices is positively and strongly associated with higher levels of firm performance, although not with a reduction in disruptive events from either supply or demand sources. An important finding is that the anticipated negative relationship between concern for disruptions and the occurrence of disruptions was shown instead to be significantly positive. This raises questions about the link between these constructs. Using HRT, it is expected that firms that are more concerned about reliability would undertake activities to reduce the occurrence of events that would negatively impact continuous supply chain operation. However it appears that more frequent and larger magnitude of supply chain disruptions are associated with elevated levels of concern. It is important to note that SEM analysis does not allow for conclusive cause-and-effect relationships, because it is based upon covariance relationships which do not incorporate a temporal element.

Table 6.2 Summary of Research Implications

Issue	Impact	Recommendation
Few previously defined or tested constructs.	Many of the constructs used here were created from a review of salient literature. Although great care was taken in designing and pre-testing the constructs, several required modification.	Creation and initial testing of constructs in this research can serve as the basis for further definition and refinement of relevant constructs.
Little previous examination of the role of complexity, uncertainty and dependency on supply chain risk.	NAT theory states that complex, uncertain and dependent systems are prone to 'normal accidents'. Supply chains exhibit these attributes and are therefore prone to failure. However, it is unclear the degree to which these attributes are related and the impact on disruptive events.	Refined and tested definitions of complexity, uncertainty and dependency within a supply chain context are needed. In addition, a deeper understanding of the role of complexity, uncertainty and dependency within a supply chain context is needed.
Little previous examination of the use of specific risk management practices utilized by firms to improve supply chain performance continuity.	There is wide variety in the practices firms can choose to use specifically to manage risk, but little research to determine which are most effective in reducing risk based upon the business environment and types of risk faced.	Further examination of risk management practices in a variety of business setting is needed, perhaps utilizing Contingency Theory.
There may be a possible linkage with risk management practices and other general 'effective' business practices.	It is possible that there is an interaction effect between practices that are 'general' and that are specific to risk management.	Examination of the role of specific risk management practices and general 'effective' business practices is needed to capture their specific contribution and their combined contribution to firm performance.
Neither NAT nor HRO have been frequently utilized in operations or supply chain research.	Evidence of efficacy for the competing theories of Normal Accidents and High Reliability	Further testing of these theories is needed to better understand their usefulness in explaining risk management in supply chains; or to develop a unifying theory.
There is a high correlation between concern for disruptions and the occurrence of disruptive events.	The study reveled results the opposite of expected regarding the relationship between concern for and the occurrence of disruptive events.	More research is needed to better understand the potential causal relationship between these two constructs.

6.3 *Managerial Implications*

Disruptions from multiple sources and across industries can lead to sizable market penalties for firms that don't manage this important business area well. The reason or cause of a supply chain disruption is not a critical factor; the market expects an uninterrupted flow of goods and services. In addition to the market and financial consequences that a firm may incur, there can also be a detrimental impact on employees, suppliers, customers and other supply chain stakeholders. Unfortunately, it is also possible that the efforts undertaken by firms to create leaner supply chains, increase efficiency, and reduce costs may have unintended consequences of creating supply chains that are more vulnerable to disruptions because of the elimination of safety buffers.

Although the management of the unexpected can be a difficult challenge for business to contend with, supply management professionals do not perceive that they must accept supply chain disruptions as part of doing business. There is a clear perception that they can positively affect both the frequency and impact of interruptions to their supply chains through proactive risk management, even if they are in supply chains that are complex and have uncertainty of supply or demand.

6.3.1 Role of Supply Chain Complexity, Dependency and Uncertainty

In general firms that reported supply chains that were more complex, had higher levels of supply and demand uncertainty, and greater dependency on supply chain partners experienced more supply chain disruptions. Supply chain complexity includes greater number and larger geographic dispersion of supply chain nodes, both of which influence the length and width of the supply chain. Interestingly, unlike the complexity of the supply chain structure, the complexity of the products does not appear to have a significant impact. This complexity is also associated with higher levels of uncertainty in both the supply of incoming material, output for internal sources, and demand from customers. Both supply chain complexity and uncertainty are correlated with higher levels of concern for disruptions, higher perceptions of supply chain vulnerability to disruptions and to a higher actual occurrence of disruptions.

The correlation of supply chain complexity and the occurrence of supply chain disruption may be influenced by the industry in which a firm operates. Firms that are more complex also report more frequent knowledge of their competitors experiencing disruptions. The data in this study supports the premise that firms that seek to manage supply chain risk, may be able to create a source of differentiation and competitive advantage, as well as mitigate or avoid negative financial consequences (Norrman & Jansson, 2004; Filbeck et al., 2005; Hendricks & Singhal, 2005a; Hendricks & Singhal, 2005b).

6.3.2 Formal versus Informal Risk Management Plans

There was much higher incidence of the use of *informal* risk management plans, but individuals that reported a higher usage of *formal* plans also had significantly higher levels of firm performance. Formal plans were also substantially more likely to undergo regular internal review and, more importantly, more likely to be shared with both up and down-stream supply chain partners. The usage of formal plans is more effective than informal plans in improving firm performance, especially if formal plans are reviewed internally, undergo testing via 'fire drills' and are regularly shared with both internal and external supply chain participants. It would appear that the very process of creating, sharing and maintaining formal plans places greater focus on this critical business activity.

6.3.3 Profiling the Supply Chain

A key first step in the process of supply chain risk management is having an up-to-date and comprehensive profile (or map) of the supply chain. Having an accurate profile of the supply chain is correlated with knowledge of the unique vulnerabilities of suppliers, important transit lanes, a firm's own facilities, and customers. It could be that the very process of explicitly identifying a firm's supply chain and the relationships between the nodes and the transit lane linkages illuminates the vulnerabilities and potential sources of risk. The explicit examination and mapping of the supply chain for sources of risk has a high correlation to the ability of the firm to also assess the probability and potential magnitude of a disruption, from both a quantitative and qualitative impact. An additional potential advantage of examining the supply chain and the node linkages is the ability to identify and utilize multiple sources of information that could provide 'signals' of impending or unfolding interruption to normal supply chain functionality.

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6.3.4 Risk Reduction Techniques

The simplest and easiest to implement forms of buffering, safety stock and supply flexibility (using at least two suppliers and having a cross-trained workforce), are the most commonly used supply chain risk reduction techniques. In keeping with JIT and lean practices, pushing safety stock back on to suppliers is used more frequently than a firm holding their own buffer stock. It is important to note that while the use of multiple suppliers may provide some protection from an interruption in supply should a single supplier fail to provide needed material or service, multiple suppliers also equates to variation in inputs, which in turn may lead to problems with internal conversion processes.

Other practices that may be used to manage risk, such as material standardization or the postponement of final product configuration are less commonly used. These practices require greater effort to implement, due to the need for cooperation across functional areas within the firm (product engineering for re-design, procurement for changing material requirements, manufacturing engineering for process re-design, etc.) and well and cooperation outside the firm to suppliers and customers.

