LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY LUT
School of Business and Management
Master's program in Supply Management

Shehrin Saleh

WHAT FACTORS INFLUENCE SUPPLY CHAIN RESILIENCE

Master’s Thesis

2021

Examiners: Professor Jukka Hallikas
Professor Katrina Lintukangas

ABSTRACT

Author: Shehrin Saleh

Title: **What factors influence supply chain resilience**

Faculty: LUT University School of Business and Management

Degree program: Master's Program in Supply Management

Year: 2021

Master's Thesis: Lappeenranta-Lahti University of Technology,
62 pages, 8 figures, 11 tables

Examiners: Professor Jukka Hallikas
Professor Katrina Lintukangas

Keywords: Supply chain resilience, supply chain disruption, influencing factors of resilience, capabilities, risk management, data analytics, sustainability.

The main objective of this thesis is to identify the factors that influence supply chain resilience. This research is quantitative in nature, and primary data was collected via a survey from 147 businesses in eight distinct industries located throughout Finland. Theoretical framework consists of resilience in supply chain management, supply risk management, data analysis and sustainability practices. The data were analyzed in both descriptive and explanatory ways. Statistical tests indicates that there is positive relationship among resilience and data analytics, risk management and sustainability practices. The article concludes by discussing how these findings can be used to influence and steer effective changes that increase a company's resilience to deal with any type of disruption.

Acknowledgement

I would like to express my gratitude to my supervisors, Professor Jukka Hallikas and Professor Katrina Lintukangas, for their constant support throughout the master's thesis writing process. I consider their valuable guidance and detailed feedback throughout the process. For me, writing a master's thesis was an engaging task and an invaluable learning experience.

I would like to express my gratitude to my family and close friends for their unwavering support. They encouraged me in remaining focused and motivated me when I require help.

Finally, I want to express my gratitude to LUT University for teaching me so many new things during this period, which has expanded my knowledge and allowed me to grow both personally and professionally.

In Lappeenranta, 21.06.2021
Shehrin Saleh

Table of Contents

1. Introduction 8

1.1 Research aim, questions, and limitations 9

1.2 Conceptual Framework 9

1.3 key Definitions 10

1.4 Research Methodology 11

1.5 Structure of the study 12

2. Literature review 14

2. 1 Resilience in Supply Chain Management 15

2.2 Resilience Factors 19

2.2.1 Data Analytics 20

2.2.2 Risk Management 23

2.2.3 Sustainability Practices 25

3. Research Design and methods 28

3.1 Research Design 28

3.2 Questionnaire, Data collection and analysis 29

4. Empirical Result & Analysis 32

4.1 Factor analysis 37

4.2 Correlation and Regression Analysis: 40

4.3 Hypothesis Testing 45

4.4 Reliability and Validity 46

5. Discussion and conclusion 48

5.1 What factors influence supply chain resilience? 48

5.2 Managerial recommendations 50

5.3 Limitations and suggestion for future research 51

References 53

List of figures

Figure 1 Theoretical framework

Figure 2 Structure of the study

Figure 3 Difference of resilience continuity and crisis management

Figure 4 Industry perception of Data analytics

Figure 5 Industry perception of Risk Management

Figure 6 Industry perception of Sustainability Practices

Figure 7 The conceptual model with t and p value

Figure 8 Normal distribution in graph

List of tables

Table 1 Summary of background of the industries in terms of industry name, revenue, and employee number

Table 2 Descriptive table by component group – Data Analytics

Table 3 Descriptive table by component – Sustainability practices

Table 4 Descriptive table by component group – Risk Management

Table 5 Descriptive table by component group - Resilience

Table 6 Summary of exploratory analysis, validity, and reliability

Table 7 Pearson’s correlation matrix for relations

Table 8 Model summary table - strength of the relationship

Table 9 Analysis of variance for statistical significance

Table 10 Coefficients- Strength of the effect independent variable ton the dependent variable

Table 11 Cronbach’s alpha values of factor analysis

1. Introduction

Supply chain needs to be more responsive to deal with the modern complexities of the current business world. Novel technology, new variables are frequently altering the environment in which the businesses work in. Moreover, with the on-going pandemic situation it is more necessary than ever to utilize study supply chain resilience as a tool to deal with and to recover from the damage. Understanding of supply chain resilience is becoming increasingly critical for supply chain managers. This is because contemporary supply chains are becoming increasingly complex, increasing the likelihood of experiencing a disruption.

Started as an operational function, over the years supply chain has become one of the most important strategic functions of an organization. With the growing complexity of today's business environment, it has developed into a determinant of success in business that some scholars claim that the competition is between integrated supply chains instead of individual companies (Mangan and Christopher, 2005). Even a small disruption in the supply chain process flow can have a major impact in the whole product flow system (Bullwhip effect). Pandemics, natural disaster, technological failure, transportation delay and/or failure, price fluctuation, cyber-attacks are some examples of disruptions that can lead to uncertainty on a local or global scale. For example, the covid-19 global pandemic created an outcry in the supply chains of many businesses all over the world. When a disruption is announced average shareholders return drops to 7.5% and after four months average loss grows to 18.5% (Singhal and Hendrick 2002). Here comes the role of a resilient supply chain management to cope with the altered situation. Prior research works acknowledge resilience in supply chain operation as a way to minimize damage and recover during unforeseen crisis times (J.S. Rha, 2020). Prior studies regarding supply chain resilience have focused on how businesses recover through resilience in crisis and relations between organizational performance and resilience. Few studies in the risk management literature have empirically explored the backgrounds of the concepts of resilience. Moreover, study related to factors that influence resilience in supply chain is scarce specially data analytics capability, sustainable practices (Negri et al., 2021), (Fosso Wamba et al., 2018). This research will look though articles that discusses supply chain resilience in different disciplines and try to find factors that influence this resilience.

1.1 Research aim, questions, and limitations

The main objective of this research is to discover the various components that have an impact on supply chain resiliency in a business. The literature review demonstrates that supply chain resilience has developed into a distinct subject over the last decade, but it also demonstrates the importance of additional research, particularly empirical research. The subject of influencing factors that enhance supply chain resilience has triggered a lack of empirical research to date. The study will attempt to investigate the factors that can affect a supply chain's resilience. As a result, the primary research question addresses the issue directly. Main research question:

