THE EFFECTS OF COLLABORATION ON THE RESILIENCE OF THE ENTERPRISE: A NETWORK-ANALYTIC APPROACH

DISSERTATION

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Abstract

The ability to anticipate and respond to supply chain disruption has emerged as a vital organizational capability in an operational environment characterized by increasing levels of turbulence, uncertainty, and complexity. Collaborative relationships between internal functional areas as well as with external customers and suppliers have been proposed as a key capability for enhancing enterprise resilience. This research answers the call for empirical investigation of the effects of supply chain collaboration on the resilience of the enterprise.

The study draws on social capital theory as a lens through which the concepts of supply chain collaboration and enterprise resilience are examined. As suggested by social capital theorists, supply chain managers derive value from the network of collaborative ties they maintain with other internal and external supply chain members. Within the context of resilience and disruption risk management, the study investigates whether certain structural and relational attributes of a manager’s network of collaborative ties lead to improved performance outcomes in turbulent operational environments.

Network data were collected through a social network analysis protocol. The data collection effort is set within the context of the demand-supply planning function of the Defense Logistics Agency, a multi-billion dollar logistics provider for military customers worldwide. Multiple regression analysis was used to test the hypothesized association...
between key attributes of collaborative networks and performance outcomes in the face of supply chain disruption.

The results indicate certain structural and relational attributes of collaborative networks are more suitable predictors of performance during periods of disruption. Specifically, the findings suggest that managers who maintain a high proportion of external versus internal collaborative ties and who interact frequently with key contacts are more likely to perform better in turbulent environments. The research yields implications for practitioners and researchers alike.
Dedication

To my family, for their love, support, patience, and faith.
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I am deeply indebted to the great many people whose patience, understanding, support, and advice made this research possible.

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Table of Contents

Abstract ......................................................................................................................... ii

Dedication .................................................................................................................. iv

Acknowledgments ...................................................................................................... v

Vita ................................................................................................................................. vii

Table of Contents ...................................................................................................... viii

List of Tables ................................................................................................................. xi

List of Figures ............................................................................................................... xii

Chapter 1 Introduction ................................................................................................. 1

1.1 Statement of the Problem ...................................................................................... 3

1.2 Research Objectives ............................................................................................. 5

1.3 Research Hypotheses ............................................................................................. 7

1.4 Limitations and Delimitations ............................................................................. 10

1.5 Definition of Key Terms ....................................................................................... 12

1.6 Contributions of the Research ........................................................................... 12

1.6.1 Managerial Implications .................................................................................. 13
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Multiple Regression and Model Estimation</td>
<td>95</td>
</tr>
<tr>
<td>4.2 Regression Diagnostics</td>
<td>98</td>
</tr>
<tr>
<td>4.3 Model Estimation</td>
<td>102</td>
</tr>
<tr>
<td>4.4 Summary</td>
<td>107</td>
</tr>
<tr>
<td>Chapter 5 Conclusions and Future Research</td>
<td>108</td>
</tr>
<tr>
<td>5.1 Research Objectives</td>
<td>110</td>
</tr>
<tr>
<td>5.2 Discussion</td>
<td>111</td>
</tr>
<tr>
<td>5.3 Research Implications</td>
<td>119</td>
</tr>
<tr>
<td>5.4 Limitations</td>
<td>123</td>
</tr>
<tr>
<td>5.5 Future Research</td>
<td>125</td>
</tr>
<tr>
<td>References</td>
<td>127</td>
</tr>
<tr>
<td>Appendix A Survey Instrument</td>
<td>141</td>
</tr>
</tbody>
</table>
List of Tables

Table 1: Definitions of resilience in supply chain management .................................. 26
Table 2: Definitions of collaboration in supply chain management .......................... 39
Table 3: Demographic characteristics of respondents .................................................. 76
Table 4: Frequency distribution of network size .......................................................... 81
Table 5: Loadings of scale items for trust construct ...................................................... 86
Table 6: Summary statistics and correlations ................................................................. 93
Table 7: Regression results for attainment to plan performance ................................. 103
Table 8: Dependent means tests on pairs of relational variables ............................... 118
List of Figures

Figure 1: Structural holes................................................................. 56
Figure 2: Conceptual model.......................................................... 63
Figure 3: DLA’s demand-supply planning organizational structure .......... 71
Figure 4: Example ego-network.................................................... 79
Figure 5: Graphical representation of residuals................................. 100
Figure 6: Conceptual model with hypothesis testing results................... 114
CHAPTER 1 INTRODUCTION

Over the past decade, the capabilities that insulate supply chains from severe
disruption have garnered increased attention from scholars and practitioners. Concern for
unanticipated events that cause disruption results from increased competitive pressures
and higher levels of turbulence and uncertainty in the modern supply chain environment.
Growth of global sourcing has lengthened supply paths, and changing customer
requirements have contributed to shorter product life cycles and faster clockspeeds for
supply chain members (Sheffi 2005; Kleindorfer and Saad 2005). Furthermore, firms
increasingly rely upon few suppliers and minimal inventory levels in order to decrease
cost and improve quality (Wagner and Bode 2008). This combination of factors creates
more opportunities for disruptions to influence supply chains, and reduces the margin for
error once disruptions occur.

The concept of resilience has emerged to describe the capability of the enterprise
to survive, adapt, and grow in the face of turbulent change (Fiksel 2006; Christopher and
Peck 2004). Enterprise resilience reflects the degree to which inherent capabilities of the
firm counteract extant vulnerabilities to disruption (Pettit, Fiksel and Croxton 2010).
Supply chain managers are continually challenged by the need to balance investment in
capabilities against the vulnerabilities to which the firm is exposed. Insufficient
capability can leave the enterprise susceptible to disruption risk, while overinvestment in
capability potentially saps profits (Pettit, Fiksel and Croxton 2010). The emergent stream of literature related to enterprise resilience addresses the relationship between organizational vulnerabilities and corresponding capabilities of the firm.

The concept of supply chain collaboration has emerged as a related topic of importance to supply chain scholars and practitioners. The act of collaboration has been described as a decision making process in which joint involvement of the parties yields greater benefit than if the parties were to make decisions independently (Stank, Keller and Daugherty 2001; Simatupang and Sridharan 2005). The supply chain management literature emphasizes the notion that operational performance depends upon the ability of managers to integrate the intricate network of relationships within the supply chain (Cooper, Lambert and Pagh 1997; Lee, Padmanabhan, and Whang 1994). From this perspective, collaborative relationships serve as a key mechanism for integrating supply chain entities (Skjoett-Larsen, Thernoe, and Andresen 2003). Empirical research has supported the idea that collaboration in its various forms has a direct impact on operational performance (Stank, Keller, and Daugherty 2001; Sanders 2007).

To date, few researchers have empirically examined the intersection between the concepts of supply chain collaboration and resilience. Recent qualitative research related to disruption and enterprise resilience suggests that supply chain collaboration may be an effective strategy for mitigating the potential consequences of disruption (Pettit, Fiksel and Croxton 2010; Braunscheidel and Suresh 2009; Elkins, Handfield, Blackhurst, and Craighead 2005). The value of collaboration for improving resilience is based on the notion that organizations manage uncertainty by establishing coordinating relationships
with other entities (Thompson 1967; Christopher and Peck 2004). Collaboration among functional areas within the firm and externally between organizations reduces uncertainty about the environment by improving visibility and transparency across the range of supply chain operations. The process of collaboration has the potential to mitigate disruption risk by serving as an early warning device and by enabling recovery once disruptions occur (Holweg, Disney, Holmstrom, and Smaros 2005). The central question, then, is not necessarily if collaboration can improve resilience, but rather how collaboration influences the ability of an enterprise to overcome environmental turbulence. To assist managers in their efforts to design for resilience, and to advance theory on the topic, more research is needed to fully understand the effects of investment in collaborative relationships among supply chain members. The current research addresses this gap.

1.1 STATEMENT OF THE PROBLEM

In the context of supply chain management, the need to become resilient to environmental turbulence has gained importance, yet our understanding of the capabilities that enhance enterprise resilience remains underdeveloped. According to Sheffi (2005), three broad strategies for improving resilience include: (1) making the supply chain more robust by adding redundancy in the form of inventory and capacity, (2) adding supply chain flexibility through techniques such as postponement and flexible contracts, and (3) establishing collaborative relationships with supply chain members. While assessing the impacts of ‘hard’ remedies such as increased inventories, additional
suppliers, and postponement strategies lend themselves to quantitative modeling methods, analysis of the effects of ‘softer’, qualitative capabilities such as collaboration remains an open research issue. Empirical research has provided qualitative support for the intuition that collaboration influences the resilience of the enterprise (Pettit, Fiksel and Croxton 2010), yet full understanding of how collaborative capability impacts resilience requires further investigation. Furthermore, while studies have investigated the role of collaboration on operational aspects of supply chain performance (Stank, Keller and Daugherty 2001; Sanders 2007), little research has explicitly examined the impacts of collaborative relationships on resilience of the enterprise.

A network perspective is adopted to investigate the effects of collaboration on supply chain performance in turbulent environments. The motivations for utilizing a network perspective are twofold. First, supply chain management scholars increasingly view the supply chain as a complex network of organizations and relationships (Christopher 1992; Christopher and Jüttner, 2000; Lambert, Garcia-Dastugue and Croxton, 2005). Second, collaborative relationships between supply chain members occur not in a vacuum, but within a network of collaborative ties that potentially span the length of the supply chain from raw material providers through end users. Collaborative ties represent a form of social network. Network theorists argue that attributes of the linkages among a network of actors are as relevant for predicting behavior as the attributes associated with the actors themselves (Wasserman and Faust 1994). The structure and quality of the collaborative network provides both opportunities and
constraints on actor behavior. Few studies, however, have investigated the concept of supply chain collaboration from a network perspective.

Based on the above information, the issue addressed by the current research involves the need to better understand the effects of collaborative relationships on enterprise resilience. Grounded in a network perspective, the study seeks to identify the attributes of a network of collaborative relationships that enable an enterprise to survive, adapt, and grow in the face of turbulent change.

1.2 RESEARCH OBJECTIVES

The primary purpose of the study is to investigate the manner and extent to which supply chain collaboration influences enterprise resilience. In viewing the web of collaborative ties from a network perspective, the research seeks to empirically examine the influence of key network attributes on performance during periods of disruption. In order to address the central purpose of the research, this study examines the following specific research objectives.

First, in order to study the impacts of collaboration on resilience of the enterprise, it is necessary to identify the salient features of the concept of supply chain collaboration. In other words, it is necessary to clarify what the term ‘collaboration’ implies in a supply chain context. The term ‘collaboration’ has been used somewhat ambiguously in the literature, as it has been used interchangeably with terms such as cooperation, coordination, and integration within the context of supply chain management (Chen, Daugherty, and Landry 2009; Mishra and Shah 2009). An objective of the research,
therefore, is to derive improved understanding of the concept of collaboration through an analysis of existing scholarly research on the topic.

The second key research objective examines how the *structure* of intra-organizational and inter-organizational collaborative relationships influences supply chain performance in the face of turbulent change. Network theorists contend that the position of an actor within a network of relations can serve as a source of competitive advantage by providing access to needed resources (Burt 1992; Coleman 1988). Thus an objective of the research is to identify key structural attributes of social networks through review of extant literature, and to empirically test whether these variables result in performance benefits during periods of disruption.

The third key research objective examines the issue of relationship *quality* and its influence on performance in the face of turbulent change. Development and maintenance of collaborative relationships require significant investment in terms of time, energy, and fiscal resources. From a network perspective, the total number of relational ties an actor can have, and the strength of ties maintained by an actor is assumed to be limited (Borgatti and Foster 2003). An objective of the study, therefore, is to identify central components of relationship strength, and to test whether these attributes influence performance during periods of disruption.

The fourth key research objective relates to methodological issues associated with the use of a network approach within a supply chain setting. As will be described in greater detail later, the research applies social network analysis as the means of investigating the relationship between collaboration and enterprise resilience. To date,
however, few studies have adopted network analysis for examining behavior within the context of supply chain management. An objective of the research, therefore, involves identification of the methodological and substantive considerations associated with a network approach to supply chain management research.

1.3 RESEARCH HYPOTHESES

The relationship between supply chain collaboration and enterprise resilience is examined through the theoretical lens of social capital theory (the theoretical grounding for the hypotheses will be developed in Chapter 2). According to social capital theorists (Coleman 1988; Lin 2001), the network of relationships developed and maintained by an individual or group, such as collaborative supply chain relationships, presents benefits to the ‘actor(s)’ in terms of superior access to information, power, and solidarity (Adler and Kwon 2002). Social capital accrues to those who maintain strategic positions within the structure of a network of relationships, and to those who maintain strong relational ties with others (Nahapiet and Ghoshal 1998; Burt 1992; Autry and Griffis 2008). The research hypotheses tested in this research relate directly to these two dimensions of social capital.

With regard to network structure, it is first hypothesized that effective size of a manager’s network of collaborative ties has influence on performance. Distinct from the simple sum of direct ties that a manager has with others, effective size of the network accounts for the redundancy effects derived from indirect ties amongst a manager’s contacts (Burt 1992; Moran 2005). Thus, information and control advantages accrue to
managers who maintain more collaborative contacts who are themselves not connected to each other.

\[ H1: \text{The effective size of a manager’s network of collaborative ties is positively related to performance during periods of disruption.} \]

In addition to network size, the social capital derived from network structure also accrues as a function of the pattern of linkages between the manager and his or her contacts. When disruption and changes in the environment threaten performance, awareness and critical information related to the disruption are more commonly gained via external contacts (e.g. customers, other functional departments) versus internal colleagues (e.g. same functional department) (Krackhardt and Stern 1988). It is, therefore, expected that managers who maintain more external ties will accrue information and control advantages that lead to positive performance.

\[ H2: \text{The degree to which a manager’s collaborative network exhibits a high ratio of external to internal ties is positively related to performance during periods of disruption.} \]

Aside from the issue of network structure and its implications for performance, another consideration involves the quality of relationships maintained by a manager. The relational perspective concerns the issue of tie strength, or the extent to which two network members are connected to one another (Granovetter 1973; Autry and Griffis
In the current study, three components of tie strength are investigated—trust, closeness, and frequency of contact.

The need to establish trust within collaborative supply chain relationships has been documented in the supply chain management literature (e.g. Lambert, Emmelhainz, and Gardner 1999; Fawcett, Magnan, and McCarter 2008). Trust reduces fear of opportunistic behavior and promotes favorable interpretation of another’s intentions and actions (Uzzi 1996). By establishing high levels of trust with network members, managers gain better access to information which in turn improves awareness of changes in the environment.

*H3: The degree of trust within a manager’s collaborative network is positively related to performance during periods of disruption.*

A second dimension of relational capital involves the issue of emotional closeness between members of the network. Collaborative exchange is facilitated through relationships governed by a sense of closeness or friendship versus arm’s length or adversarial ties (Burt 1997).

*H4: The degree of closeness within a manager’s collaborative network is positively related to performance during periods of disruption.*
The last dimension of relational capital involves the frequency with which network members interact. Frequent interaction between network members provides both an opportunity and incentive to share information (Ahuja 2000). Greater intensity (frequency of interaction) leads to improved environmental awareness and reduced levels of uncertainty (Van De Ven and Ferry 1980). Thus, performance in the face of disruption is expected to be influenced by frequency of interaction within the collaborative network.

\[ H5: \text{The frequency of interaction within a manager’s collaborative network is positively related to performance during periods of disruption.} \]

1.4 LIMITATIONS AND DELIMITATIONS

Some important limitations of the research are acknowledged. First, the study was limited in terms of its generalizability to the intended population of supply chain managers. The research was empirically grounded by studying key business processes within a single, though large and diverse, logistics organization. Due to practical challenges of collecting network data, such scaled investigations are not without precedent (Seevers, Skinner, and Dahlstrom 2010). Although focus on a single organization helps to control against effects of certain exogenous variables, it is acknowledged that peculiarities of a single firm/industry limit the ability to generalize the findings to the broader population.

Second, the current study concentrates on risks of an unpredictable, potentially catastrophic nature which are termed ‘disruptions’. Much of the literature related to
supply chain risk management focuses on high-probability/low-impact risks. While these operational risks are of managerial concern, they are beyond the scope of this research. It is acknowledged that patterns of collaboration within the supply chain and the performance implications of each may differ greatly between routine operations and periods of turbulence. Investigation of the differences between collaborative structures in these contrasting environments is left for future research. Furthermore, it is noted that an extensive variety of factors contribute to enterprise resilience, and that the proposed research addresses but a subset of these traits.

Lastly, it is appropriate to note the limitations associated with the methodological approach adopted for the proposed research. The ego-centric sampling approach used in the study involves measurement of independent variables based on perceptions of respondents regarding the structure and quality of their network of relationships. It is acknowledged that the variables related to network structure and relationship strength were not measured directly, but were based on respondents’ abilities to recall their collaborative exchanges. The use of ego-centric sampling also serves as a potential limitation due to the manner in which boundaries on the network are established. It is acknowledged that measurement of the complete network of relationships within a supply chain, while perhaps infeasible for all but the smallest of supply networks, might lead to different outcomes.
1.5 DEFINITION OF KEY TERMS

Collaboration- a process of decision making among interdependent parties for the purpose of achieving shared objectives. The collaborative relationship is governed by transparent sharing of information, trust, and mutual incentives including shared costs, risks, and benefits (derived from Stank et al. 2001; Bowersox et al. 2003).

Disruption- an unanticipated event that disrupts the normal flow of goods, materials, and information within the supply chain or its environment (Kleindorfer and Saad 2005; Wagner and Bode 2008), the consequences of which adversely impact the short- and long-term financial and operational performance of the firm (Hendricks and Singhal 2003).

Resilience- the capacity of the enterprise to anticipate and quickly recover from disruption, and to adapt strategically to emerging trends which threaten the business core (derived from Hamel and Välikangas 2003; Pettit, Fiksel and Croxton 2010).

Social Capital- the positive returns that accrue to an actor (individual person or collective group) as a result of investment in relationships with others (Lin 1999).

Structural Holes- a structural hole exists within a social network between two entities (individuals or groups) who are otherwise not connected. Information and control advantages accrue to those who bridge this gap in the network (Burt 1992).

Supply Chain- the network of organizations that are involved, through upstream and downstream linkages, in different processes and activities that produce value in the form of products and services in the eyes of the ultimate customer (Christopher 1992).

Tie Strength- the strength of an interpersonal tie is a combination of the amount of time, emotional intensity, and mutual confidence invested in a relationship (Granovetter 1973).

1.6 CONTRIBUTIONS OF THE RESEARCH

In this section several anticipated contributions of the research are highlighted. It is expected that the study will yield several practical and theoretical insights.
1.6.1 Managerial Implications

The findings of this study have implications for both managers and researchers. For managers, making the business case for investment in resilience capabilities can be a challenge, because it may never be known whether a disruption was averted, or the extent to which resilience capabilities reduced the impacts of a disruption (Sheffi 2005). A key challenge for managers is to determine strategies for mitigating supply chain risks without eroding profits. It is expected the results of this study may guide those charged with assessing the worth of investment in collaborative capabilities. From an investment perspective, improved coordination, collaboration, and communication can be less costly than resilience strategies involving redundant capacities (i.e., inventory, production equipment) (Sheffi 2005).

From a practical standpoint, the research enhances understanding of the criteria for deciding whether a given organizational network of relationships requires improving, what kinds of relational ties are desirable and when, and what a network designed for optimal resilience ought to look like. Although theoretical and experimental evidence has posited some of the features of effective network structure (Burt, 1992; Krackhardt and Stern 1988), few studies have offered empirical evidence to aid managers charged with the design of resilient network structures.

Despite growing managerial interest in social networks and their implications, much of the evidence linking social networks and business performance has been anecdotal (Seevers, Skinner, and Dahlstrom 2010). Building social capital requires considerable effort and investment in the establishment and maintenance of collaborative
relationships. The research sheds new light on the potential impacts of such investment on the ability of the organization to perform in the face of unpredictable disruption and turbulence.

