Walden University

College of Management and Technology

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Michael Paulovich

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Walden University
2014

Abstract

Resilience and Business Performance in the U.S. Supply Chain

by

Michael J. Paulovich

MBA, Webster University, 1999

AB, Harvard University, 1979

Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Business Administration

Walden University

September 2014

Abstract

Disruption to the supply chain can have significant economic effects on companies and the economy. Managers may be unclear as to which supply chain management strategies would best improve performance to increase resilience against disruptions and would benefit from information leading to optimal solutions. In this study, the research questions focused on the relationship between resilience and financial performance for U.S. supply chain companies. Based on the rational choice theory and supply chain investment principles, a correlational study was conducted using secondary financial information from 300 companies in the U.S. supply chain. The Pearson product-moment correlation coefficient was statistically significant and negative. High variability in days of inventory and cash-to-cash cycle, or low resilience, related to low levels of operating margin and return on investment ratios, or low performance. Knowledge of the positive relationship between resilience and performance may encourage managers to invest in resilience programs, and increased resilience could stimulate positive social change through lower costs of goods to consumers and reduced risk from harmful economic effects from supply chain disruptions. Further research is needed to define financial metrics for resilience.

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Dedication

This study is dedicated to my family who endured the long hours during evenings and weekends when I was in seclusion engaged in research, writing, and editing. Their love and understanding throughout the process gave me the determination to complete this undertaking.

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A doctoral study is a guided individual effort, the inspiration and guidance from Walden faculty members critical to the success, the chair Dr. Cheryl McMahan, and committee: Dr. Judith Bando and Dr. Yvette Ghormley. Former colleagues helped me refine the topic and gave me inspiration and support, David Pittelkow, Paul Ljuba, Jay Evans, Garth Case, Peter Miller, Jeff Kolars, Robert Wolf, Robert Black, and Russell Phillips. Key to my motivation to pursue doctoral level studies was the long term association with the members of the faculty of the Economics Department at the United States Naval Academy, and especially Dr. Roger Little and Dr. Ray Turner. No study of this intensity could have been successful without the understanding and support of my wife, Janet, and son Mark.

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Section 1: Foundation of the Study

The supply chain is a network connecting segments of a process to move goods from producer to the consumer (Greening & Rutherford, 2011). Numerous logistical functions occur along the supply chain (Vilko & Hallikas, 2012) using multiple modes of transportation such as trucks on land and ships on the water (Pant, Barker, Grant, & Landers, 2011). The supply chain is vulnerable to disruptions that effect performance (Wagner & Neshat 2012). To protect against disruptions, managers adopt supply chain risk management (SCRM) techniques and practices including resilience strategies (Juttner & Maklan, 2011).

Managers are not clear as to which supply chain management (SCM) strategy best improves performance (Cabral, Grilo, & Cruz-Machado, 2012). Managers need information to make decisions on investments in SCM strategies leading to competitive advantage. A wrong strategic choice by company management could affect the entire supply chain (Cabral et al., 2012). The purpose of this quantitative correlational study was to examine the relationship between resilience and financial performance for U.S. supply chain companies as this information may assist managers in developing appropriate SCM strategies.

As I describe in the background part of Section 1, the business problem was apparent as a clear strategy to reduce vulnerability and costs was not evident. To study this business problem, I identified the need to examine the relationship between resilience and business performance. The theoretical framework is the connection between SCM practices and business investment decisions in resilience strategies. Methods to measure

resilience and performance from financial ratios appear in the academic and professional literature.

Background of the Problem

A secure and efficient supply chain is crucial to the sustainment of the interdependent global economy and is vulnerable to disruptions (The White House, 2012). Supply chain disruptions include unexpected natural calamities or planned events like terrorism or pilfering (Speir, Whipple, Closs, & Voss, 2011). As the length of the supply chain increases, transactions and the associated risk of disruption also increase (Hishamuddin, Sarker, & Essam, 2013; Zsidisin & Wagner, 2010). A more complex supply chain leads to increased disruption costs (Altay & Ramirez, 2010).

Economic and Financial Effects of Supply Chain Disruptions

Disruptions to the supply chain can cause severe international economic effects (The White House, 2012). For instance, the reduction of economic output from a terrorist driven radiological event in the Los Angeles region could be close to $2 billion in the first year and $2.6 billion per year over time, as calculated from an economic model by Giesecke et al. (2012). LeBlanc and Linkin (2010) reported the damage to New York City from a winter storm in 1992 was $1 billion. In 2005, the National Flood Insurance Program (NFIP) paid over $21 billion in flood claims mostly from Katrina and three other hurricanes (LeBlanc & Linkin, 2010, p. 115-116).

Supply chain disruptions have an effect on the transportation sector. Pant et al. (2011) calculated the loss to companies using a busy port from a 2-week closure resulting from an unplanned disruption at up to $190 million based on an economic model.

Disruptions to the maritime transportation network from natural disasters such as Hurricanes Katrina, Gustav, and Ike, and earthquakes in Japan in 1995 and 2011 had significant global economic effects (Omer, Mostashari, Nilchiani, & Mansouri, 2012).

Supply chain disruptions are costly to companies. During 2012, 73% of supply chain managers reported experiencing a disruption and 59% reported lost productivity from disruptions (The Business Continuity Institute, 2012). Supply chain disruptions contribute to higher costs, increased inventory, and lower growth in sales (Ponomarov & Holcomb, 2009). Following a disruption, immediate effects may include reduced sales and increased transportation costs (Porterfield, Macdonald, & Griffis, 2012).

Supply Chain Risk Management and Resilience

To protect the supply chain from the effects of disruptions, managers must adopt strategies to identify vulnerabilities and apply mitigation measures to reduce the impacts (Wagner & Neshat, 2012). Managers employ supply SCRM techniques to reduce disruptions through prevention or effective responses (Wieland & Wallenburg, 2012). Managers' should synchronize disruption management strategies with governmental programs (Urciuoli, Mohanty, Hintsa, & Boekesteijn, 2014). The purpose of the *National Strategy for Global Supply Chain Security* in 2012 was to outline a strategy to reduce vulnerability through security and resilience (The White House, 2012).

Supply chain resilience. One strategy to emerge from SCRM analysis is resilience (Juttner & Maklan, 2011). The concept of resilience embodies subject areas of science, psychology, systems engineering, and business management and broadly implies a reestablishment of stability following a disturbance (Bhamra, Dani, & Burnard, 2011;

Ponomarov & Holcomb, 2009). Definitions for supply chain resilience vary; most imply the capability to withstand a supply chain shock and recover quickly (Cabral et al., 2012).

Business strategies that integrate concepts of resilience also reduce vulnerabilities to the supply chain from disruptions (Carvalho, Barroso, Machado, Azevedo, & Cruz-Machado, 2012b; Zsidisin & Wagner, 2010) and lessen the economic impact of disruptions (Omer et al., 2012). There is a cost associated with the implementation of strategies (proactive or reactive) used to reduce vulnerability to supply chain disruptions (Hishamuddin et al., 2013). Excess resilience capability can reduce profits (Carvalho, Duarte, & Machado, 2011; Fujimoto & Park, 2014; Pettit, Fiskel, & Croxton, 2010).

Supply chain management strategies. Guided by best practices embodied in SCM, managers consider business strategies and plans to achieve competitive advantage (DiGiacomo & Patrizi, 2010). Managers select business strategies to reduce vulnerabilities and reduce cost (Cabral et al., 2012). The degree of competition in the supply chain leads companies to adopt a lower price and lean strategies (Carvahlo et al., 2012a; Wagner & Neshat, 2012). Lean strategies based on lower inventory levels and minimal excess capacity run counter to resilience strategies (Cabral et al., 2012).

Business Problem and Business Practice Gap

Managers need to identify the right balance of programs in their strategic plan (Wieland & Wallenburg, 2012) and from conflicting business strategies to achieve lower operating costs or to reduce vulnerabilities; clear strategies have not emerged. According to Pettit et al. (2010), there is an optimal balance of investment in resilience strategies, which provide just the right level of protection against vulnerabilities, yet not reducing

profitability. Managers place equal emphasis on resilience strategies as on lean strategies (Cabral et al., 2012). Programs to reduce the effects of disruptions should show a positive return in terms of greater financial performance or customer satisfaction. Additional costs of risk reduction programs should factor against profits from greater performance (Wieland & Wallenberg, 2012).

Specifically, managers need to understand if resilience strategies improve performance to guide in the development of clear strategic plans. Johnson and Templar (2011) concluded from an empirical study that SCM programs lead to increased company performance. Implementation of SCRM practices leads to improved performance (Thun & Hoenig, 2011; Wieland & Wallenburg, 2012). Carvalho et al. (2011) and Pettit et al. (2010) claimed resilience could be a key component of competitive advantage. If resilience strategies could lead to improved performance, such strategies could contribute to competitive advantage.

A business need exists for examining the relationship between resilience and business performance so managers can make effective decisions on strategies to improve efficiency and reduce vulnerabilities from disruptions. A suitable technique to inform strategic decisions is an analysis of performance using financial measures (Carvalho et al., 2011). Financial ratios are useful for analyzing a linkage between SCM and performance (Johnson & Templar, 2011).

Managers need information to support their choice of the best SCM strategies leading to competitive advantage (DiGiacomo & Patrizi, 2010). To meet this requirement, managers use business research techniques to make informed decisions

(Naslund, Kale, & Paulraj, 2010). The identification of best practices and measures of resilience is a focus of business researchers (Cecere & Mayer, 2013). Additionally, business researchers recognize causes, effects, and recovery from non-anticipated supply chain disruptions (The Business Continuity Institute, 2012). Business research analysts identified the need to develop financial measures of resilience using industries representative of the supply chain during a distinct period (Hofman & Aronow, 2012). In practice, business research may support investment decisions, but frequently without sound academic research techniques (Naslund et al., 2010). Academic studies have not addressed the problem of resilience and performance; business research on resilience lacks the depth of academic study and broad scope beyond targeted industry case study analysis. Quantitative design using secondary data and financial ratios for generalizable results is an approach to resolve the gap in business practice. The theoretical framework is the link between SCM practices and business investment decisions. Finally, variables to measure resilience and performance from financial ratios through business research methods and techniques established in academic studies appear in the academic and professional literature.

Problem Statement

The supply chain is susceptible to costly disruptions (Carvalho et al., 2012b). Disruptions to the supply chain can have substantial economic effects; a 2-week disruption at a single busy port could cost companies $190 million (Pant et al., 2011). The effects of supply chain disruptions on companies include financial loss, decline in customer loyalty (Speier et al., 2011) and reduced capacity (Altay & Ramirez, 2010).

Managers minimize the effects of supply chain disruptions by implementing supply chain risk management strategies (Wieland & Wallenburg, 2012). Application of supply chain risk management strategies increases resilience and reduces vulnerabilities from disruptions (Juttner & Maklan, 2011). Investment in resilience programs could result in lower profits (Pettit et al., 2010). The general business problem is that clear strategies to reduce vulnerability and lower cost have not emerged in supply chain management practice. The specific business problem is that managers need to know whether resilience programs lead to improved performance to assist in the development of appropriate investment strategies.

Purpose Statement

The purpose of this quantitative, correlational study was to examine whether a relationship existed between resilience and financial performance, which could assist managers in developing appropriate strategies. There were two resilience variables: days of inventory (DOI) and cash-to-cash cycle (C2C), and two performance variables: operating margin (OM) and return on assets (ROA). The population consisted of U.S. publically traded companies that were identified in a commercial list of firms found in the North American Industrial Classification System (NAICS) two-digit code categories, Mining (21) Manufacturing (31-33), Wholesale Trade (42), and Retail Trade (44-45). Results may guide managers in choosing efficient and effective strategies to improve business performance and might demonstrate an increase in economic benefit to the consumer and to society. Practitioners may use the findings from the study to amplify business research on resilience.

Nature of the Study

An appropriate research method and design are necessary to analyze business problems facing managers in the supply chain. Business research techniques are useful to identify trends and support managerial decisions, and are without application of scholarly methods (Naslund et al., 2010). By integrating academic methods, the results from this study may add credibility to trend analyses used in business research for supporting managerial decisions.

Research Methodology and Design

A quantitative method is the most appropriate method for determining the relationship between variables through hypothesis testing and generalizability of results (Bhattacherjee, 2012). The quantitative methodology includes hypothesis testing and deductive analysis in supply chain research (Wieland & Wallenburg, 2012). Quantitative analysis is a common research method, accounting for between 46 to 85% of empirical studies found in scholarly SCM journals methodology assessments from 1985 to 2009 (Golicic & Davis, 2012).

The correlational design is appropriate to determine if a relationship exists between two variables, as well as the degree of the association and direction between two variables (Hair, Celsi, Money, Samouel, & Page, 2011). The identification of a relationship between resilience strategies and performance could add credibility to trend analysis methods found in business research. Evidence of a causal relationship would best justify business decisions and not be supported solely from correlational analysis (Hair et al., 2011).

An ex post facto experimental design from longitudinal data could test intervention measures and company level performance, and controls are a significant limitation (Wilderom, Van den Berg, & Wiersma, 2012). Experimental design requires a controlled environment and isolation of variables (Bhattacherjee, 2012). An experimental design is applicable for the analysis of supply chain disruptions (Altay & Ramirez, 2010; Omer et al., 2012), and challenging to establish controls at the firm level.

Data obtained for the correlational design was from secondary sources. Financial data drawn from company financial statements are the most objective source of secondary data as the collection is for public reporting (Calantone & Vickery, 2010). Secondary data is useful for evaluating inventory levels and factors leading to vulnerability (Wagner & Neshat, 2012). Self-reported survey financial data could be biased (Cecere, 2012).

The data collection method for SCM quantitative studies is primarily through survey (Golicic & Davis, 2012). Challenges to survey data for analysis of financial performance exists. Low response rates were a characteristic of survey collection method in supply chain studies (Subroto, 2010). Additionally, the difficulty in collecting financial information by a survey is attributable to the proprietary nature of the data, and reluctance of companies to provide information (Speier et al., 2011). Survey data from managers' perceptions on company operations could reflect bias (Calantone & Vickery, 2010). Self-reported performance data from surveys limit the validity of findings (Wagner & Neshat, 2012).

Other research methods were not appropriate for the research question. Qualitative methods suit exploratory research where there is less information on emerging topics (Hair et al., 2011). Additionally, qualitative methods are less adaptable to statistical analysis, and the results may not be generalizable (Bhattacherjee, 2012). Mixed methods research could be effective in studies to explore new subjects where variables are unidentified, and are expensive and time consuming (Golicic & Davis, 2012). Descriptive research studies with hypothesis testing of known strategies are more suited to quantitative methods (Hair et al., 2011).

Application of Business Research

Academic research methods augment applied business research techniques in preparation of information needed to assist managers in the development of appropriate SCM strategies. In practice, business research may support investment decisions without application of sound academic research methods (Naslund et al., 2010). Sodhi, Son, and Tang (2012) recommended business leaders and researchers cooperate on developing SCM conceptual frameworks. The most effective research is relevant to business problems with integration of academic principles (Naslund et al., 2010; Subroto, 2010).

The topic of resilience and performance is relevant to business managers, and the integration of business research techniques and academic methods will improve credibility. The findings of this study may assist supply chain business researchers in identifying the most effective resilience strategies. Business researchers could use the findings to advise supply chain managers on potential investments in resilience. Public

policy decision makers might apply the results and support the intent of the *National Strategy for Global Supply Chain Security* (The White House, 2012).

Research Questions

In the research questions, I focused on the specific business problem and assessment of the relationship between resilience and company financial performance. Each research question was focused on specific elements of resilience and business performance found in the literature. The hypotheses and variables, supported in the professional and academic literature, formed the basis to analyze the research questions.

Research Question 1: To what extent, if any, is there a relationship between DOI and OM for companies operating in the U.S. supply chain?

Research Question 2: To what extent, if any, is there a relationship between DOI and ROA for companies operating in the U.S. supply chain?

Research Question 3: To what extent, if any, is there a relationship between C2C and OM for companies operating in the U.S. supply chain?

Research Question 4: To what extent, if any, is there a relationship between C2C and ROA for companies operating in the U.S. supply chain?

Hypotheses

The hypotheses supported the research questions.

$H1_0$: There is no relationship between DOI and OM for companies operating in the U.S. supply chain.

$H1_a$: There is a relationship between DOI and OM for companies operating in the U.S. supply chain.

$H2_0$: There is no relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H2_a$: There is a relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H3_0$: There is no relationship between C2C and OM for companies operating in the U.S. supply chain.

$H3_a$: There is a relationship between C2C and OM for companies operating in the U.S. supply chain.

$H4_0$: There is no relationship between C2C and ROA for companies operating in the U.S. supply chain.

$H4_a$: There is a relationship between C2C and ROA for companies operating in the U.S. supply chain.

The resilience variables were C2C and DOI; the performance variables were OM and ROA.

Theoretical Framework

Business investment and SCM theories formed the foundation for this examination of resilience and financial performance. The basis of the supply chain managers' decision to invest in resilience strategies is a rational choice grounded in business investment and SCM theories and practices. Strategic decisions should connect to quantifiable performance outcomes (Brouthers, 2013).

Business Investment Theories

Many factors influence the managers' choice of SCM strategies. Managers formulate rational decisions using financial management tools to reduce costs (Bennouna, Meredith, & Marchant, 2010). As a foundation, the rational choice theory (RCT) presumes rational choice behind economic decisions (Hovi, Underal, & Ward, 2011). The RCT originated from the work of Gary Becker (1976) with the premise decisions in all activities are similar to the behavior of a rational consumer in classical microeconomic theory. Under this paradigm, managers solve SCM problems in a rational manner by identifying critical objectives, gathering pertinent data, developing plausible courses of action, and systematically analyzing and selecting appropriate projects for optimal results (Tello, Lantham, & Kijewski, 2010).

Managers in public and private sector organizations select investments for future operations and evaluate the best use of available financial resources. Business managers must operate to maximize profits for their owners or shareholders (Carroll & Shabana, 2010). A key objective of SCM is the maximization of profits (Chen, 2010). Business managers evaluate potential investments in plant, equipment, processes, and training using discounted cash flow (DCF) methods such as net present value (NPV) or internal rate of return (IRR) to ensure that the investment contributes to profit (Bennouna et al., 2010). One critique of the cost-benefit analysis is the arbitrary choice of a discount rate selected for the analysis; Burgess and Zerbe (2011) recommended the use of the social opportunity cost (SOC) approach that incorporates economic principles of social costs.

Supply Chain Theories

A supply chain is a complex system; the volume of transactions and integration of multiple organizations leads to a high degree of complexity in decision-making (Manuj & Sahin, 2011). An outcome of supply chain complexity is an increased degree of uncertainty (Manuj & Sahin, 2011). Application of SCM techniques affected resilience in the supply chain (Ponomarov, 2012). Supply chain management improves company financial performance (Modi & Mabert, 2010).

The foundation of SCRM was the integration of risk theory with management and studied within the context of SCM (Rao & Goldsby, 2009). Although there is no distinct SCRM theory, one source frequently cited for the definition of SCRM is Juttner, Peck, and Christopher (2003). Supply chain managers perceive risks of disruptions and make decisions on investments under uncertainty that could reduce risk to operations and profit (Zsidisin & Wagner, 2010).

Supply chain risk management techniques have value in the diagnosis of the supply chain risk basis, evaluation of the risks of disruptions, and in recommendation of mitigation measures (Lavastre, Gunasekaran, & Spalanzani, 2012). Globalization of the supply chain contributes to greater risk, yet most companies do not use a standardized SCRM process and apply other appropriate measures (Christopher, Mera, Khan, & Oznur, 2011). An effective SCRM will incorporate planning to prevent disruptive events, and will be useful in planning for recovery from disruptions (Ponomarov & Holcomb, 2009). Supply chain risk management is valuable useful in planning projects to protect against disruptions and reduce vulnerability (Lavastre et al., 2012). Disruptions from

terrorism are difficult to protect against because of the difficulty in forecasting the event (Cox, Prager, & Rose, 2011).

Definition of Terms

The academic and business communities accept many of the terms and concepts for the supply chain used in this study. Some terms are interchangeable. The following list contains the most common terms.

Agile: Agile is a manufacturing management principle based on the need to answer to consumer requirements and implementation of manufacturing processes with sufficient flexibility to meet changing orders (Cabral et al., 2012). Agile strategies enable companies and the supply chain to adapt to dynamic business conditions (Gligor & Holcomb, 2012).

Business investment theories: Managers use business investment theories to guide their decisions to optimize output and maximize profits (Carroll & Shabana, 2010). Managers evaluate investment options with consideration for time, interest rate, and cash flow (Bennouna et al., 2010).

Cash-to-cash cycle (C2C): C2C is an accounting measure of receivables, payables, and inventory (Hoffman & Kotzab, 2010). The calculation of C2C is days of inventory plus days receivable minus days payable (Cecere, 2012).

Days of inventory (DOI): The accounting term DOI represents the time unrefined resources transform into finished commodities, which could contain manufacturing time (Hoffman & Kotzab, 2010). DOI is average inventory divided by cost of goods sold times 365 (Cecere, 2012). DOI is a ratio used to measure supply chain performance, and a

lower ratio related to lower costs in lean manufacturing (Cabral et al., 2012). Another term used is days inventory held.

Green: Green is a common term associated with environmentally friendly procedures. Green corporate strategies could incorporate environmentally friendly and sustainable design into processes (Cabral et al., 2012).

Lean: Lean is a manufacturing principle implemented to shrink waste and decrease business activities that do not add value, incorporating the concept of just-in-time inventory control (Cabral et al., 2012). Lean strategies work best with stable and forecasted supply chains (Carvalho et al., 2011).

Operating margin (OM): The accounting expression OM is a financial ratio calculated as operating income divided by revenue (Cecere, 2012).

Operational slack: As a practical business term, operational slack defines the degree of flexibility within a process or industry. Sufficient operational slack ensures that the organization possesses sufficient flexibility to reduce the effects of a supply chain disturbance (Hendricks, Singhal, & Zhang, 2009). Operational slack is a technical operations management term, used interchangeably with the business term *excess capacity*.

Resilience: Used in the context of management strategy, resilience describes the ability of a company to deal with unpredicted disruptions and restore operations following an interruption (Cabral et al., 2012). This concept originated from biological sciences, engineering and organizational theory (Pettit et al., 2010).

Return on assets (ROA): In accounting, ROA is a financial ratio calculated as net income divided by total assets (Cecere, 2012).

Rational choice theory: Managers make decisions based on rational choice, following a systematic analysis of potential options (Tello et al., 2010). The rational choice theory originated from Gary Becker (1976).

Supply chain disruption: The term supply chain disruption represents a break to the flow of commodities (Hishamuddin et al., 2013). The concepts and expressions disturbance, disruption, vulnerability, risk describe the same occurrence or phenomenon (Carvalho et al., 2012b). A disruption describes a considerable change to the supply chain from a large-scale event while a disturbance explains periodic changes from market conditions (Greening & Rutherford, 2011).

Supply chain management: Supply chain management includes guidelines and best practices which evolved over time for effective management of the supply chain in order to gain competitive advantage (Christopher & Holweg, 2011). The objective of SCM is efficiency in the movement of goods and product information (DiGiacomo & Patrizi, 2010).

Supply chain risk management: Supply chain risk management is a field that integrates principles of supply chain management and risk management (Rao & Goldsby, 2009). The applications of practical measures diminish supply chain vulnerabilities and maintain stability by analyzing and evaluating risk (Wieland & Wallenburg, 2012).

Supply chain stability: A resilient supply chain maintains a consistent level of stability or reacquires a new level of stability (Carvalho et al., 2011; Wieland &

Wallenburg, 2013). Stability of the supply chain is a positive factor for performance (Christopher & Holweg, 2011; Ponomarov, 2012). Managers apply SCM strategies to improve stability (Bode, Wagner, Petersen, & Ellram, 2011; Hill, Doran, & Stratton, 2012).

Assumptions, Limitations, and Delimitations

Assumptions were necessary to establish a link between investment decisions on resilience strategies by managers and the variables used to quantify resilience and performance. Limitations of this study included factors that could inhibit the measurement of resilience. Delimitations included study boundaries required to maintain focus on the business problem.

Assumptions

Three assumptions formed the basis for this study. First, I assumed that managers selected strategies to improve resilience through rational investment decisions in concert with SCM principles and business practice. Second, I assumed that the measurement of resilience through financial ratios was a reflection of the outcome of the investment strategies. Third, I assumed that a comparison of the quantified resilience investment outcomes and company financial performance was possible. These assumptions were necessary to validate measurement of resilience and performance using secondary financial data.

Rational investment decision. Another assumption that I made was managers rationally choose between competing business strategies regarding investment in resilience. The basis of managers' strategic decisions came from underlying theories

presented in the Theoretical Framework section. Managers may consider a balance of security, risk, and cost in the investment decision but ultimately must evaluate the impact on profit and investments to show economic return (Nagurney, 2010).