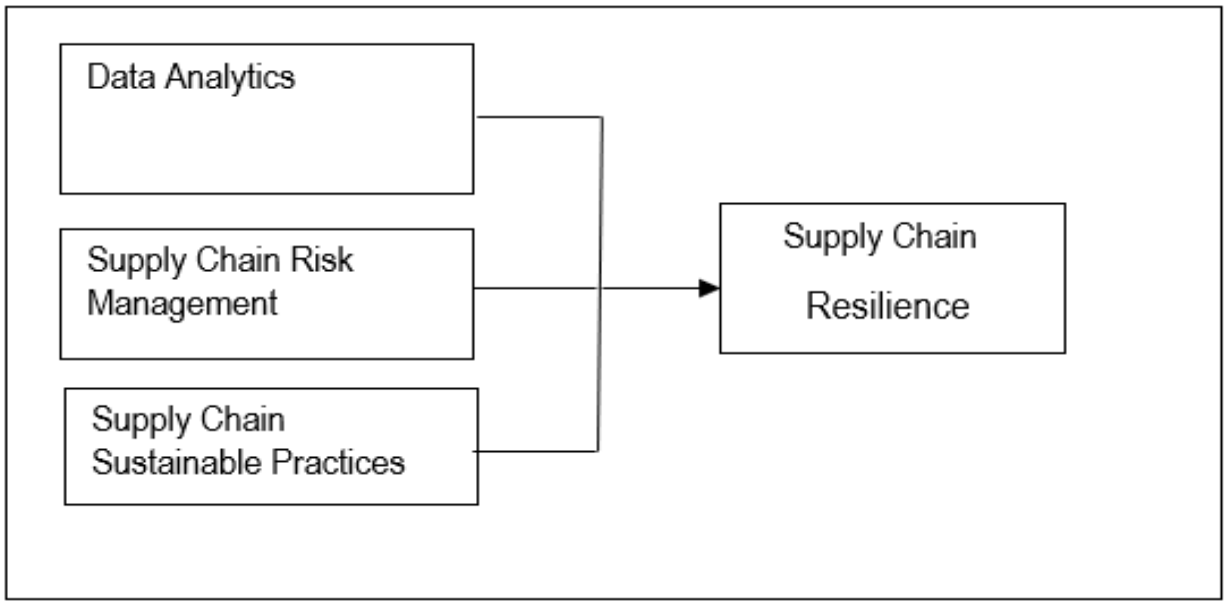
- *What factors influence supply chain resilience?*

To find the answer to this question following several hypotheses are developed based on extant literature. Through the theoretical framework presented in this thesis along with the above-mentioned questions, that form the core of the empirical study, the goal is to check the factors and their connection with resilience. There are several factors mentioned in different literature from various dimensions that are related to increased supply chain resilience. However, this study focuses on three major factors, which can be viewed as one of the study's major limitations. Furthermore, all the companies surveyed are located in Finland, limiting the scope of the observation.

1.2 Conceptual Framework

The theoretical framework for this thesis is based on relevant literature review about the topic. Recent supply chain resilience research has emphasized the importance of IT capability, collaboration, risk management, sustainable supply chain practices, and market position as factors affecting supply chain resilience (Ali et al., 2017). This paper will examine several of these factors and the nature of their relationship with supply chain resilience. Data analytics, supply chain risk management, and sustainable practices will all be examined because they are critical factors that positively impact supply chain resilience.

Figure 1: Theoretical framework



1.3 key Definitions

This chapter defines and describes key concepts in order to facilitate the reader's reading experience. Concepts are studied from a theoretical standpoint, which is relevant to this thesis context. The following chapters provide in-depth analyses and discussion of related concepts.

Resilience

The capability of a strained body to recover its size and shape after deformation caused especially by compressive stress (Oxford English Dictionary).

Supply chain resilience

The supply chain's adaptive capacity to anticipate unexpected events, react appropriately to disruptions, and recover from them by ensuring operations continue at the optimal level of connectivity and control over structure and function (Ponomarov & Holcomb, 2009).

Data analytics capability

The analytics capability is defined as the set of tools, techniques, and processes that enables an organization to process, organize, visualize, and analyze data in order to derive actionable insights (Srinivasan and Swink 2018).

Sustainability practice in supply chain

Sustainable supply chain management is defined as the process of planning, conducting, and regulating corporate value creation processes across the entire supply chain by incorporating economic, environmental, and social factors into decision-making with the goal of enhancing long-term performance and mitigating risks (Negri et al., 2017).

Risk management practices

The process by which a supply chain is prepared to prevent a disruption and, in the event of a disruption, to establish an adequate response and recovery system is referred to as supply chain risk management capability (Manhart, 2017).

1.4 Research Methodology

In a study, the problem is initially presented in a broad, generalized manner. Following the feasibility review, a working formulation can be created to transform the broad topic into a particular research issue, which is an important phase in the research. After the problem has been established, the literature review to be done in light of previous research. This will aid in the creation of a viable research hypothesis.

This thesis will look at what are the factors that influence SC resilience of companies and quantitative method has been chosen as the research methodology. 82 articles have been reviewed for this study. Around fifty percent of those studies used a qualitative method, relying heavily on literature reviews and conceptual analysis. The remaining studies were conducted quantitatively, with the primary data collection methods being survey and case study. This gives us a good base to conduct a quantitative review to justify the connections among different variables to the key concept that is, in our case, resilience. This research was conducted by questionnaire

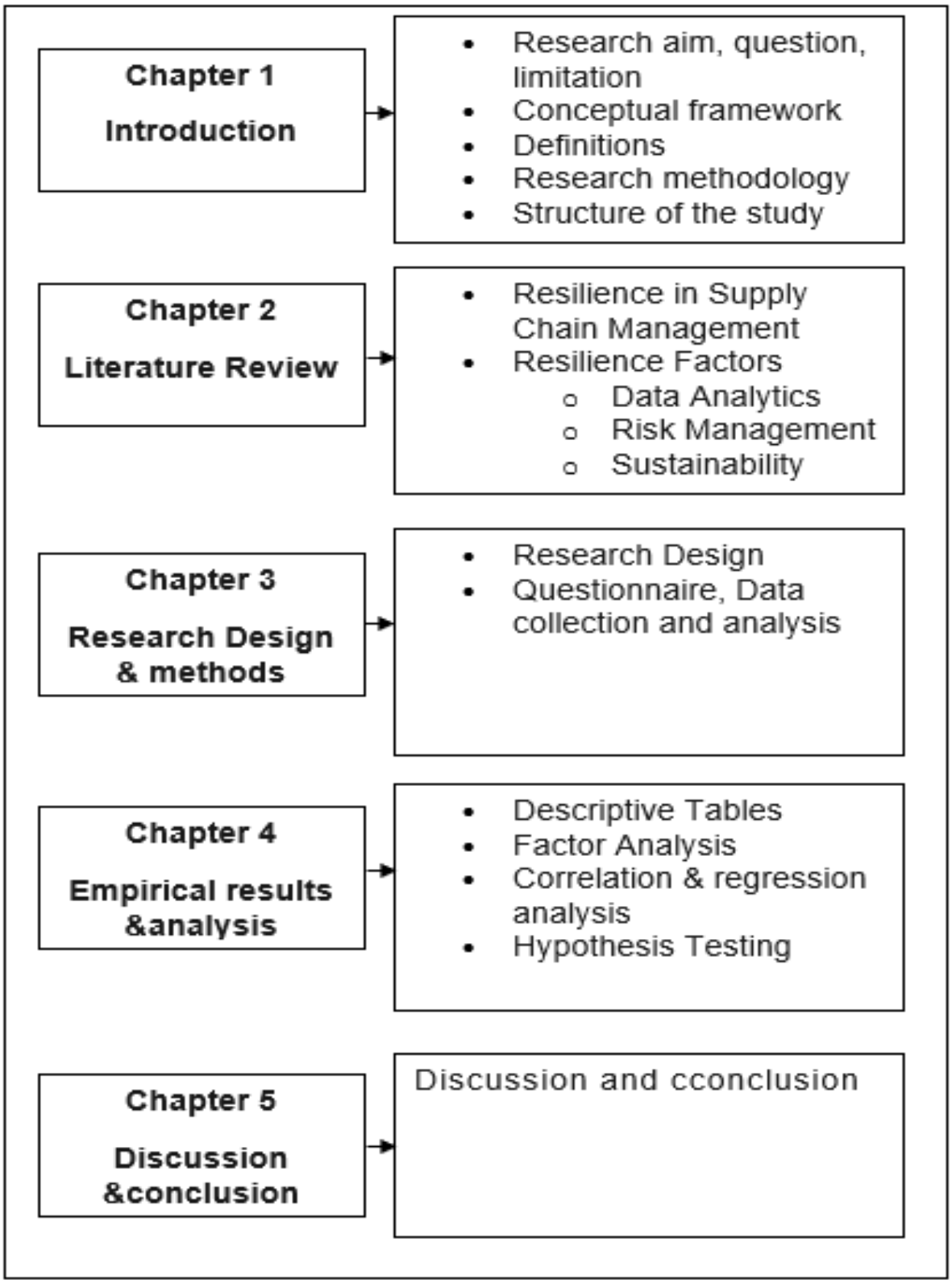
in different companies in different industries. The aim of this study is to find out the determining factors that influence resilience in supply chain management.