6.3.5 Importance of Effective Business Practices

Firms that engage in a wide variety of 'good' business practices, even if not explicitly undertaken to manage supply chain risk, are less likely to experience supply chain interruptions. There appears to be some interaction affect that makes enhances firm performance when firms have higher levels of both general effective business practices and specific risk reduction activities. Both externally focused and internally focused practices appear to be important. Externally, firms that report a higher commitment to providing accurate, timely and credible information to their supply chain partners and to the development of mutually beneficial partnerships are more successful in managing risk. Sharing information, even if not specifically undertaken for risk management, is positively correlated with fewer supply chain disruptions.

Table 6.3 Summary of Managerial Implications

Issue	Recommendation
Publically known supply chain disruptions result in: • 6.9% ↓ in sales growth • 10.7% ↑ in cost • 13.9% ↑ in inventory • 13.5% ↑ in equity risk	• Supply chain disruptions should not be accepted as a 'normal' state of business • Firms must undertake risk management to avoid costly disruption penalties
Firms should utilize a general framework for developing firm specific risk management plans.	Effective risk management planning includes: • Profiling the current supply chain • Identifying potential sources of risk • Assessing potential risk impact • Preparing formal plans • Sharing plans with partners
More frequent and impactful disruptions are associated with supply chains that have: • ↑ complexity • ↑ uncertainty • ↑ dependency	Comprehensive assessment of supply chain complexity, uncertainty and dependency to: • Identify sources of vulnerability • Create appropriate solutions
Focus on efficiency, lean and JIT activities often results in: • Removal of buffers • Increased susceptibility to supply chain disruptions	Firms need to fully understand their processes and sources of risk, including: • Material flows • Process and entity dependencies • Judicious use of buffers
Informal risk management plans are less effective because they: • Are less comprehensive in scope • Undergo less periodic review & testing • Are less likely to be explicitly shared with relevant parties	Firms should invest in the process of creating, sharing and maintaining formal plans, rather than relying on informal plans
Potential positive and cumulative interaction effect between general 'effective' business and risk management practices	Firms should not discount the impact of risk management as a subset of effective business performance management

6.4 *Discussion*

This study examines the risk management planning activities that firms may undertake in an effort to reduce vulnerability to supply chain disruptions and to create supply chains that have greater reliability in the flow of goods, services, information, and funds through the supply chain for improved firm performance. Building upon limited previously published theory driven empirical research within this topic area creates both challenges and opportunities. Most notably the need to examine multiple literature streams related to complexity, uncertainty, dependency, operational practices, and risk management. The advantage of searching outside traditional literature streams is the ability to incorporate ideas from a broader span of thought. In addition, it allows for the creation of constructs that incorporate a more holistic view of concepts. Notably, this study has synthesized several streams of literature to create a framework for supply chain risk planning.

6.5 *Research Questions*

In undertaking this study, several research questions were identified to drive the research. The questions are restated below, along with the findings.

1. *What factors drive firms to engage in supply chain continuity planning?*

   Firms that perceive they operate in supply chains with higher levels of complexity and dependency are more likely to engage in planning efforts to reduce the occurrence and frequency of supply chain disruptions. Uncertainty in supply and demand has no significant relationship with planning. In addition, firms that engage in a wide variety of effective business practices are more likely to also engage in continuity planning.

2. *How are firms undertaking the creation of supply chain continuity plans (process)? What are firms including in supply chain continuity plans (content)? What are the 'best practices'?*

Firms appear to have a clear picture of the locations of their suppliers, customers and their own facilities, but less so of their transit lanes. They also believe they have a good understanding of the vulnerabilities of suppliers and their own facilities, and consider vulnerabilities in selecting new or evaluating current suppliers; again there is a lack of understanding of transit lane vulnerabilities. Although the vulnerabilities are fairly well identified, firms do not perceive there is adequate knowledge of the probability or impact of different types of potential supply chain disruptions. Firms are more likely to engage in informal planning, although formal plans are more highly correlated to a reduction in disruptions. In general firms feel they are able to manage their supply chain risk well, and use the practices of cross-training and supplier agreements most often.

3. *To what extent are firm's engaged in supply chain continuity planning upstream, internally, downstream or some combination of directions?*

The results of this study indicate greater engagement in planning activities that are focused internally and upstream to suppliers, rather than externally towards the business environment or downstream to customers. This result is not unexpected, since the survey respondents consist primarily of professionals in the procurement area of their firm's which would likely influence the results. However, since supply chain disruptions can occur from a wide variety of sources, further research utilizing professionals with a differing or wider supply chain focus would be beneficial.

4. *Does increased supply chain continuity planning result in a reduced frequency and impact of disruptive events and in improved firm performance?*

There is little conclusive evidence that planning directly affects the frequency or impact of disruptive events, a disappointing result. There is however significant support for the significant positive relationship between higher levels of planning and firm performance. Given the strong positive relationship between planning and firm performance and the use of effective practices and firm performance, there maybe an interaction effect between planning and effective practices that impacts firm performance. This inability to provide support for causality is a limitation of cross-sectional research, and an area for future study. It is also possible that, similar to the Sand Cone Model of capabilities (Ferdows & Demeyer, 1990), these create a stronger influence when combined.

5. *Does supply chain complexity, uncertainty or dependency influence the processes and effectiveness of supply chain continuity planning processes or results?*

Higher levels of supply chain complexity and uncertainty are associated with higher levels of supply and demand disruptions, and there is no significant association from dependency. However, the strong positive relationship between planning and firm performance indicates there is potential for planning to mitigate the impact of the supply chain environment.

6.6 *Future Research*

Future research in the area of supply chain risk management has several opportunities for further development. These areas include the continued refinement of constructs that examine the supply chain structure and environment in areas that may impact the vulnerability of the supply chain to disruptive events. Specifically, constructs to capture the structural complexity of the supply, the dependency that exists between nodes, and the uncertainty in supply and demand need to be advanced and validated through multiple studies. Conceptual work has begun in these areas, but theory building and subsequent testing will require robust constructs.

In addition, there is very limited work that tests the planning activities that firms do and should engage in for improved supply chain resiliency and firm performance. There is a great deal of prescriptive advice provided to professionals through a wide variety of trade publications and main stream books. While there are many anecdotal stories that serve as examples of superior or inferior responses to supply chain disruptions, there is little empirical testing of the use of specific processes and their outcomes.

This study utilized procurement professionals; future research should entail gathering data from a broader set of supply chain professionals, including operations and supply chain managers and individuals with greater knowledge of downstream supply chain functionality. By gathering information from supply chain management professionals in a wider variety of functional areas, it will be possible to compare and contrast the perceptions of risk and risk management from the perspective of a broader range. In addition, the results will be more generalizabile with less reliance on the perspective of individuals that are primarily supply or up-stream focused.

Another important extension of the current study would be undertaking a longitudinal study to determine the relationship of risk management planning at a point in time on the occurrence of disruptive events and firm performance from that point forward. The current cross-sectional study does not allow for evidence of a cause-effect relationship between risk management planning activities and the influence the activities may have on reducing disruptive events or improving firm performance. The ability to more definitively establish such relationships through a longitudinal study would provide further insight into the specific role of risk management planning activities, along with other effective business practices, on the frequency and magnitude of disruptive events and on firm performance.

Unfortunately, such a study was not possible within the limitations of this research. A longitudinal study that measures such complex business practices would require a time difference between measurement points of at least one year in order to allow the results of planning activities to take effect. In addition, it is possible that disruptive events that have a large enough impact to be memorable to supply management professionals do not occur frequently, so allowing for a longer time differential between initial and subsequent data gathering points will help to increase the likelihood that a difference in the occurrence of disruptive events is substantial enough to be captured.