The study further demonstrates the potential value of a network analysis methodology as a powerful tool managers can wield to uncover and improve the collaborative structures of their supply chains. In highly dynamic and competitive environments, organizations increasingly excel based on their ability to manage knowledge and information (Carter, Ellram and Tate 2007). Understanding the structure of collaboration during times of crisis becomes particularly critical. As noted by McIntyre and Travis (2006), “With the assumption that some form of disruption in the global supply chain is inevitable, either from natural disaster like a tsunami, political discord or terrorist attack, every supply chain should be created and managed with the idea of balancing efficiency with resiliency [pg. 152]”.

1.6.2 Research Implications

From a research perspective, this study presents a unique network-analytic approach for investigating qualitative aspects of supply chain management. Although a network perspective has become increasingly popular in the SCM literature, comparatively few studies have leveraged network theory or tools. Several scholars have predicted the value of social capital theory and social network analysis for the study of logistics and supply chain management, yet the extant literature within these research disciplines remains largely devoid of studies that make use of such instruments (Phillips
and Phillips 1998; Carter, Ellram and Tate 2007; Autry and Griffis 2008). The current study explores the value of a network perspective for addressing supply chain management research problems.

The study also makes a contribution to the supply chain collaboration and enterprise resilience streams of literature. While an extensive amount of literature has explored the impact of collaboration on aspects of operational performance, the concept of supply chain collaboration nonetheless remains fragmented, and the manner in which collaborative structure influences resilience of the enterprise remains unclear.
CHAPTER 2 LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

In the previous section, an introduction to the research was presented. The description of the research included the motivations for the study, identification of key research objectives, outline of the theoretical perspective guiding the research, and introduction of hypotheses that test the relationships between substantive variables and outcome measure related to enterprise resilience.

In the current section, the literature related to the concepts of resilience and supply chain collaboration is reviewed. Also presented are the theoretical arguments concerning the nature of the relationship between collaboration and resilience within a supply chain context. This chapter is organized as follows: First, the concept of resilience is examined, with emphasis on implications for supply chain management. From this review, the central components of the concept are extracted and the term ‘resilience’ is defined. Next, a review of the supply chain collaboration literature is described. From this analysis a working definition of collaboration is developed, and the salient features of the construct as used within the supply chain management literature are identified. Lastly, the linkage between collaboration and resilience is examined through the theoretical lens of social capital theory. The research hypotheses are described in detail and the conceptual model linking the substantive variables is presented.
2.1 THE CONCEPT OF RESILIENCE

In this section, the concept of resilience is examined. The conceptual origins of the term are traced to such disciplines as ecology and human development. Next, the emergence of resilience within the supply chain management context is described. A definition of the term ‘resilience’ is presented based on conceptual definitions from the extant literature. The section concludes with a review of the formative elements of resilience as found in the relevant literature. The review of resilience research begins with an exploration of its early adoption in other disciplines.

2.1.1 Conceptual Origins of Resilience

Webster’s Dictionary defines resilience as “the capability of a strained body to recover its size and shape after deformation”. Within the academic literature, the concept of resilience takes its roots from ecological science (Holling 1973; Odum 1993; Willard and Klarquist 1995) and human development (Masten, Best and Garemzy 1990; Luthar 2006) to reflect the ability of an entity to recover from various forms of perturbation. From the ecological perspective, resilience has been described as a measure of the ability of a system to persist in the face of perturbation arising from ecological, biological and physical factors (Willard and Klarquist 1995). Resilience stability reflects the capability of an ecosystem to recover rapidly from disturbance (Odum 1993). Within the context of ecological science, resilient systems survive and maintain relative stability despite
changes to elements within the system and/or disruptions originating from the external environment.

In developmental science, resilience refers to an individual’s capacity for positive adaptation during or following exposure to adverse experiences of such consequence as to potentially alter the development of the person (Masten, Best and Garmezy 1990; Luthar 2006). From developmental systems theory, resilience arises from processes of interaction across the multiple levels of functioning within a living system (Masten and Obradovic 2008). As social beings, the adaptive functioning of humans is embedded in a complex array of interdependent relationships and social systems that also serve many regulatory and protective roles. Masten and Obradovic (2008) describe the resilience of living systems in terms of “social capital,” i.e., the adaptive capacity made available through relationships with others, and “human capital,” the adaptive capacity that a human individual can muster on his or her own.

After more than four decades of research within the fields of human development and ecology, the concept of resilience has more recently emerged in other areas of scientific endeavor (Ponomarov and Holcomb 2009). The term ‘resilience’ has gained traction within such disciplines as sustainability (Fiksel 2003), quality and safety management (Hollnagel, Woods, and Leveson 2006), ergonomics (Patterson et al. 2007), and strategic management (Hamel and Välikangas 2003). From the sustainable system design perspective, Fiksel (2003) identifies four fundamental properties of resilient systems. These include:
- Diversity – variety with respect to form and behavior
- Efficiency – economical use of resources
- Adaptability – flexibility to change
- Cohesion – unifying relationships and linkages between system components

As industrial, ecological, and social systems become more complex, designing for sustainability increasingly demands consideration of a resilience perspective (Fiksel 2003). Strategic management scholars reiterate some of these ideas in describing resilience as the capacity of an organization to continuously anticipate and adjust to threats before the need for change becomes imperative (Hamel and Välikangas 2003).

Although a unified theory of resilience remains under development, several conceptual consistencies amongst the scientific disciplines are of particular relevance to this research. First, the concept of resilience describes the capacity of some complex system (e.g. human body, ecosystem, process) to recover from turbulence and disruption to which it is exposed (Holling 1973; Fiksel 2003; Masten and Obradovic 2008). The systems perspective, or systems approach, is interested in the whole and in components of the system and their interactions within the context of the whole (Ackoff 1971). Systems theory is concerned with the relationships, structure, and interdependence of the components of the system versus the attributes of the components themselves (Katz and Kahn 1967). Total-system performance depends on relationships and how parts interact, not on how components act taken separately (Ackoff 1971). Organization theorists have long held a systems view (Katz and Kahn 1967; Ackoff 1971; Baskin and Aronoff 1980). Katz and Kahn (1967) conceptualize organizations as social systems consisting of the patterned relationships among individuals. As supply chain management (SCM) scholars
view the supply chain as a single entity rather than a collection of disparate parts (Ellram and Cooper 1990; Mentzer et al. 2001; Choi, Dooley and Rungtusanatham 2001), there exists a conceptual linkage between resilience and SCM.

In addition to a systems perspective, there is broad consensus amongst the disciplines that have adopted the concept of resilience with regard to the dynamic behavior of systems over time. The resilient entity possesses the capacity to maintain a steady state in face of short term perturbation (Masten and Obradovic 2008), but additionally possesses the capacity to adapt and evolve in response to persistent forces of change (Holling 1973; Hamel and Välikangas 2003). Thus, resilience reflects the capacity to prepare for and respond to disruptions and crises, but also the ability to evolve and grow in response to enduring threats to system survival (Fiksel 2003).

A final point of consistency with respect to the conceptual development of resilience involves the issue of vulnerability. Tol and Yohe (2007) describe system vulnerability to any collection of external stresses as determined by the level of exposure to a disturbance and the baseline sensitivity of the system to such disruptive events. Various interpretations of resilience emphasize the identification of vulnerabilities and corresponding capabilities or traits intended to overcome exposure to vulnerability. In the human development context, for example, Luthar (2006) contends that a central objective of resilience assessment involves identification of vulnerability and personal protection factors that might influence an individual’s ability to adapt to adverse life circumstances.
In summary, the preceding discussion traced the conceptual origins of resilience and highlighted salient features associated with the broad concept of resilience. In the next section, a review of the supply chain management literature that established a foundation for the concept of resilience within a supply chain context is provided.

2.1.2 Foundations of Supply Chain Resilience

Enterprise resilience remains a relatively new area of investigation within the field of supply chain management. Although the term enterprise resilience has gained prominence within the past decade, scholars have investigated the effects of turbulence and uncertainty in the business environment for more than four decades (Terreburry 1968, Chopra and Sodhi 2004; Tomlin 2006; Wagner and Bode 2008). Systems theorists, in particular, were among the first to develop formative models of industrial growth and stability under conditions of turbulence and disruption. The systems approach represents a useful framework for understanding the effects of complexity and turbulence on the performance of modern supply chains (Forrester 1961; Choi, Dooley and Rungtusanatham 2001). Disruption to a single member, or part, of the supply network often impacts performance of the system as a whole.

Supply chain management scholars have come to view the supply network as a system-of-systems in which the components (e.g. firms, functional departments) themselves possess the characteristics of a system (Ellram and Cooper 1990; Cooper, Ellram, Gardner and Hanks 1997). Forrester’s (1961) seminal work on Industrial
Dynamics adopts a systems approach in the study of supply chain behavior. Consistent with systems theory, the Industrial Dynamics concept deals with the relationships and time-varying interactions between the component parts of the management system (Forrester 1961). Forrester contends that structure, amplification, and delay characteristics associated with information-feedback loops have the most significant impact on the behavior of complex systems. These factors, along with distortion in information flows, combine to determine stability and growth of the system (the system correlates to resilience). Stable systems return to some initial condition after being disturbed, versus the unstable system in which initial disturbances tend to become amplified and eventually result in system entropy.

More recent scholarly work has described the supply chain network as a complex adaptive system, a system that emerges over time and adapts and organizes itself without any single system component (agent) managing or controlling it (Choi, Dooley and Rungtusanatham 2001; Surana et al. 2005; Holweg and Pil 2008). Within the context of supply chain management, complex adaptive system theory is concerned with the co-evolution of the network of firms in the supply chain and the environment within which the network is embedded (Choi, Dooley and Rungtusanatham 2001). Complex adaptive system theory entails the emergent behavior of systems and the ability of such systems to self-organize and maintain a state of quasi-equilibrium.

Building upon the aforementioned perspectives regarding supply chain behavior in turbulent environments, supply chain management scholars have recently turned their attention to the concept of resilience to reflect the capacity of an enterprise to endure and
evolve in response to disruption. Industrial enterprises, like biological, social and commercial systems, can be described as complex, adaptive, and unpredictable. As such, there is a need for such systems to possess self-organizing behavior to enable continuity of output despite perturbation and turbulence (Fiksel 2003). It is not surprising, then, to find that the concept of resilience has recently gained traction within the field of supply chain management.

Firm survival in the modern business environment is no longer an issue of one firm competing against another firm but has, instead, become an issue of one supply chain competing against another supply chain (Lambert, Cooper and Pagh 1998; Fine 1998). Consistent with Christopher’s (1992) definition, the term supply chain is defined as “the network of organizations that are involved, through upstream and downstream linkages, in different processes and activities that produce value in the form of products and services in the eyes of the ultimate customer”. Several aspects of this definition are of particular importance and their relevance to this study and shall become apparent throughout this paper. First, the definition embodies a holistic perspective in that it implicitly considers amongst the membership of the supply chain original suppliers through end customers. Companies have increasingly recognized the disadvantages inherent in a strategy of vertical integration, and have opted instead to concentrate on core competencies (Sheffi 2005). This evolution in strategy has resulted in higher levels of network complexity for contemporary supply chains. Because supply chains can be very sensitive to small perturbations from anywhere in the network, “catastrophes” are perhaps more likely to happen because of the cascading features and nonlinear effects
characteristic of complex systems (Choi, Dooley and Rungtusanatham 2001). The decisions facing contemporary business managers increasingly require consideration of influences originating both internally and externally to the organization, and beyond even first tier suppliers and customers. In the recent past, academicians and practitioners alike have acknowledged that a holistic, or systems perspective of the supply chain has become necessary to manage effectively in the current business environment (Cooper et al. 1997; Mentzer, Flint and Hult 2001).

In addition to the recognition of the supply chain as an entity, the contemporary supply chain is structurally complex. As noted by Christopher (1992), a supply chain is not a chain in the literal sense, but rather a network of organizations and relationships. The supply chain has been described as an uprooted tree in which the pattern of linkages amongst members branches out as one moves upstream or downstream (Lambert, Cooper and Pagh 1998). This more complex view of supply linkages has led many to describe the supply chain as a network (Christopher and Jüttner 2000; Lambert, Garcia-Dastugue and Croxton 2005). The network-based model has evolved over the past few decades as firms have moved away from hierarchical, vertically-integrated structures to networks of partnerships with key suppliers and customers (Christopher and Jüttner 2000).

Lastly, Christopher’s definition emphasizes the notion that organizational membership of the supply chain is interconnected through a series of relationships or linkages. The different entities that comprise the supply chain, from point of origin to point of final consumption, are connected via flows of material, information, finances, etc. (Craighead et al. 2007). Systems theorists contend that overall performance of
complex systems, including supply chains, is inherently tied to the pattern of interactions and relationships that link components (Ackoff 1971).

In summary, the supply chain management literature describes a holistic perspective of the supply chain that captures the complexity of the network of companies and the linkages amongst them. This view provides a foundation for examining the importance of enterprise resilience in the modern business environment. In the next section, the concept of enterprise resilience is examined and the related literature is reviewed in greater detail.

2.1.3 Supply Chain Resilience

Within the business context, the term resilience has been defined broadly as possessing “the skill and capacity to be robust under conditions of enormous stress and change” (Coutu 2002). Although resilience has been conceptualized and adapted to the field of supply chain management in a number of ways, there is apparent congruence in the conceptual definition of enterprise resilience in the extant literature (Table 1). These definitions share the view that resilience reflects the capacity of the enterprise to respond and recover at the same or better state after perturbation. Beyond enabling the firm to mitigate the effects of disruption, resilience can be a source of competitive advantage when the focal company is able to respond more quickly and effectively than its competition (Rice and Caniato 2003; Christopher and Peck 2004). From this perspective,
supply chain disruption offers the resilient enterprise the opportunity for growth (Pettit, Fiksel, and Croxton 2010).

### TABLE 1

**Definitions of Resilience in Supply Chain Management**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Definition of Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranfield (2003)</td>
<td>The ability to react quickly to unpredictable events</td>
</tr>
<tr>
<td>Rice and Caniato (2003)</td>
<td>The ability to react to unexpected disruption and restore normal supply network operations</td>
</tr>
<tr>
<td>Hamel and Välikangas (2003)</td>
<td>The capability to continuously anticipate and adjust to trends that threaten long-term earnings power</td>
</tr>
<tr>
<td>Christopher and Peck (2004)</td>
<td>The ability of a system to return to its original state or move to a new, more desirable state after being disturbed</td>
</tr>
<tr>
<td>Reinmoeller and van Baardwijk (2005)</td>
<td>The capability to self-renew over time through innovation</td>
</tr>
<tr>
<td>Sheffi (2005)</td>
<td>The ability to bounce back from large scale disruptions</td>
</tr>
<tr>
<td>Fiksel (2006)</td>
<td>The capacity for an enterprise to survive, adapt, and grow in the face of turbulent change</td>
</tr>
<tr>
<td>McDonald (2006)</td>
<td>The capacity of an organizational system to anticipate and manage risk effectively through appropriate adaptations of actions, systems, and processes to ensure that core functions are carried out in a stable and effective relationship with the environment</td>
</tr>
<tr>
<td>Ponomarov and Holcomb (2009)</td>
<td>The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desire level of connectedness and control over structure and function</td>
</tr>
</tbody>
</table>

Enterprise resilience is a multi-disciplinary, multi-dimensional concept (Ponomarov and Holcomb 2009). As a multi-dimensional concept, there is need to consider the potential for cross-scale interaction between different levels of the
organization. In other words, the resilience of the focal system at one level is dependent by some measure on the influences exerted by levels above and below (Woods 2006).

For example, the effectiveness of processes and actions intended to promote resilience by senior management at the strategic level may be strongly influenced by the degree to which operational managers resort to workarounds and innovative tactics in order to accomplish objectives (Woods 2006). All levels of analysis and the interdependence amongst different levels each contribute in important ways to the resilience of the system (McDonald 2006). A system of systems perspective of the supply chain illustrates this point.

Drawing on the central elements of definitions found in the extant literature, resilience is defined in this study as follows:

**Supply Chain Resilience** reflects the capacity of the enterprise to anticipate and quickly recover from disruption, and to adapt strategically to emerging trends which threaten the business core.

This definition of resilience incorporates both strategic and operational viewpoints of the concept as described in the literature. One conceptualization of resilience takes a strategic, process-oriented view (Hamel and Valikangas 2003; Reinmoeller and van Baardwijk 2005; Demmer, Vickery and Calantone 2011). From this perspective, resilience implies more than the ability to maintain homeostasis or stability in the face of severe disruption. Rather, the resilient system possesses the capability to adapt strategically in response to enduring forces of change (Hamel and Valikangas...
2003). Resilience reflects a productive tension between the capacity to maintain stability in the short term with the ability to adapt in response to changes in the environment over the long term (McDonald 2006). Resilient systems possess the capability to tolerate perturbation, and when necessary, to evolve into new forms via emergent properties (Fiksel 2003).

Scholars adopting this perspective view the resilient firm as one that possesses the capacity to make sense of its environment, generate strategic options through innovation, and realign resources more quickly than its rivals (Hamel and Valikangas 2003). To achieve resilience, Hamel and Valikangas (2003) suggest the firm must overcome four challenges: (i) conquer organizational denial by acknowledging that past business models and strategies are threatened by environmental change, (ii) continuously explore a variety of strategic alternatives through innovation and experimentation, (iii) allocate resources to novel strategic options, and (iv) devote as much energy to renewal and evolution as to optimization and operational efficiency. From this view, resilient companies recognize that in an age of turbulence, the business model that provided competitive advantage yesterday is no guarantor of success tomorrow.

The strategic perspective of resilience is shared by Reinmoeller and van Baardwijk (2005), who define resilience as the capability of the enterprise to self-renew through innovation. Based on an analysis of high-performing companies over the period 1983-2002, the authors found that resilient companies adopted a diverse array of innovation strategies to overcome the effects of turbulent change (Reinmoeller and van Baardwijk 2005). Echoing the position of Hamel and Valikangas, the authors contend
resilience is achieved through strategic diversity and realignment of resources to innovations that yield competitive advantage.

Demmer, Vickery and Calantone (2011) adopt a case study approach to investigate resilience from the strategic perspective. Consistent with previous resilience research that emphasized a strategic orientation (Hamel and Valikangas 2003; Reinmoller and van Baardwijk 2005), Demmer et al. (2011) view resilience as the capability to “dynamically reinvent the business model and strategies” as paradigm changing forces are encountered in the environment. The authors found support for the proposition that antecedents of resilience of large enterprises (eg. elimination of allegiance to status quo, environmental scanning, externalization of innovation, experimentation) apply equally well to small- and medium-sized enterprises (Demmer et al. 2011). This strategic perspective of resilience places emphasis on leadership, innovation, and development of an organizational culture capable of rapid change.

An alternate view of supply chain resilience, and the perspective most relevant to the current study, emphasizes the capacity of the enterprise to prepare for, respond to, and recover from supply chain disruption (Christopher and Peck 2004; Sheffi and Rice 2005). Two interrelated issues motivate the recent increase in attention toward disruption and related risk-- increased competitive pressures and higher levels of turbulence and uncertainty in the supply chain environment. First, competitive pressures have increased as growth of global sourcing has lengthened supply paths, and changing customer requirements have contributed to shorter product life cycles and faster clockspeeds for supply chain members (Fine 1998; Sheffi 2005; Kleindorfer and Saad 2005).
Furthermore, firms increasingly rely upon few suppliers and minimal inventories in order to decrease cost and improve quality. This combination of factors creates more opportunities for disruptions to influence supply chains, and reduces the margin for error once disruptions occur. Although initiatives such as just-in-time delivery and lean management hold the potential to improve efficiency and performance in stable environments, they concurrently increase fragility and vulnerability of the supply network during periods of disruption (Lee 2004; Blackhurst et al. 2005; Wagner and Bode 2008; Skipper and Hanna 2009). With respect to disruptions, contemporary supply chain managers are both risk takers and risk mitigators. Pressures to improve competitiveness, reduce costs, and increase customer value entice managers to assume disruption risk by adopting strategies such as global sourcing, lean inventory, and outsourcing (Jüttner, Peck and Christopher 2003). These risk drivers influence the vulnerability of modern supply chains to disruption and turbulence.