Previous studies are analyzed as part of the literature review. Supply chain management and its objectives are covered in short in the literature review section; supply chain resilience, risk management for resilience, strategy for dealing with events are discussed in detail. Following the literature review, a survey is conducted to collect data from companies. The survey questionnaire was developed in a 5-scale Likert format. Correlation and regression analysis were used to analyze the hypothesized relationships. The empirical study's findings are then summarized in the results section, the results are compared to previous research in the discussion section, and the observations are presented in the conclusions section.

1.5 Structure of the study

The structure of this thesis is shown in Figure 2. The introduction chapter discusses the study's context, research objectives and limitations, methodology, and key concepts. Following that, key concepts are evaluated and summarized in light of academic literature. Following a chapter on research methodology, which covers the rationale for the study's design, data description and collection, sampling, analysis design, and evaluation of the study's reliability and validity. The fourth chapter discusses the empirical findings from the research. The conclusion of this thesis is a discussion chapter in which the research questions are addressed, and additional research ideas are presented.

Figure 2. Structure of the study.



2. Literature review

Some organizations can effectively manage unexpected extreme events while their counterparts collapse in the face of a challenge. It is resilience that makes those organizations successful in dealing with and responding to unfamiliar situations. At organization level, resilience refers to the inherent characteristics to respond to and recover from a distressing situation. Pettit, Croxton and Fiksel, 2013 termed supply chain resilience management as a proactive method that complement and enhance traditional risk management and business continuity planning. The concept of resilience in an organization is not something ad-hoc rather it is the broad range capacity of an organization that enables it to recognize the shortcoming of its system, monitors the performance level and manages to respond to deviation promptly (Vogus and Sutcliffe, 2007). In a resilient organizational surrounding, constant monitoring of environment and stimulating of the unexpected events is done not only to eliminate such situations but also to detect those earlier and to build capacity to pertain to the unanticipated circumstances. However, despite being the greatest contributor of highest level of threats supply chain risks are the under reported to the executive board (Malindretos & Binioris, 2014).

According to (Pettit, Fiksel and Croxton, 2010) characteristics of resilience are diversity, efficacy, adaptability, and consistency. Based on these four core characteristics (Christopher and Peck, 2004) designed a multi-level framework for supply chain resilience; (1) re-engineering system where resilience will be incorporated in a system in advance of disruption (2) without collaboration identification and managing risk is impossible (3) the system needs to be agile in order to react promptly to an unforeseen situation, (4) advanced risk management culture.

Resilient organizations look for ways to improve its capability continuously by testing their assumptions of risk and overall health of the system. Strengthening capabilities, allows an organization to get a holistic look at their process, system, and other internal and external factors which leads to flexibility and avoidance of situations that meddling with the success. According to Stoltz (2004), (Timothy 2010) creating resilient leaders will bring in competitive advantage in the unforeseeable, uncertain and unruly future.

According to Pettit, 2010, (1) supply chain design, (2) enhancing capabilities through focusing on business process management, (3) visibility of demand and supply (4) relationship management of supplier and customer and (5) instilling resilience into the organizational culture are five ways to strategic resilience that is less fragile and more adaptive to changes. Flexibility capabilities enhance resilience: Resilience can be augmented through the combination of alternative production and site plans, as well as by making plans more flexible and versatile.

2. 1 Resilience in Supply Chain Management

Resilience is discussed in different disciplines, but the context is similar. In general, the term resilience refers to the capability to cope with a crisis or return to pre-crisis status promptly. Resilience theory addresses how do people get affected by and adapt to adversity, challenge, risk, and loss. Resilience is mostly discussed considering human behavior in the social environment in various academic journals. However, business resilience is getting more and more attention in present time. In business, resilience means the ability to deal with an adverse situation and continuation of business activity during the crisis situation while safeguarding its people and assets; it also depicts how quickly an organization can adapt and counter the external and internal risks and revert to regular operations (Linnenluecke, 2015). Adjusting to new circumstance and change in environment in the era ever changing business world is one important aspect of business resilience. Resilience planning is part of governance and risk management in a business organization. The adverse situations a business can face are, cyber-attacks, security and data breaches, acts terrorism, climate change, adverse weather, supply chain disruption etc.

Supply chain resilience addresses a variety of risks at various stages of the risk management process within the supply chain analysis unit. Because resilience is a critical component of risk management in the supply chain This viewpoint must also be considered in order to ascertain how it should be incorporated into the conceptual framework of resilience. The supply chain's adaptive capacity to anticipate and respond to disruptions, as well as to recover from them, by maintaining operations at the desired level of connectivity and control over structure and function.

Different authors have described supply chain in different ways. The ability to anticipate the risk, reduce its effect and return quickly by surviving, changing, adapting and growing in turbulence alterations (Day, 2013). Rice and Caniato (2003) described resilience of a supply chain as the capacity to quickly recover from an unexpected disruption, such as a natural disaster or a terrorist attack, and resume regular operations. They emphasized on developing new organizational capabilities as a means of secured and resilient supply chain network. According to them only following mandates and regulations are not enough. They believe that simply adhering to mandates and regulations is insufficient. They cited an example of how Nokia and Ericsson reacted differently in the aftermath of a fire at Philips electrics, which supplied radio-frequency chips. Nokia, by collaborating with Philips to resolve the issue, was able to maintain their sales target, whereas Ericsson suffered a $400 million revenue loss.