Appendix A: Copy of Survey

(items reduced from original size to meet dissertation page formatting requirements)

Supply Chain Survey

Instructions for the survey participant

Thank you in advance for your participation in this study examining supply chain risk management and continuity planning.

The enclosed survey should take approximately 20 minutes or less to complete. Your participation is completely voluntary and we greatly appreciate your support. The knowledge of professionals such as your self is vital to find ways to improve business performance.

As you take the survey, please keep the following in mind:

- All individual response will be kept strictly confidential. Only the survey team will have access to individual responses; all reports will summarize the data and report findings in aggregate.
- If you are unsure of the exact answer to a question, please provide your best estimate.
- If possible, please try to answer all the questions. The more of the questionnaire you answer, the better able we are to gather meaningful information and find trends. However, if you are uncomfortable with a specific question, you may leave it blank.
- As you respond to the questions, please base your answers on your knowledge of a supply chain for a specific product line/family you understand well.
- On the last page of the survey, you will have the opportunity to register for the drawing for one of five Visa® Gift Cards of $50 each.

Again, thank you for helping us to better understand how firms manage supply chain risk and in finding ways to better manage this important business issue.

If you have any questions or comments about this study, please feel free to contact us at:

Andrea Prud'homme
Michigan State University
(517) 432-5535 x272
SC_Risk@bus.msu.edu

Rich Hough, CPP
American Purchasing Society
support@american-purchasing.com

You indicate your voluntary agreement to participate by completing and returning the survey. All individual responses will be kept strictly confidential and will not be shared with any individual or organization beyond the research team. All analyses, reports and presentations of the data generated from this study will be reported at an aggregate level. If you have questions or concerns regarding your rights as a study participant, you may contact - anonymously if you wish - Dr. Peter Vasilenko, Chair of Behavioral & Social Science Institutional Review Board by phone (517) 355-2180, fax (517) 432-4503, or e-mail irb@msu.edu

You will be asked questions about supply chain disruptions and the management of supply chain risk that is meant to reduce disruptions. For the purposes of this survey, **a supply chain disruption can be small or large and is any event that reduces, delays or stops the flow of goods through the supply chain or that requires extra resources to maintain or resume the flow of goods when an event occurs.**

Supply chain focus: When answering the questions in this survey, it is important to focus on a specific supply chain that you have good knowledge about. Please indicate in the space below the product line or product family that you will be thinking about as you answer the survey questions:

____

(this question is meant to focus your responses and will not be used to specifically identify you or your firm)

		NONE			moderate			HIGH
1.	Level of concern for *market / business environment* caused disruptions (e.g. regulatory issues, currency fluctuations, economic change, competitor's actions, material cost instability, etc.)	1	2	3	4	5	6	7
2.	Level of concern for *upstream / supplier* caused disruptions (e.g. late deliveries, inability to meet demand, quality issues, material allocation, etc.)	1	2	3	4	5	6	7
3.	Level of concern for *internally* caused disruptions (e.g. interruption or delay in production output due to quality, equipment or personnel issues; inventory issues; capacity shortage; etc.)	1	2	3	4	5	6	7
4.	Level of concern for *downstream / customer* caused disruptions (e.g. changes in product requirements, changes in timing, volume or mix of demand, etc.)	1	2	3	4	5	6	7

		Extremely LOW			moderate			Extremely HIGH
1.	Complexity of the *products* sold to customers (e.g. uses new or frequently changing technology, large bill of material, quality specifications that are difficult to meet, several different versions or options of products, etc.)	1	2	3	4	5	6	7
2.	Complexity in the *business environment* (e.g. number of competitors, different customer niches, dynamic and frequently changing conditions, etc.)	1	2	3	4	5	6	7
3.	Overall complexity of the supply chain structure in terms of the *number of production or warehouse facilities* where your product is built or stored	1	2	3	4	5	6	7
4.	Overall complexity of the supply chain structure in terms of the number of *different divisions, business units, departments, or managers* of your firm that are involved in your supply chain	1	2	3	4	5	6	7
5.	Overall complexity of a *wide* supply chain with numerous suppliers, customers, distribution points, or multiple channels	1	2	3	4	5	6	7
6.	Overall complexity of a *long* supply chain with multiple tiers or echelons of suppliers and customers.	1	2	3	4	5	6	7
7.	Overall complexity in terms of the *geographic dispersion* (regionally, nationally or globally) of suppliers, production or warehouse facilities, customers, or distribution channels.	1	2	3	4	5	6	7
8.	Overall *uncertainty of supply* of material (e.g. uncertainty in availability, quality or lead time of purchased items)	1	2	3	4	5	6	7
9.	Overall *uncertainty of output* (e.g. variable quality, volume or timing of output from production)	1	2	3	4	5	6	7
10.	Overall *uncertainty of demand* (e.g. variation in timing, mix or volume of customer demand; customers changing product requirements)	1	2	3	4	5	6	7

Please indicate the level to which you agree or disagree with the following statements as they apply to your supply chain.

	Strongly **DISAGREE**			neutral			Strongly **AGREE**
1. We know our *suppliers,* including their locations and inter-relationships within our supply chain	1	2	3	4	5	6	7
2. We know our *customers,* including their locations and inter-relationships within our supply chain	1	2	3	4	5	6	7
3. We know our *production and warehouse facilities*, including their locations and inter-relationships within our supply chain	1	2	3	4	5	6	7
4. We have identified the *transit lanes* used to ship our material and products	1	2	3	4	5	6	7
5. We have a profile (or map) of our supply chain	1	2	3	4	5	6	7

	Strongly **DISAGREE**			neutral			Strongly **AGREE**
1. We know the particular vulnerabilities of our *suppliers*	1	2	3	4	5	6	7
2. We know the particular vulnerabilities of the primary transit lanes for *incoming* material and inventory	1	2	3	4	5	6	7
3. We know the particular vulnerabilities of our primary *production points* and our *warehouses*	1	2	3	4	5	6	7
4. We know the particular vulnerabilities of our *customers*	1	2	3	4	5	6	7
5. We know the vulnerabilities of the primary transit lanes used for *outbound* inventory and products	1	2	3	4	5	6	7
6. We explicitly consider vulnerabilities when *selecting new* supply chain partners	1	2	3	4	5	6	7
7. We explicitly consider vulnerabilities when *evaluating current* supply chain partners	1	2	3	4	5	6	7
8. We use multiple sources of information to identify supply chain risk	1	2	3	4	5	6	7
9. We have identified signals that we should watch for that would indicate a disruption may be starting or about to occur	1	2	3	4	5	6	7

	Strongly **DISAGREE**			neutral			Strongly **AGREE**
1. We have a process for assessing the *probability* or *frequency* of different types of supply chain disruptions	1	2	3	4	5	6	7
2. We have a process for assessing the *magnitude* or *impact* of different types of supply chain disruptions	1	2	3	4	5	6	7
3. We have a process to capture the *financial impact* of a supply chain disruption (e.g. cost of expediting, late penalties, overtime, lost sales, etc.)	1	2	3	4	5	6	7
4. We have a process to capture the *qualitative impact* of a supply chain disruption (e.g. loss of good will, damage to firm reputation, impact on supply chain relationships, etc.)	1	2	3	4	5	6	7