In addition to competitive pressures, greater frequency and magnitude of various forms of disruption over the past decade have attracted increased scholarly attention (Wagner and Bode 2008). Because of the interconnected nature of modern global supply chains, the economic and operational impacts of a disruption propagate throughout the supply network in often unpredictable ways. Thus, while the likelihood that a single event might directly impact any single facility may be small, the collective chance that such a disruption will eventually impact the supply chain is high (Sheffi 2005; Skipper and Hanna 2009). Recent disasters highlight the potential impacts of disruption. For example, the March 2011 earthquake, tsunami, and resultant nuclear-power crisis in the
northern region of Japan provide anecdotal testament to the impact of disruption on global supply chains. In the Japanese automotive industry, production fell nearly 46% in the months following the disaster (Nakamichi 2011). The quake hit Toyota hardest ($1.2 billion), as the auto maker relied heavily on single-source suppliers located in the affected region and assembled nearly half the vehicles it sells globally in Japan (“After the Quake” 2011). In contrast, rival Nissan lost less because the company held more inventory, dispersed production geographically, and maintained relationships with multiple suppliers (“After the Quake” 2011). The Japan quake is but a single example of the crippling effect that disruption can have on the enterprise, and further provides anecdotal evidence that a disruption can impact similar companies in very different ways depending on the level of resilience capability built into each system.

Disruption is not limited to natural disasters and similar random events, but additionally derives from accidental (e.g. warehouse fire, train derailment) and intentional (e.g. terrorist attack, labor strike) acts that can have a high impact on supply chain performance (Sheff 2005). A supply chain disruption is defined as an unanticipated event that disrupts the normal flow of goods, materials, and information within the supply chain or its environment (Kleindorfer and Saad 2005; Wagner and Bode 2008), the consequences of which adversely affects the short- and long-term financial and operational performance of the firm (Hendricks and Singhal 2003). A substantial body of literature has explicitly addressed the issue of disruption risk and its implications for supply chain management. The range of topics addressed within the disruption literature includes such subjects as supplier risk (Zsidisin and Ellram 2003),

31
risk management (Craighead et al. 2007; Wagner and Bode 2008; Knemeyer, Zinn and Eroglu 2009), and contingency planning (Tomlin 2006; Skipper and Hanna 2009). To date, supply chain disruption scholars have tended to take a broad view of the concept, exploring such phenomena as supply chain uncertainty and risk perception (Blackhurst et al. 2005). Supply chain resilience research intersects the broader disruption literature base.

A central aspect of supply chain resilience emphasizes the capability of the enterprise to prepare for, respond to, and seize competitive advantage from severe disruption (Sheffi and Rice 2005; Bakshi and Kleindorfer 2009). Although traditional risk management approaches (e.g. contingency planning, business continuity planning) have been developed to address certain aspects of disruption risk, such processes are regarded as inadequate for managing risk inherent in modern supply chains. Whereas traditional risk management approaches tend to concentrate on operational disruptions of a predictable nature, designing for resilience tends to focus on unforeseen disruptive events (Pettit, Fiksel and Croxton 2010). The nature of disruptions as low-probability, high-consequence events makes the use of lagging indicators (i.e., losses from actual disruptions) ineffective, and the effectiveness of mitigation strategies can be difficult to measure across the network of companies in the typical supply chain (Bakshi and Kleindorfer 2009; Pettit, Fiksel and Croxton 2010). Of note, even minor perturbations within such complex systems can produce catastrophic, cascading outcomes (Choi, Dooley and Rungtusanatham 2001). Furthermore, additive and non-linear effects
associated with even minor disruptions can make causal implications of interactions in the environment difficult for managers to discern (Terreberry 1968).

Despite the extensive amount of literature devoted to supply chain disruption, the body of work dedicated to the concept of supply chain resilience remains comparatively sparse. Although researchers have investigated the issue of supply chain turbulence from a dynamic systems perspective since the 1960’s, the term resilience did not emerge in a supply chain context until the turn of the century. Conceptual development of supply chain resilience originated with a United Kingdom (UK) government funded study of the vulnerability and risk associated with high-impact disruptions (Cranfield 2002). The researchers found that contemporary supply chains are increasingly vulnerable to disruption risk resulting from trends toward globalization, lean operations, and consolidated networks. Based on the research findings, the argument is made that traditional risk management approaches, such as business continuity planning, are inadequate in scale and scope to deal effectively with modern supply chain vulnerabilities (Cranfield 2002). Drawing on their earlier study, Christopher and Peck (2004) present a normative model of resilience grounded by four general principles: (i) consideration of risk should influence supply chain design and structure, (ii) high levels of visibility and supply chain collaboration are necessary for identifying and managing risk, (iii) the ability to react quickly to unforeseen events is critical, and (iv) the organization must foster a risk management culture that extends beyond the capabilities of traditional business continuity approaches.
Subsequent resilience research built upon the initial findings of the Cranfield study. This stream of literature, consisting primarily of conceptual works, highlights a number of formative elements found to be characteristic of resilient companies. These features are presented in the next section.

2.1.4 Formative Elements of Supply Chain Resilience

As noted by Jüttner and Maklan (2011), there still exists considerable disparity within the literature over the formative elements of supply chain resilience. To date, much of the literature devoted to supply chain resilience seeks to conceptualize its central components. In the following paragraphs, five prevalent elements of resilience found in the literature—redundancy, flexibility, velocity, visibility, and organizational culture—are presented. It should be noted that while these elements are commonly cited in the extant literature, they are not necessarily mutually exclusive dimensions.

One mechanism for enhancing resilience involves the incorporation of redundancy (Rice and Caniato 2003; Sheffi and Rice 2005). The buffering achieved through redundancy allows the firm the time necessary to continue to serve customers while simultaneously responding to disruption (Sheffi 2005). While speed and cost-effectiveness were once considered primary objectives of the successful supply chain manager, modern supply chains must acknowledge potential consequences of an efficiency-based strategy given a turbulent business climate (Lee 2002; Cranfield 2002). Forms of redundancy such as safety stock, use of multiple suppliers, and reserve
production capacity enhance enterprise resilience, yet conflict in many respects with lean, efficient production practices (Sheffi and Rice 2005).

**Flexibility** is defined as “having viable alternatives in any situation (Rice and Caniato 2003; Sheffi 2005; Pettit, Fiksel and Croxton 2010).” Operational flexibility enables swift, effective response to disruptive changes in the environment (Skipper and Hanna 2009). Various strategies for enhancing flexibility include part standardization, commonality, cross-trained workforce, and postponement (Sheffi 2005). Rice and Caniato (2003) point to production system design, sourcing strategy, and workforce development as influences on the level of flexibility of the enterprise. Such initiatives allow reconfiguration of the system in response to disruptive forces (Jüttner and Maklan 2011).

Related to flexibility, **velocity** reflects the pace at which response and adaptation take place (Christopher and Peck 2004; Jüttner and Maklan 2011). Whereas flexibility denotes an ability to change inputs and outputs in response to disruption, velocity describes the speed of response and recovery (Jüttner and Maklan 2011). As a component of agility, velocity is achieved through such initiatives as streamlined processes, lead-time reduction, and elimination of non-value added activity (Christopher and Peck 2004). Because losses attributed to disruptive events accrue with time, speed of response and recovery enhances resilience (Pettit, Fiksel and Croxton 2010).

The ability to respond to and recover from disruption is dependent on the firm’s knowledge of the status of operational assets and the environment (Pettit, Fiksel and Croxton 2010). The resilience literature emphasizes the need for **visibility**, or the ability
to see from one end of the supply pipeline to the other (Christopher and Peck 2004). The
resilient enterprise must be aware of the status of inventories, orders, and transportation,
as well as relevant events in the environment in order to anticipate, respond, and recover
effectively.

Lastly, the supply chain resilience literature emphasizes the role of organizational
culture in enabling the enterprise to respond and adapt to turbulence. Edgar Schein
(1985) defines organizational culture as

“…a pattern of basic assumptions—invented, discovered, or developed by
a given group as it learns to cope with the problems of external adaptation and
internal integration—that has worked well enough to be considered valid, and,
therefore, to be taught to new members as the correct way to perceive, think, and
feel in relation to those problems [p. 9].”

Sheffi (2005) notes that culture may be the real secret behind resilient enterprises.
Continuous communications, empowered employees, knowledgeable management, and
innovative risk taking are among the cultural elements that influence resilience (Sheffi
2005). Willingness to support strategic experimentation and allocate resources to
innovative initiatives enables the firm to self-renew in response to environmental change
(Reinmoeller and van Baardwijk 2003). Pettit, Fiksel, and Croxton (2010) identify
creative problem solving and caring for employees as additional cultural elements that
serve to mitigate vulnerability risk. Because improved resilience is often attained
through increased risk (innovation) and cost (surplus capacity), organizational leadership,
climate and culture are central to effective resilience strategy.
While not all-inclusive, the preceding paragraphs have described central elements of supply chain resilience as gleaned from the extant literature. While redundancy, flexibility, velocity, visibility, and culture represent fundamental components of resilience, these dimensions are not the focus of the current study. Rather, this research investigates the utility of a sixth formative element of resilience—supply chain collaboration. The concept of supply chain collaboration is prominent among the capabilities widely cited in the resilience literature as a strategy for mitigating supply network vulnerability (Rice and Caniato 2003; Christopher and Peck 2004; Sheffi 2005; Pettit, Fiksel and Croxton 2010; Jüttner and Maklan 2011). In the next section, the concept of supply chain collaboration is presented. The relevant literature is examined and a definition of the concept is developed. Afterward, research that has addressed the intersection of resilience and collaboration is reviewed to highlight the theoretical gap addressed by the current study.

2.2 SUPPLY CHAIN COLLABORATION

In the recent past, the concept of collaboration has received increased attention from supply chain researchers and practitioners (Bowersox, Closs, and Stank 2003; Fawcett, Magnan, and McCarter 2008; Ireland and Crum 2005; Stank, Keller, and Daugherty 2001). The impetus for collaboration research stems from the emergence of supply chain management and related emphasis on the need to integrate across inter-organizational and intra-organizational boundaries (Cooper, Lambert, and Pagh 1997; Lee, Padmanabhan, and Whang 2004). The process of collaboration serves as a primary
mechanism for integrating various supply chain entities (Skjoett-Larsen, Thernoe, and Andresen 2003; Swink 2006). Empirical research has shown that collaboration in its various forms has a direct impact on operational performance in the supply chain (Sanders 2007; Stank, Keller, and Daugherty 2001). Collaborative relationships offer the potential for supply chains to achieve unmatched levels of operational efficiency, effectiveness, and relevancy (Bowersox, Closs, and Stank 2003). Specific benefits of collaboration include reduced resource duplication, improved flexibility for responding to dynamic customer needs and environmental uncertainty, and enhanced awareness of customer requirements and supplier capabilities (Stank, Keller, and Daugherty 2001). Improved resource allocation derived from collaboration results in economies of scale, and better flexibility and awareness lead to higher levels of customer satisfaction and improved customer loyalty (Bowersox, Closs, and Stank 2003).

2.2.1 Definition of Supply Chain Collaboration

Within the context of supply chain management, the word collaboration has described a broad range of activity, including such related yet distinct concepts as cooperation, coordination, and integration (Chen, Daugherty, and Landry 2009; Mishra and Shah 2009). The term represents a multi-dimensional spectrum of activity ranging from simple data sharing to relational interdependence among supply chain members (Bailey and Francis 2008).

In Table 2, several definitions of collaboration as drawn from the relevant literature are presented. Evidence from the literature suggests that even within the field
of supply chain management, there is not always consistency in the use of terminology. Collaboration scholars have tended to emphasize the inter-organizational aspects of collaboration (Bowersox, Closs, and Stank 2003; Kahn, Maltz, and Mentzer 2006; Mentzer, Min, and Zacharia 2000; Min et al. 2005). Other researchers have defined the term in a way that explicitly accounts for cross-functional collaboration within the firm, in addition to relationships with external parties (Sanders and Premus 2005).

### TABLE 2

**Definitions of Collaboration in Supply Chain Management**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Definition of Collaboration</th>
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<tbody>
<tr>
<td>Mentzer et al. (2000)</td>
<td>Means that all companies in the supply chain are actively working together as one toward common objectives.</td>
</tr>
<tr>
<td>Stank et al. (2001)</td>
<td>A process of decision making among interdependent parties. It involves joint ownership of decisions and collective responsibility for outcomes.</td>
</tr>
<tr>
<td>Bowersox et al. (2003)</td>
<td>Cross-enterprise collaboration emerges when two or more firms voluntarily agree to integrate human, financial, or technical resources to create a more efficient, effective, or relevant business model.</td>
</tr>
<tr>
<td>Simatupang and Sridharan (2004)</td>
<td>Often defined as two or more chain members working together to create a competitive advantage through sharing information, making joint decisions, and sharing benefits.</td>
</tr>
<tr>
<td>Min et al. (2005) adapted from Anthony (2000)</td>
<td>Defined as two or more companies sharing the responsibility of exchanging common planning, management, execution, and performance measurement information.</td>
</tr>
<tr>
<td>Sanders and Premus (2005) adapted from Schrage (1990)</td>
<td>Internal collaboration is an affective, mutually shared process where two or more departments work together, have mutual understanding, have a common vision, share resources, and achieve collective goals. External collaboration is defined similarly to internal collaboration with the exception that collaboration takes place between two or more firms.</td>
</tr>
<tr>
<td>Kahn et al. (2006)</td>
<td>Demand collaboration is characterized as “cooperative behavior “ or “joint decision-making” between companies, and represents a willingness, versus a requirement, to engage in interorganizational efforts.</td>
</tr>
</tbody>
</table>
Still other definitions present a broad characterization of the act of collaboration. Stank et al. (2001) suggest that collaboration is a process of decision making among interdependent parties involving joint ownership of decisions and collective responsibility for outcomes. As defined by Simatupang and Sridharan (2005), collaboration is broadly described as two or more chain members working together through information sharing, joint decision-making and shared benefits in order to derive competitive advantage. These broader definitions allow for a wide range of collaborative interactions both within the firm, and externally.

Although a definitive recipe for supply chain collaboration remains to be developed, the review of the literature reveals a number of ingredients commonly associated with the concept. Several consistent dimensions of the concept have emerged. First, collaborators share a degree of interdependence. The act of collaboration is a decision making process in which joint involvement of the parties yields greater benefit than if the parties were to make decisions independently (Simatupang and Sridharan 2004a; Stank, Keller, and Daugherty 2001). In other words, neither party possesses the knowledge, skills, or resources necessary to unilaterally overcome the problem at hand. Interdependence among parties can occur between functional areas within the firm, as well as between supply chain members (Stank, Keller, and Daugherty 2001). The level to which organizations collaborate is directly affected by levels of interdependence between the parties (Zacharia, Nix, and Lusch 2009).
Scholars argue trust among parties forms an essential component of collaborative exchange. Collaborative relationships governed by trust feature the expectation that both partners in the exchange will refrain from opportunistic behavior (Gulati 1995). Trust is stimulated through confidence in an exchange partner’s reliability and integrity. Furthermore, trust serves as an enabler of other components of collaboration including information sharing and risk sharing (Williams 2007). Alternatively, the absence of trust diminishes the effectiveness and efficiency of collaborative exchange. Lack of trust compels increased monitoring of others’ behavior, more formalized procedures, highly specified contract terms, and duplication of effort (Williams 2007).

The act of collaboration is described as a purposed activity. There exists a specific, definable motivation for parties within the supply chain to engage in collaborative activity. Some scholars contend collaborative relationships are finite (Schrage 1995), yet duration of the relationship varies depending on the objective of the interaction. For example, the demand management/forecasting process represents a purpose for collaboration that typically involves long-term relationships (Kahn, Maltz and Mentzer 2006; Rosenzweig 2009; Xu and Dong 2004). Collaborative initiatives such as efficient consumer response (ECR), vendor-managed inventory (VMI), and collaborative planning, forecasting, and replenishment (CPFR) have emerged to address the problem of demand uncertainty in the supply chain (Whipple and Russell 2007). Aside from the problem of demand management, other frequently-researched, collaborative supply chain motivations have included new product development (Ge and
Hu 2008; Mishra and Shah 2009; Parker 2000) and process improvement/business redesign (Klassen and Vachon 2003; Shih, Rivers and Hsu 2008).

The collaborative relationship is further governed by *mutuality*. In the supply chain partnership literature, the notion of mutuality has been described as a facilitator of tailored business relationships based on willingness of the parties to develop joint goals and adopt “two-sided” thinking (Lambert 2008). Collaborating parties share costs, risks, and rewards in pursuit of the common goal (Barrett 2004). The success of collaborative undertakings depends on the commitment of significant resources (Thron, Nagy, and Wassan 2006; Whipple and Russell 2007). The collaborative relationship involves the sharing of information, people, and technology to yield the synergies that lead to improved supply chain performance (Fawcett, Magnan and McCarter 2008). The risks of investing resources in the relationship must be balanced by shared benefits with collaborative partners.

Collaborative relationships are supported by *information sharing* between parties. The achievement of collaborative goals is made possible through the exchange of critical data and information related to the activity (Barrett 2004; Bowersox, Closs and Stank 2003). Information technology (IT) has emerged as an important enabler of collaboration by enhancing the speed and transparency with which critical data are exchanged throughout the supply chain (Gustin, Daugherty and Stank 1995). Transparent sharing of information among collaborators enables improved decision making in the face of uncertainty.
In summary, the salient features of supply chain collaboration include interdependence, trust, purpose, mutuality, and information sharing among collaborators. These elements are incorporated into the definition of the term developed for the current study. Drawing from the preceding narrative, the following conceptual definition of collaboration is derived:

*Supply chain collaboration* is a relational exchange among interdependent parties within the supply network governed by transparent sharing of information, trust, and mutual incentives including shared costs, risks, and benefits for the purpose of decision making in the pursuit of shared objectives.

Having developed a working definition of collaboration, the related literature is reviewed.

A rich stream of literature has explored the broad concept of collaboration within a supply chain context. Within this body of work, researchers have commonly emphasized **technical** (Esper and Williams 2003; Sanders 2007) and/or **relational** (Ellinger 2000; Fawcett, Magnan and McCarter 2008) dimensions of supply chain collaboration. The technical component includes information, communications, and related technologies and the impact of these capabilities on collaborative performance. The relational aspect involves the less tangible, human-centric facets of collaboration such as trust, joint decision making, and problem solving (Kahn, Maltz and Mentzer 2006; Matopoulos, Vlachopoulou, Manthou, and Manos 2007).

The literature emphasizing the technical dimension tends to view collaboration as the real-time or near real-time exchange of data via electronic communications where
collaboration is facilitated by electronic data interchange (EDI) or similar computer linkages (Kahn, Maltz and Mentzer 2006). Real-time collaboration between supply chain members has been enabled by the growth of information technology (IT) (Sanders 2007). In the supply chain context, one of the primary roles of IT is to serve as the conduit for information transfer, which facilitates collaboration among the parties (Smith, Watson, Baker, and Pokorski 2007).

Despite the potential for IT and other technologies to enhance collaborative performance, the implementation of boundary-spanning information and communication technology-based systems is not a panacea. Previous research has reported on the potential for IT implementation to create conflict in the supply chain as a result of IT investment failures (Kumar and van Dissel 2001). Furthermore, the use of IT as a medium for collaboration presents security risks to the supply chain by exposing potentially sensitive information to a greater array of threats (Smith et al. 2007).

Another view of supply chain collaboration highlights the relational aspects of the exchange. As noted by Stank, Keller and Daugherty (2001, p. 32), “The success of collaboration depends upon the ability and willingness of managers to build meaningful relationships and create trust.” Collaborative behavior is based on willing cooperation among parties rather than on compliance with organizational requirements (Ellinger 2000). The literature emphasizing the relational component of collaboration has highlighted the potential for factors such as commitment (Parker 2000; Fawcett et al. 2006), trust (Fawcett, Magnan and McCarter 2008), and organizational structure to
strongly influence the effectiveness of intra- and inter-organizational collaborative relationships.