A resilient supply chain must be adaptable, as the desired state is frequently not the same as the initial state. The ability to adapt is cited as a critical component of resilient ecosystems. Holcomb and Ponomarov (2009) defines, the supply chain's adaptive capacity to anticipate and respond to disruptions, as well as to recover from them, by maintaining operations at the desired level of connectivity and control over structure and function. According to Mangan and Christopher (2005), resilient processes are adaptable, flexible, and nimble. Christopher's definition of a resilient supply chain incorporates elements such as a supply base strategy, collaborative planning, visibility, and decision-making that takes risk into account. Responding and recovering in the same or a better state is a characteristic shared by all examined perspectives, including ecological, social, psychological, economic, organizational, and emergency management. Maintaining (or regaining) control over structure and function following a disturbance is a critical property of an ecosystem's resilience. The organizational perspective echoes this theme, stating that resilience is the capacity to maintain desirable functions and outcomes in the face of adversity. While not explicitly stated, the psychological perspective on supply chain resilience also addresses the characteristics of resilience that contribute to direction and comprehension. Control, connectedness, and continuity (coherence) are three psychological principles associated with resilience that are believed to improve response times in the event of natural or man-made disasters.

The adaptive capability's dynamic nature enables the supply chain to recover from disruptions, either by returning to its original state or achieving a more desirable state of supply chain operations. Brandon-Jones et al., (2014) suggest that the adaptive capability of a system enables it to better respond to disruptions and even competitive advantage from them. They stated that tangible and intangible resources aid in capability development, which facilitates in the capture of opportunities and the mitigation of threats, resulting in a competitive advantage.

As a system that connects various specialists from the supplier to the end customer through the use of service and manufacturing in order to ensure adequate material and information flow, it is important for a supply chain is to be consistent. In today's dynamic business environment, supply chains have become more insecure and unpredictable, posing a variety of challenges. If a supply chain is disrupted in any way, it can have a detrimental effect on an organization's economic performance. No matter how minor a disruption is but the impact on production and profitability can be significant. And without a business resilience planning the recovery will be lengthier and costlier. To survive in today's changing market environment, it is critical for organizations to have a resilient supply chain. However, the planning phase can incur some cost, but the opportunity cost is indispensable. An effective business planning will alleviate the impact of causality and restore to the regular operations quicker while keeping the tasks on going during the crisis period. Moreover, it can have impact on overall improved overall performance and minimize risks. It also helps to improve or create a good image among the stakeholders as the company is more confident and committed to better service. So, in the long run a sound resilience planning gives more financial impact by reducing the negative impact on productivity caused due to a disruption.

All businesses possess certain range of risks that can cause different kind of adverse effect from financial loss to reputational damage. Some of the risks that can cause problems are:

- Natural disasters
- Economic disruption and market turbulence

- Terrorist-related incidents and disruption
- Cybercrime and cyber terrorism
- Civil emergencies, strikes, and similar actions
- Pandemic threats, including SARS, Avian Flu, COVID 19
- Compliance failures
- Disruptive technological advances
- Technology failure
- Supply chain failure

Business resilience planning refers to the guidelines that enables an employee to respond, resume and restore to a pre-determined level of operation following a disruption. Business resilience planning is the broader cultural approach toward business continuity planning which incorporates both crisis management and business continuity. Business resilience planning can be a success factor for and organization which leads to competitive advantage. This starts with identifying essential functions of the organization and prioritizing what is critical to be performed in the time of distress. It is equally important to know which business function, personnel and resources are compulsory to stay in business and what can drive out of business. One of the most crucial steps in resilient business planning is to find out the most vulnerable component and to understand the minimum level of operation needed to continue activities.

Figure 3: Difference of resilience continuity and crisis management

Business Resilience	**Business continuity**	**Crisis Management**
A tailored strategic risk management approach that integrates many disciplines in one integrated process	A standardized process driven approach that takes care of the continuation of operations in time of a major disruption	Crisis management addresses different natural or man-made crisis

2.2 Resilience Factors

Numerous studies conducted by various scholars identified a variety of factors as indicators of supply chain resilience. Different terminologies, such as capabilities, dimensions, enhancers, enablers or competencies, have used to describe these factors or elements of resilience. A systematic review on supply chain resilience conducted by Ali et. al. 2017 found 17 of such elements. Early 2000's studies emphasized agility, flexibility, robustness, visibility, redundancy, security and supply chain risk management as indicators of supply chain resilience, whereas more recent studies emphasized IT capability, collaboration, sustainability, sensitivity, risk control, and market position. In this study the term ‘capabilities and/ or practices will be used to indicate these factors.

One of the important aspects of the resilience philosophy is that it employs techniques that do not necessarily require exact quantification. Unlike conventional risk analysis, it does not involve a complete enumeration of possibilities or descriptive potential assumptions (Pettit et al.2010). In five ways, strategic flexibility makes it less fragile and more adaptable to transition. In Pettit's opinion those are – 1) Supply chain architecture 2) Focus on business process management to improve supply chain capabilities 3) Demand and supply visibility in the supply chain 4) Relationship management with suppliers and customers 5) Creating a resilient community. Resources backed up by unique capabilities creates value for the firm that helps to achieve or sustain competitive advantage (Wu et al., 2006). Brusset & Teller (2017), showed in their research that there are three main categories of factors that enhance resilience- human capital, organizational and interorganizational and physical capital resource.

To absorb the impact of adverse circumstance, accumulating different resources (including human resource) (M. Linnenluecke, 2015) is important. Vogus & Sutcliffe, (2007), Gittell et al. (2006) established financial resources and a well distribution of its enablers for organizational resilience by giving example from airlines industry of American market after terror attack that financially well-off companies not only faced limited debt but also surpassed their performance levels without cutting back manpower. Competitive advantage derived from capabilities will be more deeply

embedded in the organization's management and processes, and thus more likely to be sustainable than competitive advantage derived solely from resources (Brush & Artz, 1999). Building supply chain resilience is considered a necessary strategic capability for an organization (Sheffi and Rice 2005). In a study, Ravichandran and Lertwongsatien (2005) found that information systems capabilities are required for an organization to effectively use information technology, and that information systems capabilities are dependent on technological, human, and relational resources. Information technology, data analysis ability, sustainability and risk management practices are tactical and operational ways for a firm to bolster capabilities that leads to resilience in the system. Resilience in a supply chain can be viewed as an outcome that is dependent on the respected supply chain's capabilities such as data analytics capability, sustainability performance, and risk management capacity. In this study out of many resilience indicators sustainability performance, risk management capacity and data analytics will be studied.

2.2.1 Data Analytics

The practice of SCM is increasingly embracing big data and business and supply chain analytics to optimize information flows and decision making. It is now regarded as a critical capability for forecasting customer and market requirements in terms of cost, time, and quality (Brinch et al., 2018). Although the concept of applying information and data to supply chain is not new, it is embracing technological advancement in environments with high volumes of multidimensional data (George et al., 2018). A growing number of researchers have pointed out integration of data driven approaches into supply disruption risk analysis as this can be used to predict future and to identify real time events (Ivanov, Dolgui, and Sokolov 2020). Recorded transactions and other activities by the companies in various format like numbers, picture, texts, audio etc. produces massive amounts of internal data. Combining this substantial internal data with the Internet of Things (IoT) provides access to external data sources, allowing for a more holistic view of the business environment in manufacturing, procurement and logistics (Bi and Cochran, 2014, Lamba &Singh 2017). Machine learning, visualization, data mining are some examples of analytics techniques used for management of structured and unstructured data. The data collected and processed is utilized to

identify problems and opportunities, predict patterns of future occurrence and reasoning for those, and determine the best possible outcomes among alternative options (Wang et al., 2016). Data management resources are a critical component of business analytics activities, allowing for data-driven processes that improve operational performance (Chae et al., 2014). Big data, according to Li et al. (2006), can be used from the beginning to the end of any product's life cycle. Big data can be used for procurement, production planning, inventory management, marketing, and even design in the early stages. Big data can then be used to help with warehouse management, transportation, customer and product support, and corrective and preventive maintenance in the following stages. Big data also aids in recycling at the end of the cycle.