Measurement of resilience through financial ratios. The outcomes of a strategic management decision may be isolated and quantified in financial terms. While isolating outcomes of individual investment decisions could be difficult, observing characteristics of successful investment strategies might be possible. One key assumption that I made here was that positive outcomes from successful resilience investment strategies could be evident from companies that demonstrate resilient financial characteristics.

Measuring the financial effects of resilience strategies over time was necessary. Companies not operating over the entire observation period were not sources of data for this study. My assumption was companies with complete 10-year data operate similarly to companies not operating over the same period.

Comparison of resilience and performance. Quantified financial terms must serve to measure the outcome of resilience investment strategies. Variables originated from the resilience profile (characteristics) formed from company investment strategy and measures from financial ratios. Financial records captured business performance.

Limitations

Limitations included aspects of the study outside the researcher's control. The first limitation of the study was no accepted variable using financial ratios for the measurement of resilience was evident in the literature. An accepted measurement was

essential for valid research and conclusions. Second, no clear common business definition of the supply chain was apparent, critical to generalize results. To overcome the limitations, an approximation of the supply chain emerged from the literature.

No measures for resilience. A universal financial measure for resilience was not available. A gap exists in the measurement of resilience, requiring more research for accepted measures (Pettit et al., 2010; Reggiani, 2012). Managers' perceptions of the degree of resilience could appear in survey responses. Self-reported output data could also quantify characteristics of resilience. There were also not specific financial accounting measures for resilience. Although not a universal measure, characteristics of resilient companies measured with financial ratios could overcome the limitation.

No distinct supply chain population. No clear business categories define the supply chain. The supply chain covers a broad domain, which could include practically all economic activities involving production and distribution of goods. For business purposes, North American Industrial Classification System (NAICS) sectors are useful for categorizing companies that produce supplies, manufacture goods, and prepare products for consumers. An approximation of the supply chain exists as companies operating within certain NAICS sectors.

Delimitations

Delimitations included aspects of the study necessary to achieve the objectives within my research budget. The field of supply chain management and risk mitigation are vast subject areas, and delimitations established bounds to focus on the objectives of the study. Statistical power and cost were considerations for the selected sample size.

Supply chain as a subject area. The areas of the supply chain and risk management are subjects of hundreds of textbooks and journals. Detailed descriptions of the supply chain, risk management, and resilience could be informational and might dilute the focus of the study. Sufficient discussion appears in the literature regarding the nature of supply chain resilience, best practices for achieving resilience, and investment and decision theory. The focus of this study was limited to the relationship between resilience and performance, and not on the academic discussion of resilience.

Sample size. A large number of companies with publically reported financial data were available for this study. Frequently, empirical studies using secondary data have a large sample size; five of seven studies listed by Kroes and Manikas (2014) contained a sample size over 1,000. The cost of collecting and preparing the data consisting of financial records over a 10-year period increased with the sample size. The limiting factor for sample size was capability to achieve sufficient statistical power, the method described in Section 2.

Significance of the Study

A business need existed to examine the relationship between resilience and business performance so managers can make effective decisions on strategies that improve efficiency and reduce vulnerabilities to disruptions. A clear understanding of best strategies could lead supply chain companies to improved performance and lower vulnerability to disruptions (Cabral et al., 2012). In addition to improving company profitability, society could benefit from reduced economic effects of supply chain disruptions.

Contribution to Business Practice

The benefits of this study could include increased understanding regarding the relationship between resilience and business performance, and insight into the effectiveness of investment in resilience programs, an area of future inquiry identified by Carvalho et al. (2012a). The results may guide managers in future investment strategy decisions and government policy makers involved in the continued development of the *National Strategy for Global Supply Chain Security*. In this study, I also addressed the need for additional quantitative studies on supply chain resilience and gaps in both academic literature and business research.

Managerial implications for improved business practice. Definitive results on the relationship between investments in resilience and performance could serve as the basis for management decisions. Supply chain managers may find the results of this study support their previous and future resilience investment decisions. The proposed methods for measuring resilience have potential applicability in future management decisions.

As applied business research, the study results may be insightful for supply chain practitioners regarding the relative effectiveness of a range of resilience investments. A need exists to determine what resilience strategies lead to improved performance, and which programs and practices should support the strategies (Hendricks et al., 2009). Performance measurements are useful for managers to evaluate the efficiency and competitiveness of their company in the supply chain (Carvalho et al., 2011).

Academic and business research to support business practice. Managers use academic and business research as a basis for informed investment decisions (Naslund et

al., 2010). Business research analysts identify best practices (Cecere & Mayer, 2013). Academic researchers communicated the need for additional quantitative research on impacts of disturbances to the supply chain, on supply chain strategies and performance, and measurement of resilience.

Disturbances to the smooth flow of goods in the supply chain are common; however, there was limited research on the impacts of disruptive events (Altay & Ramirez, 2010). Studies and business best practices exist on methods to reduce vulnerabilities, the evaluation of effects of SCRM programs on vulnerability reduction and business performance requires more quantitative research (Wieland & Wallenburg, 2012). Limited quantitative research on resilience in transportation systems exists (Omer et al., 2012). In addition, most research in the area of SCRM was conceptual (Sodhi et al., 2012).

Research on the SCRM strategies for disruptive events is insufficient (Carvalho et al., 2012b) as is research on recovery from catastrophic events (Hishamuddin et al., 2013). Few quantitative studies evaluating the value of the SCRM strategies exist (Hendricks et al., 2009). Limited quantitative research evaluating risk management strategies to reduce the impact of disruptions exists (Ponomarov, 2012). Research on SCRM strategies to enhance agility and robustness and effect on performance is inadequate; measuring the effectiveness of a responsive strategy is challenging as effects become evident only after a disruptive event (Wieland & Wallenburg, 2012). Quantitative research confirming practices that increase or reduce the level of resilience is incomplete (Blackhurst, Dunn, & Craigshead, 2011).

A need exists for more in-depth academic research on the concept and measurement of resilience (Pettit et al., 2010). Measurement of resilience is currently theoretical and conceptual based on biological or engineering foundation (Reggiani, 2013). Quantifying vulnerability in the supply chain is challenging as there are no distinct measures, so constructs emerge from elements of vulnerability (Wagner & Neshat, 2012). Measurement of resilience in transportation networks is also challenging (Szyliowicz, 2013).

This study could contribute to business practice, complementing trend analysis by business researchers with the application of academic methods. Two unique aspects of the study may add to improved practice; a distinct method to assess the degree of resilience and a more realistic approximation of the supply chain used in random sampling. The application of these two unique aspects might result in successful measurement of resilience and performance with financial ratios and greater generalizability of quantitative results.

Implications for Social Change

Quantitative studies are useful in producing generalizable results and model for sound business decisions. At the business level, managers can choose suitable strategies to enhance performance, which provides a better product to consumers and increases the benefit to society (Wieland & Wallenburg, 2012, p. 889). At the macro level, this study could be useful to government officials regarding the effectiveness of government regulation, incentive programs, and the level of public spending required sustaining long-term security in the supply chain.

Supply chain resilience and national policy. The *National Strategy for Global Supply Chain Security* fosters a resilient supply chain that can withstand disruptions and recover quickly, while not hindering economic growth and prosperity (The White House, 2012). For private industry, the results of the study might serve as a basis for decisions that result in lower costs for the consumer as well as greater resilience for companies. If investments in resilience are economically feasible, more managers will invest in resilience strategies, and there will be less need for public expenditure on securing the supply chain.

Resilience and social benefit. Resilience strategies in the supply chain could lead to lower costs and greater reliability, which maintains global economic wellbeing and social benefits (The White House, 2012). Effective SCRM strategies, which include resilience strategies, potentially reduce vulnerability (Juttner & Maklan, 2011) and risk reduction strategies reduce the potential for catastrophic terrorist events and disruptions to the economy (Giesecke et al., 2012). Potential positive outcomes of lower costs and vulnerability to disruption may result in a higher level of global social benefit.

A Review of the Professional and Academic Literature

The purpose of this study was to examine the relationship between resilience and performance in the supply chain. My review of the literature includes SCM, SCRM, disruptions and vulnerabilities to the supply chain, supply chain resilience strategies, supply chain investment, and research in the supply chain. The organization of the review flowed from broad categories to focused strategies to present resilience strategies within the wider perspective of SCM.

In the two subsequent sections, I describe the literature on SCRM and disruptions and vulnerabilities fostered an understanding of the need for resilience and the context of decisions for investment in resilience. Next, I discuss the resilience strategies formed the foundation for the variables used in the study. Literature on investment considerations was fundamental to understanding the decision process. Finally, I include an examination of research design for academic studies on supply chain and resilience concluded the review. The literature review includes the main topic of resilience and performance, but also includes sufficient breadth to understand the investment decision within the context of supply chain vulnerability, SCM and SCRM.

Literature Search Strategy

Literature on the supply chain was abundant in academic journals, textbooks, and business journals. My study research strategy centered on relevant literature on the topic of supply chain resilience in academic journals and focused business research. The primary source of relevant literature was from scholarly articles that I found in 102 peer reviewed academic journals within the last 5 years, as well as six earlier articles. Other sources included one dissertation, one government study, one industry report, and four focused business research reports useful for methodology comparison.

For academic journals, potential articles surfaced from my search of keywords of the following topics in Google Scholar™ and other relevant databases. The keywords that I searched included: *supply chain management, supply chain risk management, supply chain vulnerability, supply chain disruptions, supply chain resilience, supply chain performance measures, supply chain investment, and supply chain security.* Keywords

led to additional articles, and these words included *agility, robustness, performance management, disruption management, transportation disruptions, resilience strategies,* and *risk management*. I also searched the following databases: ABI/Inform™, Business Source Complete, Emerald Management Journals, ProQuest®, SAGE Premier, Taylor and Francis Online, and Science Direct®.

Supply Chain Management

Strategies to achieve resilience within the supply chain are elements within wider efforts of management within the supply chain. Supply chain management incorporates logistical functions, customer management, and organization among participants (Lavastre et al., 2012). The objective of SCM is to enhance efficiency in the movement of goods and product information from the manufacturer to customers (DiGiacomo & Patrizi, 2010). The broad area of supply chain management was a logical starting point for an examination of the literature focused on the nature of supply chain management and emerging key topics. Relevant topics in SCM add to understanding resilience.

Researchers concluded the application of improved SCM techniques led to increased performance, yet need to determine which techniques are most beneficial (Paulraj, Chen, & Lado, 2012). By collecting perceptions of 200 managers of US manufacturing companies, Paulraj et al. found three distinct clusters of SCM techniques, relational, transactional, and translational. There was no significant difference with cost element of performance, but SCM practices in the relational cluster leads to increased performance in non-cost elements, followed by translational and relational (Paulraj et al.,

2012). This study highlighted the importance of SCM practices of relationships and collaboration in enhancing performance (Paulraj et al., 2012).

Supply chain management is a central element of corporate strategy, and flexibility in the supply chain necessary for competitive advantage (Lao, Hong, & Rao, 2010). Lao et al. conducted an empirical study based on the resource based view (RBV) and data from a survey of 201 manufacturing firms. A strong relationship exists between SCM and flexibility in the supply chain, and between flexibility and performance of the supply chain (Lao et al., 2010).

Supply chain integration, or cooperation between suppliers, the focal firm, and the customer are SCM techniques (Flynn, Huo, & Zhao, 2010). Cooperation and partnership among companies within different stages of the supply chain could lead to the efficient functioning of the supply chain (Flynn et al., 2010). Results indicated an association between supply chain integration and business performance and a greater degree between producers and consumers than with suppliers (Flynn et al., 2010).

Supply chain management improvement programs can enhance elements of performance (Caniato, Golini, & Kalchschmidt, 2013). Caniato et al. examined the effects of SCM improvement programs on performance and the moderating effect of supply chain configuration. According to Caniato et al., SCM improvement programs increase performance and supply chain configuration add a moderating effect.

Managers use models to make decisions on optimal plant location, transportation, capacity, and inventory, but the problem is more complex with a multi echelon supply chain and application of agile strategies (Pan & Nagi, 2013). Implementation of agile

strategies improves flexibility and capability to adapt to changing market conditions and customer demand (Pan & Nagi, 2013). Pan and Nagi (2013) developed a theoretical mathematical model to guide decisions under these complex conditions. Chen (2012) demonstrated with a theoretical model greater profits could be achieved through collaboration of supply chain strategies. Nagurney (2010) investigated supply chain network and capacity design using modeling techniques. Manuj and Sahin (2011) explored factors of SCM and strategic tools. Using system theory and grounded theory methodology, they developed a framework for decision-making. Manuj and Sahin found the higher degree of complexity in the supply chain leads to greater uncertainty.

Supply chain management subject areas. Focused research appeared in a number of areas within SCM related to resilience. In the articles, authors proposed programs for increasing efficiency, reducing vulnerability, and improving performance within the supply chain. The areas included quality management programs, standard management systems, safety programs, technology, information technology, and customer relations.

Kim, Kumar, and Kumar (2012) demonstrated quality management programs positively affected innovation. Quality management practices such as training, management, leadership, and process management had a significant impact on innovation. Successful SCRM, according to Lavastre et al. (2012) included collaboration with supply chain partners, engaged management, total quality management (TQM) and Six Sigma techniques.

Researchers explored the relationship between supply chain performance, standard management systems, and environment and safety. Leopoulos, Voulgaridov, Bellos, and Kirytopoulos (2010) found that companies implementing numerous management systems standards could benefit by integrating those systems. Marucheck, Greis, Mena, and Cai (2011) outlined linkages to operations management theory and product safety and recommended implementation of standardized systems or practices (ISO 9000), in addition to regulation, as a method to improve safety and supply chain security.

Researchers also investigated supply chain security and technology. Rizzo, Barboni, Faggion, Azzalin, and Sironi (2011) presented the results of their analysis of available RFID technology and proposed integration of active and passive RFID technology to resolve challenges in the application for container security. A requirement exists to develop a highly reliable seal system while reducing operating costs, with recommended solutions based on the results of experimental testing (Rizzo et al., 2011). Chai, Kim, and Rao (2011) found evidence of return on investment for information technology (IT) security initiatives, measured through stock market investment activity.

Atwater, Gopalan, Lancioni, and Hunt (2010) examined performance factors of motor carriers prior to and after 9/11, for their response to strategic surprise. The terrorist event on 9/11, a significant turning point, led to greater emphasis on supply chain disruptions. Companies that exhibited new strategies after 9/11 had lower performance factors than those that did not change strategies; companies using low-cost strategies had better performance (Atwater et al., 2010).

Supply chain investments could have an influence on customer choice and impact financial returns. Researchers examined the various factors influencing the choice of suppliers and service providers in the supply chain. Andersen, Coltman, Devinney, and Keating (2011) found reliable performance was one of the main attributes influencing the choice of logistics service providers (LSP) in the supply chain, and professionalism was not an essential factor. Hartmann and DeGrahl (2011) determined through analytical model that flexibility is a significant factor of customer loyalty for logistics service providers.

Supply chain security. Supply chain security is a subset of SCM. Speier et al. (2011) conducted a mixed methods study to determine key consideration supply chain design for security and product safety and found management compliance with standards, degree of complexity, risks to the good, and inter firm integration were key factors in the scope of security initiatives. Speier et al. also grouped security and safety initiatives into managing the following: security process, trusted providers, and partners and trading information.

There is a connection between port efficiency and security; Bichou (2011) analyzed the change in port efficiency from security regulations using an empirical model and data collected from 60 container terminals and 39 ports. Bichou found security investments in technology improved port efficiency, as well as implementation of voluntary compliance programs. Additionally, Bichou identified multiple methods of calculating costs of security, but noted challenges and limitations with each method.

In 2012, the United States government published the *National Strategy for Global Supply Chain Security* (The White House, 2012) to outline the philosophy behind policies and initiatives designed to safeguard the future of the global economy. Since the terrorist events of 9-11, the focus of supply chain security was on techniques designed to protect cargo and transportation networks from terrorist events. The new strategy adds the goal of protection of the supply chain from disruptions from natural events. Under the new strategy, the critical goal includes a supply chain that is safe, efficient, and resilient. This document only outlines the philosophy and guiding principles and a broad agenda for public and corporate cooperation to develop the actual strategies or and techniques.

Supply Chain Risk Management

Risk management is a field of study in itself, including a significant number of articles and textbook chapters written on SCRM. Risk increases with global sourcing, however, managers do not have formal risk management structures and mitigation programs according to a study by Christopher et al. (2011). Managers understand the need to minimize the effects of supply chain disruptions on company operations (Hishamuddin et al., 2013). Ellis, Shockley, and Henry (2011) reviewed 79 SCRM scholarly journal articles and found the perception of risk of disruption guides managers' decisions. Managers cannot avoid all disturbances so mitigation measures may reduce vulnerabilities (Blackhurst et al., 2011). An effective risk identification and assessment process lead to improved mitigation strategies, important parts of a company SCRM program (Kern, Moser, Nortmann, & Moder, 2012).

In a literature review and typology, Rao and Goldsby (2009) provided a background for the examination of SCRM. Rao and Goldsby analyzed the literature with respect to definitions of risk and key research and adopted a typology of sources of risk. A recurrent theme in the literature was the need to quantify risk, but Rao and Goldsby acknowledged the difficulty in developing models for that purpose.

Supply chain risk management techniques are useful to reduce vulnerability to high impact, low likelihood events; managers developed processes to evaluate and mitigate recurring supply chain disruptions, but lean supply chains have less capacity to deal with high impact events (Knemeyer, Zinn, & Eroglu, 2009). According to Knemeyer et al., risk-based models can assist managers to develop effective risk management plans. Pant et al. (2011) applied a risk-based analytical model to measure disruptions to the supply chain at ports and found security investments could mitigate impacts of a disruptive event and improve resilience.

Supply chain disruptions affect business performance and risk tolerance. Disruptions to the supply chain lead to lower profits; Hendricks et al. (2009) investigated the extent of this phenomenon by analyzing stock market valuations during supply chain disruptions between 1987 and 1998. Companies with more slack and higher vertical interrelatedness had less negative response to the stock price from interruptions of the supply chain, and disruptions affected more dispersed companies more (Hendricks et al., 2009). The risk of disruption is a key element in a supply manager's decisions according to Ellis, Henry, and Shockley (2010) who examined buyers' attitudes toward supply chain risk based on behavioral risk theory.

Managers adjust inventory levels to mitigate risk of supply chain disruptions according to Schmitt and Singh (2012). The impacts on risk and cost based on location of the disruption along the chain appear through results of a two-stage supply chain simulation (Schmitt & Singh, 2012). Managers can improve capacity and time to respond to disruptions by adjusting inventory levels and can determine the best location for the inventory in the production process (Schmidt & Singh, 2012). Schmitt and Singh found customer and supplier relations are valuable to maintain steady demand and enhance recovery from a disruption.

Zsidisin and Wagner (2010) conducted a quantitative study to examine the relationship between risk in the supply chain and disruptions by surveying perceptions of managers. There is not a reduction in the link between risk perception and supply chain disruption by resilience strategies of flexibility and redundancy (Zsidisin & Wagner, 2010). The risk management methods examined, according to Zsidisin and Wagner, might be ineffective, but resilience techniques to improve flexibility and information on the entire supply chain could be beneficial in reducing risk from disruption.

Supply chain risk management is a key tool of SCM with three stages, identification, assessment, and mitigation (Kern et al., 2012). Improved risk recognition leads to better risk evaluation and risk mitigation, thus enhanced risk performance (Kern et al., 2012). The study results validate the business decision to employ SCRM techniques and continuous process improvement techniques (Kern et al., 2012).

The capability to measure supply chain risk can be useful in developing decision tools for managers. Lockamy and McCormack (2010) adopted Bayesian network theory

to develop a model for analyzing risks connected with revenue streams from outsourcing decision options. The findings from a case study of 15 automotive led to risk profiles for outsourcing decisions (Lockamy & McCormack, 2010). Application of academic methods could be useful for business decisions (Lockamy & McCormack, 2010).

From 2000 to 2005, more articles on SCRM appeared in academic publications, with the largest increase in 2004 from practitioner and academic sectors, according to Tang and Musa (2011). In their analysis of 138 SCRM related articles from 1995 to 2008, Tang and Musa categorized risks associated with movement of goods, money, and information and noted the transition of the discussion of SCM topics from disruption response to prevention. A need for more quantitative research to guide business decisions exists as of the articles examined 78% were conceptual (Tang & Musa, 2011).

Linking the concepts of vulnerability, SCRM, and resilience, Juttner and Maklan (2011) demonstrated the relationships through the results of a longitudinal case study. Using SCRM functions, managers increase resilience and reduce vulnerabilities (Juttner & Maklan, 2011). The observation period included a significant disruptive event for the supply chain, the global financial crisis of 2007-2009 (Juttner & Maklan, 2011).

Disruption and Vulnerabilities

Resilience strategies may include protection and mitigation against supply chain vulnerabilities. The nature of disruptions in the supply chain is a significant factor in the development of resilience strategies. Disruptions to the supply chain can occur from periodic fluctuations in supply and demand or catastrophic events (Carvalho et al., 2012a;

Knemeyer et al., 2009). Disruptions in the transportation sector were a significant component of supply chain disruptions as a foundation for resilience strategies.

Vulnerabilities. There is a linkage between vulnerability and performance of companies in the supply chain as confirmed by Wagner and Neshat (2012). Companies with higher vulnerabilities had lower performance; larger and more complex companies were more vulnerable to disruptions (Wagner & Neshat, 2012). Managers of more vulnerable companies had a greater interest in logistics management and supply chain risk management programs (Wagner & Neshat, 2012). An index, developed from the framework derived from factors contributing to vulnerability, could be tested using graph theory and longitudinal quantitative data (Wagner & Neshat, 2010).

Boin, Kelle, and Whybark (2010) reinforced the commonly held belief supply chains are increasingly vulnerable to disturbances, which in turn affects economies and societies due to their increased dependency on efficient supply chains. According to Boin et al., challenges exist with restoring standard supply chains following disasters, and in establishing a dedicated supply chain to bring disaster relief. Boin et al. summarized the four organizational functions needed for resilient post disaster supply chains and concluded research is necessary to integrate SCM and emergency management fields

Disruptions. Natural disruptions reduce capacity and weaken company operations (Altay & Ramirez, 2010). In one of the few studies, which measured financial effects of disruptions, Hendricks and Singhal (2003) reported supply chain disruptions reduced investor assets by 11% for companies between 1989 and 2000. The effect of disruptions to companies includes financial loss and reduction in customer confidence

(Speier et al., 2011). Disruptions have long-term economic implications to companies (Vilko & Hallikas, 2012; Wagner & Neshat, 2012). In addition, disruptions affect a company's current industrial standing and economic situation (Carvalho et al., 2012b).

There are secondary effects from disruptions to the supply chain. With the interdependency of supply chains, one disruption will influence many companies throughout the chain (Carvalho et al., 2012b; Juttner & Maklan, 2011; Vilko & Hallikas, 2012). Disruption in transportation networks will impede the movement of commodities, and disruptions to the supply chain could bring manufacturing to a halt (Hishamuddin et al., 2013). Risk of disruption from suppliers has an impact on company performance (Zsidisin & Wagner, 2010).

Scholars measured the effects of disruptions using different methodologies and measures. Altay and Ramirez (2010) examined the financial impact of different types of natural disasters on various segments of the supply chain by comparing aggregated disaster loss data from 3,500 events with three measures of financial performance of global companies over 15 years. Disasters affected companies in all segments of the supply chain, but there was less effect from more anticipated disaster events (windstorms, floods) than immediate events (earthquakes), possibly due to the capacity of companies to make some prior arrangements (Altay & Ramirez, 2010).

Scholars explored effects of disruptions through frameworks and models. Greening and Rutherford (2011) developed a conceptual framework for understanding the reorganization of the supply chain network in response to a disruption. Greening and Rutherford differentiated between a supply chain disturbance; frequent change to the

market resolved through adjustment and adaptation, and large-scale disruption event which requires restructuring of the network. Network characteristics determine supply chain network recovery time and magnitude of response (Greening & Rutherford, 2011).

One practice to improve resilience and decrease potential for a supply chain disruption is retention of reliable suppliers. Wildgoose, Brennan, and Thompson (2012) reported supplier retention, as a critical consideration for managers and noted costs of reducing supplier risk could be in conflict with cost reduction measures. The investment decision to increase resilience should include a full risk analysis as this could lead to a mitigation strategy and help identify the optimal list of suppliers (Wildgoose et al., 2012).

Supply chain disruptions or glitches may have effects on company revenue stream, sales, and reputation (Hendricks & Singhal, 2003). Examining the effects of disruptions on stockholders, Hendricks and Singhal (2003) measured unusual stock returns following glitches. A decrease in stock value of 11% followed disruptions, a greater loss for high growth and smaller companies (Hendricks & Singhal, 2003).