A supply chain continuity plan is used to identify, manage and reduce the frequency and impact of disruptions that may occur to the supply chain

	Strongly **DISAGREE**			neutral			Strongly **AGREE**
1. We have *formal* supply chain continuity plans for our supply chain	1	2	3	4	5	6	7
2. We have *informal* supply chain continuity plans for our supply chain	1	2	3	4	5	6	7
3. We review our supply chain continuity plans *internally*	1	2	3	4	5	6	7
4. We have 'fire drills' to test our supply chain continuity plans	1	2	3	4	5	6	7
5. We periodically review supply chain continuity plans with our *suppliers*	1	2	3	4	5	6	7
6. We periodically review supply chain continuity plans with our *customers*	1	2	3	4	5	6	7

Please indicate if there has been any change in the FREQEUNCEY and IMPACT of supply chain disruptions in the following areas over the **past 12 months**:

	FREQUENCY							**IMPACT**						
	LESS often			same			**MORE** often	much **SMALLER**			same			much **LARGER**
1. Change in disruptions from business environment sources (changes in technology, government regulation, currency fluctuations, changing commodity prices, competitor actions, etc.)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
2. Change in disruptions from upstream/supplier sources (material shortages, poor supplier delivery or quality performance, in-bound logistics, etc.)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
3. Change in disruptions from internal sources (insufficient capacity, quality problems, IT failure, personnel issues, etc.)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
4. Change in disruptions downstream/customer sources (out-bound logistics issues, changes in mix, timing or volume of customer demand, etc.)	1	2	3	4	5	6	7	1	2	3	4	5	6	7

	Significantly **LOWER**			same			Significantly **HIGHER**
1. Compared to our competitors, our *sales* are	1	2	3	4	5	6	7
2. Compared to our competitors, our *profitability* is	1	2	3	4	5	6	7
3. Compared to our competitors, our overall *competitive position* is	1	2	3	4	5	6	7
4. Compared to our competitors, our *return on assets* (ROA) is	1	2	3	4	5	6	7
5. Compared to our competitors, our *return on sales* (ROS) is	1	2	3	4	5	6	7

In the next two sections you will be asked questions regarding the general types of STRATEGIES that your firm may use to manage supply chain risk. You will also be asked questions about some specific PRACTICES that could be used to implement general strategies. This list is <u>*not*</u> meant to imply that all firms should use any or all of these strategies or practices.

STRATEGIES	Strongly **DISAGREE**			neutral			Strongly **AGREE**
1. There is little we can do to reduce supply chain disruptions, so we *accept* them as part of doing business	1	2	3	4	5	6	7
2. In general, our supply chain risks are well *managed*	1	2	3	4	5	6	7
3. We utilize a strategy of *sharing* supply chain risk with our supply chain partners (e.g. buy back agreements, cost or revenue sharing, etc.)	1	2	3	4	5	6	7
4. We have strategically *transferred* most of our supply chain risk to supply chain partners (e.g. vendor managed inventory, contractual performance agreements, etc.)	1	2	3	4	5	6	7
5. In general, we try to *reduce* supply chain risk as much as possible	1	2	3	4	5	6	7
6. We have been able to *pool* supply chain risk (e.g. use of buyer consortiums, centralized warehousing, trans-shipments, postponement or delayed finalization of finished products, etc.)	1	2	3	4	5	6	7
7. We have been able to *eliminate* most of our SC risk	1	2	3	4	5	6	7

Please indicate to what extent you agree or disagree that your firm uses the following practices <u>**specifically to reduce the risk or impact of supply chain disruptions**</u>:

PRACTICES	Strongly **DISAGREE**			neutral			Strongly **AGREE**
1. Whenever possible, we use two or more suppliers for our material needs, to reduce risk	1	2	3	4	5	6	7
2. We store material and goods in multiple warehouses to reduce risk	1	2	3	4	5	6	7
3. We hold our own safety stock of raw materials/components	1	2	3	4	5	6	7
4. We have suppliers hold safety stock of materials/components for us	1	2	3	4	5	6	7
5. We hold our own safety stock of finished or semi-finished goods	1	2	3	4	5	6	7
6. We have multiple production lines/facilities for critical processes or products to decrease the risk of having only a single location	1	2	3	4	5	6	7
7. We have specific agreements with our suppliers to respond to changes in product mix, volume or delivery schedules	1	2	3	4	5	6	7
8. Our workforce is cross-trained to perform a variety of jobs as needed	1	2	3	4	5	6	7
9. We can make our products in more than one location due to *processes standardization* across facilities, production lines or work cells	1	2	3	4	5	6	7
10. We *standardize our materials/components* across product types/lines	1	2	3	4	5	6	7
11. We utilize postponement, where operations or activities (e.g. customization, final configuration, etc.) are moved to a later point in the supply chain	1	2	3	4	5	6	7
12. We offer a wide portfolio of different versions or options of our product to meet the needs of different customer segments	1	2	3	4	5	6	7

Please indicate to what extent you agree or disagree that your firm uses the following practices as part of general business practices **unrelated to risk management**:

	Strongly DISAGREE			neutral			Strongly AGREE
1. We implement processes to improve new product development (NPD) (e.g. modularization, design for manufacturability, early supplier involvement, etc.)	1	2	3	4	5	6	7
2. We concentrate on our core competencies and outsource some processes and activities (e.g. IS/IT, facility maintenance, warehousing, etc.)	1	2	3	4	5	6	7
3. We have cross-functional cooperation between departments/functions	1	2	3	4	5	6	7
4. We develop or acquire proprietary equipment, processes, and/or products	1	2	3	4	5	6	7
5. We develop strategic supply chain partnerships, where appropriate, that are designed for on-going mutual benefit	1	2	3	4	5	6	7
6. We are committed to providing quality information to our supply chain partners that is accurate, timely, adequate, and credible.	1	2	3	4	5	6	7
7. We utilize a supplier certification process for key materials or suppliers	1	2	3	4	5	6	7
8. We share critical/proprietary information with our supply chain partners	1	2	3	4	5	6	7
9. We utilize customer relationship management (CRM) for the purpose of managing customer complaints, building long-term relationships with customers, and improving customer satisfaction	1	2	3	4	5	6	7

	Strongly DISAGREE			neutral			Strongly AGREE
1. We have a strong time-based synchronization with our supply chain partners	1	2	3	4	5	6	7
2. We have knowledge of activities of our *first tier* supply chain partners	1	2	3	4	5	6	7
3. We have knowledge of activities of our supply chain *beyond the first tier*	1	2	3	4	5	6	7
4. Our employees have close personal relationships with their supply chain partner counterparts	1	2	3	4	5	6	7
5. We are aware of the strengths of our supply chain partners	1	2	3	4	5	6	7
6. We are aware of the weaknesses of our supply chain partners	1	2	3	4	5	6	7
7. We are economically dependent on our supply chain partners	1	2	3	4	5	6	7
8. We have a high degree of alignment of business activities with our supply chain partners	1	2	3	4	5	6	7
9. Our business activities are developed through knowledge that is exchanged with our supply chain partners	1	2	3	4	5	6	7
10. We adapt our IT investments to better fit with our supply chain partners	1	2	3	4	5	6	7
11. Our reputation in the market is affected by our supply chain relationships	1	2	3	4	5	6	7

	Very LOW			moderate			Very HIGH
12. In your opinion, how would you rate the *vulnerability* of your supply chain to disruptions (any event that impacts the flow of goods/services or that has a negative financial impact to maintain or resume the flow of good/services)	1	2	3	4	5	6	7

	OFTEN			sometimes			NEVER
13. You hear about your competitors experiencing supply chain disruptions	1	2	3	4	5	6	7

DEMOGRAPHIC DATA

This section seeks to gather *general* demographic information about you and your firm. This information will not be used to specifically identify you or your firm, but allows for general grouping of responses based on criteria such as industry or company size to try to find trends.