Kahn, Maltz and Mentzer (2006) present a framework for collaboration between companies predicated on technical and relational dimensions of the construct. The authors investigated the effects of four distinct types of collaboration on operational performance within the context of demand management. The authors describe transaction-based collaborations as being characterized by low levels of both information technology and relational interaction. Technology-based collaboration emphasizes the use of information technology and gives less significance to relational aspects. Alternatively, affinity-based collaboration relies predominantly on the development of relationships between actors with little emphasis toward implementation of information technologies. Lastly, integral-based collaboration involves high levels of both technical and relational commitment. Described as the most sophisticated form of collaboration, Kahn et al. (2006) relate integral-based collaboration to the concept of strategic partnering as described in the popular supply chain literature (Lambert, Emmelhainz, and Gardner 1996). Their findings, however, provide limited support for the notion that inclusion of both information technology and relational elements leads to superior performance. The authors found that affinity-based collaboration that stresses relational aspects of the collaboration leads to the greatest improvement in supply chain performance. While exclusive reliance on technology leads to improvement over transaction-based forms of collaboration, superior performance is unlikely to be realized.
without incorporating relational aspects into the collaborative strategy (Kahn, Maltz and Mentzer 2006).

The literature highlights a number of expected benefits of supply chain collaboration, including improved visibility, more efficient development of new products, and reduced inventories (Min et al. 2005). However, another area of collaboration research, and the setting for the current study, involves the area of demand-supply planning. The next section reviews the literature that has investigated the role of collaboration within the demand management process.

2.2.2 Collaborative Demand Forecasting

Collaborative forecasting is a method in which knowledge and information related to demand is gathered from a diverse set of internal and external sources and integrated through consensus into a single, more accurate forecast (Helms, Ettkin and Chapman 2000). One of the most heavily researched topics within this branch of literature focuses on one specific approach-- collaborative planning, forecasting and replenishment (CPFR) (Ireland and Bruce 2000; Barratt and Oliveira 2001; Esper and Williams 2003; Smaros 2007). Established in the late 1990s by the Voluntary Inter-industry Commerce Standards (VICS) Association, CPFR is a set of standardized business processes designed to support improved demand collaboration between buyers and suppliers (Derrouiche, Neubert, and Bouras 2008). Smaros (2007) investigated the factors that impact the feasibility and value of such collaborative forecasting systems. Empirical findings suggest that effectiveness of forecasting technologies can be influenced by a retailer’s
ability to generate accurate forecasts, and the degree to which internal integration enables timely response to CPFR updates (Smaros 2007). Extensions to CPFR systems, including collaborative transportation management (CTM) systems, enable collaborating parties to involve transportation service providers and other collaborative partners in the forecasting capabilities of CPFR (Esper and Williams 2003). The expected outcomes of CPFR, and collaborative forecasting more broadly, include improved forecast accuracy, development of a single, jointly-developed demand plan, and better internal and external decision making (Ireland and Bruce 2000).

Empirical studies have explored the factors and conditions that lead to successful implementation of demand collaboration initiatives with external supply chain members (Barratt and Oliveira 2001; Danese 2007). Danese (2007) identifies two common motivations that lead firms to pursue CPFR collaborations—efficiency and responsiveness. The author finds that firms implementing collaborative capabilities as a cost reduction strategy tend to collaborate less extensively with partners than firms that seek to achieve greater responsiveness. Contingency variables such as CPFR goals, product/market characteristics, and supply network structure each influence the nature of collaboration with external parties (Danese 2007). Barratt and Oliveira (2001) point to a number of barriers that inhibit successful implementation of collaborative initiatives. Inadequate information technology integration, lack of trust, and inadequate joint planning are listed among the primary obstacles to effective collaborative forecasting performance (Barratt and Oliveira 2001).
Holweg, Disney, Holmstrom and Smaros (2005) suggest that the major objective of external collaboration is the reduction in demand uncertainty through transparent information flow. A theoretical framework of collaboration is proposed based on the dimensions of inventory replenishment and forecasting. The authors identify three contingency variables that influence collaboration strategy—geographical dispersion, demand pattern, and product characteristics. The ideal level and form of collaboration between external parties needs to consider the relationship between these relevant factors in the demand planning context (Holweg et al. 2005).

Although much of the CPFR and collaborative forecasting literature emphasizes the role of technology in enabling supply chain collaboration (Ireland and Bruce 2000; Barratt and Oliveira 2001; Esper and Williams 2003), works to be cited in this area equally stress the importance of human judgment in the demand forecasting process (Goodwin 2002; McCarthy and Golicic 2002; Eroglu and Knemeyer 2010). The literature related to judgmental forecasting offers a mixed perspective regarding the value of human adjustment to statistical forecasts. Some authors discourage the practice of judgmental modification to statistical forecasts due to inherent shortcomings in human decision making resulting from information processing limitations and personal biases (Armstrong 1985). Alternatively, recent research finds judgmental adjustment yields improved performance under certain conditions. (Sanders and Ritzman 1995; Lawrence et al. 2006). Lawrence et al. (2006) highlight two reasons that judgmental revisions to statistically-generated forecasts lead to improved forecast accuracy. First, statistical models may suffer from data that are out-of-date. Thus, there may be a timing advantage.
associated with judgmental forecast adjustment. When changes in the historical pattern are detected or are known to be imminent, judgmental adjustment serves as the only viable alternative for estimating the magnitude and impact to the forecast (Makridakis, Wheelwright, and Hyndman 1998). Second, the forecaster may possess domain knowledge that is unaccounted for in the statistical model. In the area of sales forecasting, for example, Sanders and Ritzman (1995) show the greatest advantage of judgmental adjustment occurs under conditions of high variability—where the un-modeled portion of demand is relatively high. Judgmental forecasts tend to improve when the practitioner possesses contextual knowledge--information gained by working in a specific environment and specific group of products. Contextual knowledge enables the practitioner to interpret changes occurring in the environment, and to assess the potential impact of such events on the forecast (Sanders and Ritzman 2004).

Using a case methodology, McCarthy and Golicic (2002) develop a theoretical model of collaborative forecasting. The model suggests that elements of collaborative forecasting, such as training of boundary-spanning personnel and timely information exchange, contribute to increased responsiveness to highly variable, unpredictable customer demands.

The demand collaboration literature additionally highlights the notion that a spectrum of collaborative integration exists in practice. Whipple and Russell (2007) propose a typology of collaborative relationships that incorporates both the technical and relational aspects of collaboration. Using a grounded theory approach, the authors uncover three types of collaborative relationships. Collaborative transaction management
involves exchange of explicit (transactional) knowledge using standardized processes. *Collaborative event management* involves exchange of explicit (eg. transactional) and some tacit (eg. difficult to verbalize) knowledge to address joint decision making in response to key supply chain events. *Collaborative process management*, the richest form of collaborative relationship, involves design of joint business goals and development of the processes necessary to achieve those goals (Whipple and Russell 2007). The results indicate that a continuum of collaborative relationships exist in practice.

2.3 COLLABORATION AND RESILIENCE

Although works to be cited on the topic of supply chain resilience remain sparse by virtue of the recent emergence of the concept as a focus of scholarly investigation, the normative models of resilience developed to date provide a conceptual linkage between supply chain collaboration and the capacity of the enterprise to overcome environmental turbulence. A number of resilience scholars point to collaboration among the organizational capabilities that offer the potential for overcoming turbulence and disruption in the supply chain (Christopher and Peck 2004; Sheffi 2005; Pettit, Fiksel and Croxton 2010; Jüttner and Maklan 2011).

According to Christopher and Peck (2004), the core intuition regarding the relationship between collaboration and resilience is the notion that collaborative exchange enhances resilience by reducing uncertainty about the state of the supply chain.
The exchange of information and application of shared knowledge reduces uncertainty at each level of organizational analysis (strategic, operational, and tactical). Analogous to the notion of contextual knowledge described by Sanders and Ritzman (1995), collaboration serves as a mechanism for enhancing awareness of strategic threats and opportunities, operational disruptions in supply and demand, and tactical-level risk events (Christopher and Peck 2004).

The works to be cited in this area emphasize the capability of supply chain collaboration to provide both pre- and post-disruption resilience benefit (Sheffi 2005). The severity of supply chain disruption is mitigated through warning capabilities and recovery capabilities (Craighead et al. 2007). As an early warning capability, supply chain collaboration serves as a form of environmental scanning that enables organizations to detect pending or realized disruption threats (Sheffi 2005). The parties involved in collaborative relationships demonstrate a willingness to share sensitive information related to risk and disruptive events (Jüttner and Maklan 2011). Collaborative planning with customers improves demand visibility and enhances awareness of market trends and other customer-facing sources of disruption risk. Collaboration with suppliers alerts the organization to real or pending disruptions in supply (Christopher and Peck 2004).

In addition to the potential early warning benefits associated with collaborative relationships, such supply chain ties also reduce the likelihood of disruption by providing a mechanism for organizations to learn best practices from other supply chain members who have encountered similar disruption (Sheffi 2005).
Other resilience researchers list collaboration amongst the capabilities for mitigating supply chain disruption. Kleindorfer and Saad (2005) present a normative set of principles to guide disruption risk management activity. Among these, the authors identify collaboration, both cross-functional within the firm and externally with supply chain partners, as a necessary capability for leveraging synergies and discovering weak links in the supply network.

In their exploratory study of resilience capabilities, Pettit, Fiksel and Croxton (2010) analyze empirical data collected through focus groups with supply chain practitioners. The findings suggest that collaboration directly or indirectly affects more than half of the fourteen capability factors identified through the research. Collaborative relationships influence such factors as visibility, adaptability, anticipation, recovery, organization, market position, and security, as well as collaboration with external entities (Pettit, Fiksel and Croxton 2010).

Jüttner and Maklan (2011) adopt a case methodology within the context of a financial crisis to explore the relationship between supply chain risk management, supply chain vulnerability, and supply chain resilience. The authors find support for the positive relationship between risk management strategy and four resilience capabilities tested in the model—flexibility, velocity, visibility, and collaboration. Furthermore, the data support the proposed relationship between resilience and supply chain vulnerability. Jüttner and Maklan (2011) suggest that resilience capabilities enabled the three firms involved in their study to mitigate the potential negative consequences of recession.
The current study differs from previous research in several important respects. Currently, the supply chain resilience literature consists predominantly of conceptual works that seek to provide definition, review related literature, or develop normative models of the concept (Ponomarov and Holcomb 2009; Pettit, Fiksel, and Croxton 2010). As noted by Bhamra, Dani and Burnard (2011), the concept of resilience has received little systematic empirical attention to date. This research addresses the call for empirical, theory-based testing of the conceptual models of supply chain resilience proposed in the literature (Ponomarov and Holcomb 2009). Ellram and Cooper (1990) highlight the need to investigate the impact of relationships on supply chain performance. To date, few studies have explicitly investigated the role of collaboration as a critical component of resilience.

Set in the context of the demand-supply planning process of a large logistics enterprise, resilience is empirically tested at the operational level. Much of the work on the topic to date has adopted a strategic view of the capabilities that influence resilience. As a multi-dimensional concept, however, it is necessary to test resilience capabilities at all levels of management. The point is illustrated by Sheffi and Rice (2005)…“There are many cases in which responses to disruptions cannot be prescribed in a well-defined process, where there is a need for situational awareness and initiative at levels closest to the event and furthest from the headquarters-based strategic planners. One of the important tenets of resilience is empowering front-line employees to take initiative and actions quickly on the basis of the facts on the ground [p 47].” The current study adopts this perspective.
2.4 DEVELOPMENT OF RESEARCH HYPOTHESES

This section details the theoretical perspective that guides the research, and develops the research hypotheses to be tested. The study draws on social capital theory as a lens through which the concepts of supply chain collaboration and enterprise resilience are examined. The theory of social capital (Coleman 1988; Lin 2001) stresses that networks of relationships represent a valuable resource for obtaining positive economic and psychic returns. The core intuition of social capital is that relationships matter. Social capital may be defined simply as the positive returns that accrue to an actor (individual person or collective group) as a result of investment in relationships with others. As a result of investment in building a network of relationships, both individuals and collective actors derive value in the form of superior access to information, power, and solidarity (Adler and Kwon 2002; Autry and Griffis 2008). Social capital is manifested in information benefits which occur in three forms—access, timing, and referral (Burt 1992). In the current context, it is theorized that the character of a network of collaborative relationships not only influences access to information about environmental disruption, but such relations influence the timing of information exchange and ability of an actor (i.e., supply chain manager) to act in the face of operational disruptions.

To enhance supply chain resilience, organizations invest in capabilities that provide for the anticipation of disruptive events, and the means of overcoming such disruptions once they occur (Pettit, Fiksel and Croxton 2010). The amount of social
capital accrued by an organization as a result of investment in collaborative relationships represents a specific capability for increasing supply chain resilience. It is theorized that collaborative relationships, and the social capital inherent in those relationships, are an important influence on the organization’s ability to survive, adapt, and grow in the face of turbulent environmental change.

Social capital theorists have emphasized two primary sources of the benefits inherent in social relations— a structural dimension and a relational dimension (Nahapiet and Ghoshal 1998; Adler and Kwon 2002). As noted by Burt (1992, p. 12), “social capital is at once the resources contacts hold and the structure of contacts in the network.” An actor amasses social capital as a function of the configuration of relations within the network (Burt 1992; Coleman 1988; Granovetter 1973), and as a function of the attributes of the ties with other actors (Lin 2001). Structural capital, therefore, accrues to those who maintain strategic positions within the network. Relational capital accrues to those who foster relationships characterized by trust, closeness, and reciprocation. These dimensions of social capital are presented in greater detail in the following paragraphs.

2.4.1 Structural Capital

The structural configuration of a given network of relations may serve as both a source of opportunity and a constraint on behavior for actors within the network. The structural perspective is concerned with who an actor can reach, and how the actor reaches other contacts in the network (Nahapiet and Ghoshal 1998). Many aspects of structure have been studied by network theorists, including density, centrality, and
network range (Marsden 1990). In the current study, however, two aspects of network structure are of particular relevance—structural holes (Burt 1992) and network configuration (Krackhardt and Stern 1988). A ‘structural hole’ exists between two actors (eg. managers) who provide non-redundant network benefits (Burt 1992) (Figure 1). For example, Manager A has a redundant relationship with Manager B to the extent that there is a strong relationship with Manager C to whom Manager B already has a strong relationship. Conversely, if Managers B and C are disassociated, then a structural hole exists between these individuals and Manager A derives value in bridging the gap between them.

**FIGURE 1**

**STRUCTURAL HOLES.** Bi-directional arrows indicate the presence of a tie between actors. In the graphic on the right, Manager A bridges a structural hole between Managers B and C. Information and control benefits accrue to individuals who fill such gaps between others.

Manager A does not fill a structural hole between Managers B and C

Manager A fills a structural hole between Managers B and C
Burt (1992) argues that sparse networks comprised of few redundant ties provide the greatest social capital benefit to those who bridge such gaps in the network. Managers with collaborative networks rich in structural holes maintain broader access to information due to the diversity of contacts in their networks. Actors who bridge structural holes should be better able to mobilize embedded resources, thus they are better capable of responding once disruptions occur (Lin 1999). The information access and timing benefits to those who bridge structural holes means such individuals are better aware of disruptions, and become aware of disruptive events earlier than their peers (Burt 1992). Although densely interconnected networks promote development of trust and social norms that can enable efficiencies, such network structures may limit the inflow of diverse information and insight (Ahuja 2000).

The second important aspect of network structure involves the configuration of internal versus external ties maintained by an actor (Krackhardt and Stern 1988; Adler and Kwon 2002). From the network configuration perspective, the central concern involves whether the actor maintains a predominance of relations within the focal collectivity (i.e., workgroup, organization), or whether the individual’s relations exist with contacts external to the focal collectivity (Payne et al. 2011). Actors who develop external linkages will outperform peers (those with a prevalence of internal relationships) during periods of organizational crisis through access to a richer, more diverse set of contacts and information (Krackhardt and Stern 1988). In the absence of environmental turbulence, organizational subunits (i.e. functional departments) may tend to develop strong linkages internally at the expense of external linkages (due to similarities in work,
physical proximity, and shared budget that enhance internal dependence). Dense networks of ties within organizational subunits improve performance during normal, routine operations by enabling cooperation and coordination related to homogeneous work tasks (Krackhardt and Stern 1988). During periods of environmental disruption, however, lack of external ties limits adaptability and the development of novel solutions to emerging situations.

Thus, the structural dimension of social capital theory offers two attributes to explain the relationship between collaboration and enterprise resilience. The presence of structural holes within a manager’s network of collaborative relationships, and the ratio of external to internal ties are each expected to influence performance during disruptive events. Next, the second dimension of social capital theory, relational capital, is presented.

2.4.2 Relational Capital

In addition to consideration of the structural aspects of the network of collaborative relationships, the quality of the relations themselves provide a source of social capital to the network’s constituents. Investigations of the relational aspects of social capital have typically emphasized either the form (tie strength) or content (substantive motivations) behind development of ties (Knoke and Yang 2008). In the current study, the former aspect of relational capital is particularly salient. Namely, it is theorized that strength of relational ties, as characterized by qualities such as trust, closeness, and frequency of interaction, provides value to actors with respect to enterprise
resilience. Networks exhibiting greater tie strength are expected to yield higher performance in the face of disruption because high frequency of exchange reduces uncertainty (Autry and Griffis 2008). Greater intensity (frequency of interaction) leads to improved environmental awareness and greater levels of certainty, thus improved performance in the face of disruption (Van De Ven and Ferry 1980). Trustworthiness within the social structure engenders an expectation of reciprocity among members of the network (Coleman 1988). As stated by Burt (1992), “The issue is not whether to trust, but who to trust (p. 63).” Confidence in the information passed and care with which one individual looks out for the interests of another depend on levels of trust in the relationship. Collaborative relationships characterized by high levels of trust, closeness, and interaction yield fine-grained information transfer benefits by increasing the breadth and ordering of behavioral options (Uzzi 1996).

This outline of the theoretical perspective guiding the research has positioned the research within the framework of social capital theory. The central proposition of social capital is the notion that investment in relationships yields benefits in the form of unique access to resources. With respect to enterprise resilience, the value of collaborative relationships is manifested in terms of the structure of the network and the quality of relationships within the network. Based on these theoretical arguments, and the review of the literature described earlier in the paper, several hypotheses were proposed through which to test the relationship between collaboration and enterprise resilience.
2.4.3 Research Hypotheses

Based on the theoretical perspective outlined above, and a review of the relevant literature, several hypotheses were derived related to the expected association between collaborative relationships and enterprise resilience. It is posited that such awareness accrues to demand-supply managers through the development of collaborative relationships with other internal and external members of the supply network.

First, it is hypothesized that managers who are positioned within ‘sparse’ collaborative networks, or networks with few redundant ties among members, will benefit from information access and timing advantages. The basic indicator of interest is network size—the number of direct ties in an individual’s network (Marsden 1990). When an individual’s network of collaborative ties is rich in structural holes, the effective size of the network is enhanced. When a manager’s direct contacts are strongly connected to each other, they are likely to have similar information and therefore provide redundant informational benefit to the manager (Burt 1997). By spanning structural holes within the network, individuals are better aware of environmental disruptions, and are able to act more quickly in response to the threat of environmental disruption.

\[ H1: \text{The effective size of a manager’s network of collaborative ties is positively related to performance during periods of disruption.} \]

The second hypothesis also relates to the structure of the collaborative network. It is hypothesized that external ties are more important for managing during periods of
disruption than internal ties. Based on the assumption that managers have a limited amount of time, energy, and need for collaborative relations with others (Krackhardt and Stern 1988), it is expected that those who maintain a higher proportion of ‘external’ relationships will possess better awareness of disturbances in the environment. In addition to improved awareness, external ties provide pathways for action once the threat of disruption materializes.

\[H2: \text{The degree to which a manager’s collaborative network exhibits a high ratio of external to internal ties is positively related to performance during periods of disruption.}\]

The remaining hypotheses examine not the structure of ties between collaborators, but the quality of the ties themselves. It is hypothesized that managers who develop strong relational ties with direct contacts will achieve improved performance during periods of disruption. Tie strength, as characterized by trust, closeness, and frequent interaction yields benefits in the form of increased accuracy and timeliness of information transfer (Granovetter 1973). Strong relationships engender expectations of reciprocity among members, which in turn enables coordinated action during turbulent times.