Managers identify potential causes of supply chain disruptions and employ techniques to reduce the effects through internal practices and coordination with suppliers and customers (Revilla & Saenz, 2014). Through analysis of survey results from 1403 companies from 69 countries, Revilla and Saenz examined differences between regions in establishing key causes of and practices to reduce the risk of disruption. Techniques to manage disruptions are common globally, but causes of disruption risk vary by region (Revilla & Saenz, 2014).

Managers select appropriate SCM strategies to address disruptions, and must understand effects of disruptions, but there are few studies to support this need (Zegordi & Davarzani, 2012). Many studies examine disruptions to the overall supply chain, but there is limited research on effects of disruptions on supply chain elements (Zegordi & Davarzani, 2012). By applying a mathematical model, Zegordi and Davarzani isolate the interrelationship between supply chain elements and the effects of disruptions. Risk identification and disruption management are themes identified for future research in SCM (Stock, Boyer, & Harmon, 2010).

Researchers face the challenge of calculating the costs of disasters, and few studies captured all the economic costs from terrorism events (Giesecke et al., 2012). To address this issue, Giesecke et al. developed an economic model incorporating costs associated with property loss, interruption of business, and changes in attitudes toward risk. In their study of the economic effects to the Los Angeles region from the hypothetical detonation of a nuclear device by terrorists, Giesecke et al. determined short-term losses to be $1 billion from interruption of business and $1.9 billion total.

To assess the economic effects of natural and manmade disruptions on rational and regional economies, LeBlanc and Linkin (2010) recommend adjusting catastrophe models used by the insurance industry. Statistical models evaluate risk in natural disruptions and calculation of insurance premiums (LeBlanc & Linkin, 2010). According to LeBlanc & Linkin, the models are useful for assessing the value of property loss, yet must estimate future property values and probability of occurrence.

Disruptions to transportation systems. Transportation situations are the most frequently observed element in a supply chain disruption (Carvalho et al., 2012a). Disruptions from terrorist attacks on vulnerable transportation networks lead to significant economic costs (Cox et al., 2011). Pant et al. (2011) calculated the loss to companies using a busy port from a 2-week closure resulting from an unplanned disruption at up to $190 million based on an economic model. The economic loss caused by two interstate highway bridge collapses in Oklahoma in 2002 and Minnesota in 2007, demonstrated transportation disruptions are expensive and affect multiple levels of the supply chain (Pant et al., 2011).

Resilience for transportation infrastructure is critical to minimizing impacts of disruptions through reducing exposures and improving reaction capabilities (Omer et al., 2012). Based on network theory, Omer et al. constructed a theoretical model to assess the degree of resilience of a port based on the ratio of performance after and before a disruption to the system. Omer et al. further defined these performance measures as throughput, time, and cost and applied a case study of ports to test the model and assess the impact of resilience initiatives.

Cox et al. (2011) adopted a concept of resilience for a study of disruption to transportation systems by adapting definitions normally associated with strategies for minimizing impacts from natural disruptions. Using a mathematical model, Cox et al., developed an estimate of transportation resilience from passenger journeys before and after a disruption, in this case, the London Subway Bombing of 2005. Cox et al. identified the elements of resilience as static, including protection or mitigation measures

and dynamic for rapid recovery. Although derived from previous events, the Cox et al. model could have predictive value for future events.

Hishamuddin et al. (2013) constructed a mathematical model to discover the most advantageous recovery program following a transportation disruption subject to the lowest cost. During disruptions to transportation networks, companies are subject not only to costs due to loss of production, but with stolen or damaged cargo in shipment (Hishamuddin et al., 2013). In addition, Hishamuddin et al. found reordering costs and value of foregone sales critical to the resumption of production quickly.

Reggiani (2013) reviewed current literature and concepts on resilience as related to transportation networks. In future research, framework for understanding and measuring resilience in transportation could encompass network theory, according to Reggiani. A common measurement of resilience in transportation disruptions is indefinable (Reggiani, 2013). Reggiani recommended network modeling for understanding resilience and public policy choices for protection of the transportation network.

The transportation network is a vital element of critical infrastructure and is vulnerable to disruptions with significant economic and social consequences (Szyliowicz, 2013). An effective transportation network would be resilient; the critical elements, according to Szyliowicz, included robustness or substantial programs and processes, and redundancy or extra capacity. The additional cost associated with improving resilience should be a matter of consideration in developing national policy (Szyliowicz, 2013).

Disruptions at ports. Since September 11, 2001, when there was an increased concern over maritime vulnerability, many articles, textbooks, and reports published on the subject of port security, mostly focused on implications to homeland security. Longo (2010) considered the use of modeling and simulation to develop an efficient container inspection process that would not degrade terminal operations. The development of security standards was an essential foundation for container security, but the standards only served as guidelines for action, recommending input–output analysis for the formulation of better policies and practices for container inspection (Longo, 2010). Longo also found there was an optimal balance between new equipment (technologies) and organizational process in the container inspection procedure.

Journal articles on the effects of disruptions to ports on the supply chain and container shipping industry appeared. Paul and Maloni (2010) examined economic impacts of disruptions at ports through a simulation model. Without additional port capacity, ports were vulnerable to any disruption to the network, and design models are useful to minimize impacts of disruptions (Paul & Maloni, 2010).

Supply Chain Resilience Strategies

The focus of the literature review was on supply chain resilience, resilience strategies, and the relationship with performance. The concept of resilience and models listing elements of resilience appeared in the literature frequently. Also in the literature was a comparison of different resilience strategies. Additionally, the literature formed the foundation for the variables used in the study.

Concept of resilience. Pettit et al. (2010) formulated a framework to explain the concept of resilience and the relationship with vulnerability and business performance. Improvements in resilience come about by adding certain capabilities and would correspondingly reduce vulnerabilities, but these capabilities incur a cost or detract from efficient operations and could diminish profitability (Pettit et al., 2010). The optimal solution proposed by Pettit et al. was equilibrium between developing resilience capabilities and acceptance of some risk of vulnerability. Pettit et al. identified 14 capabilities that could enhance resilience and seven elements of vulnerability.

The concept of resilience in the biological sciences could serve as the basis for organizational resilience in the supply chain as proposed by Burnard and Bhamra (2011). In the Burnard and Bhamra model, an organization can become more resilient to disruptions through adaptive strategies to improve the capability to identify potential threats to stability and to apply preventative and responsive strategies. Ponomrov and Holcomb (2009) also explored the topic of supply chain resilience, presenting a detailed description of the foundations of the concept of resilience from the sciences. By integrating supply chain capabilities determined by a resource based view; a company could achieve greater resilience and could achieve competitive advantage (Ponomrov & Holcomb, 2009).

Resilience strategies can reduce costs of operations by flattening supply fluctuations, mostly by maintaining a steady level of inventories (Zsidisin & Wagner, 2010). Proper planning and inventory buffer stocks can reduce the costs to restore operations after a significant economic shock to the supply chain. Companies that have

greater operational slack had less negative financial effects following disruptions (Hendricks et al., 2009). Managers face the complex problem of selecting suppliers by minimizing cost and risk of disruption, adjusting inventory levels and number of suppliers (Sawik, 2011). Silbermayr and Minner (2014) demonstrated the value of multiple sources of supply using a mathematical model to determine optimal strategies for companies considering inventory stocks and supplier availability. On the demand side, resilience strategies improve or maintain company reputation and strong customer relationships, which in turn, maintain sales and revenue (Wieland & Wallenburg, 2012). Supply chain risk negatively influences customer satisfaction Zsidisin & Wagner, 2010); supply chain disruptions could influence quality and the company name (Altay & Ramirez, 2010).

Additional capacity, increased inventories, and resilience programs add cost (Christopher & Holweg, 2011). Cost of holding inventory for resilience can be expensive (Hishamuddin et al., 2013). Higher inventory levels improve resilience and reduce vulnerability, but increase inventory costs, which runs counter to the principles of lean manufacturing and low inventories for improved cost efficiency (Cabral et al., 2012). Examining lessons from the earthquake in Japan in 2011, Fujimoto and Park (2014) concluded that the creation of excessive reserve capability to reduce the effects of disruptions could diminish competitive position; improving flexibility in shifting manufacturing functions could enhance resilience at a lower cost.

Supply chain strategies designed for efficiency, such as lean, could increase vulnerability (Carvalho et al., 2012b; Hendricks et al., 2009; Thun & Hoenig, 2011;

Wagner & Neshat, 2010). Reducing inventory lowers cost but increases the risk in forecasting demand and maintaining a steady relationship with suppliers (Schmitt & Singh, 2012). More efficient supply chains have a greater chance of disruption (Ghadge, Dani, & Kalawasky, 2012; Knemeyer et al., 2009).

The focus of research on resilience was on concepts. Bhamra et al. (2011) conducted a review of the literature on resilience in the context of small-medium enterprises (SME). Of the 74 papers reviewed for themes and methodologies, approximately 70 % pertained to theory building; 16 of the papers developed theoretical models, and only 21 used a case study and six-survey method to collect data (Bhamra et al., 2011). Bhamra et al. identified the requirement for quantitative research to validate concepts. Ponomarov (2012) found both supply chain management techniques and risk management orientation positively affected resilience in the supply chain. Ponomarov explored the elements of supply chain resilience and the outcomes on performance through quantitative analysis using structural equation modeling. Ponomarov collected data from a survey of 398 senior managers from U.S. manufacturing firms. In terms of outcomes, increased resilience leads to lower variability, improved supply chain capital, and enhanced supply chain knowledge (Ponomarov, 2012).

Resilience strategy literature. In one of the pioneering studies on supply chain resilience strategies, Carvalho et al. (2012a) examined impacts of disruptions to the supply chain, and effective strategies to increase resilience. Carvalho et al. initially outlined the nature of disruptions, the impacts on companies, and finally, strategies to protect against and respond to the problems. The study by Carvalho et al. consisted of the

analysis of 38 case studies with secondary data that culminated in the development of an inductive model. Carvahlo et al. identified four key areas of disruptions, seven types of failures in the supply chain, and categories of resilience strategies based on position of the company in the supply chain.

Lean SCM strategies lead to increased vulnerability and risk; supply chain managers employ preventative and reactive SCRM strategies to reduce risk (Thun & Hoenig, 2011). In their study of 67 German automotive companies, Thun and Hoenig found managers employed SCRM preventative strategies more than reactive strategies and experienced better performance. Reactive strategies oriented towards reduction of outside disruptions and second order effects while preventative strategies incorporated flexibility (Thun & Hoenig, 2011).

Expanding on a previous framework for supply chain resilience (Pettit et al., 2010). Pettit et al. (2013) developed a tool to measure resilience using the grounded theory methodology. Pettit et al. (2013) observed a relationship between resilience and performance. Pettit et al. compared a score of resilience and variation of performance and observed higher resilience score with lower supply chain volatility scores, indicating an opportunity for improved performance with resilience. Finally, Pettit et al. identified connections between vulnerability and mitigation techniques, used to find the optimal balance for investment in resilience.

Wieland and Wallenburg (2012) examined the elements of SCRM and strategies to prevent and respond to disruptions. Through a survey of 270 companies, they found a relationship between preventative strategies, or robustness, and positive business

performance and buyer worth. A relationship exists only between responsive strategies, or agility, and buyer worth (Wieland & Wallenburg, 2012). Using case studies to add depth to the quantitative data, Wieland and Wallenburg determined preventative strategies addressed supplier related threats while responsive strategies addressed customer related risks, and the need for both strategies to improve profitability.

Based on resource dependency and information processing theory, Bode et al. (2011) examined the behavior of companies following a supply chain disruptions to determine why they chose the response strategies. Bode et al. explored response strategies from 455 responses to survey of managers of European manufacturing companies the response strategies as they related to the relationship with partner firms. Stability was a critical factor, and level of trust and supply chain direction are also crucial (Bode et al., 2011).

Current supply chain business principles can be divergent; Cabral et al. (2012) proposed a decision support model derived from the analytical network process and used to incorporate the concepts of lean, agile, resilient, and green. The activities embodied in the four concepts produce different outcomes; the Cabral et al. model was useful in displaying impacts on performance, measured as key performance indicators. From a case study of a German auto manufacturing company, Cabral et al. found the key strategy was agility, yet resilient and lean strategies were also significant. Further, maintaining strategic stocks is the preferred method for enhancing resilience and a key practice for the focal firm and inventory cost is the best measure for strategic stock (Cabral et al., 2012).

From a simulation experiment based on a case study of a Portuguese automobile manufacturer, Carvalho et al. (2012b) observed the behavior of a supply chain with designs focused on resilience with respect to performance. Their model tested two resilience strategies for redundancy (inventories) and flexibility (transportation) for the relationship with the two performance measures of lead time ratio and total cost. Carvalho et al. (2012b) found through their simulation a minimization of effects of a disruption by implementation of either strategy, but the reduced total cost and improved lead time ratio occurs when implementing the flexibility strategy.

Supply chain management strategies can be used to foster stability. Hill et al. (2012) used a case study of seven supply chains to explore different SCM corporate strategies to create stability. Hill et al. identified two main strategies, operational techniques for physical preparation and planning methods to reduce uncertainty and risk. Managers initially use strategies of physical preparations before implementing planning methods and are more likely to advise other members of the supply chain of their planning, but not the physical preparations (Hill et al., 2012). According to Hill et al. company managers make decisions on physical preparations which impact on the overall supply chain, and stability in the supply chain can occur with harmonized activities.

With higher degrees of complexity and increasing vulnerability to disruptions, Christopher and Holweg (2011) demonstrated supply chain has become more unstable. Christopher and Holweg argued currently accepted practices of SCM evolved when supply chains were relatively steady, with standardized practices to adjust to changing market conditions. Christopher and Holweg developed a metric known as the *Supply*

Chain Volatility Index by comparing the coefficient of variation of numerous business indicators. Christopher and Holweg argued traditional supply chain practices failed to build in the flexibility or capability needed to adapt to an unstable environment, and they introduced some best practices to improve effectiveness. According to Christopher and Holweg, decision models for capital investments are fitting for stable, predictable environments and bias toward scenarios involving adaptable systems and practices. Business managers should consider more flexible and adaptive practices to achieve competitive advantage in the supply chain.

Disruptions affect supply chain relationships. Porterfield et al. (2012) investigated which aspects of supplier relationships were critical during recovery from supply chain disruptions. Using data from 15 interviews with supply chain managers, Porterfield et al. found a willingness among supply chain associates to collaborate to foster recovery. To maintain successful partnerships, managers had greater consideration for the process leading to recovery than a rapid and inexpensive resumption of operations (Porterfield et al., 2012).

Resilience is one of many SCM strategies; Carvalho et al. (2011) presented a conceptual overview of four current SCM strategies, lean, agile, resilience, and green (LARG). At a conceptual level, Carvalho et al. analyzed each SCM strategy using supply chain performance indicators found in the literature and compared how they interact. Finally, Carvalho et al. outlined performance outcomes associated with each SCM strategy, setting the stage for further empirical testing.

The characteristics of an effective supply chain determine the SCM practices to increase and reduce resilience, Blackhurst et al. (2011) explored supply chain characteristics. Blackhurst et al. used a case study methodology to find 19 resilience factors and developed a framework based on systems theory and RBV theory to categorize companies relative to the degree of resilience. Using the framework, managers could evaluate the level of resilience for their company and identify beneficial SCM practices to increase resilience, and used as a basis for further empirical testing (Blackhurst et al., 2011).

Shukla, Lalit, and Venkatasubramanian (2011) examined the effects on supply chain network performance under conditions of uncertainty caused by potential disruptions. Through quantitative modeling and simulation method, Shukla et al. analyzed supply chain efficiency and robustness to determine the trade-off between the two strategies. Shukla et al. measured robustness as the opportunity cost of lost order fulfillment following disruptions, and through simulation they found investment in resilience (robustness) can lead to financial benefits with little loss of efficiency.

Measuring Resilience

Previous measures of resilience were conceptual (Reggiani, 2012). The measurement of resilience is a complex task, developed for this study based on the three assumptions of the study and the theoretical framework. Previous researchers identified SCRM strategies to reduce effects of disruptions; the characteristics of these strategies are a basis for measurement of resilience.

Objective of resilience strategies. Resilience strategies can address market fluctuations and disruptions to the supply chain (Christopher & Holweg, 2011). Disturbances cause the supply chain to fail, and resilience strategies reduce the effects of the disruption and speed the recovery (Carvalho et al., 2012b; Omer et al., 2012). Managers must consider the effects of resilience strategies all along the supply chain due to the complexity and interdependency of the elements (Carvalho et al., 2012a; Reggiani, 2013). Managers adopt resilience strategies to reduce vulnerabilities to the supply chain (Pettit et al., 2010; Wieland & Wallenburg, 2012). Wagner and Neshat (2012) found performance decrease with vulnerability, so implementation of resilience strategies should decrease vulnerability and potentially increase performance.

Characteristics of resilience strategies. Resilience strategies could reduce vulnerabilities; some general characteristics appear in the academic and professional literature. Strategies to create resilience emerge through the application of risk management practices (Zsidisin & Wagner, 2010). SCRM strategies are a key element for building resilience (Wieland & Wallenburg, 2013). Resilience strategies serve the purpose of allocating resources for contingency against fluctuations or sudden loss and maintaining the capability to recover and react from a disturbance. Wieland and Wallenburg (2012) summarized two SCRM characteristics as agility aimed at response and robustness aimed at prevention, and if aligned at the right level will lead to competitive advantage. Similarly, according to Cox et al. (2011), strategies for static resilience focused on minimizing losses (inventories) and for dynamic resilience fostered rapid recovery (flexibility). Hill et al. (2012) found two common strategies to make

supply chains more stable; the strategies included cushioning and managing uncertainty. The resilience strategies identified by Hill et al. have similar characteristics to robustness and agility. Other authors used similar keywords to describe the characteristics of resilience within the context of supply chain studies. Common themes in the description of resilience strategies emerge when arrayed in Table 1. In the first column, authors of articles align with keywords describing resilience strategies in the second column and context in the third column. Table 1 is a compilation of keywords describing resilience strategies by authors of articles appearing in scholarly SCM journals.

The first common element of resilience strategy displayed in Table 1 is robustness. A robust chain can endure shocks and can remain steady; strategies to improve robustness include increased inventory and supplier diversification and supply network configuration (Wieland & Wallenberg, 2012). Common SCM practices foster a steady supply of raw materials and goods and could include plans for redundant sources of supplies or increased levels of inventory (Wieland & Wallenburg, 2012). Practices to improve redundancy could include management of suppliers (Ghadge et al., 2012) and buffer stocks (Zsidisin & Wagner, 2010).

The second common element displayed in Table 1 is a reactive resilience strategy with agility and flexibility that ensures that the supply chain can quickly adjust to market conditions and significant disturbances (Wieland & Wallenberg, 2012). Agility is similar to what Cox et al. (2011) called dynamic resilience or capability to recover after a disruption.

Table 1

Characteristics of Resilience

Author	Resilience strategies	Context
Wieland and Wallenburg (2012)	Agility (Respond) (p. 888) Robustness (Prevent)	SCRM
Omer et al. (2012)	Rebound from shock	Port Continuity
Carvalho et al. (2012b)	Redundancy Flexibility (p. 340)	SCM
Carvalho et al. (2011)	Redundancy Flexibility (p. 155)	SCM
Cox et al. (2011)	Static (maintain) Dynamic (recover) (p. 308)	Transportation
Pettit et al. (2010)	Agility Redundancy	SCRM
Szyliowicz (2013)	Robustness Redundancy	Transportation
Zsidisin and Wagner (2010)	Flexibility Redundancy	SCRM
Hill et al. (2012)	Cushioning (p. 878) Reduce Demand Uncertainty	SCM

Note: Table compiled from keywords on resilience found in scholarly journals on SCM.

These resilience strategies focus on managing customer demand and recovery from disasters (Ghadge et al., 2012) and maintenance of business continuity (Wieland & Wallenberg, 2012).

Two dominant resilience strategy themes emerge, protect the supply chain (robustness, redundancy), and repair the supply chain (agility, reactive, flexibility). Supply chain management practices support both themes (Wieland & Wallenburg, 2012). Resilience concept and strategies are helpful for business managers, but understanding the effect of resilience strategies on business performance is essential for sound investment decisions.

Measurement of resilience by perception of managers. Some authors of academic studies estimated resilience through perceptions of managers. Wieland and Wallenburg (2012) developed a survey instrument to test agility, robustness, customer value, and business performance by adapting existing scales and terminology found in the industry. They found agility had an impact on customer value while robustness had an impact on both customer value and business performance.

Cabral et al. (2012) proposed the use of key performance indicators (KPI) of SCM practices, which included resilience, to gauge their impact on performance. Through statistical analysis of a case study results, Cabral et al. proposed some KPIs for supply chain strategies, and found inventory cost and order fulfillment rate the most notable for resilience. Cabral et al. also found strategic stock and rapid response to be the most significant practice contributing to the resilience strategy.

Measurement of resilience by financial ratios. An alternative to measurement of resilience from perception of managers or self-reported performance data is with financial ratios found in publically available statements. Financial ratios are useful to provide an objective review of trends and performance to augment manager's perceptions (Altay & Ramirez, 2010). Measurement of financial performance is critical for analyzing resilience programs (Hofman & Aronow, 2012).

Altay and Ramirez (2010) examined macro level impacts of disruptions on the supply chain by measuring the level of response by aggregate firm-level data from financial ratios. Altay and Ramirez analyzed firm leverage, total asset turnover related to inventory, and operational cash flow related to response flexibility to determine impacts to different disasters. The Altay and Ramirez study focused on the impact of disasters, but the use of these ratios links to resilience strategies of robustness and agility. Johnson and Templar (2011) analyzed SCM with company performance through financial ratios.

Analysis of financial ratios is a predominant method in business research. Financial ratios can indicate specific business behavior. Business analysts used different financial ratios to study business performance of selected companies in the supply chain over the period from 2000 to 2011 (Cecere, 2012; Cecere & Mayer, 2013). To identify business trends, Cecere (2012) compared C2C and gross margin for selected companies over time. Cecere and Mayer (2013) compared DOI with OM. Hofman and Aronow (2012), business research analysts, examined ROA, inventory turns, and revenue growth over a 3-year period to identify trends and best practices.

Measuring Performance

In a literature review, Akyuz and Erkan (2010) explored the status of research on supply chain performance measures by examining 24 articles in scholarly supply chain journals. Akyuz and Erkan found a need for managers to use performance measures for greater efficiency, but systems to measure performance are not available. A need exists to develop and validate performance measures to support effective business operations and decisions (Akyuz & Erkan, 2010).

Based upon case studies of the experiences of humanitarian organizations, Charles, Lauro, and Wassenhove (2010) proposed a framework to measure the degree of agility in a supply chain. Charles et al. argued system maturity models and supply chain performance tools such as supply chain operations reference (SCOR) models are inadequate to evaluate agility. Based on their interviews, Charles et al. identified a set of quantitative and qualitative metrics to evaluate the level of agility in a supply chain.

Supply chain management techniques and performance relate to performance. Cook, Heiser, and Sengupta (2011) gathered perceptions of 145 supply chain professionals and used results to modify the universal understanding that generic SCM strategies led to better performance. Different SCM techniques are effective based on where a company operates in the supply chain (Cook et al., 2011).

Quantitative studies examined different aspects of supply chain performance. Fugate, Mentzer, and Stank (2010) examined the elements of logistics performance and the relationship with organizational performance using survey data from perceptions of 336 managers of manufacturing companies in the supply chain. Efficiency, effectiveness,

and differentiation contributed to logistics performance, and a positive relationship to organizational performance (Fugate et al., 2010). Gligor and Holcomb (2012) found a positive relationship between agility and operational performance.

To investigate the relationship between SCM and individual firm performance, Johnson and Templar (2011) conducted a quantitative study using secondary data from 177 manufacturing companies from the United Kingdom over a 10-year period from 1995 to 2004. Johnson and Templar developed a supply chain model variable based on cash and asset financial ratios and tested them against company performance measures, which measured performance in terms of productivity, profitability, and liquidity. Supply chain management efforts lead to improved company performance (Johnson & Templar, 2011).

Eroglu and Hofer (2011) reported a limitation of previous analyses of the relationship between lean inventory strategies and performance from biased survey data; cross-sectional empirical studies did not account for industry differences, and empirical research based on wide characterizations of industries was ineffective. By developing a composite measure for the degree of lean practices, Eroglu and Hofer analysed the relationship between this composite index and performance (return on sales and return on assets) of 1600 manufacturing firms in the United States from 2003 to 2008. The relationship is not linear; there is an optimal level of lean practices, and results differ by industry (Eroglu & Hofer, 2011).