1. Please indicate the primary industry your firm is involved in:

- Agriculture
- Communications
- Construction
- Finance, Insurance or Real Estate
- Government
- Health Services
- Hospitality/Food Service
- Manufacturing
- Retail or Wholesale Sales
- Transportation/Warehousing
- Utilities
- Other: ____________

2. What is the annual gross revenue of your company?

- Less than $10 million
- $10 to 249 million
- $250 to 499 million
- $500 to 749 million
- $750 million to 1 billion
- Over $1 billion

3. How many employees does your company have?

- Less than 100
- 100 to 249
- 250 to 999
- 1,000 to 4,999
- 5,000 to 9,999
- Over 10,000

4. What is your primary functional area or department?

- Engineering
- Facilities management
- IT/IS
- Logistics
- Manufacturing/production
- Procurement/purchasing
- Production control/planning
- Project management
- Risk/Business continuity management
- Warehousing
- Other: ____________

5. What position level are you in your company?

- VP
- Director
- Manager
- Supervisor
- Individual Contributor
- Other: ____________

6. What level of your organization do you work in?

- Corporate Level
- Strategic Business Unit Level
- Plant Level
- Other: ____________

Please include any comments about supply chain risk management that you think are important:

____

____

____

____

____

Are there any best practices that you would like to share?

____

____

____

____

____

What issues or topics do you think need more exploration or research?

____

____

____

____

____

THANK YOU FOR COMPLETING THE SURVEY, YOUR INPUT IS GREATLY APPRECIATED

If you would like to be entered for the chance to win one of the ten $50 Visa gift cards, please provide the information below. This information will only be used to send the gift card to you, if your name is drawn. You may still send the survey anonymously if you wish.

Name: ______________________________

Address: ______________________________

____

____

State: ______________ Zip Code: ______________

e-mail: ______________________________

Phone: ______________________________

Appendix B: Copy of survey contact materials

«MARSTAT» «FIRST» «LAST»
«COMPANY»
«CADDRESS»
«CITY», «STATE» «ZIP»

Dear «FIRST»:

The American Purchasing Society and researchers from Michigan State University have teamed together to study supply chain risk management. Your professional knowledge and experience is invaluable in helping us to better understand what drives firms to engage in supply chain risk management planning, the types of planning firms under take, and the effect of such plans on the occurrence of supply chain disruptions.

Your input into this study is vitally important, regardless of the level of planning your firm engages in or the frequency or size of supply chain disruptions you may experience. We need data from as many professionals as possible to determine how firms try to manage this process and to identify 'best practices' so firms can improve to reduce the likelihood and impact of a wide variety of disruptive incidents – *insights that you can use within your own firm*!

In exchange for your valuable input to the survey, we are providing you with the following opportunities:

For your firm: A summary report of the findings will be made available to APS members to allow you to begin improving your supply chain.

For you: As a special thank you for your participation, you will have the opportunity to enter a drawing for **one of ten Visa Gift Cards of $50 each**.

You may return the survey in the enclosed postage paid envelope, or you may complete the survey electronically at: **www.msurisk.org**

Thank you for your input on this important business topic,

Richard H. Hough

Richard H. Hough, CPP
American Purchasing Society
support@american-purchasing.com

Professional Purchasing

Andrea M. Prud'homme

Andrea M. Prud'homme
Michigan State University
SC_risk@bus.msu.edu

BROAD College of Business
Michigan State University

You indicate your voluntary agreement to participate by completing the survey. All individual responses will be kept strictly confidential and will not be shared with any individual or organization beyond the research team. All analyses, reports and presentations of the data generated from this study will be reported at an aggregate level.

If you have questions or concerns regarding your rights as a study participant, you may contact, anonymously if you wish, Dr. Peter Vasilenko, Chair of Behavioral, Social Science Institutional Review Board via:
phone (517) 355-2180, fax (517) 432-4503 or e-mail irb@msu.edu

Supply Chain Continuity Survey

Dear XXX:

The American Purchasing Society and researchers from Michigan State University are teaming together to study supply chain risk management. Your knowledge and experience is invaluable in helping us to better understand what drives firms to engage in risk management, the types of planning firms under take, and the effect of such plans on the occurrence of supply chain disruptions.

Your input into this study is vitally important, regardless of the level of planning your firm engages in or the frequency or size of supply chain disruptions you may experience. We need data from as many professionals as possible in order to determine 'best practices'– *insights that you can use within your own firm.* .

In exchange for your valuable input to the survey available at the link below, we are providing you with the following opportunities:

For your firm:
1) A summary report of the findings will be made available to APS members.
2) A short article, *18 Ways to Guard Against Disruption*, is available to you at the end of the questionnaire if you complete the survey electronically.

For you:
1) As a special thank you for your participation in the survey, you will have the opportunity to enter a drawing for **one of ten Visa Gift Cards of $50 each**.

You may return the survey in the enclosed postage paid envelope. Or you may log on to the website to complete the survey electronically: **www.msurisk.org**

Thank you for your support!

Richard H. Hough

Andrea M. Prud'homme

Richard H. Hough, CPP
American Purchasing Society
support@american-purchasing.com

Andrea M. Prud'homme
Michigan State University
SC_risk@bus.msu.edu

You indicate your voluntary agreement to participate by completing the online survey. All individual responses will be kept strictly confidential and will not be shared with any individual or organization beyond the research team. All analyses, reports and presentations of the data generated from this study will be reported at an aggregate level.

If you have questions or concerns regarding your rights as a study participant, you may contact - anonymously if you wish - Dr. Peter Vasilenko, Chair of Behavioral, Social Science Institutional Review Board by phone (517) 355-2180, fax (517) 432-4503, or e-mail irb@msu.edu

Copy of e-mail message sent:

We need your help!

The American Purchasing Society and researchers from Michigan State University are teaming together to study supply chain risk management. Your knowledge and experience in supply chain and materials management is critical to helping us to better understand what drives firms to engage in risk management, the types of planning that firms under take, the effect of such plans on the occurrence of supply chain disruptions.

A short article, *18 Ways to Guard Against Disruption*, is available to you at the end of the questionnaire

As a special thank you for your participation in the survey, you will have the opportunity to enter a drawing for one of ten Visa Gift Cards of $50 each.

Please go to the following website to complete the survey:

http://nebula.bus.msu.edu/SC_Risk/sc_risk.htm

Please feel free to share this opportunity with other supply chain management professionals!