Optimization and simulation model used for decision support that are equipped to test existing supply chain designs and the deployment of contingency and recovery policy. Digital technology can impact performance of supply chain by influencing the agility, adaptability, and alignment Dubey et al. (2018). Computerized decision support model can allow end-to end visibility in real time and predict future impact and reaction and improve resilience and test contingency plan. (Brusset & Teller, 2017) found in their research that use of supply chain management software along with information technology tools & routines to integrate internal organization and external stakeholders (suppliers, distributors, customers 3PLs) can help bringing in resilience.

Sanders (2016) identified four applications for big data: source, manufacture, movement, and sale. Data analytics can be used for segmentation of supplier, evaluation of sourcing channel options, integration and negotiation with suppliers as a part of strategic sourcing. Data analytics can also help with better demand planning, and production by generating performance report, capacity constraint analysis, inventory optimization. Supply chain information systems can collect and extract valuable insights from historical data, thereby assisting in timely decision-making (Belhadi et al.,2020). Big data in supply chains will be a valuable research method in the future (Richey et al., 2016; Hofmann and Rutschmann, 2018). Boone et al., (2019) discuss crowdsourced data as a game-changing data tool available to supply chain analysts, but few examples have been published thus far (Sternberg and Lantz, 2018). As Lechler et al. (2019) point out, data accuracy is becoming increasingly important

as statistical models become more general. Additionally, it highlights the importance of algorithms capable of handling datasets that are not intended for scientific research, such as those with missing or inaccurate data points.

Thanks to modern technology, we now have a high level of accessibility, data quality, and clarity. As a result of these benefits, IoT, digital twins, block chain technology, and other technologies may help to increase the durability of supply chains (Hofmann et al.,2019). Handfield et al. (2019) used three references to contextualize the changing landscape of procurement analytics (interviews from executives, a study of new and emerging infrastructure channels, and a survey of chief procurement officers). Despite their discovery that procurement analytics will continue to improve, their research revealed that advanced procurement analytics are underutilized, and data quality and consistency issues are impeding significant analytics advancements. They concur those current ad hoc methods for capturing unstructured data should be replaced by a dedicated data governance framework, and that organizations should implement a dependable, systematic approach to acquiring and maintaining trusted organizational data focused on internal expenditure reviews and contract databases. Additionally, the report cited a plethora of accessible channels that could not always be combined as a source of complexity. When paired with a discussion of metrics, new research questions about the cost and complexity of increased data access, as well as the resulting need for analytics, emerge. Lechler et al. (2019) employ a Delphi analysis methodology to examine how real-time data collection reduces SCM uncertainties in real-world situations, thereby addressing the challenges associated with gathering suitable, timely, and accurate data in volatile, uncertain, complex and ambiguous environments. The "uncertainty paradox" is worth noting for researchers and clinicians: on the one hand, increased real-time data may be beneficial for reducing supply chain uncertainty, but such data frequently introduce new complications, which are defined as data-related uncertainty. As demonstrated by leading journals in the field of machine learning (an extension of Artificial Intelligence) in supply chain networks, the emphasis is on inference rather than explanation based on existing theories. Machine learning is a term that refers to a system or algorithm that learns automatically and recognizes patterns that enable real-world prediction. According to Handfield et al. (2019), supply chains may transition from optimization to prediction, which supply chain analysts may welcome. This almost certainly necessitates a shift

in SCM toward more inductive analysis methods. According to Stank et al. (2019), a greater emphasis on robust execution and application of inductive methods is likely to result in some of the recent demands for increased managerial relevance in supply chain research being met.

It is assumed that with improved digitalization, automation, analytics practices a company can improve its technological capabilities and technological capabilities has a positive relationship with resilience. Thus, the first hypothesis to test is:

Hypothesis 1: Data analytics has positive relation with supply chain resilience.

2.2.2 Risk Management

Supply chains have undergone various changes as a result of industry globalization, which demands numerous value-adding procedures, thus increasing supply chain vulnerability (Singh Srai and Gregory 2008). The more complicated a supply chain is, the more susceptible it is to vulnerability. Resilience is a novel concept that is distinct from conventional risk management. Since the 1970's, risk analysis techniques have played a significant role in corporate decision-making, particularly when combined with financial models (Carter, Hertz and Thomas, 1984). To begin, it defines all possible outcomes of a project by calculating and comparing potential returns to potential risks associated with the investment (Carter 1972). Currently, the leading approach to enterprise risk management comes from the Treadway Commission's Committee of Sponsoring Organizations (COSO 2004). A typical view of the traditional risk management process is as a cycle beginning with hazard identification, followed by risk assessment, control analysis, control selection, and control implementation, and finally review, which is continuous improvement providing feedback to step 1. Risks can be quantified using historical data or by making additional assumptions based on the data and subjective information. However, it will be extremely difficult to apply this to each link in a global supply chain in order to account for every possible disruption. Risk assessment is a critical step in the risk management process because it determines the estimated severity of the event. Additionally, the conventional risk assessment approach is incapable of dealing with unpredictable events, which is its

primary shortcoming. The concept of supply chain resilience can be used to supplement an existing risk management system and address weaknesses. Enabling supply chains to withstand unforeseeable disruptions can significantly boost competitive advantage. To build a resilient supply chain, one must take the initiative, and each organization should have a board member with a thorough understanding of risk, an element of SCR, and the supply chain structure (Choi and Hong 2002).

The firm can integrate the risk management system with the firm's stakeholders. Particularly, supply chain integration will strengthen its resilience to numerous anticipated incidents (Zhu et al., 2017). According to Lavastre et al., (2012) the supply chain must be resilient to certain risks. As a result, identifying risk factor is important. Generally, supply chain challenges are divided into two categories: operational risks and disruption risks (Paulraj, Chen and Lado, 2012; Tang, 2006). Operational threats are those that arise as a result of insufficient or failed processes, people, and systems (Zhao et al., 2013). Three primary sources of supply-demand volatility in a supply chain are upstream from supplier production, downstream from customer demand, and internally from the focus firm's procurement and distribution processes (Germainet al., 2008). Additionally, all supply chain participants face competitive/technological risks, which pose operational risks. Competitive and technological challenges, manifested in the magnitude of unexpected technological advancements, have the potential to quickly render existing technology obsolete. To stay ahead of the competition, businesses must develop their creative capabilities through their trading relationships (Jean et al., 2012). Disruption challenges are environmental issues that have a negative impact on the overall business climate across industries (Ritchie and Marshall, 1993). Regulatory threats resulting from rule changes, infrastructure risks resulting from human-caused issues (such as strikes and industrial accidents), and catastrophic risks resulting from terrorist attacks, epidemics, and flooding are all examples (Wagner and Bode,2009). To achieve a balance of coverage and condensation of all risk sources: organizational risks (i.e. risks associated with the focal organization's production and/or distribution), industrial risks (including demand/market risks, supply risks, and competitive/technological risks). Rao and Goldsby's (2009) illustrates supply chain risks, which ranges from the organization itself to the environment (that affect the overall business context across the supply chain).