With the goal to determine if inventory lean characteristics were a moderating variable between lean strategies and performance, Hofer, Eroglu, and Hofer (2012)

empirically analyzed the relationship between lean strategies and financial performance using survey and secondary data. Hofer et al. also tested an indirect pathway to determine if there is a relationship between lean strategies and inventory lean characteristics. Lean inventory characteristics were partially a mediating factor (Hofer et al., 2012). The contribution by Hofer et al. was the methodology for measurement of performance resulting from business strategies using a blend of survey attributes and financial ratios from objective data into a regression-oriented model.

Yang, Hong, and Modi (2011) examined the relationship between lean and environmental strategies and financial and environmental performance through data obtained through the International Manufacturer Strategy Survey (IMSS-IV). The sample was 309 managers from manufacturing companies in International Standard Identification Code (ISIC) 28-35. Yang et al. measured financial performance through managers' perception of ROA and ROS and found lean strategies positively related to business performance.

Model of Financial Measures of Resilience and Performance

Financial ratios afford the most objective measure of resilience and performance with a common scale of money. For successful use of secondary data in the analysis of resilience and performance, studies found in the academic literature must support variables (Modi & Mabert, 2010). Financial ratios can be aligned to measure the effects from implementation of resilience strategies. Previous researchers used financial ratios to estimate aspects of resilience and performance as summarized in Table 2. In the first column, financial ratios used to measure resilience align with respective authors in

column two. Financial ratios used to measure performance in column three align with corresponding authors in column four.

Table 2

Financial Ratios Used to Measure Resilience and Performance

Resilience		Performance	
Financial ratio	Author	Financial ratio	Author
C2C	Cecere (2012) Hendricks et al. (2009)	Gross Margin	Cecere (2012)
Days of Inventory	Cecere (2012)	Operating Margin	Cecere and Mayer (2013) Hendricks et al. (2009)
ROA Inventory Turns Revenue Growth	Hofman and Aronow (2012)	ROA	Hofman and Aronow (2012) Modi and Mabert (2010)
		ROA Profit Margin C2C Asset Turnover	Lanier et al. (2010)
TAT OCF Leverage	Altay and Ramirez (2010)	ROS ROA	Hofer et al. (2012) Eroglu and Hofer (2011)

Financial measures of resilience. Cash-to-cash cycle is an accounting metric used to evaluate working capital management and the balance of receivables, payables and inventory (Hoffman & Kotzab, 2010). The capability to stabilize cash flow over the business cycle is an element of resilience (Pettit et al., 2010). C2C is an accepted measure of SCM effectiveness (Johnson & Templar, 2011). The C2C metric is useful for

evaluation of the status of companies in the supply chain with respect to control of inventory and flexibility with suppliers and customers (Mayer, 2012).

The C2C metric is also a reliable measure for the repair component of resilience strategies, closely connected to agility. Pure agile SCM strategies lead to greater efficiency and lower C2C, through reduction in inventory and accounts receivables, but increase in the days payable component lowers C2C but can reduce resilience (Mayer, 2012). The flexibility to respond to supply chain disruptions requires sound practices and sufficient reserves to stabilize cash flow. Operational cash flow (OCF), another financial ratio, decreases following supply chain disruptions and disasters (Altay & Ramirez, 2010), which should increase C2C. Stable cash flow absorbs supply chain variability. Stable C2C would indicate an effective agility and repair resilience strategy and a resilient company.

Measurement of inventory (DOI) is a valuable tool in SCM, and reduction of inventory levels is a tenet of lean and just in time strategies (Cabral et al., 2012). Inventory metrics is useful to gauge supply chain efficiency (Modi & Mabert, 2010). Supply chain disruptions have financial impacts on inventory levels and cost (Porterfield et al., 2012). Inventory turnover is a measure of supply chain performance (Carvalho et al., 2011). To analyze the impacts of both short-term fluctuation and significant disruptions in the supply chain, measurement of inventory levels is effective.

To ensure robustness in the supply chain, company managers consider buffer stocks as a hedge against risk (Carvahlo et al., 2012b; Hendricks et al., 2009). Inventory cost is the best measure for strategic stocks according to a case study of a German

automobile manufacturer (Cabral et al., 2012). The financial ratio, DOI, is effective for measuring the resilience strategy of robustness, to protect the supply chain from disruptions. In a case study of auto manufacturers, managers considered inventory cost and order fulfillment rate to be the most notable performance measures for resilience (Cabral et al., 2012). The financial ratio, DOI, is a useful metric to measure inventory over time, which should be decreasing if the company is becoming more efficient; however, a stable level of inventory is essential (Mayer, 2012).

Minimum inventory is an element of lean strategy (Carvalho et al., 2011). Robustness strategies for resilience require buffer stocks and higher levels of inventory. Company managers who can balance the two competing practices should achieve stable inventory levels over time, smoothing short-term fluctuations and mitigating the shock of disruptions. Resilient supply chains should be resistant to both predictable fluctuations and unknown disturbances (Carvalho et al., 2012a).

The first strategy for resilience consists of repair to the supply chain following a disruption. The effects of this strategy captured in C2C; a resilient company will have a stable C2C over time reflecting adjustment to short-term fluctuations and significant disruptions. The second strategy consists of protection of the supply chain from disruptions, reflected by DOI; a company will have stable days of inventory over time that indicates successful mitigation against short-term fluctuations and significant disruptions.

Although DOI is an element in C2C, the effects of inventory and cash management have separate observations. Companies require working capital for

unforeseen events or variability; managers observe the effectiveness of working capital management in the C2C metric, which measures the effects of management of inventory and cash (Hoffman & Kotzab, 2010). The C2C metric best measures effects of working capital management of cash; the most effective technique to optimize working capital was through management of receivables and payables and not inventory according to Hoffman and Kotzab (2010). A stable C2C would indicate that company managers optimized working capital in terms of cash (payables and receivables) for anticipated and unforeseen events. In conclusion, the DOI ratio measures the effects of management strategies on inventory and C2C ratio measures cash management.

Financial measures of performance. Companies that have attained a level of competitive advantage should perform better than companies that did not. Qualitative, physical, and financial metrics evaluate company performance at the strategic and operational level (Cook et al., 2011). Wieland and Wallenburg (2012) proposed business performance measures that involved profitability and customer delivery metrics. Johnson and Templar (2011) calculated company performance using ratios that measured productivity, profitability, and liquidity. There is not a universally accepted single measure of performance; one method used was managers' perception of performance relative to other companies (Cook et al., 2011; Fugate et al., 2010; Yang et al. 2011).

Two common financial ratios used in evaluating supply chain performance included gross margin and OM (Cecere, 2012). Hendricks et al. (2009) used OM as a way to measure impacts of disruptions on business performance. Hofman and Aronow (2012) used revenue growth and ROA to measure business performance. Lanier, Wempe, and

Zacharia (2010) considered ROA, C2C, asset turnover, and profit margin, measurements of company level performance. ROA is a common metric of used to measure firm performance (Modi & Malbert, 2010; Wagner & Neshat, 2010), as a performance indicator for management of assets (Carvalho et al., 2011). In 13 studies comparing lean manufacturing strategies to financial performance cited by Hofer et al.(2012) five used ROA and seven used profitability as financial measures of performance. Of seven studies analyzing inventory and financial performance, two used ROA and two used profitability as measures of financial performance (Hofer et al., 2012). Of 11 studies analyzing leadership and performance cited by Wilderon et al. (2012) six studies used financial performance measures involving profit/profit margin and two used ROA.

Financial stability is critical to achieving positive firm performance (Hofman & Aronow, 2012; Modi & Mabert, 2010). Modi and Mabert developed an index from financial information such as sales; inventory; cost of goods sold; and plant, property, and equipment and measured stability by the coefficient of variation. Hofman and Aronow considered successful firms with both ROA above the median and below median standard deviation.

Model description. The financial ratios used to measure resilience for this study will be C2C for the protection strategy and DOI for the repair strategy. Hendricks et al. (2009) used the similar financial ratios to measure operational slack, a concept similar to resilience. The financial ratios used to measure performance will be OM and ROA, consistent with measures used in academic and business research studies identified in Table 2. Johnson and Templar (2011) reported operating margin aligns with profitability

and liquidity, and ROA aligns with productivity. In an analysis of manufacturing companies, Kroes and Manikas (2014) found no relationship between C2C and performance and DOI negatively related to performance.

A visual display of the concepts (resilience strategies and elements of performance) and alignment with financial ratios appears in Figure 1. The resilience strategies, found in the left blocks, align with financial ratios used to measure resilience. The elements of performance align with the financial ratio used to measure of performance.

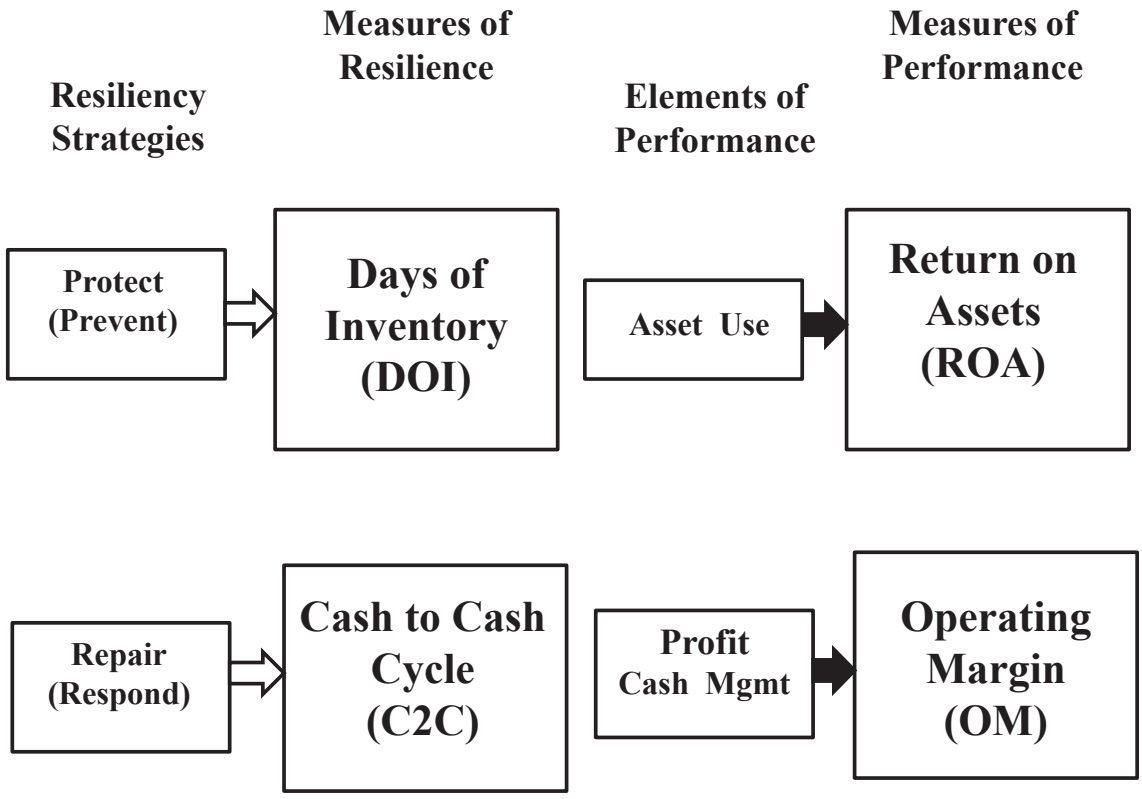

Figure 1. Conceptual model for financial measures of resilience and performance. Resilience strategies align with financial ratios used to measure resilience. Elements of performance align with financial ratios to measure performance. Conceptual model was synthesized from findings of studies and business research.

Investment in Supply Chain Management and Resilience Strategies

Managers of both private companies and public organizations must make decisions on investments necessary to increase the level of security. Shown in the Theoretical Framework section, managers' decisions derive from classical investment theory, the foundation in rational choice theory (RCT), or alternate approaches to investment. The literature also included other factors, such as uncertainty and complexity that influenced managers' supply chain security investment decisions.

Classical approach to assessing supply chain investment. Bennouna et al. (2010) conducted a study to examine the method most frequently used for the capital budgeting decision. Bennaouna et al. conducted a survey of 88 Canadian companies and determined discounted cash flow (DCF) remains predominant (83%) in concert with the use of net present value (NPV) and internal rate of return (IRR) methods. Bennouna et al. also reported despite the availability of techniques and tools managers did not always apply the practical skills to decision making.

Cost-benefit analysis. Cost-Benefit analysis is a method to rank investments by net contributions. Burgess and Zerbe (2011) proposed the social opportunity cost (SOC) method is a better tool. Burgess and Zerbe compared three possible discount methods; the SOC, the social time preference (STP) and the Marginal Cost of Funds (MCF) by the elements included in the discount rate, and concluded that the SOC had properly incorporated elements and the estimate included the most accurate discount rate. Belzer and Swan (2011) identified the security risk linked to low paid employees in highly

vulnerable industries such as transportation. Company managers will seek lower costs, which may lead to gaps in security; government regulation may be necessary to ensure the proper levels of security (Belzer & Swan, 2011).

Research in Resilience in the Supply Chain

Understanding strategies for resilience and disruption management are germane for managers and scholars (Urciuoli et al., 2014). Supply chain research methodologies and designs appear in the literature review. In addition to qualitative and quantitative methodologies, the literature includes discussion on the use of secondary data in supply chain research. Finally, professional literature from business research highlights the need for scholarly research.

General research design. Golicic and Davis (2012) presented an overview of different research methodologies used in research on the supply chain, reported 46% to 85% of the empirical supply chain studies used quantitative methods, and fewer than 10% used mixed methods. Further, they stated with proper application of mixed methods methodology researchers will have a better understanding of the emerging phenomena in supply chain management, and knowledge in the field will advance more rapidly. Carter, Craig, and Easton (2011) reviewed the literature over the last 20 years on sustainable supply chain management, finding an increased use of inferential statistics over time and increased use of sophisticated statistical methods, regression testing, structural equation modeling, and factor analysis.

Scholarly journals articles with comprehensive literature reviews were helpful in understanding the state of research. Ghadge et al. (2012) conducted a systematic literature

review, and content analysis of supply chain management literature in scholarly journals from 2000-2010 to identify key themes and future research directions. Ghadge et al. found risk management themes and six areas for future research and identified potential risk mitigation strategies.

According to Singhal and Singhal (2012), researchers can gain new insights in the field of supply chain with multiple research methods that triangulate supply chain knowledge. Singhal and Singhal outlined the history of research methods from early mathematical oriented models focused on operations management to new techniques to study the complex supply chain. Goldsby and Autry (2011) highlighted the need to reassess theories and findings from previous SCM research and improve the validity of prior studies and currency of findings. They proposed replication of studies to corroborate past studies and guide future research and meta-analysis of previous studies to increase sample size and increase quality of the results. Additional in-depth academic research can add to the contribution to business practices (Goldsby & Autry, 2011).

Quantitative design. Tangpong (2011) presented a review of empirical studies in supply chain management and operations management from 2002-2007 and summarized methods as surveys (25%), case studies (19%), models (23%), experiments (6%), secondary sources (15%), and multiple sources (12%). Tangpong outlined the benefits of content management as a research design and presented a process to conduct a successful analysis with an example of a study. Additionally, Tangpong noted content analysis is useful for analysis of the supply chain below the company level at the activity level, as well as being less expensive than other collection methods.

Sodhi et al. (2012) used multi-stage field research to investigate gaps in research on SCRM. Using direct observation and surveys, Sodhi et al. found no clear definition of SCRM, limited research on an SCRM response process, and need for more quantitative research. Sodhi et al. recommended greater cooperation between industry and academic researchers to develop a solid conceptual base for future empirical research.

A demand for research exists to solve business problems according to Subroto (2010), yet there is limited validity in business research and quantitative measures and the need to apply academic methods to analyze the large volume of business data. In response, Subroto discussed the challenge of research in the supply chain and suggested a process to adapt widely focused survey databases for use in hypothesis testing of more closely focused research questions. Quantitative studies with academic validity could contribute to business research and development of theory (Subroto, 2010).

Qualitative designs. Most of the research on supply chain security was either conceptual or qualitative, with relatively few quantitative studies. Barratt, Choi, and Li (2011) reviewed case studies published from 1992 to 2007 in leading operations management journals to determine if the studies contained key elements of effective qualitative design. Barratt et al. found inductive studies were better developed and had greater effectiveness for theory building. Denk, Kaufmann, and Carter (2012) examined studies on SCM published in scholarly journals between 2004 and 2009 using grounded theory methodology and found that many studies did not use established techniques. Denk et al. recommended future researchers follow procedures to improve the validity and reliability of their results.

Goffin, Raja, Claes, Szejczewski, and Martinez (2012) discussed the value of the Repertory Grid Technique (RGT) for qualitative research in SCM and for exploratory studies to identify constructs. According to Goffin et al., the RGT could provide a higher degree of validity and reliability in qualitative studies. Goffin et al. also used additional coding techniques to improve the validity and reliability.

In an alternative approach, Borgstrom (2012) proposed the use of a qualitative approach for analyzing SCM based on the constructivist worldview. The mystery construction method was useful for exploring practical applications and defining limits for research problems (Borgstrom, 2012). This methodology, according to Borgstrom has considerable application with practical problems.

Secondary data. As a research design, empirical analysis using secondary sources has limitations as the data does not usually specifically fit the research question derived from theoretical constructs (Busse, 2010). In a study of logistics providers in the supply chain, Busse outlined a method to adapt data from a general survey to conduct the analysis. An accepted process for evaluating secondary data sources to determine their applicability in supporting research questions in supply chain management does not exist (Busse, 2010). To overcome this deficiency, Busse recommended careful adjustment of the data to fit the analytical test and care in transcribing data, rounding, and accounting for missing data by accepting the average value.

Calantone and Vickery (2010) discussed how the use of secondary data contributes to academic research in supply chain management when properly aligned with research questions and constructs. Secondary data from public sources has high

validity, and archival data does not have bias contained in survey responses of perceptions, and data does not have the researcher's influence (Calantone & Vickery, 2010). Calantone and Vickery outlined some guidelines to ensure alignment of research objectives and secondary data and presented four examples of studies with secondary data and aligned research objectives.

According to Rabinovich and Cheon (2011), secondary data in supply chain research supports meta-analysis, event studies, and archival data sources. Rabinovich and Cheon also recommended other data collection methods to gather secondary data, content analysis, geospatial information systems (GIS), and simulation. Even with additional data collection methods, use of secondary data is only plausible if there is alignment of the research question and constructs with the available data (Rabinovich & Cheon, 2011). Secondary data can augment other collection methods to improve the quality of the results (Rabinovich & Cheon, 2011).

Successful analysis of secondary data requires the application of a theoretical framework, alignment with a suitable database, and proper statistical technique (Modi & Mabert, 2010). To demonstrate, Modi and Mabert applied these principles to study SCM techniques and innovation using secondary data. The important contribution of the article by Modi and Mabert was a step by step explanation of the modification of company financial data to fit measures of supply chain stability, efficiency, and performance.

Professional literature and business research. Managers conduct research to assist managers in making business decisions. Business research can be useful to understand the business problem and add depth to academic studies. For this study, the

inclusion of professional literature added credibility to study variables and highlighted a gap in the literature.

Research on the supply chain should be relevant for managers and contain academic principles according to Naslund et al. (2010) who presented a process to encompass academic principles. In a review of academic journals, Naslund et al. found that few of the articles on action research embodied accepted academic techniques. The application of case study design techniques could improve the credibility of action research (Naslund et al., 2010).

Consultants from Supply Chain Insights (SCI) published a number of monographs on the subject of supply chain resilience. In the earliest paper, Conquering the Supply Chain Frontier, Cecere (2012), the founder of the company, sought to identify top companies in the industry based on case study analysis of five companies over a 12-year period using selected financial ratios. Cecere (2012) also argued resilience is a stage in the maturity cycle of a company, achieved when a company can operate effectively during variations in supply and consumer demand. Cecere (2012) also identified C2C and DOI as two useful financial ratios that could be used to evaluate company performance, and plotted C2C against gross margin over a 10-year period for five select companies to identify trends for best practices.

In the second paper, What Drives Supply Chain Excellence: a Look Back and a Look Forward, Cecere and Mayer (2013) sought to identify industries that exhibited characteristics of resilient operations by managing disruptions. Cecere and Mayer identified 2007 to 2009 as a challenging period for companies in the supply chain due to

global disruptions. Cecere and Mayer analyzed the performance of 40 companies from six selected industries by comparing the financial ratios of DOI and OM, concluding that electronics industry is the most resilient due to stable inventory and costs.

In the third paper, Supply Chain Metrics that Matter: the Cash to Cash Cycle, Mayer (2012) outlined the significance of C2C as a useful metric to evaluate progress of companies and industries in improving costs and cash position. By analyzing each of the elements of the C2C ratio in a case study of 18 companies in five industries, Mayer (2012) highlighted industry trends and practices. Mayer (2013) showed C2C was slowly declining for 11 industries.

The Business Continuity Institute reported the results of its fourth annual survey of global supply resilience in terms of disruptions and responses (The Business Continuity Institute, 2012). They surveyed 532 supply chain professionals on their perceptions of sources of disruptions, magnitude of impacts to company operations, and effectiveness of programs to roster rapid recovery. Business Continuity Institute researchers considered unplanned disruptions from adverse weather, international events, unlike other business research focused on anticipated market fluctuations in demand and supply. According to the Business Continuity Institute report, 73% of managers reported some form of disruption during the year, and 59% of managers reported a loss of production and most disruptions occurred from unanticipated loss of information systems and adverse weather.

Consultants from Gartner explored the use of financial metrics to measure supply chain resilience to evaluate the effectiveness of resilience programs (Hofman & Aronow,

2012). They acknowledged financial measures of resilience do not presently exist, and proposed use of financial ratios of ROA, inventory turns, and revenue growth (Hofman & Aranow, 2012). Hofman and Aronow recommended future analysis should incorporate relevant time frame and industry.

Literature Review Conclusion

A review of the academic and professional literature served as the basis for the theoretical framework and variables used in the study. The review consisted of an examination of the broad categories from SCM and SCRM to the focused areas of resilience strategies. The literature review was useful to highlight trends in research methodology and benefits of academic research to bridge the gaps in knowledge for managers.

Content of the literature. Considerable literature on SCM and SCRM is useful to provide perspective and context for the study. Focused research on disruptions, vulnerabilities, and strategies is less prevalent, yet could help to understand different approaches to using resilience to reduce vulnerabilities. However, sufficient qualitative and quantitative research was available to form the basis of the theoretical framework and variables.

Gaps in business practice. Studies on the relationship between resilience and performance in the supply chain exist although limitations to the methodologies in establishing definitive results are evident. Case studies were useful in building a framework for understanding the elements of resilience and performance (Carvalho et al., 2012a) and measurements (Cabral et al., 2012). One quantitative study on resilience and

performance was conclusive, yet relied on survey data from managers' perceptions (Wieland & Wallenberg, 2012). One scholar investigated slack (one part of resilience) and performance using financial ratios drawn from secondary data (Hendricks et al., 2009). Supply chain practitioners used business research techniques to explore resilience and performance using financial ratios, but for the purposes of trend analysis and using non-random sample populations (Cecere, 2012; Cecere & Mayer, 2013; Hofman & Aronow, 2012; Mayer, 2012). Academically based methods employing a quantitative study based on financial ratios from secondary data of a random population could reduce the business practice gap.

Benefit of academic research. Academic research could capture the history of resilience strategies in the supply chain during the period from 2002 to 2012. Best practices found in the research could reveal optimal investment strategies for private business, and augment government policy. Managers require focused and timely information, commonly found through business or action research, although lacking the standards of academic research (Naslund et al., 2010). Academic theories can be useful for the management applications (Ketchen & Hult, 2011).

Transition and Summary

Section 1 was an introduction to the business problem associated with disruptions to the supply chain and the need to develop resilience strategies to mitigate financial loss. The research questions aligned with the specific business problem, focused on the relationship between resilience and business performance. A theoretical framework based on theories of strategic management planning, business investment, and SCM practices

formed the foundation for measurement of resilience and performance. A conceptual model to measure resilience and performance from financial ratios originated from academic studies and business research presented in the review of the literature. The literature supported the theoretical framework with commonly accepted strategies and investment theory as the basis for managers' investment decisions. Finally, a justification for variables and measures appeared in the literature.

A gap in business practice existed on knowledge of the relationship between resilience and performance, resulting in a lack of information for managers in their choice of competing supply management strategies. This limitation further limits full implementation of the *National Policy for Global Supply Chain Security*. Examination of the relationship between resilience and performance in the United States supply chain served to reduce the gap in business practice. The results for this study may assist managers in the identification of best practices associated with resilience strategies. Additionally, these results might indicate an optimal private sector strategic investment strategy to support public policy initiatives. The research design, data collection method, and data analysis appear in Section 2. Section 3 includes the findings and application.