Your input into this study is vitally important, regardless of the level of planning your firm engages in or the frequency or size of supply chain disruptions you may experience. We need data from as many professionals as possible in order to determine best practices so that firms can put plans in place to reduce the likelihood and impact of a wide variety of disruptive incidents – insights that you can use within your own firm with the findings from this study that we will share with you!

Please take a bit of time out of your busy day to help us better understand how we can more effectively reduce supply chain disruptions.

Andrea Prudhomme and Ken Boyer
Michigan State University
SC_Risk@bus.msu.edu

Rich Hough
American Purchasing Society

All information that you provide is strictly confidential; name/address information will be utilized only to mail the gift cards. Your privacy will be protected to the maximum extent allowable by law. All reports and data from this survey will be an aggregate summary of the results, but no individual will be identified by name or address.

You indicate your voluntary agreement to participate by completing the online survey. Please email or call if you have any questions regarding this study. You may also contact Peter Vasilenko, Ph.D., Chair University Committee on Research Involving Human Subjects (UCRIHS) at (517) 355-2180 or ucrihs@mus.edu. Thank you for your cooperation. We look forward to hearing from you.

Copies of post cards sent to contact sample
(shown larger than actually sent to meet dissertation formatting guidelines)

Supply Chain Study

The **American Purchasing Society** and **Michigan State University** are teaming together to study supply chain risk management. We need your valuable experience and professional opinions to help us better understand this important business issue.

Your input into this study is vitally important, regardless of the level of planning your firm engages in or the frequency and size of supply chain disruptions you may experience.

The final results of this study will be made available to APS members to provide insights that you can use within your own firm to reduce supply chain disruptions.

In a few days you will receive a survey by mail, along with a postage paid envelope for you to return your completed survey. Please take a bit of time out of your busy day to help us enhance our understanding supply chain risk management, and how APS members can better plan for and recover from supply chain disruptions.

To make your participation as convenient as possible, you can also electronically access the survey immediately at:
www.msurisk.org

Thank you for your participation in this important study!

Rich Hough, CPP American Purchasing Society support@american-purchasing.com	Andrea Prudhomme Michigan State University SC_risk@bus.msu.edu

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The **American Purchasing Society** and **Michigan State University** will soon begin the analysis of the responses they have received so far from their study of supply chain risk and continuity management survey.

If you haven't already done so, **there is still time for you to participate in this important study**!! By completing the survey, your valuable experience and professional opinions will provide us with important insight into this critical business issue.

Your contribution to this study is vitally important, regardless of the level of planning your firm engages in or the frequency and size of supply chain disruptions you may experience.

The final results of this study will be made available to APS members to provide you with insights that you can use within your own firm to reduce supply chain disruptions.

Please take a bit of time out of your busy day to help us enhance our understanding of supply chain risk management, and how APS members can better plan for and recover from supply chain disruptions.

To make your participation as convenient as possible, you may electronically access the survey:

www.msurisk.org

If you would like a hard copy of the survey, please contact Andrea at SC_risk@bus.msu.edu or (517) 432-5535 x272 and a paper survey with a preaddressed / postage paid return envelope will be mailed to you right away.

Thank you for your participation in this important study!

Rich Hough, CPP American Purchasing Society	Andrea Prud'homme Michigan State University

Appendix C: Scale Item Results from Survey

All response options are a Likert type scale of 1 to 7. Anchor and midpoint terminology detailed below. Items in all *italics* were dropped from scales.

SUPPLY CHAIN COMPLEXITY

	(scale: 1 = Extremely Low 4 = Moderate 7 = Extremely High)	Std λ	Mean	Std Dev
C1	*Complexity of the products sold to customers (e.g. uses new or frequently changing technology, large bill of material, quality specifications that are difficult to meet, several different versions or options of products, etc.)*	*n/a*	*4.40*	*1.67*
P12	*We offer a wide portfolio of different versions or options of our product to meet the needs of different customer segments*	*n/a*	*4.79*	*1.91*
C2	*Complexity in the business environment (e.g. number of competitors, different customer niches, dynamic and frequently changing conditions, etc.)*	*n/a*	*4.57*	*1.37*
C3	Overall complexity of the supply chain structure complexity in terms of the number of production or warehouse facilities where your product is built or stored	0.69	4.01	1.51
C4	Overall complexity of the supply chain structure in terms of the number of different divisions, business units, departments, or managers of your firm that are involved in your supply chain	0.66	3.88	1.64
C5	Overall complexity of a wide supply chain with numerous suppliers, customers, distribution points, or multiple channels	0.77	4.26	1.54
C6	Overall complexity of a long supply chain with multiple tiers or echelons of suppliers and customers.	0.76	3.93	1.53
C7	Overall complexity in terms of the geographic dispersion (regionally, nationally or globally) of suppliers, production or warehouse facilities, customers, or distribution channels.	0.59	4.39	1.57

SUPPLY CHAIN UNCERTIANTY

	(scale: 1 = Extremely Low 4 = Moderate 7 = Extremely High)	Std λ	Mean	Std Dev
C8	Overall uncertainty of supply of material (e.g. uncertainty in availability, quality or lead time of purchased items)	0.74	4.61	1.58
C9	Overall uncertainty of output (e.g. variable quality, volume or timing of output from production)	0.82	4.28	1.58
C10	Overall uncertainty of demand (e.g. variation in timing, mix or volume of customer demand; customers changing product requirements)	0.66	4.50	1.53

SUPPLY CHAIN DEPENDENCY

(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
D1 We have strong time-based synchronization with our supply chain partners	0.74	4.61	1.54
D2 We have knowledge of activities of our *first tier* supply chain partners	0.79	5.07	1.42
D3 We have knowledge of activities of our supply chain *beyond the first tier*	0.75	4.35	1.55
D4 *Our employees have close personal relationships with their supply chain partner counterparts*	*n/a*	*4.23*	*1.73*
D5 We are aware of the strengths of our supply chain partners	0.65	5.24	1.30
D6 We are aware of the weaknesses of our supply chain partners	0.53	5.02	1.38
D7 *We are economically dependent on our supply chain partners*	*n/a*	*4.60*	*1.68*
D8 We have a high degree of alignment of business activities with our supply chain partners	0.70	4.55	1.47
D9 Our business activities are developed through knowledge that is exchanged with our supply chain partners	0.68	4.58	1.53
D10 We adapt our IT investments to better fit with our supply chain partners	0.54	3.78	1.72
D11 *Our reputation in the market place is affected by our supply chain relationships*	*n/a*	*5.17*	*1.62*

LEVEL OF CONCERN FOR DISRUPTIONS

(scale: 1 = None 4= Moderate 7 = High)	Std λ	Mean	Std Dev
AC1 *Level of concern for market/business environment caused disruptions (e.g. regulatory issues, currency fluctuations, material cost instability, economic change, competitor's actions, etc.)*	*n/a*	*4.64*	*1.57*
AC2 Level of concern for upstream/supplier caused disruptions (e.g. inability to meet demand, late deliveries, quality issues, material allocation, etc)	0.67	5.53	1.34
AC3 Level of concern for internally caused disruptions (e.g. interruption or delay in production output due to quality, equipment or personnel issues; inventory issues; capacity shortage; etc.)	0.71	4.73	1.68
AC4 Level of concern for downstream / customer caused disruptions (e.g. changes in product requirements, changes in timing, volume or mix of demand, etc.)	0.64	4.45	1.63
(scale: 1 = Very Low 4 = Moderate 7 = Very High)			
D12 *In your opinion, how would you rate the vulnerability of your supply chain*	*n/a*	4.45	1.37
(scale: 1 = Often 4= Sometimes 7 = Never)			
D13 *You hear about your competitors experiencing supply chain disruptions*	*n/a*	4.29	1.39