Researchers from Cranfield University School of management argues that the recent trend of globalization and focus on cost cutting due to lean manufacturing have negative effect on supply chain risk. Management tool like this is inflexible and creates resistance to change. The lack of excess inventory leads to not only lesser opportunity for innovation but also lesser safeguard against disruptions. Moreover, in their findings they claim that there is a lack of understanding of the impact of a strategic business decision has on supply chain vulnerability, manager's focus on internal risks in deciding general strategy and also continuity planning led to increased supply chain vulnerability. Supply chain is vulnerable to both internal and external risks and concurrent occurrence of both intensifies damage to the system. Through a coordinated risk management approach among supply chain these risks can be identified and managed thus reducing the vulnerability. According to researchers at Cranfield university School of management (2002), identified some issue that nurtures the resilience mindset in an organization risk awareness in the executive level, integrate risk management as an integral part of supply management, ownership and awareness at all employee level and understanding the co relation between business strategy and risk profile. However, unlike traditional risk analysis the concept of resilience does not need quantification of assumptions of a descriptive future (Pettit et al.2010). Supply chain risk management continues to be a significant managerial challenge that has a direct impact on an organization's performance (Altay & Ramirez, 2010). Therefore, the third hypothesis is,

Hypothesis 2: Risk management improves supply chain resilience.

2.2.3 Sustainability Practices

The environmental impact of supply chain has become a growing concern as global warming and its effects have gained international recognition and businesses have been expected to incorporate sustainability in their activities. In General, sustainability is defined as utilizing resources that are capable of mitigating current problems without depleting resources that should be used to mitigate future generations' problems (Hohenstien et al. 2015; Kusrini and Primadasa 2018). Supply chains, ideally, would

address the three dimensions of sustainability (economic, environmental, and social) by incorporating the three types of objectives into their strategy. As a result, it is necessary to integrate resilience and sustainability into supply chain management in order to boost competitiveness (Zavala-Alcívar et al. 2020). Available energy sources, water consumption, supplier's Green House Gas emissions performance are some of the environmental criteria, labor practices and decent work, human rights, and product responsibility are some examples considered as social criteria. This alignment and integration of environmental management practices into traditional Supply Chain Management practices such as natural resource conservation, pollution reduction, and product recycling, is known as Green Supply Chain Management (GSCM). All of the supply chain activities like production, packaging, logistics, sourcing, product design have impact on environment. GSCM is predicated on the understanding that an individual business's environmental impact extends well beyond its corporate boundaries. Businesses adhering to green principles must ensure that the goods and services they purchase (3PL services) come from suppliers who adhere to minimum environmental standards. A green supply chain perspective not only helps reduce environmental impact, but also increases profit by reducing waste in various processes (Hafezalkotob A., Zamani S., 2018). Businesses must understand and manage their greenhouse gas emissions in order to comply with reporting and regulatory requirements (i.e., ISO 14000, PAS 2050, Carbon Trust 2006), maintain a sustainable competitive advantage, and be prepared for future government climate change policies.

Green supply chain practices include green product development, green packaging and eco-labelling of products, supplier audits, and proper workplace and employee involvement management etc (Sharma M.M., 2013). Green supply practices can be classified into two categories: green design and green operations. Green design takes a systematic approach to environmental impact; life cycle assessment and environmentally conscious design are two aspects. Green operations usually deal with manufacturing with appropriate materials and technologies that helps to conserve resources and to re-use waste produced from one production in another one to create something valuable. Waste management being an important part of green supply chain is considered as a measure to reduce hazardous waste generated as a byproduct of the manufacturing process and operations and then treated, arranged,

or disposed of. Waste reduction can be accomplished at the source, or pollution can be avoided at every stage of an organization's procedures (Sharma M.M., 2013). including upstream suppliers. Waste management focuses on waste prevention rather than waste management after it has been generated. So, it is important to have reduce waste at suppliers end as well. To ensure sustainable practices at the supplier's end, the purchasing contract should include a clause requiring the supplier to follow regulatory environmental requirements and incorporate environmentally friendly methods into all of its operations. Supplier audits can be performed by the core company or by a third party to ensure that the supplier is adhering to the terms of their contract.

Numerous security benefits accrue to both providers and manufacturers as a result of sustainability procedures (Khorasani and Almasifard 2017). Jain et al. (2017) facilitated understanding of how sustainability contributes to supply chain resilience. It aides in the selection of higher-quality products and the reduction of waste and dangers throughout an organization (Hafezalkotob and Zamani 2018). A study by Fahimnia &, Jabbarzadeh, (2016) shows that practicing sustainability helps to build a resilient supply chain environment. Number of studies in SCR have demonstrated that flexibility is critical for supporting dynamic skills and maintaining the critical link between sustainable competitive advantage and integrated competences (Yang et al. 2018). Managing the carbon footprint of products throughout the supply chain is critical for businesses seeking to reduce carbon emissions and mitigate the effects of climate change. Sustainable practices in supply chain contribute to increased agility by mitigating risks and thus accelerating innovation. Increased adaptability as a result of a green supply chain leads to innovative processes and continuous improvements, which in turn supports supply chain resilience. This leads to the fourth hypothesis,

Hypothesis 3: Better Sustainability practices leads to higher resilience capacity.

3. Research Design and methods

In this chapter research design and methods are discussed. Research design, questionnaire, and data collection methods are described, followed by an examination of how the data were analyzed. Finally, reliability and validity of the research is analyzed.

3.1 Research Design

The theoretical segment of the study (the literature review) presented in previous chapters serves as the foundation for the empirical portion of the study. An empirical study was conducted to ascertain the relationship between supply chain resilience and a firm's various capabilities and to address the research questions. The research was conducted by conducting surveys in over a hundred companies located throughout Finland and representing a variety of industries. Quantitative research is used in this study and to test and explore relationships between the variables, regression analysis was used as the data analysis method. The research design directs the implementation of a research method and the subsequent data analysis (Bell, Bryman & Harley, 2015). This includes the objectives derived from the research questions, the sources of data collection, the research constraints, and any ethical concerns. Following that, the research methods will be determined, including the data collection techniques and the most appropriate method of data analysis. (Saunders, Lewis, and Thornill 2009). The first step is to choose between qualitative, quantitative, or mixed methods. The empirical research conducted in this study is quantitative in nature. Quantitative research is a distinct method of investigation that entails the collection of numerical data and the establishment of a link between theory and actual events using deductive approach. The primary objective of quantitative research is to suggest that a hypothesis (or set of hypotheses) is deduced from the theory and then tested using numerical data collected. If the quantitative analysis of the data is to be performed by a computer, 'Codes' act as tags that are placed on data about individuals to enable the information to be processed by the computer (Bell, Bryman & Harley, 2015). Once the test is done, techniques of quantitative data analysis is used to test the relationship between variables. At final stage, the researcher interprets the result of the data

analysis and discuss about the implications of the findings. This study is based on survey which is one of the most used quantitative research methods in business economics. A survey design provides a quantitative description of a population's trends, attitudes, and opinions, or tests for associations between population variables, by examining a sample of that population. Three types of questions are addressed by survey designs: (a) descriptive questions; (b) relationship variable between; or (c) relationships between variables over time. According to Saunders et al. (2016), research can be exploratory, descriptive, or explanatory in nature. This research is exploratory in nature, as there is already published literature; however, this study aims to describe how the phenomena is perceived in businesses, providing a deeper understanding of the field.