When supply chains become unstable, trust among partners in a supply chain can erode quickly. The conflict and mistrust generated by supply chain instability feed back to worsen the instability in a vicious cycle (Sterman 2000). The need to establish trust within collaborative supply chain relationships has been well-documented in the supply chain management literature (Lambert, Emmelhainz, and Gardner 1999; Fawcett,
Magnan, and McCarter 2008). Trust reduces fear of opportunistic behavior and promotes favorable interpretation of another’s intentions and actions (Uzzi 1996). By establishing high levels of trust with network members, managers gain better access to information which in turn improves awareness of changes in the environment.

\[ H3: \text{The degree of trust within a manager’s collaborative network is positively related to performance during periods of disruption.} \]

The next dimension of relational capital involves the issue of emotional closeness between members of the network. Closeness, or the feeling of friendship toward others in the collaborative network, has been regarded as the best indicator of tie strength across a variety of social relationships (Marsden and Campbell 1984). Collaborative exchange is facilitated through relationships governed by a sense of closeness or friendship versus arm’s length or adversarial ties (Burt 1997).

\[ H4: \text{The degree of closeness within a manager’s collaborative network is positively related to performance during periods of disruption.} \]

The last dimension of relational quality assessed involves the frequency of interaction with network members. Frequent interaction between network members provides both an opportunity and incentive to share information (Ahuja 2000). Greater intensity (frequency of interaction) leads to improved environmental awareness and reduced levels of uncertainty (Van De Ven and Ferry 1980). Thus, performance in the
face of disruption is expected to be influenced by frequency of interaction within the collaborative network.

H5: The frequency of interaction within a manager’s collaborative network is positively related to performance during periods of disruption.

Figure 2 shows the conceptual model that links the theoretical constructs and the hypothesized relationships.

FIGURE 2
CONCEPTUAL MODEL
2.5 SUMMARY

In this section, the literature related to the concepts of resilience and supply chain collaboration was reviewed, and the salient features of the concepts were highlighted. The conceptual linkage between collaboration and resilience was examined through the theoretical lens of social capital theory. Based on key features of collaborative networks, several hypotheses were presented. In the next section, the methodology for testing the hypotheses is presented.
CHAPTER 3 METHODOLOGY

In the previous sections, an introduction to the research and review of the relevant literature were presented. The description of the research included the motivations for the study, identification of key research objectives, outline of the theoretical perspective guiding the research, and introduction of hypotheses that address the relationship between substantive variables and the outcome measure related to enterprise resilience. In addition, a review of relevant literature was presented which explored the concepts of collaboration and enterprise resilience. Despite the scholarly attention given separately to these emergent concepts, they have yet to be fully examined simultaneously. Social capital theory serves as the lens through which to investigate the effects of collaborative relationships on supply chain performance in the face of disruption. The chapter concluded with a graphical representation of the conceptual model that guides the research.

In the current section, the methodology for addressing the research objectives is presented in detail. First, the research design is described, to include background and motivation for adopting a social network analysis methodology for the study. Next, the research setting and sampling frame are identified. In describing the data collection procedures, the development of the survey instrument is described as well as the
operational measures for each of the substantive variables. The chapter concludes with a summary of the descriptive statistics and correlation among the substantive variables.

3.1 RESEARCH DESIGN

To address the research objectives, the study employs a social network analysis (SNA) approach. Whereas traditional social science methodologies tend to focus on the attributes of the individual or organization, social network analysis is concerned with the pattern of relationships among a network of actors (Carter, Ellram and Tate 2007). The SNA methodology is distinguished from other behavioral methods by the notion that the relationship or linkage between actors represents the unit of analysis rather than the actors themselves (Wasserman and Faust 1994. For this reason, it is argued that SNA serves as a better means of investigating the effects of collaborative supply chain relationships.

Prior to deciding upon a network-analytic approach of investigation, however, alternative methods were considered. Qualitative methods including case-based research and grounded theory may prove useful for more fully exploring the relationship between the concepts of collaboration and enterprise resilience. However, it is argued through the theoretical development presented earlier in the paper that sufficient evidence currently exists to warrant quantitative assessment of the relationship between substantive variables. While such approaches may yield additional insights into the relationship between latent constructs, it is argued that social network analysis is ideally suited to the
current research objectives by virtue of its capability to describe and analyze relationships within a network.

Because the use of social network analysis is relatively new to logistics research, more detailed introduction related to the methodology is described in the following section.

3.1.1 Social Network Analysis

A social network analysis approach is adopted for this research to investigate the relationship between supply chain collaboration and enterprise resilience. The method finds its roots in fields that include sociology, social psychology, and strategic management. Over the past decade, the network perspective has emerged as a viable research approach for investigations within and between organizations in a supply chain (Carter, Ellram and Tate 2007; Borgatti and Li 2009). The network of relationships that exists among individuals who serve as organizational boundary spanners serves as both an enabler and constraint on inter-organizational behavior (Galaskiewicz 2011). The need for methods that facilitate analysis of relationships among supply chain members has increased as scholars and practitioners increasingly recognize the significance of integration both within and between organizations (Gustin, Daugherty and Stank 1995; Cooper et al. 1997; Chen, Daugherty and Landry 2009).

Social network analysis has been defined as a technique for mapping and investigating relations among a group of actors (Carter, Ellram, and Tate 2007). Within a supply chain context, different entities (actors), generically referred to as nodes in graph
lexicon, are involved in the conversion, the logistics (i.e., warehousing, transportation, etc.), or the making and selling of materials (i.e., raw materials, work in progress, and finished goods), with the materials reaching final customers in some desired form and quantity. Relationships among nodes, in graph lexicon, are generally denoted by arcs and depicted with unidirectional or bidirectional arrows signaling the direction of flows of interaction (Craighead et al. 2007). The term relationship can be used to represent a variety of interactions such as workflows, communication, and joint problem solving between supply chain members. Social network analysis is a behavioral research method that can be applied both between and within organizations in the supply chain (Carter, Ellram, and Tate 2007). The central objectives of SNA are to measure and represent the structure and content of relations, and to explain why they occur and what the possible consequences of such structure might be (Knoke and Yang 2008). The network perspective views the system as a set of actors (nodes) interrelated through one or more types of relations (ties). Consistent with systems theory, the approach highlights the importance of linkages among components for explaining overall system behavior.

A social network analysis approach is adopted for several reasons. First, SNA provides comprehensive procedures for collecting, analyzing, and describing relational structures within the supply chain. Relational structures provide the complex pathways for assisting (or possibly hindering) the flows of information, knowledge, and intelligence that ultimately enable firms to anticipate and respond to disruptive events (Knoke and Yang 2008). Second, the unit of analysis is not generally restricted. Data can be analyzed at the individual level, or at an aggregated level such as a functional
department, firm, or industry. The current study investigates the structure of collaborative relationships maintained by managers within the Defense Logistics Agency’s demand management division. Third, the use of SNA has seen limited application in the supply chain literature despite its potential for revealing insights into the consequences of collaborative structures within the supply network (Carter, Ellram, and Tate 2007). Uncovering issues and challenges associated with a network-analytic approach within supply chain management is listed amongst the objectives of the study. Thus, the adoption of social network analysis represents a methodological contribution of the research.

3.2 RESEARCH SETTING

In its broadest conceptualization, the study population includes the range of collaborative relationships that potentially occur within the context of supply chain management. However, the vast diversity of this population in terms of context, and other variables make study of the entire population from a network perspective infeasible. As noted by Choi, Dooley and Rungtusanatham (2001), it may not be possible to model and understand the interactions within a complete supply network including first, second, third, and fourth tier customers and suppliers. Therefore, it is necessary to delimit the setting from which the sample will be drawn. In this study, the sampling frame is restricted in two ways. First, data are collected from a single organization, the Defense Logistics Agency (DLA). The DLA operates a global logistics network, providing
sourcing and supply for nearly 100% of consumable items and 84% of the spare parts needed by military customers worldwide (DLA 2011). For the purposes of this research, the DLA serves as an exemplar of an enterprise susceptible to environmental turbulence and uncertainty. Due to the expanse of its markets and diversity of products supported, the DLA has served as the sole research setting for previous investigations within the field of supply chain management (Mentzer, Flint and Hult 2001).

The sampling frame is further limited to the pool of managers associated with the DLA’s demand-supply planning process. The pool of potential respondents includes middle managers drawn from three different areas within the organization’s demand-supply function, including demand managers (responsible for forecasting customer demand), supply managers (responsible for validating demand forecasts and monitoring inventory positions), and procurement managers (responsible for sourcing new requirements) (Figure 3).

It is asserted that the DLA’s demand-supply planning process serves as a suitable setting for the research based on several factors. Beginning with Forrester’s (1958) conceptualization of information distortion, demand amplification and the bullwhip effect in upstream supply channels (Lee, Padmanabhan and Whang 1994), the need for supply chain collaboration within the context of demand management has been greatly emphasized. Reflected in such initiatives as Collaborative Planning, Forecasting, and Replenishment (CPFR), collaborative supply chain relationships are expected to align supply and demand across the network of supply chain members (Ireland and Crum 2005). With respect to demand planning, accurate forecasting has become problematic
for companies operating in a business climate characterized by high uncertainty and turbulence (Sanders and Ritzman 2004). Statistical forecasting models may have difficulty taking into account the impacts of unanticipated disruptions that have occurred recently or are expected to occur in the near term (Goodwin 2002). When such changes in the environment are detected, human judgment is the only viable means of correcting the demand forecast (Makridakis, Wheelwright, and Hyndman 1998). Based on these suppositions, it is posited that the process of judgmental adjustment to statistical forecasting methods directly influences supply chain resilience.

FIGURE 3

DLA DEMAND-SUPPLY PLANNING ORGANIZATIONAL STRUCTURE

Turbulence and disruption similarly influence the organization’s supply planning and procurement processes. Informal interviews with DLA managers suggest that
disruptions including dramatic budget adjustments, unanticipated changes in military operations tempo, and industry dynamics each potentially influence performance of supplier-facing managers. Demand and supply planners operate predominantly within an exception-based process. As such, these managers focus on items that have encountered some form of disruption that has created an out-of-tolerance condition.

A second motivation for setting the research within DLA’s demand-supply planning process involves the benefit of a relatively homogenous group of managers who nonetheless maintain diverse relations with internal and external supply chain members and who manage a very diverse mix of SKUs. This dichotomy allows for the mitigation of potential harmful effects of exogenous variables related to heterogeneity among managers and business processes that would likely be encountered by an industry-wide sample, while providing a fertile setting for the study of enterprise resilience. Internal validity error results when variables other than the independent variables included in the analysis account for significant differences in the dependent variable (Malhotra and Grover 1998). Homogenizing the sample frame serves as a primary means of controlling against potential effects of exogenous variables. Therefore, the researcher accepts the possibility of sampling bias in exchange for the enhanced internal validity that results from controlling against extraneous effects on the dependent variable.

3.3 SAMPLING PROCEDURE

An a priori sample size analysis was conducted to estimate the sample size needed to detect the hypothesized effects. Four parameters were used to compute desired sample
size: (1) probability level, (2) number of predictor variables, (3) anticipated effect size, and (4) desired power of the test (Keppel and Wickens 2004). Based on desired Type I error rate of $a = 0.05$, a model with five predictor variables, a medium effect size ($f^2 = 0.15$), and moderate statistical power (0.60), it was estimated that a minimum sample size of 63 responses would be needed to achieve the desired level of statistical power.

In the initial research design, a sampling procedure was developed with the goal to ensure that all participants were members of the target population (e.g. had encountered a disruption in the course of their management responsibilities). Disruptions to the demand management process were to be identified through the exceedance of pre-established thresholds within the enterprise business system. In early discussions with senior managers, however, it was determined that all planners within the sample frame generally face periods of disruption throughout the year by virtue of the number of items managed and the scale of operations. As such, the entire pool of planners fit the criteria of the sampling frame, and careful selection from amongst the planners was deemed unnecessary.

To solicit participation in the study and enhance overall response rate, a two-stage process was developed and implemented. First, each planner was sent an email outlining the purpose of the study and inviting their participation. The initial communication to recipients included a message from supervision in which they advocated participation in the research. This note of sponsorship was necessary to help ensure that potential respondents felt protected from organizational retribution for choosing to participate in the study. In addition to email communication, the pool of managers was invited to
attend one of several informational briefings intended to provide greater detail about the study, introduce the researcher, and offer the opportunity to have concerns about participation addressed. A total of 218 invitations to participate were sent to members of the target sample. From this number, 56 individuals indicated a willingness to participate in the study. Due to scheduling conflicts, two individuals who expressed a willingness to participate in the study were not able to be surveyed. In addition, one of the completed surveys was discarded due to a preponderance of missing data. The data collection effort yielded in a total of 53 usable surveys resulting in a final response rate of 24.31%. While lower than hoped for, the response rate exceeds the rate of 20% considered desirable for survey-based research (Malhotra and Grover 1998).

The translation of latent constructs into measurable variables via survey instrument can introduce several sources of error. Sampling error reflects the error introduced in selection of the sampling frame and in representativeness of the sample of the broader intended population (Malhotra and Grover 1998). As noted above, it is argued that the choice of sampling frame is justified based on the size and diversity of supply chain relations maintained by DLA. Although limiting the sample in this way may introduce a measure of bias as compared to the broader population, it is argued that the pool of managers within the sample frame is generally representative of supply chain collaborators.

In addition to ensuring the sample is representative of the intended population, it is also necessary to assess the degree to which respondents represent the sample frame. As such, several steps were taken to address the issue of nonresponse bias, described as
the substantial difference between the answers of respondents and those who opt not to respond (Lambert and Harrington 1990). As noted by Lambert and Harrington (1990), the best protection against nonresponse bias involves taking steps to increase response rate. As described above, efforts taken to improve response rate in the current study include introductory briefings, assurance of confidentiality of responses, follow-up email messages, and incorporation of a face-to-face survey protocol.

Nonresponse bias was subsequently assessed by comparing survey results against known values related to demographic factors for members of the sampling frame (Armstrong and Overton 1977). Demographic characteristics of the sample of respondents are presented in Table 3. Although demographic data on nonrespondents were not available for statistical difference testing, senior DLA managers noted no significant differences between the sample of respondents and the broader sample frame on factors including age and work experience. Based on these findings, it is inferred that nonresponse bias is most likely to have only marginal influence on research results.

3.4 DATA COLLECTION PROCEDURES

The collection of data was accomplished via face-to-face administration of a survey instrument and unstructured interview protocol with the sample of demand-supply planning managers (outlined above). Paper-based, self-administered questionnaires were completed by respondents, with the interviewer present during completion of the questionnaire. This design was adopted for several reasons. First, face-to-face data
collection is an approach commonly used by network researchers (Knoke and Yang 2008) as such studies are inherently sensitive to missing values and overall response rate.

### TABLE 3

**DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of Respondents</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Work Experience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 10 years</td>
<td>27</td>
<td>50.94 %</td>
</tr>
<tr>
<td>10-20 years</td>
<td>10</td>
<td>18.87 %</td>
</tr>
<tr>
<td>20-30 years</td>
<td>10</td>
<td>18.87 %</td>
</tr>
<tr>
<td>More than 30 years</td>
<td>6</td>
<td>11.32 %</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-35</td>
<td>13</td>
<td>24.52 %</td>
</tr>
<tr>
<td>36-45</td>
<td>8</td>
<td>15.10 %</td>
</tr>
<tr>
<td>46-55</td>
<td>21</td>
<td>39.62 %</td>
</tr>
<tr>
<td>56-65</td>
<td>11</td>
<td>20.76 %</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>30</td>
<td>56.60 %</td>
</tr>
<tr>
<td>Male</td>
<td>23</td>
<td>43.34 %</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand Planner</td>
<td>11</td>
<td>20.76 %</td>
</tr>
<tr>
<td>Supply Planner</td>
<td>24</td>
<td>45.28 %</td>
</tr>
<tr>
<td>Procurement</td>
<td>18</td>
<td>33.96 %</td>
</tr>
</tbody>
</table>

Second, face-to-face administration of the survey allows the interviewer to assist in clarifying and motivating respondents to provide complete and accurate responses to survey items. Lastly, face-to-face administration of the survey instrument provides the opportunity to ask additional interview questions.
Additional supporting data were obtained from informal interviews with senior managers, archival documentation including emails and written correspondence, and electronic data interchange information. The network data gleaned through the surveys refer not only to the patterns of interaction, but to the relational aspects as measured via strength of ties. Analysis of these data yields both a graphic and statistical description of the structure of collaboration within the supply chain during periods of severe disruption. The computer software application UCINET (Borgatti, Everett, and Freeman 2002) was used to perform quantitative analysis and visual diagramming to aid in interpretation of the data.

Network studies commonly emphasize one of two levels of analysis—one relying on complete network data and the other relying on ego-centric data (Marsden 1990). When the research objective concerns comparison of entire social structures, then complete enumeration of the closed population becomes necessary. Saturated (aka “complete”) data includes information on all actors and their connections within the network using either self-report or behavioral data on ties. Because data are gathered from the entire population, estimates of population parameters is not necessary. However, data collection efforts can be time consuming and costly, and perhaps impossible for all but the very smallest of populations (Wejnert 2010). While a network level of analysis may yield important insights for supply chain management theory, such an undertaking is challenging and not essential for addressing the objectives of the current research. The ego-centric approach for sampling and analysis adopted for this research is better suited for studying network effects at the individual (node) level of analysis (Wasserman
and Faust 1994). Figure 4 illustrates an example of a supply chain manager’s ego-network of collaborative ties. The respondent’s ego-network serves as the unit of analysis for the study. The ego-network approach relies on a two-stage survey design for gathering data pertaining to an actor’s attributes, their direct personal ties, and attributes of those ties (Wejnert 2010). Enumerating an actor’s local network of collaborative relationships in this manner allows for statistical inference not possible with other forms of network data (Marsden 1990). The ego-centric approach offers the additional advantage of providing an inherent mechanism for specifying boundaries on the network. Survey instruments labeled name generators and name interpreters (Burt 1984) are common tools for determining membership in the network and obtaining additional data on actors within the network. (Marsden 1990). The name generator uses sociometric questions to generate a list of core contacts within the respondent’s network. Name interpreter items ask the respondent to characterize the relationship with each listed contact, and to inform about the ties among the contacts (Burt 1992). Details related to the instruments developed for this study are presented in the subsequent section.
The ego-centric sampling approach does have limitations, however, that deserve attention. First, the lack of direct data on both the actor and all other direct and indirect contacts in the network limits the range of research questions that can be addressed using such an approach. Given the current research objectives, however, enumeration of the manager’s local network of contacts is deemed adequate. A second concern relates to the inherent reliability concerns associated with self-report data. Sociometric data are often collected by having people report on their interactions with others. Previous research has found that respondent accuracy can be poor at times, and that half of what people report
about their own interactions is inaccurate (Killworth and Bernard 1977). More recent research, however, suggests that respondent accuracy improves substantially when the interactions involved are stable patterns of relationships (Kogovsek and Ferligoj 2005). The survey instrument developed for this study is structured in such a way that respondents are prompted to report on the strongest, most stable ties maintained with other supply chain members.

3.4.1 Survey Instrument Development

The purpose of the research instrument is to provide valid and reliable measures for each of the substantive variables. Consistent with standard ego-centric network protocol (Burt 1984), a two-part survey instrument was developed. The questionnaire asked respondents first for background and demographic information (e.g. age, gender, work experience) and, second, to complete an ego-centered network assessment (Burt 1984; Marsden 1990). This assessment consisted of a set of name-generating questions which asked respondents to identify the most important people within their work environment (internal and/or external to the organization), focusing on the past 12-month period (Appendix A). Respondents were asked to identify two types of contacts: (1) individuals within the work environment that were important sources of advice for routine task execution, and (2) individuals in the work environment that were most important for overcoming problems related to disruption. The name generator survey produced a list of the key contacts, which serves as the respondent’s network of collaborative ties. Respondents were not explicitly limited on the number of contacts
they could identify. The number of contacts listed by the sample of respondents was generally consistent with the degree obtained in similar organizational network studies (Moran 2005). As noted in Table 4, the average number of direct ties reported was seven and the largest network size was 16.