EFFECTIVE PRACTICES

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
EP1	We implement processes to improve new product development (NPD) (e.g. modularization, design for manufacturability, early supplier involvement, etc.)	0.70	4.76	1.74
EP2	*We concentrate on core competencies and outsource some activities (e.g. IS/IT, facility maintenance, warehousing, etc.)*	*n/a*	*4.74*	*1.63*
EP3	We have cross-functional cooperation between different departments/functions	0.65	5.04	1.57
EP4	We develop/acquire proprietary equipment, processes, or products	0.61	4.90	1.71
EP5	We develop strategic supply chain partnerships, where appropriate, that are designed for on-going mutual benefit	0.77	5.26	1.39
EP6	We are committed to providing quality information to our supply chain partners that is accurate, timely, adequate, and credible.	0.78	5.45	1.44
EP7	We utilize a supplier certification process for key materials/suppliers	0.63	4.87	1.93
EP8	We share critical/proprietary information with supply chain partners	0.58	4.63	1.77
EP9	We utilize customer relationship management (CRM) for the purpose of managing customer complaints, building long-term relationships with customers, and improving customer satisfaction	0.65	4.71	1.79

PROFILE THE SUPPLY CHAIN

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
PR1	We know our suppliers, including their locations and inter-relationships within our supply chain	0.75	5.80	1.14
PR2	We know our customers, including their locations and inter-relationships within our supply chain	0.58	5.50	1.23
PR3	We know our production and warehouse facilities, including their locations and inter-relationships within our supply chain	0.76	5.87	1.17
PR4	We have identified the transit lanes used to ship materials/products	0.65	5.34	1.42
PR5	*We have a profile (or map) of our supply chain*	*n/a*	*4.78*	*1.64*

RISK INDENTIFICATION

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
RI1	We know the particular vulnerabilities of our suppliers	0.78	5.01	1.35
RI2	We know the particular vulnerabilities of the primary transit lanes for incoming material and inventory	0.72	4.80	1.42
RI3	We know the particular vulnerabilities of our primary production points and our warehouses	0.79	5.11	1.39
RI4	*We know the particular vulnerabilities of our customers*	*n/a*	*4.63*	*1.47*
RI5	We know the vulnerabilities of the primary transit lanes used for outbound inventory and products	0.60	4.95	1.36
RI6	We explicitly consider vulnerabilities when selecting new supply chain partners	0.76	5.37	1.48
RI7	We explicitly consider vulnerabilities when evaluating current supply chain partners	0.75	5.31	1.50
RI8	*We use multiple sources of information to identify supply chain risk*	*n/a*	*5.07*	*1.61*

RISK ASSESSMENT

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
RA1	We have a process for assessing the probability or frequency of different types of supply chain disruptions	0.89	3.90	1.70
RA2	We have a process for assessing the magnitude or impact of different types of supply chain disruptions	0.89	4.02	1.67
RA3	We have a process to capture the financial impact of a supply chain disruption (e.g. cost of expediting, late penalties, overtime, lost sales, etc)	0.74	4.22	1.75
RA4	We have a process to capture the qualitative impact of a supply chain disruption (e.g. loss of good will, damage to firm reputation, impact on supply chain relationships, etc.)	0.82	3.99	1.76

AUDIT OF CONTINUITY PLANS

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
AP1	We have formal supply chain continuity plans for our supply chain	0.80	3.78	1.83
AP2	*We have informal supply chain continuity plans for our supply chain*	*n/a*	*4.52*	*1.52*
AP3	We review our supply chain continuity plans *internally*	0.83	4.20	1.77
AP4	We have 'fire drills' to test our supply chain continuity plans	0.66	2.66	1.61
AP5	We periodically review our supply chain continuity plans with our suppliers	0.77	3.69	1.81
AP6	We periodically review our supply chain continuity plans with our customers	0.64	3.07	1.62
RI9	*We have identified signals that we should watch for that would indicate a disruption may be starting or about to occur*	*n/a*	*4.75*	*1.56*

RISK MANAGEMENT STRATEGIES

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
ST1	*There is little we can do to reduce supply chain disruptions, so we accept them as part of doing business*	*n/a*	2.83	1.65
ST2	In general, our supply chain risks are well managed	.70	4.55	1.42
ST3	We utilize a strategy of sharing supply chain risk with our supply chain partners (e.g. buy back agreements, cost or revenue sharing, etc.)	.54	3.85	1.76
ST4	We have strategically transferred most of our supply chain risk to supply chain partners (e.g. vendor managed inventory, contractual performance agreements, etc.)	.52	3.72	1.76
ST5	In general, we try to reduce supply chain risk as much as possible	.68	5.25	1.51
ST6	We have been able to pool supply chain risk (e.g. use of buyer consortiums, centralized warehousing, trans-shipments, postponement or delayed finalization of finished products, etc.)	.62	3.79	1.80
ST7	We have been able to eliminate most of our supply chain risk	.80	3.58	1.68

RISK MANAGEMENT PRACTICES

	(scale: 1 = Strongly Disagree 4 = Neutral 7 = Strongly Agree)	Std λ	Mean	Std Dev
P1	*Whenever possible, we use two or more suppliers for our material needs, to reduce risk*	*n/a*	*4.98*	*1.77*
P2	*We store material and goods in multiple warehouses to reduce risk*	*n/a*	*3.66*	*2.04*
P3	*We hold our own safety stock of raw materials/components*	*n/a*	*4.45*	*1.91*
P4	*We have suppliers hold safety stock of materials/components for us*	*n/a*	*4.80*	*1.72*
P5	*We hold our own safety stock of finished or semi-finished goods*	*n/a*	*4.56*	*1.84*
P6	We have multiple production lines/facilities for critical processes or products to decrease the risk of having only a single location	.60	3.72	2.01
P7	We have specific agreements with our suppliers to respond to changes in product mix, volume or delivery schedules	.60	4.51	1.84
P8	Our workforce is cross-trained to perform a variety of jobs as needed	.60	4.85	1.66
P9	We can make our products in multiple locations due to standardization (processes across facilities, production lines or work cells	.63	3.93	2.00
P10	We standardize our materials/components across product types/lines	.61	4.53	1.79
P11	We utilize postponement, where operations or activities (e.g. customization, final configuration, etc.) are moved to a later point in the supply chain	.66	3.84	1.63

CHANGE IN DISRUPTION – SUPPLY

	(scale: 1 = Less Often 4 = Same 7 = More Often)	Std λ	Mean	Std Dev
DF2	*FREQUENCEY: Change in disruptions from upstream/supplier sources (material shortages, poor supplier delivery or quality performance, in-bound logistics, etc.)*	*n/a*	*4.33*	*1.56*
DF3	FREQUENCEY: Change in disruptions from internal sources (quality problems, insufficient capacity, IT failure, personnel issues, etc.)	0.88	3.94	1.64
DI2	*IMPACT: Change in disruptions from upstream/supplier sources (material shortages, poor supplier delivery or quality performance, in-bound logistics, etc.)*	*n/a*	*4.33*	*1.56*
DI3	IMPACT: Change in disruptions from internal sources (insufficient capacity, quality problems, IT failure, personnel issues, etc.)	0.88	3.94	1.64