Section 2: The Project

To justify the investment in resilience programs, managers need to know whether resilience strategies lead to improved performance. An analysis of the relationship between resilience and business performance in the current academic literature centered on case studies and managers' perceptions found in survey data, business research using longitudinal secondary data focused on trend analysis. The method for this study helped me to extend business research trend analysis by incorporating academic methods. In an empirical study, Hendricks and Singhal (2003) found that supply chain disruptions decreased investor assets, conceptually characterized by ROA and operating income. In theory, the converse phenomenon found by Hendricks and Singhal should be evident; implementation of resilience strategies to reduce effect of disruptions may lead to increased operating income and ROA. In the next section, I present the quantitative correlational study, including a description of the hypothesis testing and a random sample of companies in the supply chain. The procedures I described in this section included: the identification of the supply chain population, selection of companies, collection of specific financial information, analysis by statistical techniques, and considerations for validity, reliability, and ethical research.

Purpose Statement

The purpose of this quantitative correlational study was to examine whether a relationship existed between resilience and financial performance for companies operating in the U.S. supply chain. The two resilience variables were DOI and C2C, and the two performance variables were OM and ROA, the relationship determined by the

Pearson product-moment correlation test. Publically traded companies comprised the population found from a commercial list found in the North American Industrial Classification System (NAICS) two digit code categories, Mining (21) Manufacturing (31-33), Wholesale Trade (42), and Retail Trade (44-45). An analysis using G*Power 3.1 confirmed sufficient statistical power for the sample size of 300. Results of the quantitative analysis may guide managers in choosing efficient and effective strategies to improve business performance and demonstrate an increase of economic benefits to the consumer and society. Findings could amplify business research conducted by practitioners on resilience and reduce the gap in business practice.

Role of the Researcher

As the researcher, I collected, prepared, analyzed, and interpreted secondary data found in financial records. The financial data was an objective record of transactions by individual companies influenced by market conditions and managerial decisions. As the researcher, I did not influence any of these events. My decisions on population, period of study, variables, and measures affected the outcomes of the analysis; I designed the collection parameters to reduce any bias by employing techniques of other researchers and using methods based on extant review of the literature.

The secondary data that I used for the study originated from financial records publically available in annual reports, and compiled in a commercial database. I purchased a custom database of financial records prepared by a commercial company frequently used for academic and business research according to study parameters. The specifications were the study population, specific financial ratios, and time horizon. After

the company delivered the database, I prepared the records for analysis by organizing the records for the required calculations as described in the data organization techniques section. Prior to the analysis phase, I calculated the elements necessary for entry into Predictive Analytics SoftWare-18 (PASW-18®) as described in the data analysis technique section.

During the analysis phase, I organized the data for processing using PASW-18® software for testing as outlined in the data analysis section. Based on preliminary findings, I conducted secondary tests and further analyzed the data. Finally, I analyzed the results of the statistical tests, drew conclusions, and presented the results based on the research question and hypotheses.

In the area of supply chain resilience, I have experience as a trained lead auditor for ISO 28000 (Supply Chain Security) and Organizational Resilience. The latter subject area entails evaluation of company programs for crisis management, business continuity, and recovery management, practical aspects of resilience strategies. My experience with auditing organizational resilience did not influence the development and interpretation of the objective secondary data. Further, no conflict of interest existed as my employment is not in supply chain activities, and I do not participate actively in professional supply chain groups.

Participants

I did not use participants in this study. The information required for the analysis was available from financial reports of the selected public companies. The financial information is available to the public, and I purchased a custom dataset of relevant

information compiled from a commercial research database. Discussion on recruiting, establishing rapport, and collecting data from participants was not applicable to this study.

Research Method and Design

Resilience strategies can reduce vulnerability from supply chain disruptions (Juttner & Maklan, 2011), and the existence of a relationship between these strategies and business performance is unconfirmed (Wieland & Wallenburg, 2012). There is significant academic and professional dialogue on strategies used to address disruptions to the supply chain, and few quantitative studies evaluating the financial value associated with these approaches (Hendricks et al., 2009). The research design should rely on the subject of inquiry (Bhattacherjee, 2012) and efficiently address the research question with pertinent information (Hair et al., 2011).

Method

Two approaches for research studies include positivist (or deductive) for theory testing, and interpretive (or inductive) for theory development (Bhattacherjee, 2012). For this study, the deductive approach and quantitative methodology was most applicable. Wieland and Wallenburg (2012) supposed sufficient understanding on supply chain strategies and performance to establish variables for deductive hypothesis testing. A deductive approach using a quantitative methodology and hypothesis testing best supports examination of relationships between variables and produces generalizable results (Bhattacherjee, 2012). Quantitative analysis is a common method for SCM research (Golicic & Davis, 2012).

Other research approaches and methods were not appropriate. Qualitative methods are applicable to exploratory research where there is little information on emerging topics (Hair et al., 2011). A study of SCM practices using the exploratory qualitative method could orient toward the constructivist worldview, and may not be useful for deductive research (Borgstrom, 2012). Qualitative studies with an inductive approach were useful for developing theory (Barratt et al. (2011).

Qualitative case study research is the foundation for empirical work in SCRM (Sodhi et al., 2012). In cases in which quantitative data is unavailable or does not provide sufficient evidence, qualitative research can be useful for evaluation of policy decisions (Donmoyer, 2012). Additionally, qualitative methods are less adaptable for statistical analysis, and the results may not be not generalizable (Bhattacherjee, 2012). Study topics involving descriptive research through hypothesis testing of known strategies were more suited to quantitative methods (Hair et al., 2011). Mixed methods research, selected for studies to explore new subjects where variables are unidentified, are expensive and time consuming (Golicic & Davis, 2012), and not considered in this study.

Research Design

The correlational research design was useful for the determination of a relationship among the variables, whether positive or negative, and relative strength of the relationship (Hair et al., 2011). Correlational design supports hypothesis testing (Bhattacherjee, 2012). Descriptive research incorporates statistical analysis to identify relationships and trends (Hair et al., 2011) and could add credibility to trend analysis used

in business research. The results from the correlational study may assist managers in formulating effective resilience strategies (Tang & Musa, 2011).

Alternative quantitative designs were not suitable. A causal-comparative design was also used to support business decisions; however, the establishment of causal relationships cannot occur solely from correlational analysis (Hair et al., 2011). The element of covariance, a critical element of causal research (Bhattacherjee, 2012), would be challenging to establish in an ongoing business environment without experimental controls. The presence of a relationship and positive or negative direction are sufficient to augment business research trend analysis (Hair et al., 2011).

A hypothetical modeling analysis of supply chain disruptions incorporated experimental design (Omer et al., 2012). Experimental research design has application in the supply chain, and difficulty in controlling variables in field experiments exists (Deck & Smith, 2013). Experimental design requires control the independent variables and is seldom part of field research (Bhattacherjee, 2012). Testing resilience and performance through ex post facto experimental design from longitudinal data would require controls; the ability to manipulate strategies at the company level is a significant limitation (Wilderom et al., 2012).

The source of data was a consideration for quantitative design of this study. Empirical data collection methods in SCM research included surveys (25%), case studies (19%), models (23%), experiments (6%), secondary sources (15%), and multiple sources (12%) (Tangpong, 2011). The study design included company level secondary data. Financial data drawn from corporate financial statements are the most objective source of

secondary data as the collection is for public reporting, not associated with the study, and does not contain the researcher's influence (Calantone & Vickery, 2010). Through a methodical process of rounding and accounting for missing data, secondary databases can be adapted for empirical studies in the supply chain (Busse, 2010).

Survey data has limitations. Self-reported survey financial data could be biased (Cecere, 2012). In a review of the literature on supply chain performance measurement, Cook et al. (2011) asserted that most of the quantitative data comes from surveys, and more firm level data is necessary. Additionally, the difficulty in collecting financial information by the survey method is attributable to the proprietary nature of the data, and reluctance of companies to provide information (Speier et al., 2011; Zsidisin & Wagner, 2010). Researchers could experience low response rates when conducting survey-based quantitative studies (Subroto, 2010). Without controls for specific industrial sectors, survey data may have possible bias from self-selection (Erglu & Hofer, 2011).

When dealing with supply chain disruptions, longitudinal data may be more beneficial, and secondary data are useful for evaluating inventory levels and financial positions over time (Zsidisin & Wagner, 2010). Longitudinal data is effective for analyzing business trends and variations over time (Hair et al., 2011). According to Calantone and Vickery (2010), the characteristics of a reputable secondary source of data for a study includes an accurate measurement of the variables (constructs), a credible standard, a focus on the research question, freedom from perceptual bias, and a definable population.

Population and Sampling

Two essential elements of the study follow in this section, the identification of the supply chain population and calculation of sample size sufficient for statistical power. The first element, identification of the supply chain population, is essential to deliver generalizable results (Paulraj et al., 2012). The population that I selected for this study replicates similar supply chain populations selected by other by academic researchers as displayed in Table 3. Random selection from the supply chain population supported hypothesis testing for this study.

Supply Chain Population

A universally accepted definition for the supply chain population for research does not exist; researchers understand the supply chain as a set of connected economic activities (Altay & Ramirez, 2010). Previous SCM research featured individual industry populations; an assortment of industries can be effective to generalize results to a broader group (Paulraj et al., 2012). Complete research on the supply chain should extend beyond manufactures only and should incorporate suppliers and end consumers (Flynn et al., 2010). For greater perspective, research should not just focus on suppliers and should include customers and the logistical component (Paulraj et al., 2012).

Researchers categorize elements of the supply chain. In a study by Lanier et al. (2010), three elements were representative of the supply chain, suppliers, sellers, and buyers. Altay and Ramirez applied four accepted echelons or positions in the supply chain, raw materials, manufacturer, wholesale and retail distributors (p. 60).

Supply chain position (echelon) by classification codes. A research method for estimating a representative population of the supply chain was to select companies based on classification codes; other scholars used a similar technique as shown in Table 3. A common classification system is the North American Industrial Classification System (NAICS), two digit codes categorize target companies by general industry, and down to six digits for most specific activities (Eroglu & Hofer, 2011). A comparison of studies appears in Table 3, listing sample size, classification codes, and database. In the studies listed in the first column of Table 3, SCM researchers selected companies from the supply chain populations categorized by industrial classification codes. Some studies displayed in Table 3 included manufacturing industries while others focused on expanded elements of the supply chain. Use of classification codes was applicable to studies employing financial databases (COMPUSTAT® S&P and Worldscope). Classification codes were also applicable for selecting companies for survey solicitations, as in the case of Lao et al. (2010) and Paulraj et al. (2012).

Table 3

Use of Classification Codes to Define Supply Chain Population in Empirical Studies

Author	Sample	Ind	*n*	Specificity	Database
Hofer et al. (2011)	US Mfctr	24	1421	4 Digit NAICS	COMPUSTAT ®S&P
Eroglu and Hofer (2011)	US Mfctr	54	1600	6 Digit NAICS	COMPUSTAT ®S&P
Modi and Mabert (2010)	US Mfctr		148	4 Digit SIC	COMPUSTAT ®S&P
Lanier et al. (2010)	US Co		402	2 Digit SIC	COMPUSTAT ®S&P
Yang et al. (2011)	Intl Mfctr		309	2 Digit ISIC	IMSS-IV
Altay and Ramirez (2010)	Intl SC		10.000	2 Digit SIC	Worldscope

Note. The author compiled the information on each study. Sample was either international or US manufacturer. Ind is the number of industries represented. *n* is sample size. Specificity indicates the level of detail for the industry codes for North American Industrial Classification System (NAICS), International Standard Industrial Classification (ISIC) and Standard Industrial Classification (SIC). Database used for compiling secondary data included COMPUSTAT® Standard and Poor, International Manufacturing Strategy Survey (IMSS) and Worldscope.

Company as a unit for study. For this study, the company or firm is the base unit. Financial ratios are useful to measure the effects of strategic decisions made by managers. Firm level data is useful for measuring SCM initiatives (Modi & Mabert, 2010). Company level analysis is suitable for evaluating performance through publicly available financial information (Lanier et al., 2010).

Sample of companies in the supply chain. The supply chain is both diverse and expansive. For this study population, not included are the categories Agriculture, Forestry, Fishing, and Hunting (11) and Transportation and Warehousing (48-49) due to and the relative distance from core supply chain activities. The four 2-digit categories, which apply to this study, included Mining (21), Manufacture (31-33), Wholesale (42), and Retail (44-45). Altay and Ramirez (2010) used similar categories to replicate the supply chain. To understand the size of the supply chain, a comparison of a relative number of companies categorized by NAICS codes in Table 4 reflects the total number of companies listed by NAICS.com and public companies listed in LexisNexis™.

Table 4

Supply Chain Echelons by Classification, NAICS, and Number of Companies

Echelon	Classification	NAICS	Total companies[1]	Public companies[2]
Raw Materials	Agriculture	11	553,708	17
	Mining	21	37,975	533
Focal	Manufacture	31-33	762,527	2705
Distribution	Wholesale	42	929,149	224
	Retail	44-45	2,206,681	320
	Transport and Warehouse	48-49	564,628	153

Note. 1. Source: NAICS.com website on 7 July 2013 US businesses. 2. Public-Parent U.S. companies generated by NAICS from LexisNexis™ database search. Table compiled from two databases.

Under the NAICS classification system, companies appear by industrial activity. These codes can approximate activities on the supply chain. A graphical depiction of the representative supply chain for the study appears in Figure 2. In Figure 2, the three echelons or stages of the supply chain identified by Alty and Ramirez (2010) and Lanier et al. (2010), align with NAICS category codes used in studies by researchers displayed

in Table 3.

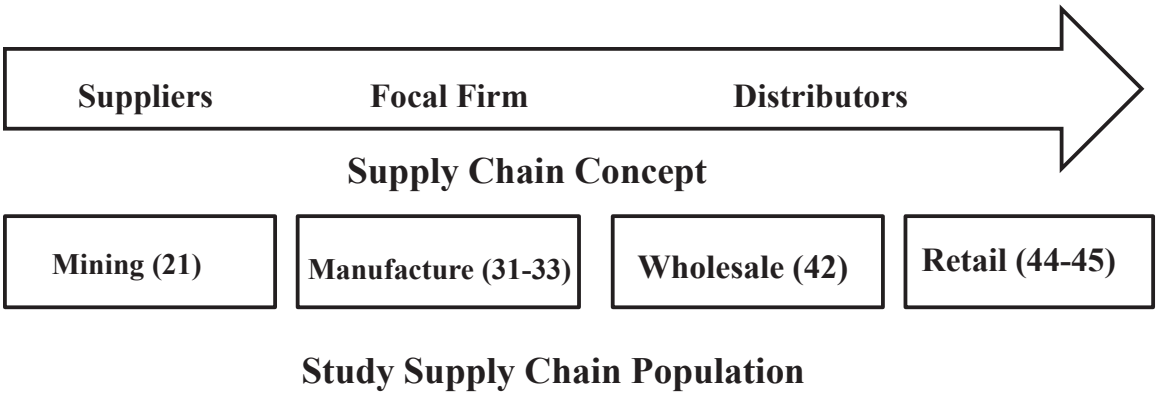

Figure 2.Supply chain population for study. Elements or echelons of the supply chain, suppliers, focal firm, and distributors, are aligned with NAICS category codes for companies to be included in the supply chain population.

Study populations in business research. Business research analysts previously examined resilience and performance in terms of industry trends. Gartner/AMR analysts examined resilience and financial performance using a case study of 25 top Fortune 500 companies over 3 years (Hofman & Aronow, 2012). The small sample size was not effective for comparison of similar companies in the supply chain (Johnson & Templar, 2011). The Gartner/AMR sample did not include small companies and focused on certain high technology sectors (Cecere, 2012). Research analysts Cecere & Mayer (2013) examined over 75 selected companies in six industries for trends over a 10-year period. For the trend analysis, researchers used industry leaders and not a randomly selected sample.

Study Sample Size

A power analysis, using G*Power 3.1 software developed by Faul, Erdfelder, Lang, and Buchner (2007) was conducted to determine the appropriate sample size for this study. An a priori power analysis, assuming a medium effect size (ρ= .30), a = .05, indicated a minimum sample size of 82 was required to achieve a power of .80. Increasing the sample size to 134 increased power to .95 (Figure 3). Therefore, a minimum sample size of 82 was required for the study.

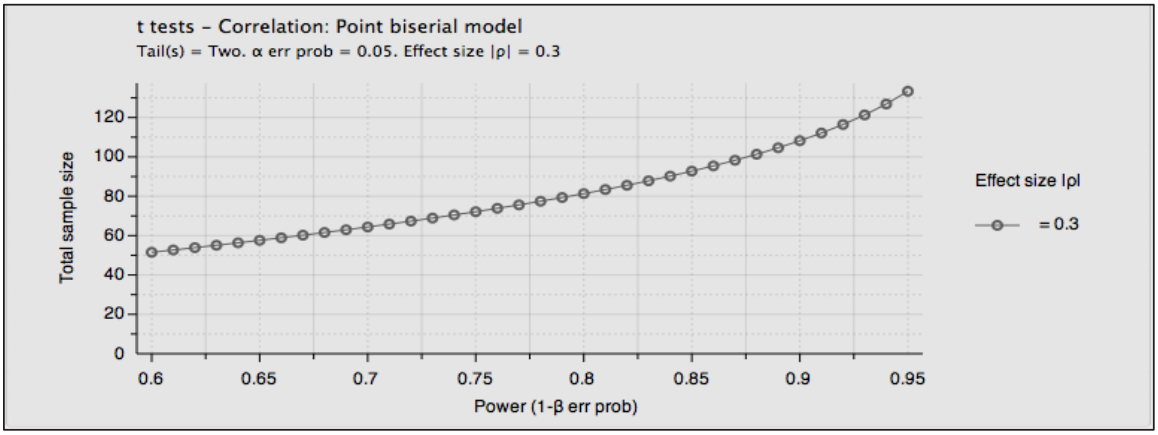

Figure 3. Power as a function of sample size. As sample size increases, statistical power is increased. The graph was produced with G*Power 3.1, author's permission for screenshots not required according to instructions in www.gpower.hhu.de/en.html.

A randomly selected sample drawn from a representative population, with similar characteristics, will achieve greater impartiality and can be generalizable (Hair et al., 2011). An approximate supply chain population emerged from the application of NAICS codes for representative industries as outlined in the previous section. Access to financial records was essential; public companies operating in the United States form the study population. Researchers should select a sampling frame with an inclusive and precise list

of organizations of the study population and the sampling unit to reflect the measurement of financial activity. (Hair et al., 2011). For this study, the sampling unit was individual public companies, and the sample frame was the COMPUSTAT ®Standard and Poor's list of companies. Standard and Poor's list of companies is suitable for research where the study population is businesses (Bhattacherjee, 2012).

The study population, conceptualized in Figure 2 estimated as 3,936,332 companies, was the sum of companies in column 4 from Table 4. The sample frame from the COMPUSTAT® S&P custom database included 2,816 public companies from the designated NAICS codes. This list is also consistent with 3302 public companies in the LexisNexis™ database for the same NAICS category codes, calculated from column 5 in Table 4. Excluding companies without complete 10-year data for the longitudinal panel, the sample frame was 1604 companies. A simple random sample, where all companies on the list have an equal chance of selection by random number generator, provides the greatest generalizability (Bhattacherjee, 2012). For this study, I selected a sample of 300 companies from the sample frame using a random number generator.

Ethical Research

A researcher has an ethical obligation to protect privacy and safety of participants and present a truthful account of the outcomes (Hair et al., 2011). In this study, the data originated from secondary sources and no participants required protection in research. Protection of privacy is not an issue as the corporate financial information used in this study was available in publically published annual reports. A requirement for participant consent did not exist for disclosure of publicly reported information. Researchers are

expected to follow accepted practices in collection, analysis, and interpretation of data (Bhattacherjee, 2012). The Walden University IRB approval number was 02-19-14-0182312. The plan for disseminating findings to stakeholders appears in the recommendation for action section.

There was no risk of harm to participants or from disclosure of data as the corporate financial information for this study was available to the public. No association between company names or ticker symbol appeared with the data set. I will have sole access to the dataset and safeguard all data on a password-protected external drive. At the conclusion of the study, I will maintain the external drive and paper data material in a locked box for 5 years. Electronic destruction of the external drive and shredding of paper data material will occur at the end of five years

Data Collection

In the review of the professional and academic literature section, the conceptual model in Figure 1, was a depiction of the linkages between resilience strategies and elements of business performance with financial ratios. Included in this section were an explanation of the measurement instrument for the study concepts and measurement method for the variables. Additionally, the discussion included a description of raw data reception, organization, and preparation for analysis by statistical tools.

Instruments

The instrument for this study was a longitudinal panel of financial data collected from secondary sources as company financial records. Four variables, C2C, DOI, OM, and ROA, supported the examination of the relationship between resilience and financial

performance for companies in the U.S. supply chain. The resilience variables were measurement of the level of resilience based on the variability of the respective C2C and DOI financial ratio. The performance variables were a measurement of average the OM and ROA financial ratio.

Study variables. Researchers measure abstract **c**oncepts in models with variables (Hair et al., 2011). Existing or adapting current measures found in the literature were a basis for evaluating constructs. (Bhattacherjee, 2012). Studies found in the academic literature should support variables (Modi & Mabert, 2010). The four study variable**s** directly related to resilience and performance appeared in academic studies (Table 2). The variables also were found in the literature as measures for different aspects of SCM. Measurement of inventory (DOI) is a metric for SCM (Cabral et al., 2012). C2C is a recognized measure of SCM value (Johnson & Templar, 2011). The metric of OM was adapted to assess effects of disruptions on performance (Hendricks et al., 2009). ROA is a common metric of used to measure firm performance (Modi & Malbert, 2010; Wagner & Neshat, 2010).

Measurement of resilience variables. There were no readily apparent financial measures for resilience in the literature (Pettit et al., 2010; Reggiani, 2012). Wieland and Wallenburg (2012) derived subjective measures of resilience from survey data, Pettit et al. (2013) found qualitative measures from focus groups, and Cabral (2012) identified qualitative KPIs for resilience. Financial measures are the most objective (Calantone & Vickery, 2010). The specific financial measures for this study appeared from logical

derivation from other studies found in the literature. Use of logic may be necessary to link concepts and associations (Bhattacherjee, 2012).

A connection between resilience and supply chain stability exists. In concept, resilience infers maintenance of and reestablishment of stability following a disturbance (Bhamra et al., 2011; Ponomarov & Holcomb, 2009). Resilience implies the capability to endure a supply chain shock and recover quickly (Cabral et al., 2012). Stability is a critical factor for company managers (Bode et al., 2011). In concept, variability decreases performance in the supply chain (Christopher & Holweg, 2011). Company managers employ resilience strategies of prevention and flexibility to maintain stability in their functions (Bode et al., 2011). Additionally, stability for both the supply chain and individual companies has a positive effect on performance (Hill et al., 2012). A resilient supply chain maintains a consistent level of stability or reacquires a new level of stability (Carvalho et al., 2011; Wieland & Wallenburg, 2013).

The opposite of stability or variability is detrimental to performance (Christopher & Holweg, 2011). Managers attempt to stabilize supply chains to reduce variability and protect profit and cash flow (Hill et al., 2012). Ponomarov (2012) found a negative relationship between resilience and variability exists. Modi and Mabert (2010) considered the absence of damaging variability to infer company stability. A logical conclusion was higher stability equates to higher resilience, and higher variability suggests lower resilience.

The logical connection between resilience and stability included measurement of the resilience variables. For the DOI variable, the measurement of resilience was

variability, with low variability equating to high resilience. Modi and Mabert (2010) constructed an index for supply chain stability by calculating, with multiple variables, the smooth movement of input resources measured by variability of DOI over time. Cecere and Mayer (2013) analyzed variability of DOI over time for companies in six industries as an indicator of resilience, with low variability indicating greater resilience. Resilience strategies may be designed to reduce variability. Maintenance of sufficient buffer stocks or inventory cushions was an effective strategy to mitigate losses during supply chain disruptions (Bode et al., 2011; Cabral et al., 2012; Hill et al., 2012). For lean manufacturing, lower DOI adds values and performance (Cabral et al. 2012).

For the C2C resilience variable, the measurement of resilience was variability, with low variability equating to high resilience. Stable cash flow during fluctuations is an element of resilience (Pettit et al., 2010). Effective cash management is an essential characteristic for companies when responding to supply disruptions as disasters negatively affect cash flow (Altay & Ramirez, 2010). Cash-to-cash cycle is a cash flow and working capital management metric (Hoffman & Kotzab, 2010). The C2C metric measures the flexibility of a company with regard to suppliers and customers (Mayer, 2012). For lean manufacturing, lower C2C relates to greater performance (Cabral et al., 2012).