**TABLE 4**

**FREQUENCY DISTRIBUTION OF NETWORK SIZE**

<table>
<thead>
<tr>
<th># of direct ties</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.89</td>
<td>1.89</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.89</td>
<td>3.77</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>9.43</td>
<td>13.21</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5.66</td>
<td>18.87</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>18.87</td>
<td>37.74</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>11.32</td>
<td>49.06</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>16.98</td>
<td>66.04</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>11.32</td>
<td>77.36</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>5.66</td>
<td>83.02</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>1.89</td>
<td>84.91</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>1.89</td>
<td>86.79</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>3.77</td>
<td>90.57</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>1.89</td>
<td>92.45</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>1.89</td>
<td>94.34</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>3.77</td>
<td>98.11</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>1.89</td>
<td>100.00</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

The name interpreter questionnaire then asks respondents about the character of the relations with each of the contacts identified via the name generator. With respect to tie strength, respondents comment on the levels of trust, closeness and frequency of interaction maintained with each of the contacts. Furthermore, the respondent provides
information regarding the existence (or absence) of ties among their direct contacts. The two-stage ego-centric approach was conducted face-to-face with the respondent, and was designed to be completed within a fairly short period of time. Respondents typically required between 30-45 minutes to complete the survey. After completing the paper-based survey, an unstructured interview protocol was administered in which respondents were invited to relate a work experience in which collaboration with other supply chain members played a significant role. Interview data were collected to add richness to the information obtained through the network survey.

3.4.2 Research Measures

The instruments described above, together with archival data and interview data collected separately, are used to measure the predictor variables, outcome measure, and control variable. The explicit measure for each of the variables is described in the following paragraphs.

Independent Variables

Hypothesis 1 tests whether networks rich in structural holes have a positive influence on performance during periods of disruption. The first of the independent variables involves the measure of the size of an individual’s network of collaborative ties after taking into account redundancy among contacts. The presence or absence of structural holes within a demand manager’s collaborative network is assessed using Burt’s (1992) measure of the effective size of the network. The effect of structural holes
is measured through the variable ‘Effective_Size’ using the ‘Networks > Ego Networks > Structural Holes’ routine in UCINET (Borgatti, Everett, and Freeman 2002). According to Burt (1992), the effective size of the network measures structural holes as a function of the number of direct contacts an individual is connected to, minus a ‘redundancy’ factor that accounts for ties among contacts. Using the vernacular of social network analysis, the formula for deriving the effective size measure is

\[ \sum_j \left[ 1 - \sum_q p_{iq} m_{jq} \right], \quad q \neq i, j \]  

(Eq 1)

where \( p_{iq} \) represents the proportion of actor \( i \)’s relations invested in tie with \( q \), and \( m_{jq} \) marginal strength of relationship between actor \( j \) and \( q \). In other words, the effective size of an individual’s network of contacts is not necessarily equal to the degree or simple summation of direct linkages reported by respondents. The information benefits derived from the network are lessened by the extent to which an individual’s contacts are connected to each other. For example, a dense network in which all contacts are tightly interconnected would yield an effective size of unity, because the identical informational benefits may be derived from any contact within such a network. Because effective network size is truncated at zero, and because the effective size of the network can be no greater than the total number of direct contacts within the network, the measure was log-transformed to reduce skewness.
The second hypothesis related to network structure involves the significance of maintaining external connections for improving environmental awareness during periods of disruption. The second independent variable measures the degree to which an actor maintains external versus internal ties. External linkages occur between members of different organizations and different organizational subunits. Thus, external relationships aid in overcoming disruption by providing access to more diverse information. The ratio of external to internal ties within a manager’s collaborative network is assessed through Krackhardt and Stern’s (1988) measure of the $E-I_{Ratio}$ of the network. The variable ‘E-I_Ratio’ is measured using the ‘E-I Index’ routine in UCINET (Borgatti, Foster, and Freeman 2002).

$$E - I \text{ Index} = \frac{EL - IL}{EL + IL} \quad (Eq \ 2)$$

where $EL$ = the number of external linkages and $IL$ = the number of internal linkages. The E-I index is bound between values of -1.00 and 1.00, with a value of -1.00 indicating all of a respondent’s contacts are external and a value of 1.00 indicating all of the respondents contacts are internal. To aid in distinguishing between internal and external ties, a categorical variable was included on the name interpreter instrument by which respondents indicate whether a given contact works in the same office, the same organization but different office, or outside of the manager’s organization. Consistent with Krackhardt and Stern (1988), contacts reported to work outside of the respondent’s office were considered external ties.
The relational aspects of social networks have garnered the attention of network theorists for more than three decades (Granovetter 1973; Marsden and Campbell 1984; Nahapiet and Ghoshal 1998; Autry and Griffis 2008). Three common components of relational quality were assessed—closeness, trust, and frequency of interaction. The survey items used to measure the relational variables were each adopted from existing network studies. As is typical in network research, several variables were measured by using a single question (Borgatti and Cross 2003). While some have expressed concern over the practice of relying on single-item scales (e.g., Churchill 1979), network scholars have demonstrated the reliability of individual questions when procedures are put in place to aid respondents in reporting on their network of linkages (Marsden 1990). To enhance the respondent’s ability to report accurately on their network ties, the survey questions focus on a highly specific type of relation (e.g., work-related collaboration) rather than elicitation of all possible social ties. Furthermore, respondents were asked to report on their most recent (past 12 months) collaborative relations. Previous research has shown that respondent accuracy improves when asked to report on the strongest, most recent ties (Marsden 1990).

Hypothesis 3 tests whether relationships governed by trust have a positive influence on performance in the face of disruption. High levels of trust indicate a ‘strong’ relationship. Trustworthiness engenders expectations of reciprocity, and serves as a barrier against opportunistic behavior (Gulati 1995). The three-item composite scale developed and tested by Moran (2005) was adopted to measure the degree of trust between the manager and each contact. The Likert-type scale measures the degree to
which goals and values are shared, information exchange is honest and truthful, and 
competence is demonstrated by the contact.

Convergent validity reflects the degree to which scale items converge or load 
together on a single construct (Mentzer and Garver 1999). Confirmatory factor analysis 
was used to assess the extent to which scale items capture the content of the trust 
construct. The scale was empirically validated using a maximum likelihood discrepancy 
function with Varimax rotation. A two-step approach described by Hofer and Knemeyer 
(2009) was adopted that involves (1) examining whether factor loadings are positive and 
statistically significant (Table 5), and (2) calculating the “variance extracted” by the 
construct.

<table>
<thead>
<tr>
<th>Scale item</th>
<th>Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. This individual shares my overall goals</td>
<td>0.785</td>
</tr>
<tr>
<td>2. This individual attempts to be honest and truthful in the information they provide</td>
<td>0.895</td>
</tr>
<tr>
<td>3. This individual is very competent in the areas in which we interact</td>
<td>0.868</td>
</tr>
</tbody>
</table>

As shown in Table 5, all parameter estimates were positive and statistically 
significant, and each exceeds the benchmark value of 0.70 indicating substantial 
magnitude as suggested by Garver and Mentzer (1999). The variance explained by the
trust factor was 0.72, which exceeds the recommended value of 0.50 (Garver and Mentzer 1999). The assessment of convergent validity suggests that the three scale items converge on a single factor (trust).

In addition to scale validity, Cronbach’s coefficient $\alpha$ was used to assess the internal consistency of the items comprising the trust scale. In Moran’s (2005) previous use of the scale, a Cronbach $\alpha$ of 0.68 was reported. The $\alpha$ for the trust scale in the current study was 0.88, which exceeds the threshold of $\alpha = 0.70$ as recommended by Nunnally and Bernstein (1994) for a purified scale.

The notion of closeness is a common measure of relational quality in network studies (Moran 2005). The findings of Marsden and Campbell (1984) suggest feelings of closeness serve as a primary indicator of tie strength from amongst the variety of relational measures available. The closeness scale was adopted from Moran (2005). Respondents were asked to report on the degree of closeness maintained with each of their direct contacts (1 – 7 Likert-type scale, where 1 is ‘distant, arm’s length’ and 7 is ‘very close’). The overall closeness of a manager’s relationships is taken as the average level of closeness reported across all contacts.

The final hypothesis tests whether frequency of interaction positively influences performance during periods of disruption. More frequent interaction is expected to yield stronger relationships and richer information benefits (Marsden and Campbell 1984; Nahapiet and Ghoshal 1998). To measure this indicator, respondents were asked to rate the frequency of interaction with each contact (1 – 7 Likert-type scale, where 1 is ‘Less
than once per month’ and 7 is ‘Daily’). The overall frequency of interaction of a
manager’s network is taken as the average level of interaction across all contacts.

Content validity reflects the degree to which the construct of interest is adequately
represented by the scale of items. To address the issue of content validity, the
substantive variables were measured through the use of previously validated items found
in the literature. In addition, the research instrument was pretested with domain experts
to test readability of the instruments and to address the issue of content validity. The
survey items were reviewed by a panel of four practicing managers possessing domain
knowledge/experience to assess whether the instrument might be easily understood and
completed within the desired timeframe. A small number of items were revised to
enhance clarity.

Common method bias is most powerful when a single respondent reports on both
the predictor and criterion variables (Podsakoff et al. 2003). To remedy the potential for
method bias, the predictor variables and outcome variable (to be presented shortly) were
obtained from different sources. Survey data were obtained to measure the independent
variables and archival manager performance data obtained from the DLA’s enterprise
business system serve as a proxy for outcome variable, resilience. As an additional guard
against method bias, procedures were established to ensure respondent anonymity, and
senior management approval regarding participation in the study was made known to
respondents. The intent of these actions was to both increase response rate and also
reduce respondent anxiety over giving truthful answers (Posakoff et al. 2003). In
summary, these efforts reduce the likelihood that common method bias is a significant problem in this study.

In summary, the independent variables just described represent salient aspects of the concept of collaboration from a network perspective. Supply chain collaboration is regarded as a capability to enable the enterprise to anticipate or overcome disruptions, thus enhancing enterprise resilience. In the subsequent section, the dependent variable intended to serve as a proxy measure of resilience during periods of disruption is described.

**Dependent Variable**

The outcome measure used in this study is intended to reflect the degree to which the enterprise is resilient to the effects of environmental turbulence. Enterprise resilience is a latent construct, and to date reliable scales have yet to be developed for the comprehensive measurement of the concept. Within the context of DLA’s demand-supply planning process, however, metrics are available that may serve as reliable indicators of performance during periods of disruption. Specifically, resilience performance is measured using the metric *attainment to plan*, which indicates the percent of customer orders that are delivered at the right time (e.g. received by the scheduled delivery date), in the right quantity, and with the right quality for forecastable items shipped from DLA warehouses. The calculation for attainment to plan is given by the formula: $\text{ATP}\% = (\text{Deliveries Achieved} / \text{Deliveries Possible}) \times 100$. All managers within DLA’s demand-supply planning function are responsible for a set of items (SKUs). The
attainment to plan calculation for each manager is made using data from DLA’s EBS database based on the subset of SKUs managed. Data were retrieved for a period of 12 months covering the pool of managers within the sample frame. To assess a manager’s performance, the individual’s median attainment to plan score over the past year was used.

The use of secondary data offers unique advantages, notably the benefit of reduced subject bias and measurement ambiguity. The effectiveness of secondary data, however, is ultimately determined by the degree to which the data accurately reflect the operationalization of the intended construct (Rabinovich and Cheon 2011). In the current study, the operationalization of the resilience construct as measured via attainment to plan was validated through interviews with DLA managers. Levels of disruption and turbulence tend to be high within DLA’s demand-supply planning function due to challenges associated with changing customer needs (military operations tempo), funding, and a dynamic industrial base. Because DLA demand-supply planning operates on an exception basis, performance is directly reflected in the degree to which DLA managers anticipate and respond to various forms of operational disruptions.

Both the customer-facing and supplier-facing structures within the demand-supply planning function influence whether customer orders are received by the needed arrival date. From the demand management perspective, attainment to plan is influenced by the degree of demand planner forecasting accuracy. When disruptions occur during the forecasting horizon, a manager’s collaborative relationships provide access to the information necessary to reduce uncertainty about the event to yield more accurate
predictions of future demand and provide the necessary pathways to take action to adjust the forecast.

Attainment to plan is equally influenced by the effectiveness of supplier-facing managers. When disruptions occur during demand execution, the supply manager’s collaborative relationships provide access and early warning related to potential impacts on delivery performance. Managers with knowledge about potential or actual disruptions in the supply chain can take action to prevent or mitigate the effects of such disturbances.

The functions of demand planning, supply planning, and procurement each impact attainment to plan in unique ways. Demand planners add collaborative intelligence from customers in order to adjust statistical forecasts when disruptions occur. As forecast accuracy improves, the opportunity to achieve attainment to plan increases (Scott 2010). Similarly, supply planners collaborate with inventory staff to ensure sufficient stocks are available to satisfy forecast demand. Buyers within the procurement function stay alerted to disruptions originating with vendors and distributors.

*Control Variable*

In order to accurately estimate the relationship between substantive variables and the outcome measure, it is essential that important influences on the dependent variable be identified and accounted for in the model. In the current context, demographic attributes were collected to serve as controls. Specifically, respondents were asked to report on the total amount of work experience they had in their current position. Prior research has shown a positive relationship between experience and performance (Seevers,
Skinner and Dahlstrom 2010). The amount of job-related knowledge and skill accumulated by a manager is expected to be positively related to the performance outcome. Summary statistics and bivariate correlations are presented in Table 6.
# TABLE 6

**SUMMARY STATISTICS AND CORRELATIONS**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min-Max</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Work Experience (Years)</td>
<td>13.33</td>
<td>11.18</td>
<td>1.33 – 35.42</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Effective Size (Log)</td>
<td>1.20</td>
<td>0.84</td>
<td>0.00 – 2.64</td>
<td>-0.06</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) E-I Ratio</td>
<td>0.31</td>
<td>0.53</td>
<td>-1.00 – 1.00</td>
<td>0.16</td>
<td>0.29*</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Trust</td>
<td>5.92</td>
<td>0.60</td>
<td>4.67 – 6.93</td>
<td>0.11</td>
<td>-0.05</td>
<td>0.05</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Closeness</td>
<td>4.53</td>
<td>1.12</td>
<td>1.00 – 6.43</td>
<td>0.05</td>
<td>-0.02</td>
<td>-0.03</td>
<td>0.72**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Frequency of Contact</td>
<td>4.23</td>
<td>1.15</td>
<td>1.67 – 6.67</td>
<td>0.17</td>
<td>-0.26</td>
<td>-0.32*</td>
<td>0.41**</td>
<td>0.31*</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>(7) Attainment to Plan</td>
<td>0.81</td>
<td>0.04</td>
<td>0.71 – 0.90</td>
<td>0.01</td>
<td>-0.17</td>
<td>0.13</td>
<td>0.61**</td>
<td>0.53**</td>
<td>0.45**</td>
<td>--</td>
</tr>
</tbody>
</table>

Notes: N = 53; **p < 0.01, *p < 0.05
3.5 SUMMARY

This chapter has presented the research methodology. In the preceding sections, descriptions of the research setting, research design, sampling procedure, and data collection procedures have been presented. In general, this chapter has described the methods and tools by which the research questions will be answered. In the following chapter, the analysis and results will be presented.
CHAPTER 4 RESULTS

In the previous section, the methodology for addressing the research objectives was presented. The description of the research design included the background and motivation for adopting a social network analysis approach for investigating the relationship between collaboration and resilience. The sample frame and development of the survey instrument were presented, including description of the operational measures for each of the substantive variables. The previous chapter concluded with a descriptive summary of the data.

In this chapter the results of the data analysis are presented. Multiple linear regression (MLR) is used to test the hypotheses relating collaboration to resilience. The motivation for selecting a multiple regression approach is described, as well as the diagnostic procedure used to verify that the requirements of MLR have been satisfied. The mathematical model is presented, and the findings are reported for each of the posited hypotheses described previously.

4.1 MULTIPLE REGRESSION AND MODEL ESTIMATION

To estimate the relationship between the outcome variable related to enterprise resilience and the predictor variables representative of key aspects of collaborative relationships, a multiple linear regression (MLR) approach (JMP 10.0) was adopted.
Several alternative analytical approaches were considered, including partial least squares and structural equation modeling. Partial least squares (PLS) is a useful technique for constructing predictive models when the factors (variables) are many and highly collinear. Note that the emphasis is on predicting the responses and not necessarily on trying to understand the underlying relationship between the variables. PLS is therefore better suited to exploratory analyses where little theory exists to suggest relationships among the substantive variables. Because the current study adopts a theory testing model, a confirmatory method of analysis was preferred over exploratory approaches such as partial least squares.

Structural equation modeling (SEM) is a powerful technique for estimating the relationships among a group of latent constructs (Garver and Mentzer 1999). By incorporating both a measurement model and structural model in a simultaneous test, SEM offers potential advantages over more traditional statistical approaches. To accurately estimate the measurement model, however, each latent construct in an SEM model is represented by a set of items. Estimates of error variance cannot be determined with only a single indicator. Thus, single indicators provide an inadequate representation of the latent variables that are used in SEM. Because single-item measures were adopted in the current study, structural equation modeling is not a suitable approach for estimating the relationship between the substantive variables and the outcome measure related to resilience.

The multiple linear regression system of data analysis was selected because of the model’s inherent ability to handle complexities commonly found in the behavioral sciences (Cohen, Cohen, West and Aiken 2003). Additionally, MLR provides for the
measurement of effect size to quantify the strength of the relationship between the independent variables and outcome measure. Multiple regression represents a preferred strategy for inference testing in this case due to the ability of the procedure to deal with continuous independent variables. Additionally, when the factors (independent variables) are few in number, are not significantly redundant (collinear), and have a well-understood relationship to the responses, then multiple linear regression represents a preferred means of turning data into information (Cohen et al. 2003). MLR is most appropriate when the model is relatively simple (several independent variables and a single dependent variable) and effects from moderating and mediating variables are not tested (Cohen et al. 2003). The model estimated in the current study demonstrates these qualities.

A two-stage hierarchical approach was used to assess the overall contribution of main effects. Model 1 includes only the control variable work experience as a predictor, and this variable is regressed on the proxy measure of resilience, attainment to plan. The hierarchical procedure enables the researcher to assess the impact of substantive variables after controlling for potential influence of confounding variables. Previous research has shown that work experience can have significant influence on managerial performance (Moran 2005), yet experience is not among the predictors of interest to this study. Thus Model 1 is used to estimate the amount of variability in the outcome measure that is accounted for by the confounding variable prior to conducting inference testing on the main effects.

In order to test the research hypotheses, a second model was formulated in which the substantive variables were added to the initial model containing only the control variable as a predictor (Eq 3). An evaluation was made of the change in r-squared that
occurs as a result of including all substantive variables in the model after controlling for manager experience. In the current study, the Model 2 specification is formulated as follows:

\[ ATP_i = \beta_0 + \beta_1 WE_i + \beta_2 ES_i + \beta_3 EI_i + \beta_4 TR_i + \beta_5 CL_i + \beta_6 FOC_i + \varepsilon_i \quad (Eq \ 3) \]

where \( ATP \) represents the predicted value of the dependent variable attainment to plan, \( \beta_0 \) is the least squares intercept, and \( \beta_1 - \beta_6 \) represent the least squares estimates for each of the independent variables work experience (WE), effective size (Log)(ES), E-I ratio (EI), trust (TR), closeness (CL), and frequency of contact (FOC). The term \( \varepsilon_i \) represents the error term. The model is estimated based on the sample of subscript \( i = 1, \ldots, 53 \) observations.

Prior to interpreting the model results, the data were analyzed to determine whether the assumptions of multiple regression had been met. The diagnostic procedure is described in the subsequent section.

4.2 REGRESSION DIAGNOSTICS

The data analysis began with an assessment of the data for violations of the assumptions of ordinary least squares regression, and the identification and evaluation of outliers that may cause problems for estimation and inference. Multiple regression, like all statistical techniques, requires that certain assumptions be made. When underlying assumptions of MLR become violated, coefficient estimates may become biased and/or the estimate of the standard error may become biased (Cohen et al. 2003). These
problems may lead the researcher to make false conclusions during hypothesis testing. A combination of graphical methods and regression diagnostics was employed to detect problems related to heteroscedasticity, non-normality, and stray values.