CHANGE IN DISRUPTION – DEMAND

	(scale: 1 = Much Smaller 4 = Same 7 = Much Larger)	Std λ	Mean	Std Dev
DF1	*FREQUENCY: Change in disruptions from business environment sources (changes in technology, government regulation, currency fluctuations, changing commodity prices, competitor actions, etc.)*	*n/a*	*4.27*	*1.58*
DF4	FREQUENCEY: Change in disruptions downstream/customer sources (out-bound logistics issues, changes in mix, timing or volume of customer demand, etc.)	0.98	3.88	1.58
DI1	*IMPACT: Change in disruptions from business environment sources (changes in technology, government regulation, currency fluctuations, changing commodity prices, competitor actions, etc.)*	*n/a*	*4.34*	*1.49*
DI4	IMPACT: Change in disruptions downstream/customer sources (outbound logistics issues, changes in mix, timing or volume of customer demand, etc.)	0.87	3.97	1.60

FIRM PERFOMRANCE

(scale: 1 = Significantly Lower 4 = Same 7 = Significantly Higher)	Std λ	Mean	Std Dev
PM1 Compared to our competitors, our sales are	0.62	4.86	1.35
PM2 Compared to our competitors, our profitability is	0.78	4.86	1.38
PM3 Compared to our competitors, our overall competitive position is	0.77	5.05	1.31
PM4 Compared to our competitors, our return on assets (ROA) is	0.95	4.76	1.28
PM5 Compared to our competitors, our return on sales (ROS) is	0.96	4.77	1.30

Appendix D: Summary of Final Revised Hypotheses

Normal Accident Theory Hypotheses

H1a: *Higher levels of perceived supply chain complexity are positively associated with higher levels of continuity planning* (CPLX $\xrightarrow{+}$ PLAN)

H1b: *Higher levels of perceived supply chain dependency are positively associated with higher levels of continuity planning* (DPND $\xrightarrow{+}$ PLAN)

H1c: *Higher levels of perceived supply chain uncertainty are positively associated with higher levels of continuity planning* (UNCT $\xrightarrow{+}$ PLAN)

H2a$_S$: *Higher levels of perceived supply chain complexity are positively associated with greater frequency and impact of disruptive events – supply* (CPLX $\xrightarrow{+}$ DES)

H2a$_D$: *Higher levels of perceived supply chain complexity are positively associated with greater frequency and impact of disruptive events – demand* (CPLX $\xrightarrow{+}$ DED)

H2b$_S$: *Higher levels of perceived supply chain dependency are positively associated with greater frequency and impact of disruptive events – supply* (DPND $\xrightarrow{+}$ DES)

H2b$_D$: *Higher levels of perceived supply chain dependency are positively associated with greater frequency and impact of disruptive events – demand* (DPND $\xrightarrow{+}$ DED)

H2c$_S$: *Higher levels of perceived supply chain uncertainty are positively associated with greater frequency and impact of disruptive events – supply* (UNCT $\xrightarrow{+}$ DES)

H2c$_D$: *Higher levels of perceived supply chain uncertainty are positively associated with greater frequency and impact of disruptive events – demand* (UNCT $\xrightarrow{+}$ DED)

High Reliability Theory Hypotheses

H3a: *Higher levels of the use of effective practices are positively associated with higher levels of continuity planning* (EFPR $\xrightarrow{+}$ PLAN)

H3b: *Higher levels of concern for disruptions are positively associated with higher levels of continuity planning* (CNRN $\xrightarrow{+}$ PLAN)

H4a: *Higher levels of the use of effective practices are positively associated with firm performance* (EFPR $\xrightarrow{+}$ FMPF)

H4b: *Higher levels of concern for disruptions are positively associated with firm performance* (CNRN $\xrightarrow{+}$ FMPF)

H5a$_S$: *Higher levels of the use of effective practices are negatively associated more frequent and larger impact disruptive events – supply* (EFPR $\xrightarrow{-}$ DES)

H5a$_D$: *Higher levels of the use of effective practices are negatively associated more frequent and larger impact disruptive events – demand* (EFPR $\xrightarrow{-}$ DED)

H5b$_S$: *Higher levels of concern for disruptions are negatively associated more frequent and larger impact disruptive events – supply* (CNRN $\xrightarrow{-}$ DES)

H5b$_D$: *Higher levels of concern for disruptions are negatively associated more frequent and larger impact disruptive events – demand* (CNRN $\xrightarrow{-}$ DED)

Planning Hypotheses

H6: *Higher levels of continuity planning are positively associated with higher levels of firm performance* (PLAN $\xrightarrow{+}$ FMPF)

H7$_S$: *Higher levels of continuity planning are negatively associated with more frequent and larger impact disruptive events – supply* (PLAN $\xrightarrow{-}$ DES)

H7$_D$: *Higher levels of continuity planning are negatively associated with more frequent and larger impact disruptive events – demand* (PLAN $\xrightarrow{-}$ DED)

H8$_S$: *More frequent and larger impact disruptions – supply are negatively associated with firm performance* (DES $\xrightarrow{-}$ FMPF)

H8$_D$: *More frequent and larger impact disruptions – demand are negatively associated with firm performance* (DED $\xrightarrow{-}$ FMPF)

Appendix E: Summary of Data Analysis Statistics

Issue	Result	Reference
Final sample size	298 usable responses	(Hu & Bentler, 1998; MacCallum et al., 1996; Marsh et al., 1988; Rigdon, 1995)
Final response rate	9.5%	
Statistical analysis software	SPSS 15.0	
SEM Software and input data	EQS 6.1, raw data table	(Bentler & Wu, 2003)
Missing data	Imputation using EM method	(Hair Jr. et al., 2006)
Normality	Acceptable kurtosis (< +/-3), skewness (<+/- 2) and Mardia-Based Kappa of 0.084	(Bollen, 1989; Hair Jr. et al., 2006)
Number of manifest variables	Hypothesized = 6, and 1 second order construct of 6 variables After CFA = 8, and 1 second order construct of 4 variables	
Number of latent variables	92 to start, 75 after CFA	
Manifest to latent variable ratio	At least 3:1, other than one construct with 2:1	(Rigdon, 1995)
Correlated measurement errors	None found	
Recursiveness	Recursive model	
Evidence of model identification	*df* = 2,319 for CFA model *df* = 715 for path model	
Power determination	Power adequate at >0.80	(MacCallum et al., 1996; McQuitty, 2004)
CFA model fit	$\chi^2_{(2319)}$ = 4294.784 CFI =0.83; SRMR = 0.55; RMSEA = 0.054	(M. W. Browne & Cudeck, 1993; Hu & Bentler, 1999)
Full path model fit	$\chi^2_{(715)}$ = 2068.6 CFI = 0.78; SRMR = 0.14; RMSEA = 0.080	(M. W. Browne & Cudeck, 1993; Hu & Bentler, 1999)

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