This study roughly follows research process steps introduced by Bell, Bryman & Harley, (2015). The procedure begins with the formulation of a preliminary research problem. The most critical stage of the study is defining the research problem and questions, as they influence subsequent decisions about data collection and research methods in general. The final two stages involve collecting and analyzing data, as well as reporting and presenting the findings. Prior to the empirical portion of the study and data collection, the study's foundation was established by presenting theoretical background and a literature review on resilience in supply chains and indicators of resilience in combining with the research questions and objectives. Following the theoretical section, data was gathered via survey questionnaire and analyzed to determine the answers to the research questions. The stage of data collection and analysis will be discussed in greater detail in the following sub-chapter. Finally, the analyzed data will be compared to prior academic literature findings, and the research questions will be addressed and discussed.

3.2 Questionnaire, Data collection and analysis

Questionnaire was designed around the research problems and the previously introduced relevant literature and theories. As above mentioned, the data was collected using an online survey. The survey was conducted by research team of LUT university in 2020. The survey form contained different questions related to the research problems of this study. The questions were categorized around 12 different

themes that were directly related to, or supported, the research problems. Due to time limitation, this research works with only 4 themes. The themes use for this study are i) Data Analytics, ii) Sustainability Practices, iii) Risk Management, and iv) Resilience. The questions have been carefully considered and designed to be simple to understand. To avoid confusion, the plan was to use straightforward language. There were several questions under each theme to measure the level of different practices the companies follow. A 5-point Likert scale was determined to be the appropriate scale. The respondents rated the claims on a scale of strong agreement to strong disagreement, extreme importance to extreme unimportance, or extreme likelihood to extreme improbability.

After collecting the data, it was imported into SPSS software for exploratory factor analysis. Factor analysis is a dimension reduction technique that enables the examination of relationships between factors that each represent a summary of the original items studied under a single construct (Hair et al., 1998). The principal component analysis method was chosen for this study and varimax is used as a rotation method. The objective was to identify groups, or factors, that best described the variable group. The factor loadings, which are the correlations between individual items and the new factor, are examined, and only items with loadings greater than 0,6, as recommended by (Hair et al., 1998), are kept in the factor. According to Fabrigar et al. (1999), each factor should contain four to six variables. Additionally, a reliability test is conducted to determine whether factors are suitable for further analysis. Cronbach's alpha is used to determine reliability of measures, as it reflects the factors' internal consistency. Cronbach alpha, ranges from 0 to 1 where higher number represents higher reliability. Cronbach's alpha values between 0.70 and 0.80 are considered acceptable, while values greater than 0.80 are considered fairly high, indicating that the measure is reasonably reliable (Hair et al., 1998). Communality attempts to measure the accuracy or validity of a variable. If the value is less than 0,30, the variable is not accurately measured. (Hair et al., 1998). Thus, the successful measure should be greater than 0.30 and, preferably, closer to 0.50. (Fabrigar et al, 1999). The Kaiser-Meyer-Olkin (KMO) test is used to determine the factors' sufficiency. The KMO test has a scale of 0 to 1, with 0.5 representing the model's acceptance threshold. Everything greater than 0.5 represents an acceptable level of factorial simplicity (Kaiser, 1974). For the purposes of this thesis, the mean was chosen as the most

appropriate way to express the data's central tendency. linear correlation analysis is used to determine whether the items considered to be representative of a single factor are correlated and thus suitable for factor analysis. Pearson correlation coefficients can range from -1 to 1, where a negative sign indicates a negative relationship between variables, a zero indicates no relationship, and a plus sign indicates a positive relationship.

The final step in data analysis is regression, which is the most frequently used analysis for examining relationships. Simple linear regression is used to validate the hypothesis. This method was chosen because it is the most appropriate for analyzing the relationship between an independent variable and a dependent variable. The reported coefficients, both unstandardized and standardized, the t-value and p-value, as well as R, R squared, and F–value, all indicate the validity and significance of each relationship studied. The final step in data analysis is regression, which is the most frequently used analysis for examining relationships. Simple linear regression is used to validate the hypothesis. This method was chosen because it is the most appropriate for analyzing the relationship between an independent variable and a dependent variable. The reported coefficients, both unstandardized and standardized, the t-value and p-value, as well as R, R squared, and F–value, all indicate the validity and significance of each relationship studied. Unstandardized beta reflects the change in the dependent variable as a function of the independent variable's unit change. R is the simple correlation coefficient between the independent and dependent variables. R squared denotes the independent variable's level of variance in explaining the dependent variable. Additionally, the p-value is used to determine the significance of the analysis, with $p < 0.05$ denoting significant results. Hair et al., (1998) defines the t-value as a measure of confidentiality, indicating that the coefficient is not equal to zero when the reported level of error is used. The F-value indicates the model's overall significance.