To assess the assumptions of homoscedasticity and error independence, the raw residuals versus predicted scores were plotted and inspected. The presence of systematic variation in the residuals provides an indication that the model may be misspecified in some way. The plot of raw residuals versus predicted scores provided visual evidence of common error variance across the range of predictor values. Therefore, the threat of unequal error variance is not expected to significantly influence model coefficient estimates. Multiple regression further assumes that residual errors are independent. The assumption of independent errors was a notable concern in the current study because respondents work in relative proximity to each other. The potential for spatial autocorrelation becomes an issue for estimation in this case because observations may be correlated as a function of group membership (e.g. demand planning, supply planning, procurement). Visual inspection of the residual plots offered no evidence of the clustering of errors that would indicate a lack of independence. As a further test of the independence assumption, the Durbin-Watson statistic was calculated, resulting in a value of 1.82. Durbin-Watson values near 2.0 indicate a lack of serial dependency in the data, while values approaching 0.0 indicate positive autocorrelation and value >4.0 indicate negative autocorrelation. Our results suggest the assumption of independent errors has been met.

Graphical means were employed to test the assumption of normality. First, univariate frequency histograms were inspected to provide an indication of normality of
the distribution as well as to detect the presence of outliers. Based upon visual inspection of the univariate data, the independent variable effective size was log-transformed to improve skewness for this truncated variable. As an additional test of normality, an inspection was made of the model residual errors. As illustrated in Figure 5, a histogram plot of residuals approximates a normal distribution. In addition, a normal quantile plot of residuals approximates a straight line, which provides further evidence that the assumption of normality has been satisfied and the model is suitable for inference testing.

FIGURE 5

GRAPHICAL REPRESENTATION OF RESIDUALS—HISTOGRAM, BOX PLOT, AND NORMAL QUANTILE PLOT

The inspection of the box plot and residual plot did, however, reveal a concern in the form of an outlier observation (highlighted on the normal quantile plot depicted in Figure 5). Errant data points are of particular concern for multiple regression because
such observations can have a large effect on the estimates of regression coefficients, and ultimately lead to inaccurate inferential conclusions about the relationship between predictors and the outcome measure. *Cook’s distance* was used to assess the influence of the outlier observation, with Cook’s D values substantially larger than 1.0 indicating the potential for significant influence on estimation. Cook’s D influence for the outlier observation was 0.099, indicating the observation is not a strong influence on model estimates. In fact, no observation in the dataset resulted in a Cook’s distance of greater than 1.0, which indicates outliers and influential data points are not a significant problem.

As part of the regression diagnostic procedures, the data were analyzed to determine whether multicollinearity, or high correlation among independent variables, might be a problem. When substantial correlation among a set of independent variables exists, the interpretation of regression coefficients may be misleading. Because MLR regression coefficients represent the unique variance in the dependent variable accounted for by the independent variable, the issue of multicollinearity must be addressed prior to interpretation of model results. Variance inflation factor (VIF) was used to test for the presence of collinearity among the independent variables. As a rule of thumb, a VIF score of 5 or greater serves as an indication that one or more of the predictor variables are highly correlated, which can have an uncertain effect on the coefficient estimates. In the current model, all VIF scores were less than 5, indicating the coefficient estimates are not significantly influenced by multicollinearity.

The results of the regression diagnostic procedures outlined above suggest the key assumptions of the MLR approach have generally been satisfied, and no important problems are present in the data that might mislead the analysis of model outputs. While
the regression assumptions are typically violated to some extent in all models, the robustness of the MLR procedure is expected to yield reliable, interpretable results. In the next section, the coefficient estimates are analyzed to test the hypothesized relationships between the substantive variables and the outcome measure, *attainment to plan*.

### 4.3 MODEL ESTIMATION

To test the hypotheses, a two-stage hierarchical model was developed in which the effect of the control variable was first estimated on the criterion and subsequently a model is specified in which all substantive variables are included in the model. The results of the hierarchical regression modeling are reported in Table 7. All reported regression coefficients were standardized. Model 1 represents the baseline model in which only the control variable, *work experience*, is regressed on the dependent measure, *attainment to plan*. The control variable did not have a significant impact in this model or the subsequent omnibus model (Model 1: \( t = 0.04, p = 0.967 \); Model 2: \( t = -1.45, p = 0.153 \)).

The squared multiple correlation, \( R^2 \), was evaluated for each of the models to estimate overall goodness of fit. \( R^2 \) reflects the amount of the dependent variable’s variance accounted for by the optimally weighted composite of independent variables (Cohen et al. 2003). However, \( R^2 \) obtained from sample data tends to produce a positively biased estimate of the population squared multiple correlation (Cohen et al. 2003). To account for the potential influence of sample size and number of predictor variables, an adjusted-\( R^2 \) is reported.
In Model 1, the overall F-test is not significant ($F(1,51) = 0.002$, $p = 0.967$), with an effective adjusted-$R^2$ of $<0.001$. These results indicate that work experience accounts for an exceptionally small proportion of the variability in the performance measure.

### TABLE 7

**REGRESSION RESULTS FOR ATTAINMENT TO PLAN PERFORMANCE**

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent Variables</th>
<th>$\beta^a$</th>
<th>$t$ Value</th>
<th>$p$</th>
<th>Hypothesis</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Constant</td>
<td>0.000</td>
<td>87.14</td>
<td>0.000**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Work Experience (Years)</td>
<td>0.006</td>
<td>0.04</td>
<td>0.967</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model 1 Summary:
- $R^2$: $<0.001$
- Adjusted $R^2$: $<0.001$
- F-statistic: 0.002

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent Variables</th>
<th>$\beta^a$</th>
<th>$t$ Value</th>
<th>$p$</th>
<th>Hypothesis</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Constant</td>
<td>0.000</td>
<td>12.36</td>
<td>0.000**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Work Experience (Years)</td>
<td>-0.156</td>
<td>-1.45</td>
<td>0.153</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effective Size (Log)</td>
<td>-0.150</td>
<td>-1.37</td>
<td>0.177</td>
<td>$H_1$</td>
<td>Not Supported</td>
</tr>
<tr>
<td></td>
<td>E-I Ratio</td>
<td>0.294</td>
<td>2.50</td>
<td>0.016*</td>
<td>$H_2$</td>
<td>Supported</td>
</tr>
<tr>
<td></td>
<td>Trust</td>
<td>0.053</td>
<td>1.98</td>
<td>0.053</td>
<td>$H_3$</td>
<td>Marginal Support</td>
</tr>
<tr>
<td></td>
<td>Closeness</td>
<td>0.215</td>
<td>1.45</td>
<td>0.153</td>
<td>$H_4$</td>
<td>Not Supported</td>
</tr>
<tr>
<td></td>
<td>Frequency of Contact</td>
<td>0.333</td>
<td>2.64</td>
<td>0.011*</td>
<td>$H_5$</td>
<td>Supported</td>
</tr>
</tbody>
</table>

Model 2 Summary:
- $R^2$: 0.515
- Adjusted $R^2$: 0.452
- F-statistic: 8.150**
- $\Delta R^2$: 0.515

$^a$ standardized beta estimates

* $P < 0.05$

** $P < 0.01$
In Model 2, the level of significance of overall predictability was tested using the squared multiple correlation. A test of the null hypothesis that the population squared multiple correlation is zero ($\rho^2 = 0$) was conducted. As shown in Table 7, the overall F-test for the omnibus model is significant ($F(6,46) = 8.150, p < 0.0001$) with an adjusted-$R^2$ of 0.452 indicating the model with all substantive variables included accounts for nearly 45% of the variability in attainment to plan performance. Based on this result, the null that $\rho^2 = 0$ is rejected and it is concluded that Model 2 accounts for a statistically significant proportion of the variability in the dependent variable.

In addition to the determination of the statistical significance of the findings, the practical significance of the results is estimated using the concept of effect size. As such, the effect size was constructed for the omnibus model. The following formula is used to measure effect size:

$$f^2 = \frac{R^2_{Y,A}}{1 - R^2_{Y,A}} \quad (Eq \ 4)$$

where the denominator represents the error estimate and the numerator represents the proportion of variance explained by the model. In other words, the effect size represents the signal-to-noise ratio produced by the model. Using Cohen’s (1988) guidance, a cutoff of $f^2 = 0.15$ was used to differentiate minor versus interesting effects. As reported in Table 7, $R^2_{Y,A} = 0.452$, so $f^2 = 0.452 / 0.548 = 0.82$, which in subjective terms represents a very large effect size. An effect of this magnitude provides compelling evidence to suggest that the components of collaboration investigated in this study strongly influence managerial performance in disruptive environments.
To test the individual hypotheses relating substantive variables to the outcome variable, the regression coefficients estimated in Model 2 were inspected. Each regression coefficient in a multiple regression equation represents the proportion of variance in the dependent variable accounted for by a given predictor after partialling out the effects of all remaining predictors. A significance level of $\alpha = 0.05$ was used for all tests.

Hypothesis 1 proposes a positive relationship between the effective size of a manager’s network of collaborative ties and performance in turbulent environments. The standardized regression coefficient of effective size (log) on attainment to plan is -0.150 which is not significant ($t = -1.37$, ns). This result indicates a lack of support for the hypothesis that the effective size of a manager’s network of collaborative ties is related to performance in this dataset.

Hypothesis 2 posits a positive relationship between the ratio of external versus internal ties maintained by a manager and performance in turbulent environments. The standardized regression coefficient of E-I Ratio on attainment to plan is 0.294 which is significant and in the hypothesized direction ($t = 2.50, p < .05$). The data provide support for Hypothesis 2, indicating a positive relationship between performance in disruptive supply chain settings and the proportion of external ties maintained by managers.

Hypothesis 3 proposes a positive relationship between trust and performance in turbulent environments. The standardized regression coefficient of trust on attainment to plan is 0.053 which marginally exceeds the level of significance ($t = 1.98$, ns). The
model results demonstrate mild rejection of the hypothesis that networks characterized by high levels of trust are positively related to performance success.

Hypothesis 4 proposes a positive relationship between closeness and performance in turbulent environments. The standardized regression coefficient of closeness on attainment to plan is 0.215 which is not significant (t = 1.45, ns). The findings indicate a lack of support for the hypothesis that performance in disruptive settings is positively related to collaborative networks characterized by high levels of closeness with key contacts in this dataset.

Hypothesis 5 proposes a positive relationship between the frequency of interaction among network contacts and performance in turbulent environments. The standardized regression coefficient of frequency of interaction on attainment to plan is 0.333 which is significant and in the hypothesized direction (t = 2.64, p < .05). Hypothesis 5 is supported, indicating performance in the face of disruption is positively related to the frequency with which managers communicate with the contacts within their collaborative network.

To summarize the results of the regression modeling, mixed support was found for the hypothesized relationships between key attributes of collaborative networks and managerial performance in the face of disruption. The model results provide support for the hypothesis that performance outcomes are positively related to the ratio of external ties maintained by a manager. Additionally, the results used to test the hypothesis that frequency of interaction is positively related to performance were significant and in the expected direction. The hypotheses testing the influence of effective network size, trust, and closeness were not supported by the data. Overall, Model 2 accounted for a
significant amount of the variability in the proxy measure of resilience, attainment to plan
\(F(6,46) = 8.150, p < 0.0001\). The full model accounts for 45.2\% of the variability in the
dependent measure, which represents a large effect.

4.4 SUMMARY

In this chapter the results of the research were presented. A multiple linear
regression approach was used to test the hypotheses relating collaboration to enterprise
resilience. MLR was selected due to the inherent capability of the procedure to support
confirmatory analysis and inference testing. The mathematical model was presented, and
the findings were reported for each of the individual hypotheses. The findings indicate
mixed support for the proposed hypotheses. Performance in the face of disruption, as
measured via the proxy variable, attainment to plan, was significantly related to the ratio
of external to internal ties maintained by managers, as well as the frequency with which
managers interact with contacts within their network demonstrated. The remaining
hypotheses tested in the model were not supported by the data. In the subsequent
chapter, these findings are addressed in greater detail, and present implications of the
research for practitioners and researchers
CHAPTER 5 CONCLUSIONS AND FUTURE RESEARCH

In a global marketplace characterized by high levels of disruption and turbulence, an emerging managerial challenge is to balance improvements in operational efficiency with investment in capabilities that insulate supply chains from unpredictable shocks. Longer supply paths, increasingly demanding customers, and propensity toward leaner operations render contemporary supply chains more vulnerable to internal and external disruption. The concept of resilience has emerged over the past decade to reflect the degree to which the enterprise is postured to survive, adapt, and grow in the face of such turbulent change. Conceptual models of resilience suggest supply chain collaboration may serve as a vital organization capability during periods of disruption. The current research addresses the need to better understand the manner in which supply chain collaboration influences performance during periods of disruption.

There were several underlying motivations for conducting this research. First, although there is widespread agreement that collaboration ought to enhance the resilience of the enterprise, no theory has been offered to explain the relationship between these concepts. The current study is the first known attempt to provide a theoretical lens to the intersection of supply chain collaboration and resilience. Through the lens of social capital theory, important structural and relational components of collaborative networks were identified which help to explain organizational outcomes in turbulent operational settings. Although the linkage between collaboration and supply chain performance has
received scholarly attention (Stank, Keller, and Daugherty 2001; Sanders 2007), the theoretical model tested in the current study investigates attributes of collaborative networks that become vital during periods of disruption.

Second, the research is the first attempt to empirically test theory related to supply chain resilience. To date, the scholarly attention devoted to the concept of resilience has focused on extracting its formative elements and highlighting its importance to the field of supply chain management. To advance resilience theory and improve understanding of the effects of various organizational capabilities on supply chain performance in a turbulent business environment, rigorous testing is in order.

A third impetus for the research was methodological in nature. The study answers the call for supply chain management research that adopts a social network analysis approach (Carter, Ellram and Tate 2007; Borgatti and Li 2009). As scholars and practitioners increasingly recognize the important role of relationships within the field of supply chain management (Cooper et al. 1997a), new approaches for investigating the effects of such relationships on various aspects of supply chain behavior may be useful. Social network analysis holds tremendous promise as a means of investigating the manner in which supply chain ties serve as both an opportunity and constraint on behavior. The need to better understand the unique capabilities and limitations associated with social network analysis was another motivation of the research.

The study represents an important contribution to the literature for several reasons. First, the research adds conceptual clarity to the topics of supply chain collaboration and resilience. By virtue of the recent emergence of these two concepts within the field of supply chain management, there remains a need to progress toward
universal agreement over exactly what these concepts entail. Through a review of the literature streams devoted to supply chain collaboration and resilience, consistencies with regard to the central components of each concept were extracted and leveraged to form the operational definitions used in the research. In addition, the research makes a small but vital step toward understanding the methodological challenges associated with the study of collaborative networks and resilience.

In this chapter the conclusions of the research are summarized. To begin, the motivation and objectives of the research are reviewed and the results described in the previous chapter are evaluated and interpreted. Next, the implications of the research for both theory and practice are presented. The chapter concludes with an acknowledgement of the limitations of the study and recommended opportunities for future extensions of the research.

5.1 RESEARCH OBJECTIVES

The primary objective of the research was to investigate the intersection between the concepts of supply chain collaboration and resilience. To address the overall research objective, it was first necessary to identify the salient features of supply chain collaboration. Social capital theory was then adopted as the theoretical lens through which to relate the effects of collaboration on performance in supply chain settings characterized by high levels of disruption. Specifically, the study sought to determine whether certain relational and/or structural attributes of collaborative networks serve as reliable predictors of performance during periods of disruption. Methodologically, a final goal of the research was to better understand the unique capabilities and limitations
associated with a social network analysis approach of investigation. The extent to which the research objectives were satisfied is summarized in the next section.

5.2 DISCUSSION

This study represents one of the first attempts to rigorously test a theory-based model of supply chain resilience. Furthermore, the study is among the first within the field of supply chain management to view ties between supply chain members through the lens of social capital theory (Autry and Griffis 2008). The essence of social capital theory is the notion that relationships matter. The manner in which supply chain managers derive value from the network of collaborative ties can be explained by the structural and relational attributes of social networks.

An extensive review of the literature was provided in chapter two. Grounded in this literature base, salient features of social networks were identified that theory suggests ought to have direct influence on organizational resilience. Structural aspects of collaborative networks proposed to be significant included the proportion of external ties maintained by supply chain managers, and degree to which managers bridge ‘structural holes’ in the supply chain as indicated by the effective size of their network of ties. Theory also suggests that certain relational characteristics ought to bring value to managers faced with disruption, including development of trust and closeness with direct ties, as well as frequent interaction with other members of the network. Although specific measures of supply chain resilience have yet to be developed and validated, a proxy for resilience, attainment to plan, was adopted in the study to indicate the performance of managers operating in environments particularly prone to disruption.
A conceptual model of the linkage between collaboration and resilience was developed and tested. Five hypotheses were posited to test the relationship between key elements of supply chain collaboration and resilience.

Data collection and development of the survey instrument were described in chapter three. To control against the myriad of exogenous variables that might potentially influence collaboration and resilience performance, the sample frame was restricted to a single, though large and global, logistics provider managing a wide range of products. Using a network analytic approach, the two-stage survey incorporated a name generator through which the structure of the respondent’s ‘ego-network’ was captured, as well as a name interpreter questionnaire through which the respondent reported on the relational qualities maintained with each identified contact. The network data were collected via face-to-face administration of the survey instrument from a sample of mid-level managers charged with demand-supply planning for the host organization. A total of 53 responses were collected, for a 24.31% response rate. Performance in the face of disruption, as measured via proxy in the metric attainment to plan, was obtained from the organization’s ERP database for each respondent in the sample. The multi-item scale for trust was assessed for convergent validity and reliability. A single score for each of the substantive variables was computed for each respondent by averaging the scores reported across all contacts with the respondent’s ego-network.

Chapter four presented the results of multiple linear regression modeling used to test each of the proposed hypotheses. A two-stage hierarchical modeling approach was used to ensure spurious effects of the control variable, work experience, could be
accounted for prior to testing the posited hypotheses related to the substantive variables. Somewhat unexpectedly, managerial experience had no detectable effect on performance in either model. One possible explanation may result from significant restructuring of the demand-supply planning process implemented by DLA in 2002. Previous to the restructuring, managers were generally responsible for all aspects of item management, to include customer-facing efforts to estimate demand and supplier-facing efforts to ensure availability of stock to satisfy demand. Post-restructuring, these responsibilities have been divided into the functional areas currently in place and described previously—demand planning, supply planning, and procurement. This re-organization may partially explain the lack of significance of work experience, as the collaborative ties developed by more seasoned managers were disrupted greatly which likely tempered any advantage a more experienced manager might have otherwise had over newer peers.

As reported in chapter four, the results of hypothesis testing were mixed. The results of hypothesis testing are summarized in the conceptual model presented in Figure 6. With regard to structural aspects of collaborative networks, the findings do not support Hypothesis 1 that effective size of a manager’s network of collaborative ties has direct, positive impact on resilience performance. In the current context, it was expected that managers who maintain a network of contacts rich in structural holes would accrue control and information advantages that lead to superior performance during turbulent times (Burt 1992). Although the lack of statistical significance related to this aspect of
network structure is unexpected, several possible explanations for the finding are proposed. First, testimony obtained from informal interviews with respondents suggests that networks comprised of very few contacts can be effective when performance is driven by a limited number of SKUs. When a small group of critical items account for a large proportion of a manager’s responsibility, then evidence from the field suggests that high levels of performance can be achieved without investment in a large number of collaborative ties. In addition to evidence from practice, theory may help explain the lack of significance regarding effective network size. There remains disagreement amongst
social capital theorists regarding the specific means by which individuals extract value as a function of network structure (Adler and Kwon 2002; Moran 2005). One viewpoint (Burt 1992), and the view tested in the current study, argues information advantages accrue to those who establish contacts with others who are themselves unconnected. Given this view, managers accrue social capital as a result of access to non-redundant sources of information via structural holes in the network. An alternative perspective (Coleman 1988), however, suggests that social capital is instead inhered in dense, interconnected networks of social relationships. Such ‘closed’ networks yield exchange-inducing social norms that engender expectations of unsolicited information flow within the group. It may be that ‘bonding ties’ espoused by closed network theorists are better predictors of performance during periods of disruption than ‘bridging ties’ and the advantage of unique information such linkages are expected to yield. This ‘paradox of embeddedness’ issue remains an open issue for supply chain researchers.