Company financial information collected from annual reports over the 10-year period formed the basis for analysis of the degree of variability of the two resilience variables in this study. The simplest measure of variability is the range between the highest and lowest value for each year. Variance is a more precise measure of variability

than range, and the standard deviation is most precise (Hair et al., 2011). Modi and Mabert (2010) measured variability with a standard deviation from the historical norm. Hofman and Aronow (2012) used standard deviation to measure variability of company performance over a 3-year period. Cecere and Mayer (2013) presented standard deviation of selected financial ratios over a 10-year period to demonstrate variability of the supply chain. Christopher and Holweg (2011) used coefficient of variation (CoV) to measure volatility of various different financial indicators with different factors to obtain a single solution without scale and normed. For this study, the standard deviation of company levels of C2C and DOI over a 10-year period determined the degree of variability and measure of resilience.

Measurements of performance variables. For the performance variables, measurement of company performance was the average ratios of ROA and OM over the 10-year period. Hofman and Aronow (2012) analyzed business trends of selected steady performing Gartner Top-25 companies and categorized companies with above average performance and less volatility from the norm. For more detailed company comparison, Hofman and Aronow concluded a more comprehensive proxy would be required to combine growth and stability.

Longitudinal panel. The use of longitudinal data adds depth to the study of resilience as recommended by scholars (Blackhurst et al., 2011; Pettit et al., 2012; Ponomarov, 2012) and allows for the observation of company financial information during disruptions and disturbances (Christopher & Holweg, 2011). Effects of resiliency strategies should be apparent through analysis of a longitudinal panel. Use of longitudinal

data in this study expands on trend analysis conducted by business research analysts, Cecere and Mayer (2013) and Hofman and Aronow (2012).

Cross-sectional data offers insight into a comparison of performance among companies, and longitudinal data is better for understanding the effects of cash flow (Kroes & Manikas, 2014). The study sample did not include cross-sectional data. Longitudinal data is more effective for analysis over time (Hair et al., 2011). Modi and Mabert (2010) stated that the use of longitudinal, secondary data is an effective method for examining SCM initiatives and performance. Limitations exist in previous academic studies examining resilience or performance, and authors cited the need for longitudinal panels in future research (Blackhurst et al., 2011; Flynn et al., 2010; Paulraj et al., 2012; Pettit et al., 2012; Ponomarov, 2012; Yang et al., 2011). Business research analysts identified the need for longitudinal panels to draw meaningful conclusions (Hofman & Aronow, 2012). Business research analysts Cecere and Mayer (2013) observed industry trends over a 10-year period. Academic researchers Hendricks et al. (2009) and Modi and Mabert (2010) used a 10-year period for their longitudinal study.

The 10-year observation period for this study was dependent on sufficient observation of financial effects from company resilience strategies implemented during periods of supply chain disturbances and disruptions. In the literature, the term disturbance and disruptions occasionally refer to similar events (Carvalho et al., 2012b). Moreover, Greening and Rutherford (2011) composed a more precise distinction, noting disturbances involved frequent changes in market conditions while disruptions required greater revision of the entire supply chain network following catastrophic events.

Greening and Rutherford did note company managers might employ similar resilience strategies for disturbances and disruptions.

Measurement of the effects of implementation of resilience strategies in response to supply chain disturbances (market fluctuations) required multiple years of observation. For disruptions, the observation period must be longer. First, companies do not recover quickly from disruptions; financial impacts in cash flow measurements appear within a year following disasters and greater than a year for capital measurements (Altay & Ramirez, 2010).

The economic environment following 2001 included disruptive events, a longitudinal panel between 2003 and 2012 may capture financial outcomes. Cecere (2012) used a similar 10-year period, beginning with the early implementation of SCM strategies in the early 2000s and encompassed the supply chain disruptions associated with a global recession in 2008. Christopher and Holweg (2011) developed an index of volatility and found the years around 2008 were the most disruptive for the supply chain, resulting from the global economic recession. Juttner and Maklan (2011) examined the period from 2007 to 2009 to ensure inclusion of the effects of the economic disruption caused by the global financial crisis in their study of SCRM and resilience. Academic studies follow significant events. For instance, peaks in published scholarly journal articles on SCRM occurred following disruptions, in 2004 following 9-11 and again in 2009 following the global recession (Ghadge et al., 2012).

Data required for variables. Company financial information from annual reports provided required data to measure the variables. For the resilience variable sample

consisted of annual DOI and C2C data for each year in the 10-year period from each company. For the performance variable sample consisted of OM and ROA ratios for each year in the 10-year period from each company. There were 1,200 data elements for the variables; I did not include the raw data in the study, and remains available upon request.

Strategies for validity and reliability. The academic and business research literature supports the validity of the financial ratios to measure resilience and financial performance. Existing or adapted measures found in the literature can be used to measure constructs (Bhattacherjee, 2012). Cross-sectional data has limitations, and longitudinal data improves validity (Flynn et al., 2010). Publically reported financial data are a reliable and accepted business metric (Calantone & Vickery, 2010). Reputable professional database services may be considered reliable, but the reliability of the study dataset was cross checked against actual public records (annual report) for accuracy.

Data Collection Technique

Corporate annual reports contain archival secondary financial data required for measurement of the variables. (Du & Zhou, 2012). Corporate financial data required for this study was available in the COMPUSTAT® Standard and Poor's database. The purchase of the custom dataset containing the required ratios from Standard and Poor Capital IQ followed approval from the Institutional Research Board (IRB).

The custom dataset from COMPUSTAT ®Standard and Poor contained the calculated ratios for the variables, DOI, C2C, OM, and ROA. As described in the definition of terms section, calculation of each of the ratios followed from financial elements within the corporate annual report, found in balance sheets and income

statements. The custom data set contained financial reporting elements in addition to the ratios for the variables, in the event additional analysis was required. The financial report elements used in calculating the variables included the custom dataset are average inventory, cost of goods sold, accounts receivable accounts payable, revenue, operating income, net income, and total assets.

Data Organization Techniques

The COMPUSTAT® S&P dataset contained the financial reporting elements from public company financial records. The data set purchased for the study contained 24,000 individual points from 3000 company/year observations with eight specific financial record reporting items. Standard and Poor Capital IQ delivered the dataset electronically on a Microsoft Excel 2007® spreadsheet.

An exclusive Microsoft Excel 2007® workbook contained the archived raw data file, clearly marked as original raw data to serve as the source document. I created a duplicate workbook to serve as a base for subsequent calculations needed to arrange the data into a usable form. A record of each subsequent calculation on a spreadsheet enhanced the capability to retrace steps back to the original data. The original and subsequent statistical test data archived in Microsoft Excel 2007® workbooks were stored on a password protected external drive. The external drive is appropriately labeled and safeguarded in a locked storage container for 5 years.

Data Analysis Technique

Following collection, data may be prepared by editing, coding and transformation (Hair et al., 2011). Preparation for subsequent statistical analysis included organization of

the data on Microsoft Excel 2007® spreadsheets and workbooks. The COMPUSTAT® S&P data set included the four financial ratios, DOI, C2C, OM, ROA and financial reporting elements used for the ratios. A data set should be inspected for missing values that could affect the results (Hair et al., 2011). Inspection of the study dataset resulted in the elimination of some cases, described in Section 3. Data transformation could prepare a variable to support the research question (Hair et al., 2011). For the resilience variables, DOI and C2C, the degree of variability for each company was the result of the calculation of the standard deviation for the 10-year period. For each company or case in the dataset, the DOI and C2C variable was the standard deviation of the respective DOI and C2C observations over the 10-year period. Transformation of the DOI and C2C variables included calculation in Microsoft Excel 2007®.

For the performance variables, OM and ROA, the performance level was the result of the calculation of the average for the 10-year period. For each company or case in the dataset, the OM and ROA variable was the average of the respective OM and ROA observations over the 10-year period. The calculations of each variable occurred using the Microsoft Excel 2007® spreadsheets standard deviation or average function and cross-checked with PASW18® software. The prepared data coding included DOI, C2C, OM, and ROA for subsequent analysis.

Investigation of the research questions and test of the study hypotheses continued with evaluations of each of the four variables continued with the Pearson product-moment correlation test on PASW18® software. Scientific researchers are certain with

the output from validated and powerful statistical software packages like SPSS (Clark, Shoaib, Hewitt, Stanford, & Bate, 2012).

The following hypotheses supported the research questions.

$H1_0$: There is no relationship between DOI and OM for companies operating in the U.S. supply chain.

$H1_a$: There is a relationship between DOI and OM for companies operating in the U.S. supply chain.

$H2_0$: There is no relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H2_a$: There is a relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H3_0$: There is no relationship between C2C and OM for companies operating in the U.S. supply chain.

$H3_a$: There is a relationship between C2C and OM for companies operating in the U.S. supply chain.

$H4_0$: There is no relationship between C2C and ROA for companies operating in the U.S. supply chain.

$H4_a$: There is a relationship between C2C and ROA for companies operating in the U.S. supply chain.

The Pearson product-moment correlation test served to determine if a relationship was significant, if the direction was positive or negative, and the strength (Hair et al., 2011). A level of significance of 95% includes consideration of both Type I and Type II

errors, by determining the risk in drawing improper conclusions from the test (Hair et al., 2011). The greatest risk could be in rejecting the H_0 when true (Type I error), as the results could be used erroneously to demonstrate the relationship between resilience and performance, justifying the investment in resilience strategies. There is a lower level of risk involved with accepting H_0 when false (Type II error); business managers have not yet determined if resilience strategies lead to improved business performance (Cabral et al., 2012). With a sample of 300, there was less than a 5 % chance of a Type I error and less than 1% of a Type II error. Analytical tests with error rates less than 5 % for Type I and 1% for Type II contain sufficient statistical power (1-β) to control Type I and II errors (Hair et al., 2011).

To reject the null hypothesis and accept the alternate hypothesis the statistical test must be significant (Hair et al., 2011). The Bonferroni correction was used to reduce the risk of a Type I error, computed by dividing *p* by number of correlations calculated by number of variables (k) x (k-1)/2 (Green & Salkind, 2008). For the four variables, there were six correlations and $p < .008$ (.05/6 = .008). The Pearson product-moment coefficient measured the strength of the correlation, a small coefficient considered .10, medium coefficient .30, and large coefficient .50 (Green & Salkind, 2008).

The Pearson product-moment correlation test determined if there was a relationship between resilience variables of DOI, C2C and performance variables of OM, and ROA. Academic and business research literature as outlined in the literature review formed the basis for resilience and performance variables. Examination of the variables through hypothesis testing supported the research question. The research question was

viewed through the theoretical framework to provide supply chain managers greater understanding of investment in SCM strategies.

Reliability and Validity

Validity of a study involves consideration that the variables accurately depict the constructs in the conceptual model (Hair et al., 2011). An optimal balance between internal and external validity exists through study design (Bhattacherjee, 2012). Reliability of a study involves consistent and dependable measurement of variables (Bhattacherjee, 2012).

Reliability

Consistent measurements are a characteristic of a reliable instrument (Bhattacherjee, 2012). Scholarly researchers used longitudinal firm level financial data from COMPUSTAT® in studies and considered the data exceptionally objective (Calantone & Vickery, 2010). Quality of financial databases, critical to financial decision-making, may be reduced by different representations of financial terminology, computational errors, and missing data (Du & Zhou, 2012). Researchers should verify instruments for reliability (Bhattacherjee, 2012). One method to evaluate the integrity of information is data triangulation (Hair et al., 2011). For this study, data triangulation technique was adapted to review the dataset for dependability by comparing other data sources. The source of the study dataset was the COMPUSTAT© commercial database compiled from individual company annual reports. To check for potential inaccuracy in transcription in the study custom dataset, a random sample of input financial data was reviewed and compared for consistency with information reported in company annual

reports and the Google ® Finance database. A comparison of a sample of 2% of randomly selected companies (6 firms) evaluated accuracy. The comparison included financial information for three selected reporting elements from 2 years of annual reports and Google® Finance with information reported in the custom dataset. For the reporting elements where a successful comparison could be conducted, over 70 % entries matched directly or with close rounding. Of the remaining, entries were close, likely due to representations of the financial terms. Numerous online financial databases exist, but may differ in the representation of financial terminology (Du & Zhou, 2012). Threats to reliability from missing data was addressed by eliminating relevant entries, further discussed in section 3.

Validity

Validity of a study involves consideration that the variables accurately depict the constructs in the conceptual model (Hair et al., 2011). An ideal balance between internal and external validity exists through study design (Bhattacherjee, 2012). Reliability of a study involves consistent and dependable measurement of variables (Bhattacherjee, 2012).

Internal validity involves credibility of the variable development and developing causal and logical deductions. (Bleijenbergh, Korzilius, & Vershuren, 2011). A study has sufficient content validity if the variables measure the theoretical constructs, assessed subjectively (Hair et al., 2011). Face or content validity follows with alignment of the variables and constructs (Bhattacherjee, 2012). For this study, the variables (DOI, C2C, OM, ROA) were aligned with the respective constructs (resilience and performance)

based on other studies found in the literature as depicted in Table 2 and presented in Figure 1.

Construct validity entails plausible measurement of the construct (Hair et al., 2011). The variable must measure the theoretical construct and evaluation of validity may occur theoretically or quantitatively using existing or adapting current measures found in the literature (Bhattacherjee, 2012). For this study, I selected measures which directly, indirectly from the literature or logically derived from other studies.

Similar financial variables in my study appeared in previous studies. In the context of resilience Cecere and Mayer (2013) and Modi and Mabert (2010) examined DOI; Hendricks et al. (2009) and Hofman and Aronow (2012) examined OM; Hofman and Aronow (2012), Lanier et al. (2010); Modi and Malbert (2010), and Wagner and Neshat (2010) examined ROA in their respective studies. Measures found in academic studies indirectly support measurement of the resilience variables. Researchers indirectly examined C2C in the context of resilience (Cabral et al., 2012; Hoffman & Kotzab, 2010; Kroes & Manikas, 2014; Mayer, 2012, Pettit et al., 2010). Research by Bode et al. (2011), Cabral et al. (2012), and Hill et al. (2012) indirectly supported the DOI variable. Cabral et al. (2012) underlined the use of DOI and Johnson and Templar (2011) emphasized the use of C2C to evaluate SCM performance. Finally, as outlined previously in the literature review, researchers confirmed the linkage between resilience, stability, and variability (Bhamra et al. 2011; Bode et al., 2011; Cabral et al., 2012; Carvalho et al., 2011; Christopher & Holweg, 2011; Hill et al., 2012; Ponomarov, 2012; Ponomarov & Holcomb, 2009; Wieland & Wallenburg, 2013).

Quantitative evaluation of validity may also follow, two variables measuring the same construct can be assessed for convergent or discriminant validity through correlation analysis (Bhattacherjee, 2012). Convergent validity was apparent if there was a correlation between two theoretically based variables measuring the same construct (Hair et al., 2011). Evaluation of the two resilience variables (DOI, C2C) and two performance variables (OM, ROA) showed a positive and strong correlation, indicating convergent validity.

External validity is the ability to consider the applicability of outcomes of the sample to a greater population (Bhattacherjee, 2012). Qualitative studies have a greater focus on external validity and involve larger sample sizes (Bleijenbergh et al., 2011). A random sample guarantees external validity (Bhattacherjee, 2012). For this study, a random sample was selected from a list of public companies operating within specific NAICS codes as displayed in Table 4 and Figure 2. Random samples were selected by NAICS codes in studies by Lao et al. (2010) and Paulraj et al. (2012).

One possible threat to external validity with previous studies was applicability to the entire supply chain. Kroes and Manikas (2014) noted limitations when the study only on examined manufacturing and not the entire supply chain. To mitigate against a potential threat to validity from generalization, the study included an expanded population of companies in NAICS codes outside of manufacturing as shown in Figure 2. One limitation to this study is COMPUSTAT® data consists of public companies. Findings from databases of public companies may not be generalizable to industries with mostly small and private companies (Eroglu & Hofer, 2011). Finally, this study was

limited to U.S. companies. Results of studies using U.S. data may not be generalizable globally due to differences in SCM procedures (Eroglu & Hofer, 2011).

Transition and Summary

Business leaders need to understand the relationship between resilience strategies and financial performance. In Section 2, I outlined the methodology for a quantitative correlational study that incorporated hypothesis testing and a random sample of companies in the supply chain. The incorporation of a longitudinal data set of financial ratios analyzed using correlational statistical techniques integrates business research trend analysis with academic methods. The research question, hypotheses, and theoretical framework from Section 1 formed the basis for the detailed procedures introduced in Section 2. These procedures included the identification of the supply chain population, selection of companies for the sample, description of the instrument used to collect specific financial information, and steps used to analyze the data using statistical techniques. Presented in Section 2 was a discussion on validity, reliability, and ethical research. Following in Section 3, is a presentation of the results of the analysis of the data, discussion of conclusions, application to professional practice, implications for social change, recommendations for future study, and reflections.

Section 3: Application to Professional Practice and Implications for Change

The purpose of this quantitative correlational study was to examine whether a relationship existed between resilience and financial performance for companies operating in the U.S. supply chain. The statistical test to determine the relationship between two resilience variables, DOI and C2C and two performance variables, OM and ROA was the Pearson product-moment correlation test. The source of the data was company financial reports. Information on the relationship between resilience and performance could guide managers in the selection of efficient and effective resilience strategies leading to improved business performance and greater economic benefits to consumers and society.

The dataset was asymmetrical; results of the Pearson product-moment correlation test on data transformed by rank based inverse normal transformation (RIN) indicated a negative correlation between variables. The direction of the correlation indicated a positive relationship between resilience and performance. Observation of outliers in the dataset potentially represented companies with exceptionally low resilience (unstable DOI/C2C) and unusually negative performance (OM/ROA), suggesting a possible relationship between low resilience and adverse financial performance existed.

Section 3 includes an overview of the study, a presentation of the findings, and relevance of the findings to business practice and social change. Study conclusions lead to recommendations for action and further study. Finally, Section 3 contains my reflections on the project and a final summary of the study.

Overview of Study

Managers do not have an understanding as to which supply chain management (SCM) strategy best improves performance (Cabral et al., 2012). For the best resilience strategy, an optimal balance between protection from vulnerability and profitability exists (Pettit et al., 2010). An understanding of the relationship between resilience and financial performance could assist managers in developing appropriate resilience strategies.

In this study, I conducted a quantitative study using a correlational design and employing the Pearson product-moment correlation in order to analyze the relationship between resilience and business performance. The Pearson product-moment correlation test is appropriate for analysis of variables from ratio data (Green & Salkind, 2008; Hair et al., 2011). The variables were the focus of the research questions.

Research Question 1: To what extent, if any, is there a relationship between DOI and OM for companies operating in the U.S. supply chain?

Research Question 2: To what extent, if any, is there a relationship between DOI and ROA for companies operating in the U.S. supply chain?

Research Question 3: To what extent, if any, is there a relationship between C2C and OM for companies operating in the U.S. supply chain?

Research Question 4: To what extent, if any, is there a relationship between C2C and ROA for companies operating in the U.S. supply chain?

The following hypotheses supported the research questions.

$H1_0$: There is no relationship between DOI and OM for companies operating in the U.S. supply chain.

$H1_a$: There is a relationship between DOI and OM for companies operating in the U.S. supply chain.

$H2_0$: There is no relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H2_a$: There is a relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H3_0$: There is no relationship between C2C and OM for companies operating in the U.S. supply chain.

$H3_a$: There is a relationship between C2C and OM for companies operating in the U.S. supply chain.

$H4_0$: There is no relationship between C2C and ROA for companies operating in the U.S. supply chain.

$H4_a$: There is a relationship between C2C and ROA for companies operating in the U.S. supply chain.

These data that I used to support the analysis consisted of financial ratios found in company financial information. The sample contained 300 publically traded U.S. companies randomly selected from a commercial list from COMPUSTAT® database of companies identified by the North American Industrial Classification System (NAICS) two-digit code categories, Mining (21) Manufacturing (31-33), Wholesale Trade (42), and Retail Trade (44-45). The results of the parametric test on transformed data indicated a correlation between resilience and performance.

Presentation of the Findings

The presentation of the results of this study includes the demographics of the sample, descriptive statistics from the sample, results of the Pearson product-moment correlation test, and conclusions. The purpose of this study was to examine the relationship between resilience and performance. The findings of this study complement previous research on SCM and SCRM and performance by Johnson and Templar (2011), Paulraj et al. (2012), and Thun and Hoenig (2011) and enrich survey-based research on resilience and performance by Wieland and Wallenburg (2012). Study findings may contribute to the gap in business practice regarding investment decisions in concert with business investment principles and rational choice theories. Finally, the findings might add depth to business trend analysis conducted by business research analysts, and potential improvements in business practice.

Data Collection and Evaluation of the Sample Data

A power analysis, using G*Power 3.1 software developed by Faul, Erdfelder, Lang, and Buchner (2007) was conducted to determine the appropriate sample size for this study. An a priori power analysis, assuming a medium effect size (ρ = .30), a = .05, indicated a minimum sample size of 82 for this study. A sample size of of 134 increased power from .80 to .95.

Selection of the sample of 300 companies from the COMPUSTAT® S&P custom database resulted from 2,816 public companies from the designated NAICS two-digit codes: Mining (21), Manufacturing (31-33), Wholesale Trade (42), and Retail Trade (44-45). Excluding companies without complete 10-year data for the longitudinal panel, the

sample frame was 1,604 companies. A simple random sample, from a random number generator, provides the greatest degree of generalizability (Bhattacherjee, 2012).

Data preparation. Corporate annual reports contained archival secondary financial data required for measurement of the variables in this study. The variables DOI, C2C, OM, and ROA sample consisted of data for each year in the 10-year period for each company. The required 1,200 data elements for the variables were available in the COMPUSTAT® Standard and Poor's database. The purchase of the custom dataset containing the required ratios from Standard and Poor Capital IQ followed approval from the Institutional Research Board (IRB).

Following collection, data may be prepared by editing, coding and transformation (Hair et al., 2011). Preparation for subsequent statistical analysis included organization of the data on Microsoft Excel 2007® spreadsheets and workbooks. The COMPUSTAT® S&P data set included the four financial ratios, DOI, C2C, OM, ROA and financial reporting elements used for the ratios. A data set should be inspected for missing values that could affect the results (Hair et al., 2011). Inspection of the study dataset and missing data resulted in the elimination of some cases, described later in Section 3. Data transformation could prepare a variable to support the research question.

For the resilience variables, DOI and C2C, the degree of variability for each company was the result of the calculation of the standard deviation for the 10-year period. For each company or case in the dataset, the DOI and C2C variable was the standard deviation of the respective DOI and C2C observations over the 10-year period. Transformation of the DOI and C2C variables included calculation in Microsoft Excel

2007®. For the performance variables, OM and ROA, the performance level was the result of the calculation of the average for the 10-year period. For each company or case in the dataset, the OM and ROA variable was the average of the respective OM and ROA observations over the 10-year period. The calculations of each variable occurred using the Microsoft Excel 2007® spreadsheets standard deviation or average function and cross-checked with PASW18® software. The prepared data coding included DOI, C2C, OM, and ROA for subsequent analysis.

The data consisted of financial ratios from annual reports from 300 randomly selected companies operating in the U.S. supply chain over a 10-year period from 2003-2012. Table 5 includes the sample of supply chain companies by NAICS. The sample proportions approximate population of companies operating in the supply chain, as shown previously in Table 4. The greatest percentage of the sample was in manufacturing with roughly equal percentages of the sample in the other three echelons.

Table 5

Demographics of Sample

NAICS	*n*	%
21 Mining	21	7
31-33 Manufacturing	235	78
42 Wholesale Trade	24	8
44-45 Retail Trade	20	7
	300	100

Missing data. Missing data have an impact on the validity of a study (Hair et al., 2011), and it is necessary to report degree and causes of missing data as well as the method used to manage it (Schlomer, Bauman, & Card, 2010). There was missing data in

14 cells, or less than .02 % of the data in the C2C and DOI panels. In the ROA panel, there were two cells missing data or less than .006%. The missing data is not significant, and no additional value considered necessary in the calculation of the mean and standard deviation. There is a risk that mean substitution could underestimate variance (Schlomer et al., 2010), but this risk appears minor.

In the DOI panel, there were 168 cells of 3,000 or 5.6% with a zero value. For the cases with zero value of DOI, the accounting element used to calculate DOI, inventory held, was zero. The cause is apparent as the companies held no inventory. This is not missing data as zero inventories reflect the actual information; some companies operate without physical inventory (Du & Zhou, 2012). Not counted in the sample were companies without reported DOI for the entire period as the calculation of a standard deviation was not possible. The adjustment to DOI was $N = 293$. However, retained in the analysis were companies that reported both zero DOI and positive DOI over the study 10-year period. Not counting the companies with no inventory over the 10-year period, there were 98 cells with zero DOI, or 3.3% of the remaining sample.

Eliminated from the DOI sample were the seven cases with companies/cases reporting zero DOI over the 10-year period. A case of zero would indicate high resilience (no variability) when, in fact, the company did not have inventory. The analysis also included the seven companies reporting zero DOI, which listed a C2C amount over the 10-year period. In this case, the pairwise deletion method allows for maximum retention of data and method of choice for bivariate correlation (Schlomer et al., 2010).