As proposed by Hypothesis 2, the findings indicate that managers who maintain a high proportion of contacts with individuals outside of their local work area tend to outperform their peers. Such external ties provide enhanced environmental awareness and pathways for action once disruptions occur. The number of contacts a manager can reasonably maintain is constrained by the time and resources available to the individual. As indicated in Table 4, the frequency distribution of network sizes reported by respondents, the average number of important contacts reported was 5-6. Because the number of contacts in a manager’s network is bounded, a premium exists for developing ties externally. Consistent with previous network research (Krackhardt and Stern 1988),
the findings suggest that managers who invest in external relationships are better postured to respond to a disruption.

The findings with regard to relational aspects of the network were equally mixed. Hypothesis 3 posits networks characterized by high levels of trust will lead to improved performance in the face of disruption. As noted by Galaskiewicz (2011), “Where there is risk, trust is necessary and networks can generate trust [p. 5]”. Trust has been described as the ‘active ingredient’ of social capital (Moran 2005) because it reduces uncertainty and vulnerability that potentially hamper interdependent relationships. The importance of trust was consistently mentioned in interviews with managers. As noted by one DLA manager, “The people you trust are the people you go to, regardless of the person that is technically responsible for the process”. Surprisingly however, this hypothesis was not supported. This finding was explored more deeply through post hoc analysis. As noted previously, each regression coefficient in a multiple regression equation represents the proportion of variability in the dependent variable accounted for by a given predictor after partialling out the effects of all remaining predictors. Because the regression estimate for the trust variable only modestly exceeded the established significance level ($\alpha = 0.05, p = 0.053$), post hoc testing using a forward stepwise regression procedure was conducted to determine the impact of trust in a more parsimonious model. A model was fitted using a forward, one variable at a time stepwise personality with a minimum Bayesian Information Criterion stopping rule. The trust variable was the first predictor selected for inclusion in the model ($R^2 = 0.37$) from the group of substantive variables (to include the control variable work experience). Subsequent iterations of the stepwise procedure resulted in the variables frequency of contact ($\Delta R^2 = 0.05$) and E-I Ratio ($\Delta R^2$
- 0.03) being selected in turn for inclusion in the model. The results of stepwise regression post hoc testing seem to indicate trust plays an important role in achieving high performance in turbulent settings, although this result should be interpreted with caution. Despite the rather widespread use of stepwise regression procedures, several scholars take a dim view of the approach as a means of theory testing (Cohen et al. 2003). In the absence of theory to guide a specific ordering of variables for inclusion in the model, the possibility exists that a new sample would result in a re-ordering of the variables. The post hoc stepwise results obtained here require further validation, but the findings suggest that trust may well play an important role in the general population despite the modest statistical significance indicated by the current data.

Hypothesis 4 proposed a positive relationship between performance during disruption and degree of closeness a manager maintains with collaborative contacts. The data, however, do not support this hypothesis. This result suggests that developing emotional bonds with other key supply chain members is not necessarily vital for performing well in this disruptive work setting. This result is consistent with the findings of previous network research which report managers often characterize relations with key contacts as distant and not necessarily friendly (Burt 1997).

The findings indicated support for Hypothesis 5 which tested the influence of frequency of interaction on the performance outcome. Frequent interaction with key network members provides both an opportunity and incentive to share information (Ahuja 2000). Awareness of changes in the environment improves and uncertainty is reduced when network interaction occurs on a frequent basis (Van De Ven and Ferry 1980).
When the relational aspects of collaborative networks are taken as a group, the mixed findings are particularly noteworthy when considering the three variables—trust, closeness, and frequency of interaction—have been used together in other network studies to yield a single measure of the construct ‘tie strength’ (Burt 1997; Moran 2005). To investigate the matter further, post hoc assessment was accomplished using dependent means testing for each possible matched pair of relational variables trust, closeness, and frequency of contact. As shown in Table 8, a significant difference was detected between trust and the other two measures of relationship quality ($\alpha = 0.05$, $p < .0001$).

This finding provides evidence that development of trust in the current setting may not always be congruent with feelings of closeness or frequency of interaction. Future research should examine whether setting has a moderating effect on the association between these aspects of relationship quality.

TABLE 8

DEPENDENT MEANS TESTS ON PAIRS OF RELATIONAL VARIABLES

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean Difference</th>
<th>t-Ratio</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closeness ↔ Frequency of Contact</td>
<td>0.297</td>
<td>1.626</td>
<td>.0550</td>
</tr>
<tr>
<td>Trust ↔ Frequency of Contact</td>
<td>1.686</td>
<td>11.611</td>
<td>&lt;.0001*</td>
</tr>
<tr>
<td>Trust ↔ Closeness</td>
<td>1.389</td>
<td>12.534</td>
<td>&lt;.0001*</td>
</tr>
</tbody>
</table>

*p < 0.01
Lack of support for two of three hypotheses used to test relational aspects of collaboration may result from the unit of analysis (the ego-network) adopted in the study and the use of aggregated data to describe these networks. In the current study, relational variables were computed using average scores across all contacts within an individual’s network of collaborative ties. A single score for measures of trust, closeness, and frequency of contact was computed for each respondent. In practice, however, managers and organizations develop a spectrum of relationships ranging from arm’s length to collaborative and partnering (Lambert, Emmelhainz, and Gardner 1996). Network theorists suggest that the ideal network strategy would include both strong and weak ties (Uzzi 1997). As such, it can be assumed that the strength of collaborative ties maintained by a manager might vary among the contacts within the network as a function of the contact’s relative importance to the manager. In the current study, network data were collected on 372 collaborative ties comprising 53 separate social networks. Had dyadic performance data been available, it is possible that a different result regarding the influence of relational aspects of network ties might have been obtained.

Lastly, it is acknowledged that the ability to detect the proposed effects might be enhanced by increasing sample size. A priori power analysis suggested a minimum sample size of 63 responses would be necessary to detect the proposed effects. Although the sample of 53 resulted in adequate power in Model 2, it is possible that additional data might influence the significance of individual parameter estimates.

5.3 RESEARCH IMPLICATIONS

The results of the research offer new insights for managers and researchers alike.
5.3.1 Managerial Implications

The study yields several implications for practitioners. The research lends support for the intuition that management should devote resources to the building of interpersonal network ties with supply chain members, particularly in settings vulnerable to disruption. The informational benefits accrued through close contacts serve as a primary avenue for anticipating and responding to supply chain disruption. The research highlights several areas of emphasis within the realm of demand management and judgmental forecasting in particular. As noted by McCarthy and Golicic (2002) training of boundary-spanning personnel and timely information exchange contribute to increased responsiveness to highly variable, unpredictable customer demands.

Despite the recognition that supply chains increasingly must design for resilience, making the business case for investment in resilience capabilities can be a challenge. It may never be known whether such investment thwarted disruption, or the extent to which resilience capabilities reduced the potential consequences of a disruption (Sheffi 2005). A key challenge for managers is to determine strategies for mitigating supply chain risks without eroding profits. As compared to other resilience capabilities such as added redundancy and flexibility, investment in collaboration serves not as a system buffer, but an approach that can yield improved performance outcomes during periods of routine operations as well.

In highly dynamic competitive environments, organizations increasingly excel based on their ability to manage knowledge and information (Carter, Ellram and Tate 2007). Understanding the structure of collaboration during times of crisis becomes particularly critical. As noted by McIntyre and Travis (2006), “With the assumption that
some form of disruption in the global supply chain is inevitable, either from natural disaster like a tsunami, political discord or terrorist attack, every supply chain should be created and managed with the idea of balancing efficiency with resiliency [pg. 152]). As such, the research highlights the potential value of social network analysis to managers charged with better understanding the nature of supply chain ties within the enterprise. SNA may hold particular promise for managers due to the improved ability of such individuals to gain full and unrestricted access to the member of the organization’s social network.

5.3.2 Implications for Theory

The research yields implications for theory as well. The concepts of supply chain collaboration and resilience have attracted a great deal of scholarly attention over the past two decades, yet few studies have empirically tested the relationship between these emergent concepts. From a research perspective, this study is among the first to empirically test theory related to the concept of resilience. As described in the review of the literature, the conceptual descriptions of resilience found in the extant literature appear to be converging toward unified theory. This study takes a small, but important step toward understanding the supply chain capabilities that underlie a resilient enterprise.

Additionally, the research highlights the value of social capital theory for explaining supply chain behavior. The concept of supply chain collaboration was framed in the research as specific form of social network. Although the value of social ties has received a great deal of scholarly attention in the organizational and strategic
management literature streams, the theory of social capital has to date received much less attention in the field of supply chain management. The research findings provide evidence that structural and relational aspects of supply chain relationships can be useful for explaining supply chain behavior.

The study also makes a contribution to the supply chain collaboration and enterprise resilience streams of literature. The amount of scholarly attention devoted to the topic of collaboration within the field of supply chain management serves as testament to the importance of such networks. Despite an impressive amount of literature devoted to the impacts of collaboration on aspects of operational performance, the concept of supply chain collaboration nonetheless remains fragmented, and the manner in which collaborative structure influences resilience of the enterprise remains unclear. This study adds clarity to our understanding of supply chain collaboration by viewing the concept through the theoretical lens of social capital.

Methodologically, the study sheds new light on several of the capabilities and unique challenges associated with the use of social network analysis in the field of supply chain management. The issues related to SNA in the current study are outlined in greater detail in the subsequent section. This study presents a unique network-analytic approach for investigating the ‘softer’, more qualitative aspects of supply chain management. Although a network perspective increasingly dominates the SCM literature, comparatively few studies have leveraged network theory or its associated tools.
5.4 LIMITATIONS

Several limitations of the study must be acknowledged. First, the degree to which the aforementioned findings are generalizable to the broader population of supply chain managers is constrained by several factors. The selection of sample frame was driven by the desire to control for exogenous influences likely to be encountered in a more heterogeneous sample of managers. It is acknowledged that despite the methodological advantage inherent in such a restricted design, sampling across a broader pool of supply chain managers and across a variety of different business processes may lead to different outcomes. This issue is left for future research.

Several issues related to the use of social network analysis deserve attention. First, investigations of social networks ideally involve full network data so that measurement error and the potential for common method bias might be minimized (Moran 2005). The collection of full network data remains a significant challenge for supply chain management scholars by virtue of the expanse and multi-echelon nature of modern supply networks. Ego-centric networks serve as a useful unit of analysis because the problem of establishing boundaries on the network is implicitly addressed, although it is recognized that analysis of full network data may provide a richer picture of the influences of collaboration on various performance outcomes.

Another challenge associated with the use of SNA is a supply chain setting involves the dynamic nature of the business environment. In the current study, respondents were asked to describe the collaborative relationships they had maintained over the preceding 12 months. Network research has shown that a respondent’s ability to recall the nature of their relations with others improves when the emphasis is on
relatively recent ties. Through informal interviews, many respondents reported difficulty in reporting on the nature of supply chain relationships over even a modest time horizon due to changes in job policy and responsibility and turnover of personnel in the areas of the supply chain in which they interact. As a result, many respondents reported on the nature of collaborative ties with other functional areas (eg an aggregated perspective) versus strictly interpersonal relations with specific individuals. While an inherent benefit of social network analysis involves the capability to aggregate network data, the issue is highlighted here to call attention to the implications for research design and data analysis for supply chain scholars who adopt the SNA approach in the future.

Although network data may be obtained through a variety of sources, the approach typically involves administration of a survey. Because respondents must complete a separate questionnaire to describe the unique relation with each contact in their network, the time required to administer a network survey increases linearly with the number of contacts identified by respondents. As a result, researchers adopting this approach must carefully weigh the desire to investigate many variables related to social networks versus the risk that potential respondents will balk at the amount of time needed to complete the questionnaire.

A final issue of importance for those who would adopt SNA involves the challenge of assessing validity. To assess respondent accuracy, network theorists often recommend a strategy based upon reciprocation of survey responses (Marsden 1990). In the current study, a sample of 10 contacts was interviewed to determine whether the presence and strength of relations was consistent with respondent’s reporting on the relationship. Unexpectedly, a comparison between respondent reporting and that of their
contacts found little statistical consistency with respect to relational attributes. Follow-up questioning revealed a possible explanation for this counterintuitive result. In the current setting, the issue of reciprocity can be difficult to leverage as a means of assessing survey validity due to genuine asymmetry inherent in many of the relationships under study. By way of example, a demand planner considered Customer A to be amongst the most important collaborative contacts, yet Customer A did not count the demand planner amongst their most important collaborative ties. The expectation of reciprocity in the relationship is confounded by dynamics associated with supply chain relationships. Supply chain relations are frequently subject to varying governance structures and objective functions. The context of the relationship therefore plays an important role, and limits the ability to generalize findings to other supply chain settings (Galaskiewicz 2011).

5.5 FUTURE RESEARCH

Given the limitations acknowledged in the previous section, several opportunities to extend the current study through future research are offered. Despite the noted challenges associated with the use of social network analysis within the context of supply chain management, the approach nonetheless offers a valuable means of investigating the network of relational ties that integrate modern supply chains. One of the salient features of social network analysis is the ability to study multiple levels of analysis. Further research is needed to understand the challenges and opportunities associated with using interpersonal data to draw conclusions about an aggregated, organizational level of analysis. In addition, this study employed but a fraction of the attributes available to
social network scholars. There are opportunities to explore supply chain behavior resulting from network characteristics such as centrality, density, and connectedness, amongst others.

In the current study the role of technology as an enabler of collaborative interaction within the supply chain was not explicitly investigated. In view of the importance of information technology for enabling real-time data sharing throughout the supply chain, future research is needed to examine how technology-mediated and interpersonal collaboration and related to performance in the face of disruption.

To further advance the testing of resilience theory, measures need to be developed that capture the depth and breadth of the concept. In the current study, the focus was on tactical aspects of resilience and the capacity of the enterprise to perform well despite short term disruptions to the operation. As noted in the review of the literature, however, the concept of resilience also embodies a strategic, long-term view in which emerging trends which threaten the business core must be identified and addressed. New measures and scales must be developed to more fully capture the essence of enterprise resilience.

This study is among the first to apply a network analytic approach in an empirical investigation of a real-world supply chain. As noted by Lambert (2008), “At the end of the day, supply chain management is about relationship management [p. 6]”. Systems theorists would argue that the attributes associated with the linkages among supply chain components are at least as important as the attributes associated with the supply chain components themselves in regard to overall supply chain performance. There is much more to learn about the effects of supply chain ties on the performance of the enterprise.
REFERENCES


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Fawcett, Stanley E., Jeffrey A. Ogden, Gregory M. Magnan, and M. Bixby Cooper, 2006. “Organizational commitment and governance for supply chain success,”


APPENDIX A

SURVEY INSTRUMENT
Survey Cover Letter:

August/September 2011

Dear Demand Planner,

I would like to enlist your help. I am a doctoral student in Logistics at The Ohio State University. I am conducting a survey on supply chain collaboration as part of my doctoral dissertation research. The purpose of this study is to examine how different aspects of supply chain collaboration influence organizational performance, particularly during periods of severe disruption. Modern supply chains are increasingly vulnerable to various forms of disruption, defined as low-probability, high consequence events. Improved understanding of the capabilities that enable organizations to overcome environmental turbulence has become critical for supply chain managers.

Your participation in this survey is important for enhancing our understanding of the role of collaboration as a means of improving enterprise resilience. Your responses will lead to new insights regarding the attributes of collaborative ties that are most relevant for promoting organizational performance when disruptive events occur.

- The survey should take approximately 25-35 minutes to complete, depending on your responses.
- Consistent with federal guidelines, the study will include adequate provisions to protect the confidentiality of your responses. There is a small risk of a breach of confidentiality, but all efforts will be made to keep everything you tell me in the strictest confidentiality. I will not link your name to anything you say in the text of my dissertation or any other publications. There are no other expected risks of participation.
- The survey is voluntary. By entering and answering questions in the survey, you are consenting to participate. You can skip questions and stop at any point in the survey without any negative consequences to your assignments, promotions or benefits.
- I would like to make a tape recording of our discussion, so that I can have an accurate record of the information that you provide to me. I will transcribe that recording by hand, and will keep the transcripts confidential and securely in my possession. I will erase the recording after I transcribe it.
- How this information will be used. Results of this survey will be aggregated with existing data, and incorporated in a research model. Findings will be documented in a doctoral dissertation and publicly presented at The Ohio State University.

If you have questions or concerns, please contact me at (937) 255-3636 ext 4337, randall.155@osu.edu. If you have any questions about your right as a research participant, please contact The Ohio State University’s Office of Responsible Research Practices at (614) 688-8457 (or (800) 678-6251 if calling from outside the (614) area code), or visit online at http://orrp.osu.edu/irb/participants/.

Thank you for your time and consideration.

Sincerely,

Christian E. Randall
Doctoral Candidate
The Ohio State University
Collaboration Network Generation Survey

Survey Instructions: Please try to answer every question. Select or give the answers that you believe to be most true based on your experience. This survey consists of three parts. Part I asks for basic background/demographic information. Part II asks name generating questions designed to identify your most important contacts (i.e., collaboration partners) within the work environment. To protect confidentiality, you may use initials to name your contacts. Two lists of contacts will be generated during this process: (1) contacts deemed important during periods of "normal operation", and (2) contacts deemed important during periods of disruption. In Part III of the survey, you will be asked questions pertaining to the nature of your relationship with each of the individuals identified in Part II. Please answer the complete set of questions for each of the contacts identified in Part II.

Part I. Demographic Information

Please provide the following background and demographic information. Answer the questions by circling the letter of choice.

1. Gender:
   A. Male
   B. Female

2. Age Group:
   A. 20 and younger
   B. 21-25
   C. 26-35
   D. 36-45
   E. 46-55
   F. 56-65
   G. 65 and older

3. Work Experience: Please indicate the amount of experience you possess in your current position. Include previous work experience if that position involves similar duties and responsibilities.

   Years:_____ Months:_____
Part II. Name Generator

4. Task execution contacts: Over the past 12 months, who are the key people who contribute the most to your ability to do your job as Demand Planner? For example, the individuals you contact routinely in order to accomplish your daily work activities.

5. Problem-solving contacts: Over the past 12 months, who are the key people in your work environment that help you the most to overcome problems caused by either internal or external disruptions?

6. For each of the two groups of contacts identified above, please think about each pair of contacts and indicate whether a relationship exists between them. For example, does the pair of contacts know each other well, or are they closer to being total strangers.
Part III. Name Interpreter

Survey Part III Instructions: For each contact identified above, please answer each of the following questions.

Contact: ______________________

7. Please indicate where this individual works in relation to you.
   A. In my office/department (e.g. demand planning staff).
   B. In my organization, but not my office/department (e.g., Land & Maritime Supply Chain, DSCC).
   C. Outside of my organization (e.g., customers, other agencies).

The following items relate to strength/quality of the relationship.

Relational Trust

On a scale of 1 to 7, indicate the extent to which you agree or disagree with the following items. 
(1 = Strongly disagree ———————————————————————————— 7 = Strongly agree)

8. This individual shares my overall goals.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

9. This individual attempts to be honest and truthful in the information they provide.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

10. This individual is very competent in the areas in which we interact.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Closeness

11. On a scale of 1 to 7, indicate the extent to which you feel a sense of friendship with this individual in your working relationship.

<table>
<thead>
<tr>
<th>Distant/Arm's Length</th>
<th>Quite Distant</th>
<th>Somewhat Distant</th>
<th>Neutral</th>
<th>Somewhat Close</th>
<th>Close</th>
<th>Very Close</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Frequency of Interaction

12. On a scale of 1 to 7, indicate the frequency of interactions you have had with this individual over the past 12 months.

<table>
<thead>
<tr>
<th>&lt; Once per Month</th>
<th>Once Per Month</th>
<th>2 or 3 Times Per Month</th>
<th>Weekly</th>
<th>1 or 2 Times Per Week</th>
<th>Daily</th>
<th>&gt; Once per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
Collaboration Network Unstructured Interview

**Interview Instructions:** The following interview questions allow the respondent the opportunity to provide context for the character of collaboration that occurs and to more fully elaborate on aspects of collaboration that have not been fully revealed in the survey data.

Key questions:

1. Please describe a situation in which your normal work routine was impacted by a disruptive event.
   
   A. Please describe the nature of the disruption.
   
   B. Please describe any similarities or differences you perceive in the nature of collaboration that takes place during periods of normal operation versus periods of disruption.

2. How did you become a demand planner?

3. Please share any other thoughts or comments you may have related to the issue of supply chain collaboration.