Three assumptions pertain to the Pearson product-moment correlation test; interval or ratio scales measure the variables, there is a linear relationship, and interval measures appear normally distributed (Hair et al., 2011). Green and Salkind (2008) added the additional assumption that each case is independent of the case in the other variable. For this study, the data was continuous financial information. The relationship between variables appears to be linear and with independent cases as confirmed from scatterplots. A visual inspection of scatterplot pattern created by plotting predicted and residual values is an accepted method to evaluate linear relationship between variables, as well as independence of cases (Green & Salkind, 2008). Scatterplots of each of the correlations between the study variables on transformed data appears in Figure 4. Evaluation of the study variables with transformed data appeared by plotting predicted and residual values. Through visual inspection of the scatterplots, no indications of abnormal patterns appeared, indicating confirmation of assumptions.

Normal distribution. Debate among scholars exists regarding the need to have a normal distribution for bivariate analysis as the Pearson product-moment correlation test maintains statistical power and low Type I error rates (Bishara & Hittner, 2012). Sample data should approximate a normal distribution to comply with parameters of certain statistical tests (Drezner, Turel, & Zerom, 2010). A normal distribution is a requirement for the Pearson product-moment coefficient test (Hair et al., 2011; Green & Salkind, 2008).

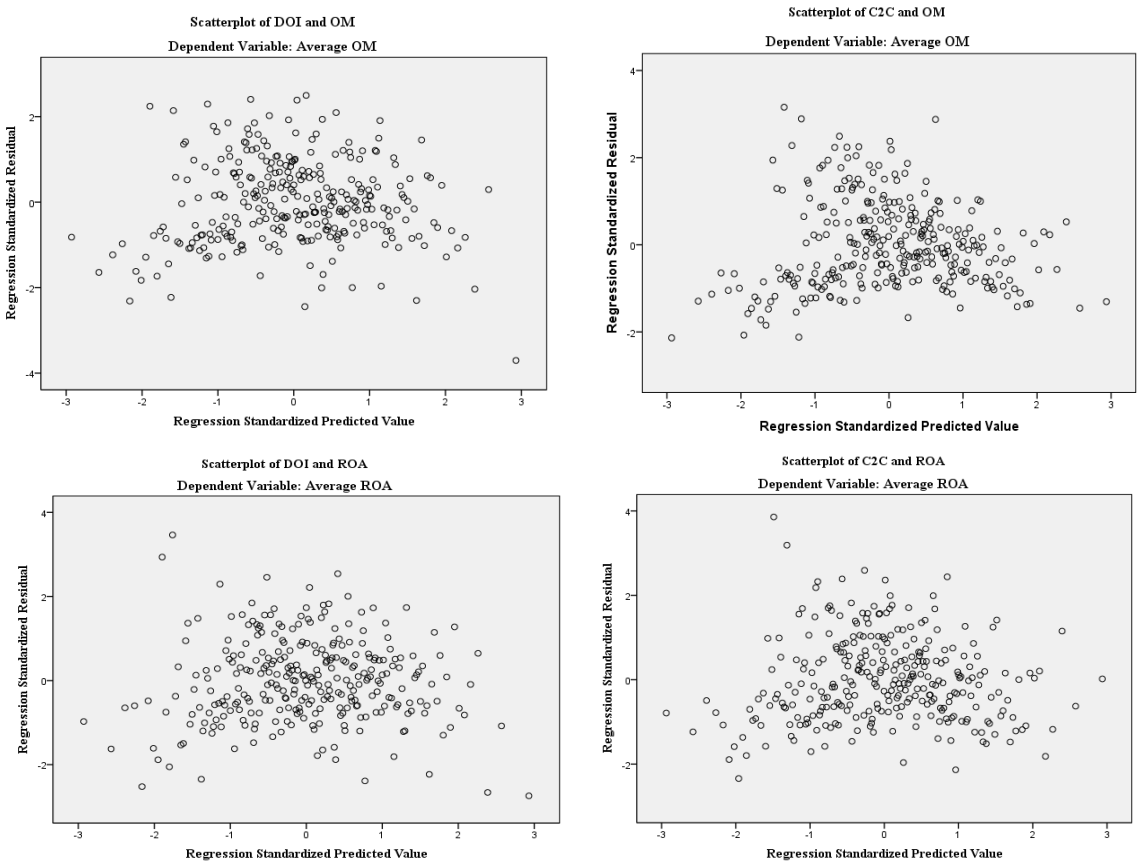

Figure 4. Scatterplot of study variables. Plot displayed to visually test the assumption for linear pattern and homogeneity-of-variance. Each plot depicts pattern of predicted and residual values for each variable from transformed data. No patterns are visible, assumptions were not violated.

Inspection of the dataset followed the preparation for analysis. Data should be properly prepared for quality statistical analysis (Lusk, Halperin, & Heilig, 2011). A formal test like the Shapiro-Wilks test may confirm a normal distribution, assessment of skew and kurtosis, and visual inspection of graphical representations (Drezner et al., 2010).

Initially, a visual inspection of histograms, QQ Plots, and boxplots evaluated each measure. A comparison of histograms between the study sample and prototype samples

found in Doane and Seward (2011) confirmed asymmetry in the dataset. Evaluation of skewness and kurtosis statistics using techniques described by Doane and Seward (2011) further established asymmetry in the dataset. A Shapiro Wilk test may confirm asymmetry (Drezner et al., 2010). The conduct of a Shapiro-Wilk test confirmed asymmetry for the raw data of this study.

The initial dataset was asymmetrical, skewed and leptokurtic, heavily influenced by outliers, also confirmed through visual inspection. Financial data on asset returns frequently have asymmetrical distributions, skewed and leptokurtic, commonly referred as flat-tailed (Xiong & Idzorek, 2011). Series financial data characteristically displays elevated kurtosis (Grane & Veiga, 2010). Outliers can cause incorrect results, and should be recognized and eliminated to reduce skew and kurtosis and improve the quality of the financial data (Grane & Veiga, 2010). Researchers need to select a technique to identify outliers, Leys, Ley, Klein, Bernard, and Licata (2013) recommended Median Absolute Deviation (MAD) and noted a popular use of mean plus or minus 3 standard deviations from the mean. Loh and Stulz (2011) recommended identifying the outliers for trimming by considering 5% from each tail and the Least Trimmed Squares method.

For cases where the data exhibit exceptionally nonnormal properties, making Pearson product-moment correlation test infeasible, Bishara and Hittner (2012) recommend evaluating transformed data with Pearson correlation test or nonparametric Spearman test. The Pearson product-moment correlation test is less effective with extreme nonnormal data, and some nonlinear transformations can distort results (Bishara

& Hittner, 2012). The high kurtosis and strong skew in a dataset could lead to a Type I error if evaluated by the Pearson test. (Bishara & Hittner, 2012).

The RIN technique, used in medical research for nonnormal distributions, involves rank ordering the data and performing subsequent statistical transformations (Beasley, Erickson, & Allison, 2009). In a study comparing different transformation techniques for nonnormal data, Bishara and Hittner (2012) found the RIN most effective, with acceptable Type I error rate control. Beasley et al. (2009) compared transformation techniques and found the RIN technique acceptable for transformation of extraordinary nonnormal data with large sample size and simple design. For this study, the dataset was transformed using the RIN and evaluated by Pearson product-moment correlation test.

The dataset was transformed using the RIN technique to obtain the normal score for each measure using Rankit's formula. Following transformation, the dataset approximated a normal distribution without distortions of skew or kurtosis. An evaluation of the dataset by Pearson product moment correlation test followed transformation.

Descriptive Statistics

Findings include an evaluation of the descriptive statistics from the dataset and evaluation of the inferential statistics from the Pearson product-moment correlation test. Observations about outliers could prompt additional study. Finally, conclusions emerge from study results and discussion of outliers. The descriptive statistics for the variables appear in Table 6. Examination of descriptive statistics highlights extreme minimum value for OM and high maximum values for DOI and C2C as outliers discussed in the previous section.

Table 6

Descriptive Statistics for Resilience and Performance Variables

Variable	*N*	*M*	*SD*	Min value	Max value
DOI	293	111.66	906.78	0.34	12310.49
C2C	300	352.13	1841.58	1.30	22117.85
OM	300	-858.85	7449.02	-113604.65	58.50
ROA	300	-12.29	73.36	-869.06	70.03

A review of 10-year trend of the industry-wide untransformed sample indicates potential for a relationship between the variables. As displayed in Figure 5, industry-wide sample trend indicated decreasing resilience from 2004 to 2006 (both C2C and DOI SD increasing) while OM decreased. From 2006 to 2007, resilience increased (both C2C and DOI SD decreased), and OM increased. From 2011 to 2012, C2C increased and DOI decreased while OM decreased. From the descriptive statistics trend analysis, there is potential for a relationship between resilience and performance, with C2C and OM more accurate indicators.

Correlational Analysis

The Pearson product-moment correlation test serves to determine if a relationship between two variables was significant, if the direction of the test was positive or negative, and the strength of the relationship (Hair et al., 2011). With an unknown direction, a two-tailed test should be used (Hair et al., 2011). A level of significance of 95% includes consideration of both Type I and Type II errors, by determining the risk in drawing improper conclusions from the test (Hair et al., 2011). With a sample of 300, there was less than a 5 % chance of a Type I error and less than 1% of a Type II error. Analytical

tests with error rates less than 5 % for Type I and 1% for Type II contain sufficient statistical power (1-β) to control Type I and II errors (Hair et al., 2011).

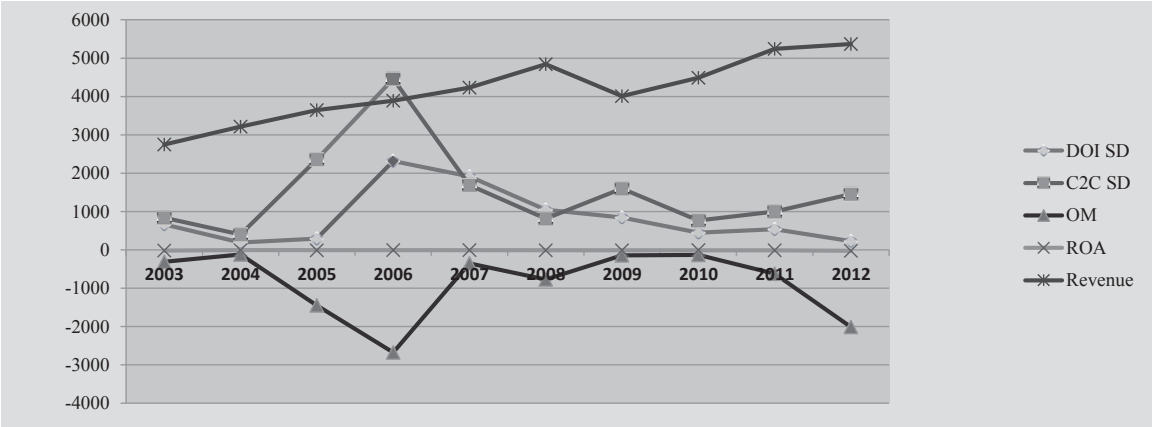

Figure 5. Descriptive statistics of resilience and business performance measures over the 10-year period. Resilience measure is the standard deviation of DOI and C2C; business performance measure is average OM and ROA for 300 companies. The unit of measure for DOI and C2C is days, and for OM and ROA is percent. Revenue is measured in $M.

To reject the null hypothesis and accept the alternate hypothesis the statistical test must be significant (Hair et al., 2011). The Bonferroni correction was used to reduce the risk of a Type I error, computed by dividing *p* by number of correlations calculated by number of variables (k) x (k-1)/2 (Green & Salkind, 2008). For the four variables, there were six correlations and $p < .008$ (.05/6 = .008). The Pearson moment-coefficient measured the strength of the correlation, a small coefficient considered .10, medium coefficient .30, and large coefficient .50 (Green & Salkind, 2008).

Although not required for a correlational analysis, a bivariate linear regression was also useful to examine the relationship between the two variables. The bivariate linear regression calculates the squared value (r^2) of the Pearson product-moment product coefficient (r) as a predictor of a dependent variable from an independent variable (Green

& Salkind, 2008). The value r^2 is the percent of the total variance determined from the regression (Hair et al., 2011). The regression coefficient shows the variance of the dependent variable that comes from the independent variable (Hair et al., 2011). Rejection of a hypothesis may occur at the .05 level if the 95% confidence interval does not enclose the value of zero (Green & Salkind, 2008).

Research question 1. The research question was, to what extent, if any, is there a relationship between DOI and OM for companies operating in the U.S. supply chain? The hypotheses for the research question included,

$H1_0$: There is no relationship between DOI and OM for companies operating in the U.S. supply chain.

$H1_a$: There is a relationship between DOI and OM for companies operating in the U.S. supply chain.

The Pearson product-moment correlation test served to test the significance, direction, and strength of the relationship, the significance level of .95 required to reject the null hypothesis and accept the alternate hypothesis the statistical test must be significant (Hair et al., 2011). The correlation between DOI and OM was significant, $r(291) = -.195$, $p < .001$. The correlation was significant, and the effect size was small. Rejection of the null hypothesis occurred, and there is a negative correlation between DOI and OM, indicating that lower variability in DOI or higher resilience is related to higher OM. A bivariate linear regression analysis evaluated the prediction of OM on DOI. A scatterplot of the two variables is shown in the Figure 6, indicating that the two variables

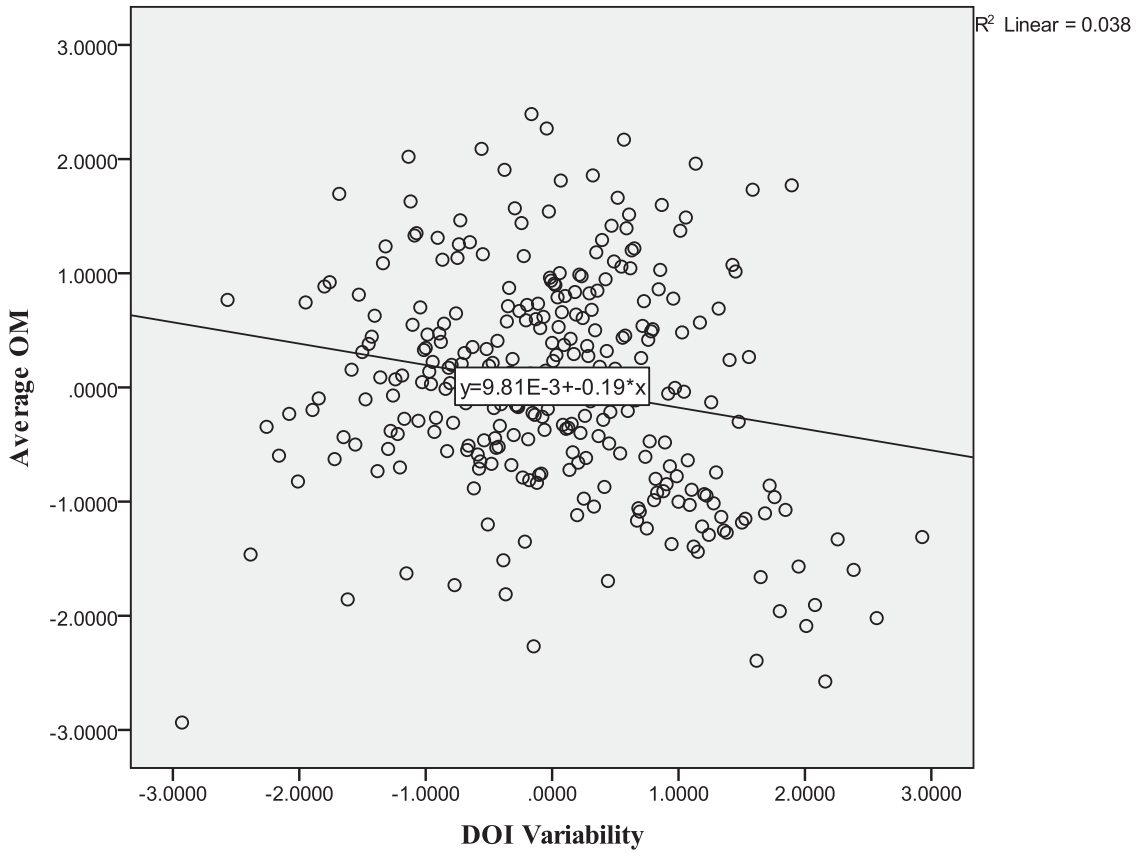

Figure 6. Scatterplot and fit line for DOI and OM. Scatterplot demonstrates relationship between DOI variability and average OM. The standardized regression equation is displayed with the fit line at total. The fit line and liner equation demonstrate the negative relationship between DOI variability and average OM. The r^2 linear value is displayed in the upper right corner.

are linearly related and as DOI variability increases, OM decreases. The 95% confidence interval for the slope, -.296 and -.078 does not contain the value of zero, and, therefore, DOI is significantly related to OM. The correlation between DOI and OM was -.195. The unstandardized regression coefficient of was -.187, indicating for an increase in DOI variability by 1 there was a corresponded to a decrease of .19 in average OM.

Approximately 4% of the variance of OM accounted for its linear relationship with DOI variability.

Research question 2. The research question was, to what extent, if any, is there a relationship between DOI and ROA for companies operating in the U.S. supply chain? The hypotheses for the research question included,

$H2_0$: There is no relationship between DOI and ROA for companies operating in the U.S. supply chain.

$H2_a$: There is a relationship between DOI and ROA for companies operating in the U.S. supply chain.

The Pearson product-moment correlation test served to test the significance, direction, and strength of the relationship, the significance level of .95 required to reject the null hypothesis and accept the alternate hypothesis the statistical test must be significant (Hair et al., 2011). The correlation between DOI and ROA was significant, $r(291) = -.245$, $p < .001$. The correlation was significant, and the effect size was small. Rejection of the null hypothesis followed and there is a negative correlation between DOI and ROA, indicating that lower variability in DOI or higher resilience is related to higher ROA. A bivariate linear regression analysis evaluated the prediction of OM on ROA. A scatterplot of the two variables appeared in the Figure 7, indicating that the two variables are linearly related and as DOI variability increases, ROA decreases. The 95% confidence interval for the slope, -.355 and -.133 does not contain the value of zero, and, therefore, DOI is significantly related to ROA. The correlation between DOI and ROA was -.245. The unstandardized regression coefficient of was -.244, indicating for an

increase in DOI variability by 1 there was a corresponded to a decrease of .244 in average ROA. Approximately 6% of the variance of ROA accounted for its linear relationship with DOI variability.

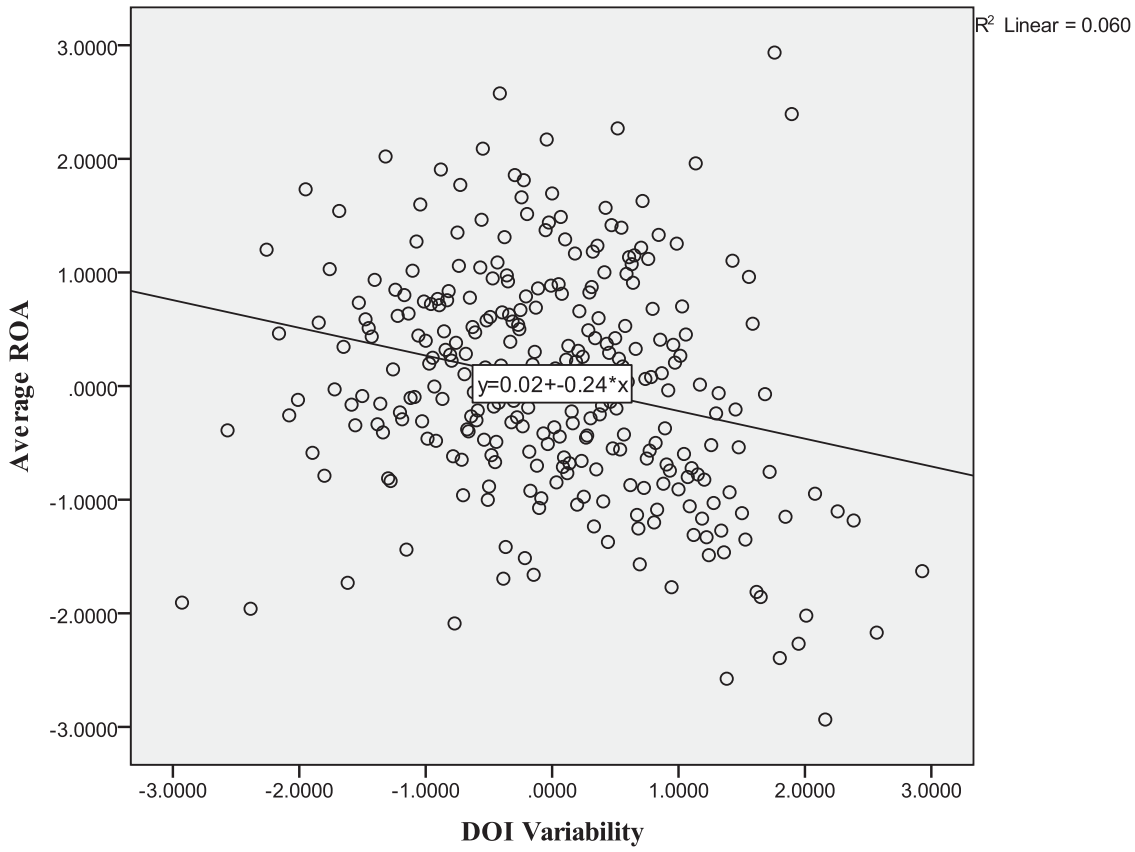

Figure 7. Scatterplot and fit line for DOI and ROA. Scatterplot demonstrates relationship between DOI variability and average ROA. The standardized regression equation is displayed with the fit line at total. The fit line and liner equation demonstrate the negative relationship between DOI variability and average ROA. The r^2 linear value is displayed in the upper right corner.

Research question 3. The research question was, to what extent, if any, is there a relationship between C2C and OM for companies operating in the U.S. supply chain? The hypotheses for the research question included,

$H3_0$: There is no relationship between C2C and OM for companies operating in the U.S. supply chain.

$H3_a$: There is a relationship between C2C and OM for companies operating in the U.S. supply chain.

The Pearson product-moment correlation test served to test the significance, direction, and strength of the relationship, the significance level of .95 required to reject the null hypothesis and accept the alternate hypothesis the statistical test must be significant (Hair et al., 2011). The correlation between C2C and OM was significant, $r(298) = -.306$, $p < .001$. The correlation was significant, and the effect size was medium. A rejection of the null hypothesis followed, and there is a negative correlation between C2C variability and average OM, indicating that lower variability in C2C or higher resilience is related to higher OM.

A bivariate linear regression analysis evaluated the prediction of C2C on DOI. A scatterplot of the two variables appeared in Figure 8, indicating that the two variables are linearly related and as C2C variability increases, average OM decreases. The 95% confidence interval for the slope, -.415 and -.198 does not contain the value of zero, and therefore C2C is significantly related to OM. The correlation between C2C and OM was -.31. The unstandardized regression coefficient of was -.31, indicating for an increase in C2C variability by 1 there was a corresponded to a decrease of .31 in average OM.

Approximately 9% of the variance of OM accounted for its linear relationship with C2C variability.

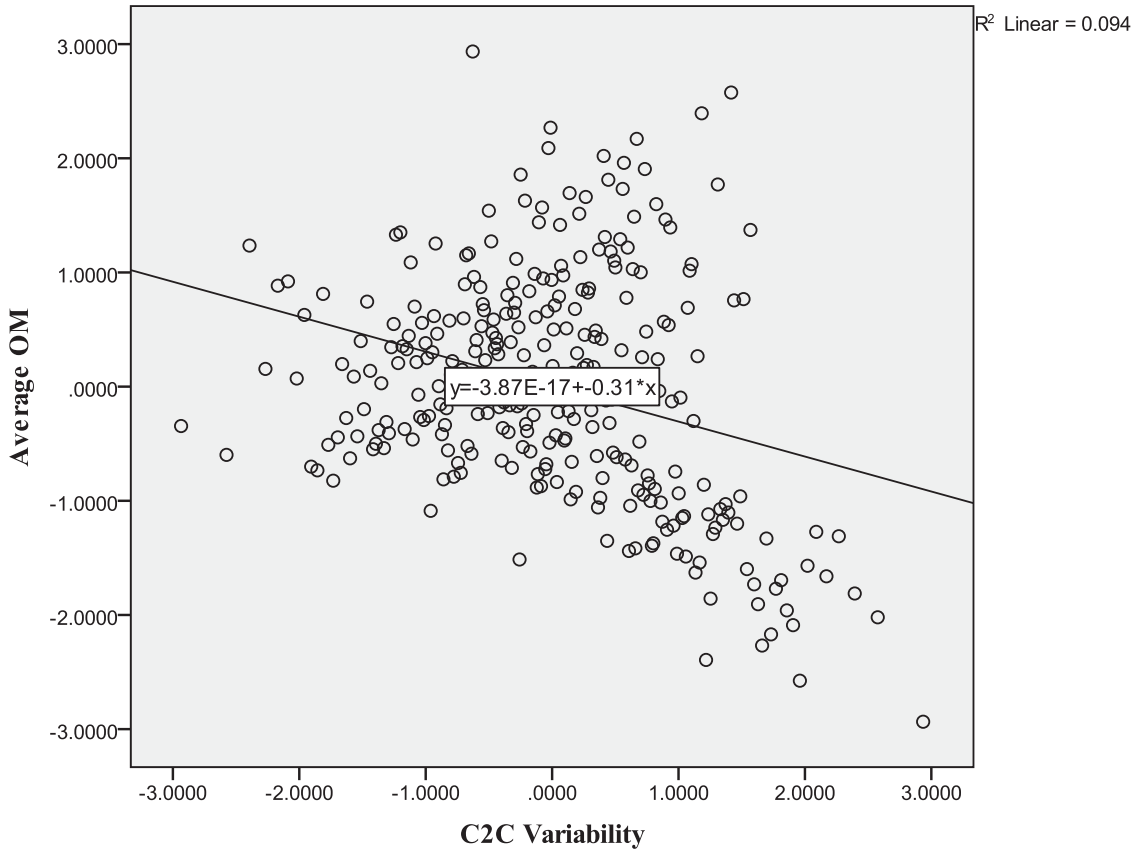

Figure 8. Scatterplot and fit line for C2C and OM. Scatterplot demonstrates relationship between C2C variability and average OM. The standardized regression equation is displayed with the fit line at total. The fit line and liner equation demonstrate the negative relationship between C2C variability and average OM. The r^2 linear value is displayed in the upper right corner.

Research question 4. The research question was, to what extent, if any, is there a relationship between C2C and ROA for companies operating in the U.S. supply chain? The hypotheses for the research question included,

$H4_0$: There is no relationship between C2C and ROA for companies operating in the U.S. supply chain.

$H4_a$: There is a relationship between C2C and ROA for companies operating in the U.S. supply chain.

The Pearson product-moment correlation test served to test the significance, direction, and strength of the relationship, the significance level of .95 required to reject the null hypothesis and accept the alternate hypothesis the statistical test must be significant (Hair et al., 2011). The correlation between C2C and ROA was significant, $r(298) = -.403$, $p < .001$. The correlation was significant, and the effect size was medium. A rejection of the null hypothesis occurred, and there is a negative correlation between C2C variability and average ROA, indicating that lower variability in C2C or higher resilience is related to higher ROA.

A bivariate linear regression analysis evaluated the prediction of C2C on ROA. A scatterplot of the two variables shown in the Figure 9 indicated that the two variables are linearly related and as C2C variability increases, average ROA decreases. The 95% confidence interval for the slope, -.507 and -.299 does not contain the value of zero, and therefore C2C is significantly related to OM. The correlation between C2C and OM was -.40. The unstandardized regression coefficient of was -.40, indicating for an increase in C2C variability by 1 there was a corresponded to a decrease of .40 in average OM.

Approximately 16% of the variance of OM accounted for its linear relationship with C2C variability.

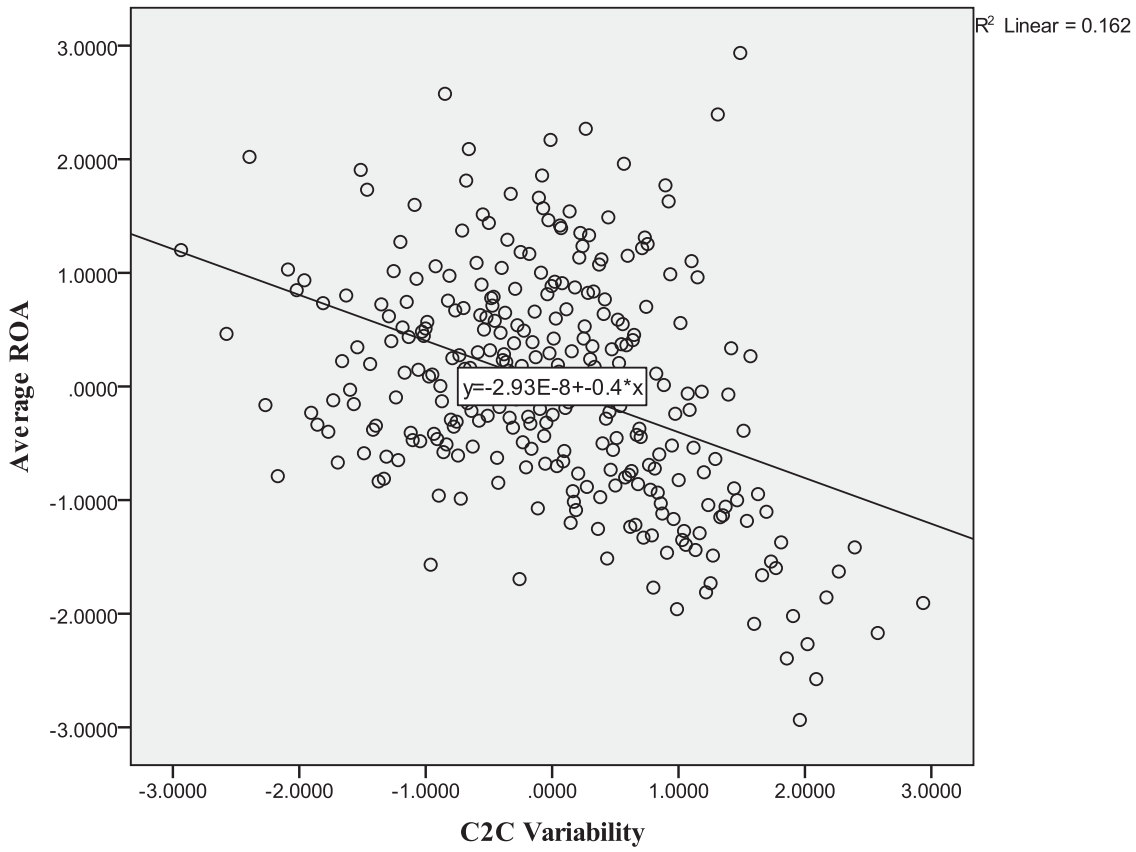

Figure 9. Scatterplot and fit line for C2C and ROA. Scatterplot demonstrates relationship between C2C variability and average ROA. The standardized regression equation is displayed with the fit line at total. The fit line and liner equation demonstrate the negative relationship between C2C variability and average ROA. The r^2 linear value is displayed in the upper right corner.

Results of correlational analysis. The relationship between resilience and financial performance was investigated using Pearson's product moment correlation test. Using the Bonferroni approach to control for Type I error across the six correlations, a *p* value of less than .008 (.05/6 = .008) required for significance. The results of the

correlational analysis presented in Table 7 indicate all four correlations were statistically significant ($p <$. 008).

Table 7

Results of the Test of Variables Resilience and Performance

Variables	DOI	C2C	OM	ROA
1. DOI	1.0	**.685	**-.195	**-.245
2. C2C	**.685	1.0	**-.306	**-.403
3. OM	**-.195	**-.306	1.0	**.702
4. ROA	**-.245	**-.403	**.702	1.0

Note. Dataset transformed by RIN. $N = 300$ for C2C, OM, ROA. $N = 293$ for OM.
** $p < .008$ (2-tailed)

The results of each of the parametric statistical tests inform the hypotheses. In each case, there is sufficient significance to reject the null hypothesis. A rejection of the null hypothesis followed for each of the research questions. There is a negative correlation among the four variables indicating a negative relationship between DOI and C2C variability and average OM and ROA shown in Figure 10. Higher variability of DOI and C2C correlates with low OM and ROA and lower DOI and C2C variability correlates with higher average OM and ROA. These correlations indicate higher resilience (lower variability) (DOI, C2C) relates to higher levels of business performance (OM, ROA).

There were strong correlation coefficients between resilience measures DOI and C2C ($r = .69$) and with performance measures OM and ROA ($r = .70$). Pearson coefficients greater than .5 are strong (Green & Salkind, 2008). Two correlated variables measuring the same construct indicate convergent validity (Bhattacherjee, 2012; Hair et

al., 2011).

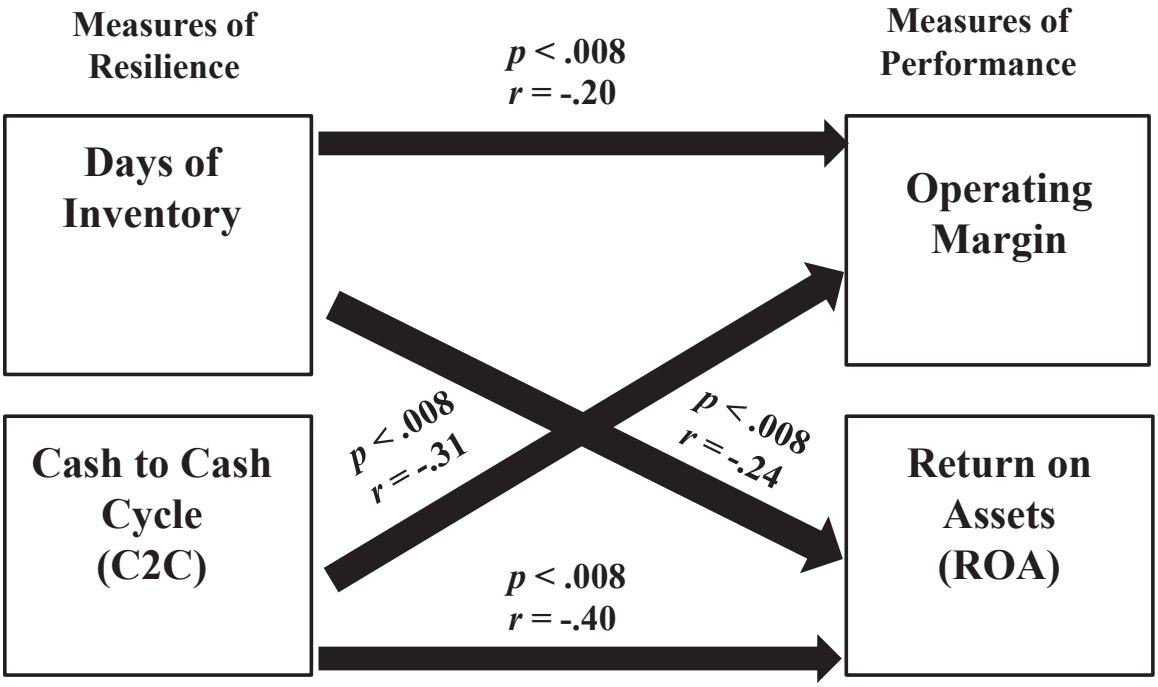

Figure 10. Results of the Pearson product-moment correlation test. Test conducted on transformed dataset. The value for $p < .008$ as required for significance corrected by Bonferroni approach to control for Type I error. $N = 293$ for DOI/ROA and DOI/OM and $N = 300$ for C2C/OM and C2C/ROA.

Secondary Analysis

The dataset was asymmetrical and potentially heavily influenced by outliers. For nonnormal datasets, Bishara and Hittner (2012) recommend test of transformed data with Pearson coefficient or nonparametric Spearman Rank Correlation Coefficient test. Secondary analysis included analysis of the untransformed dataset using nonparametric tests. Additional analysis evaluation centered on observation of the effects of outliers that may enlighten potential future research.

Nonparametric test. For asymmetrical datasets not approximating a normal distribution, nonparametric tests are appropriate. Two nonparametric tests appropriate to assess a bivariate correlation are the Kendall's tau-b and Spearman (Green & Salkind, 2008). Table 8 displays the results of the two tests. Detection of a small negative correlation (Kendall's tau-b and Spearman Rho < .4) for all four resilience and performance comparisons exists. Nonparametric tests reconfirmed the large positive correlation among the resilience measures (DOI/C2C) and performance measures (OM/ROA). Nonparametric test results confirm study results from parametric test on data transformed by RIN and suggest that an increase in resilience (lower variability) correlates with greater performance.

Table 8

Nonparametric Test of Resilience and Business Performance

	Kendall's tau-B		Spearman's Rho		Pearson Coefficient	
	N	Tau	*N*	Rho	*N*	*r*
DOI/OM	293	**-.125	293	**-.185	293	**-.195
DOI/ROA	293	**-.171	293	**-.250	293	**-.245
C2C/OM	300	**-.171	300	**-.262	300	**-.306
C2C/ROA	300	**-.150	300	**-.366	300	**-.403
DOI/C2C	293	**.600	293	**729	293	**.685
OM/ROA	300	**.534	300	**698	300	**.702

Effect of outliers on dataset and outlying cases. The dataset was asymmetrical and potentially heavily influenced by outliers. An examination of the scatterplots in Figure 4 highlights the position of influential outliers in the dataset. The outliers for DOI and C2C were unusually high variability (right of center of data). For OM and ROA, the

outliers were below zero, or negative returns. Outliers could be an example of cases of low resilience (unstable DOI/C2C) and negative performance (OM/ROA).

The relationship between resilience and performance in outlying cases may appear through visual examination of the scatterplots and dataset. From visual inspection of the dataset, unusually high variability in resilience measures (SD for DOI was 906.7 and C2C was 1857.4) is apparent. For ROA, there were 90 cases, or 30% of the sample with negative ROA averages for the 10-year period. For OM, there were 50 cases, or 17% of the sample with negative OM averages for the 10-year period.

Formal tests for a normal distribution may not account for distributions where critical insight exists in the tails, modification to formal tests should be considered to accommodate these cases (Chicheportiche & Bouchard, 2012; Drezner et al., 2010). Eliminating the outliers can transform data to normal distributions, but can remove valuable data points. Sophisticated statistical models could measure effects of financial activity with asymmetrical data and fat tails (Xiong & Idzorek, 2011).

Conclusions from analysis and observations on outliers and outlying cases. The results from the descriptive statistics indicate a potential relationship between resilience and OM as a trend over the 10-year period. The results from the inferential statistics indicate a relationship between resilience and performance among all four variables. The correlations were negative for all variables, high variability of the resilience measures DOI and C2C relate to low-performance measures OM and ROA, low variability of resilience measures related to high performance. High variability of DOI and C2C equates to low resilience, the converse of variability is stability, stable DOI

and C2C equates to high level of resilience. The results suggest there is a positive relationship between resilience (DOI and C2C) and performance (OM and ROA). From the observation of the outlying cases, a potential relationship between resilience and performance exists specifically with high variability and negative returns. A connection could exist between a lack of resilience and negative financial returns.

The conclusion from the Pearson product-moment correlation test on data transformed by RIN compliments other findings found in the literature and business practice. Quantitative studies examining resilience strategies and performance with financial data are not apparent in the literature (Pettit et al., 2010). Using survey methods, Thun and Hoenig (2011) and Wieland and Wallenburg (2012) found a relationship between SCRM strategies and performance. Hendricks et al., (2009) highlighted the lack of quantitative data available to evaluate economic effectiveness of strategies to reduce vulnerability of supply chain disruptions.

The potential link between low resilience and negative financial implications in cases of outliers is consistent with findings of an older study by Hendricks and Singhal (2003) in that supply chain disruptions decreased investor assets. The observations of low resilience and negative financial returns are also consistent with a body of research on supply chain volatility/stability and performance (Christopher & Holweg, 2011; Pettit et al., 2013). Finally, the results of the inferential statistical analysis and appearance of outlying cases are consistent with elements of the theoretical framework, basis of business decisions grounded in rational choice, fundamental business investment theory.

The findings are also consistent with SCM and SCRM principles that managers make decisions for reduction of risk (Wagner & Neshat, 2010).

Applications to Professional Practice

In current academic literature, discussion on the relationship between resilience and business performance centers on case studies and managers' perceptions found in survey data. Business research contains trend analysis on selected industries. A need exists to identify appropriate resilience strategies. To support managers' decision on investment strategies, a need exists to determine which strategies lead to improved performance (Hendricks et al., 2009) and quantitative research required to confirm optimal level of resilience (Blackhurst et al., 2011). The existence of a relationship between resilience and performance could assist managers' in their financial decision. The finding of the Pearson product-moment correlation test demonstrates a relationship between resilience and performance, providing insight for managers' decision to invest in resilience. Investment in resilience programs could improve performance. Study findings may help justify an investment in resilience as the investment decision could be warranted on risk as well as cost.

The findings on resilience and performance cases may not directly assist managers in the decision for investment in resilience. The findings do not point to positive financial benefits from investment in resilience strategies or to the effectiveness of specific programs. The appearance of outlying cases may show that potential negative outcomes could occur with low resilience. The outlying cases may provide a greater

understanding of supply chain variability and demonstrate the potential of negative financial effects with supply chain disruptions.

The use of academic techniques to extend business research is essential to support managers' decisions (Naslund, 2010). Business research on resilience using financial ratios lacked academic depth. The asymmetrical dataset is common for longitudinal financial measures and presents challenges for data analysis (Xiong & Idzorek, 2011). The transformation of the nonnormal dataset using RIN advanced a less complex technique to evaluate longitudinal financial data (Bishara & Hittner, 2012). The appearance of outliers in the dataset in this study is useful in identifying future areas for study in this field, relationship of resilience and performance in outlying cases. Finally, a need exists to explore common financial measures of resilience (Pettit et al., 2010) and this study presented a simple set of measures with four financial ratios derived from the literature. The study measures and variables may serve as a basis for either continued research or future exploration of different measures.

Implications for Social Change

Effective resilience strategies could lead to lower costs, greater global economic health, and social benefits (The White House, 2012). Proper resilience strategies could improve benefits to the consumer and society (Wieland & Wallenburg, 2012). A confirmation of the relationship between resilience and performance may guide managers toward best strategies. The results of the Pearson product-moment correlation test confirmed the existence of a positive relationship between resilience and performance.

The results of this analysis could provide a basis for SCM investment and may lead to positive economic benefits through lower costs and risks.

The appearance of outliers suggests the potential for adverse financial effects with low resilience. Economic losses are related to disruptions (LeBlanc & Linkin, 2010; Omer et al., 2012; Pant et al., 2011; The Business Continuity Institute, 2012). The appearance of outlying cases suggest that even without evidence to support investment in resilience from lower costs or higher performance, reduction of risks from severe economic loss may benefit companies and consumers. The appearance of outlying cases support the objective of the *National Strategy for Global Supply Chain Security* to reduce vulnerability from severe losses from disruptions. Reduced vulnerability of the supply chain will improve the economic health and social well-being (The White House, 2012).

Recommendations for Action

Supply chain managers and government policy officials could benefit from the results of this study for contribution to future business practice and social change. For supply chain strategic leaders, the existence of a relationship between resilience and performance could support investment in resilience programs. Outlying cases appearing in the data highlights potential for adverse financial effects from lack of resilience and supply chain disruptions. Managers can adjust SCRM analysis and implement resilience strategies based on risk, in the absence of confirmed financial performance linkage (Wagner & Neshat, 2010). Government officials may adjust policies and programs supporting the *National Strategy for Global Supply Chain Security.*

Strategic level supply chain leaders and government officials may subscribe to professional organizations to share relevant information. These groups include formal industry professional groups, government partnership groups, and informal industry collaborative sites. The most efficient method to share the findings of this study is by contacting leaders or moderators of professional organizations. An executive summary of the study results could contribute to further discussion amongst industry leaders and government officials on the merits of investment in resilience strategies.

Business researchers may also benefit from the study results. The existence of a relationship between resilience and performance corroborates trend analysis on resilience. The appearance of outlying cases and the effects of outliers could highlight areas of concern for companies or industries with low resilience and at risk of large financial loss. Study in the area of outlying cases could lead to improved business practices.

Recommendations for Further Study

The specific business problem was managers need to know if resilience programs lead to improved performance to assist them in development of appropriate strategies. The results of this study confirmed the relationship between resilience and performance. Further research using longitudinal financial data may support my findings. Asymmetrical data sets are common with financial data, and more sophisticated statistical methods can be used (Xiong & Idzorek, 2011).

Business managers also need to understand which resilience programs are most effective. Few quantitative studies exist on the level of resilience practices needed (Blackhurst et al. 2011) and the financial effectiveness of different approaches

(Hendricks et al., 2009). The appearance of outlying cases from this study may show the potential relationship between low resilience and adverse financial outcomes. Future studies should continue to focus on resilience programs and performance and on the positive performance outcomes from higher levels of resilience. Future researchers may require more complex financial performance models. Future researcher could focus on the utilization of benchmark performance data to isolate variations in performance.

A need exists to identify financial measures of resilience (Pettit et al., 2010). This study may contribute to the refinement of financial measures for resilience and performance. Wieland and Wallenburg (2012) developed subjective measures of resilience from survey data. Pettit et al. (2013) developed similar measures from focus groups. Furthermore, Cabral (2012) identified qualitative KPIs for resilience. However, financial measures are the most objective (Calantone & Vickery, 2010).

The most useful information for business managers would be the determination of cause and effect if increased resilience did lead to improved performance. Difficulty exists to establish causation with financial data in identification of appropriate elements to measure covariance. This study entailed observation of resilience over a 10-year period, distinctively marked with two key supply chain and financial disruptions. These observations may have improved understanding of resilience over time and were not sufficient to determine causation. Further research using a case study method may serve to identify significant financial metrics for companies experiencing disruptions.

Reflections

Development of a quantitative model with company level financial data presented some unique research challenges. The study entailed examination of the relationship between four financial variables from secondary financial information of a sample of 300 companies operating in the U.S. supply chain during a 10-year period. Development of variables, identifying a population for random selection, and preparation of financial information and focus on the business problem were research challenges.

Universally accepted financial measures for the variables were not evident in the literature, and financial measures appeared in academic studies and business research with sufficient frequency to establish a pattern. Additionally, another challenge was expanding the supply chain population beyond previous studies with focused on manufacturing. Both challenges served to expand my understanding of the methodologies in current literature and observe how scholars overcome limitations.

There were unique challenges with using financial data. Direct access to data services such as Wharton Research Data Service, which includes COMPUSTAT® S&P, is instrumental for research. Access to the database directly could have provided insight into different potential variables. Access to a database was not available, and a custom dataset served as the foundation for the study. Future researchers would benefit from direct access to financial databases.

The importance of maintaining focus on the application to business practice was also a critical lesson. There was potential to address the academic dialogue in areas such as SCM, SCRM, risk management, inventory, and finance, all related to the research

problem, but not crucial to the research question. The purpose of the doctoral study was to examine a business problem and its relation to business practice, an essential part of research and analysis.

Summary and Study Conclusions

For this study, the results indicated a positive relationship between resilience and performance. The dataset was asymmetrical; a Pearson product-moment correlation test on data transformed by RIN provided results. A relationship exists between resilience and financial performance. The appearance of outlying cases represent a potential link between low resilience (unstable DOI/C2C) and negative performance (OM/ROA). For outlying cases, a possible connection between low resilience and adverse financial performance may exist.

The findings could assist managers in developing appropriate risk management strategies to prevent against financial loss from disruptions. The findings could also aid government leaders' efforts to adjust policies and programs supporting the *National Strategy for Global Supply Chain Security.* The results may also guide business researchers and scholars towards a refined measure of resilience and improved future business practice.

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Curriculum Vitae

Michael Paulovich

Professional Experience

Director, Program Management Office Dept of Defense, Washington, DC	Nov 2011 to Present
Project Manager/Bus Analyst Battelle Memorial Institute, Arlington, VA	Jun 2008–Nov 2011
Maritime Security Analyst Cubic Applications, Inc., San Diego, CA	Feb 2008–June 2008
Proposal Manager/ Consultant 3D Risk Solutions, New York, NY	2007 to 2008

Military Experience

United States Marine Corps	1979–2007

Education

Harvard University	AB Cum laude in Economics	1979
Webster University	Master of Arts (Management)	1983
	Master of Business Administration (MBA)	1999
Naval War College	Master of Arts (National Security and Strategic Studies)	2002
Walden University	Doctoral Candidate	2014

Executive Education

Harvard University	Kennedy School of Government Senior Executive Fellows Seminar	2014

Certificates and Training

- Project Management Professional (PMP®) — April 2009
- Seminar on Next Generation PMO — 2010
  conducted by Project Management Institute
- Six Sigma Green Belt Certification — June 2011
- ISO 28000 Lead Auditor Training — August 2010/July 2011
  (RABSQA-AU, TL,SCY,RES/ Supply Chain Security, Organizational Resilience)
- FEMA Emergency Management Institute IS-00120.
  An Introduction to Exercises (HSEEP)

Professional Association Memberships

- Project Management Institute–member
- ASIS International–Associate
- U.S. Rowing Association Referee