4. Empirical Result & Analysis

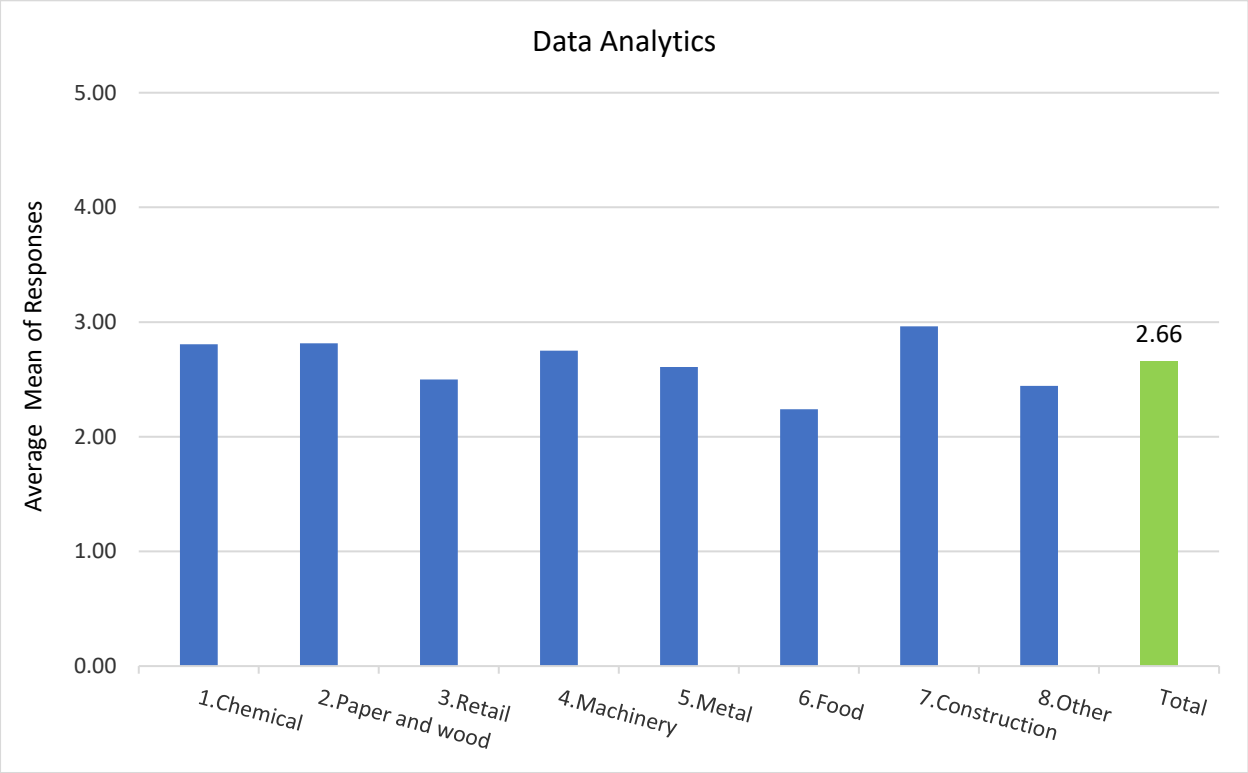
In this chapter, the results of the survey will be analyzed using multiple measurements and statistical methods. Firstly, analysis of the respondent companies is done to get a more comprehensive background. Secondly, explanatory methods are used to investigate the relationships implied by the constructed hypotheses. Factor analysis, correlation, and simple regression are used.

A total of 149 Finnish companies were surveyed for this study who represent 8 industries. Out of these industries, construction, food and chemical industries have the most respondents representing 23%, 18% and 18% respectively of the total number of respondents. In terms of net income industry paper & wood, retail and construction comprises the majority having a revenue of 10-15 million €. When segregated by the number of personnel per industry others, retail and chemical industries have bigger number having around 7 thousand up to around 60 thousand employees. This difference in size by income and employees might not be significant for the result of the study.

Table 1: Summary of background of the industries in terms of industry name, revenue, and employee number

Industry	Number of Companies	Total Revenue by industry	Total Employee Numbers by industry
1. Chemical	26	14,680,918	60,096
2. Paper and wood	12	36,960,747	19,237
3. Retail	12	14,991,328	35,504
4. Machinery	8	3,082,036	7,588
5. Metal	15	8,413,125	16,734
6. Food	27	7,722,558	22,641
7. Construction	34	25,830,769	40,363
8. Other	13	8,245,464	42,260
Grand Total	**147**	**119,926,945**	**244,423**

Figure 4: Industry perception of Data analytics



Figures 4,5, and 6 show the perception of the respondent companies about the data analytics, sustainability practices and risk management. From the graphs it is clear that sustainability practices and risk management deemed as more important having an average response rate of 3.79 and 3.69 respectively. Whereas the average score for data analytics is 2.66. The construction, paper & wood, and chemical industries have the highest mean for data analytics at 2.96 and 2.81, respectively, while the food and retail industries have the lowest mean at 2.44 and 2.5. Machinery, paper & woods, and other industries assigned a score of 4.1 to 4.3 to risk management. The food industry gave the lowest average rating of 3.31. Finally, the companies in paper and wood industries ranked sustainability practices as the most important, with a score of 4.01; other industries ranked sustainability practices at 4.03.

Figure 5: Industry perception of Risk Management

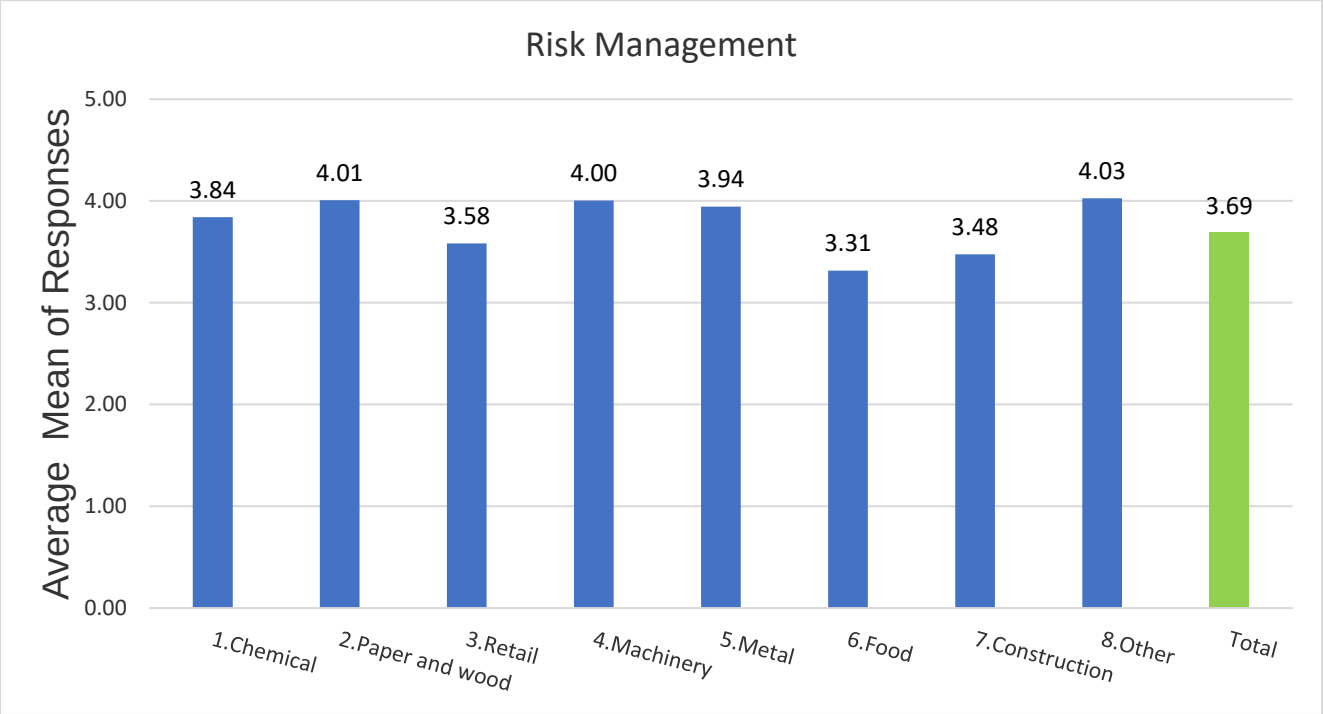


Figure 6: Industry perception of Sustainability Practices

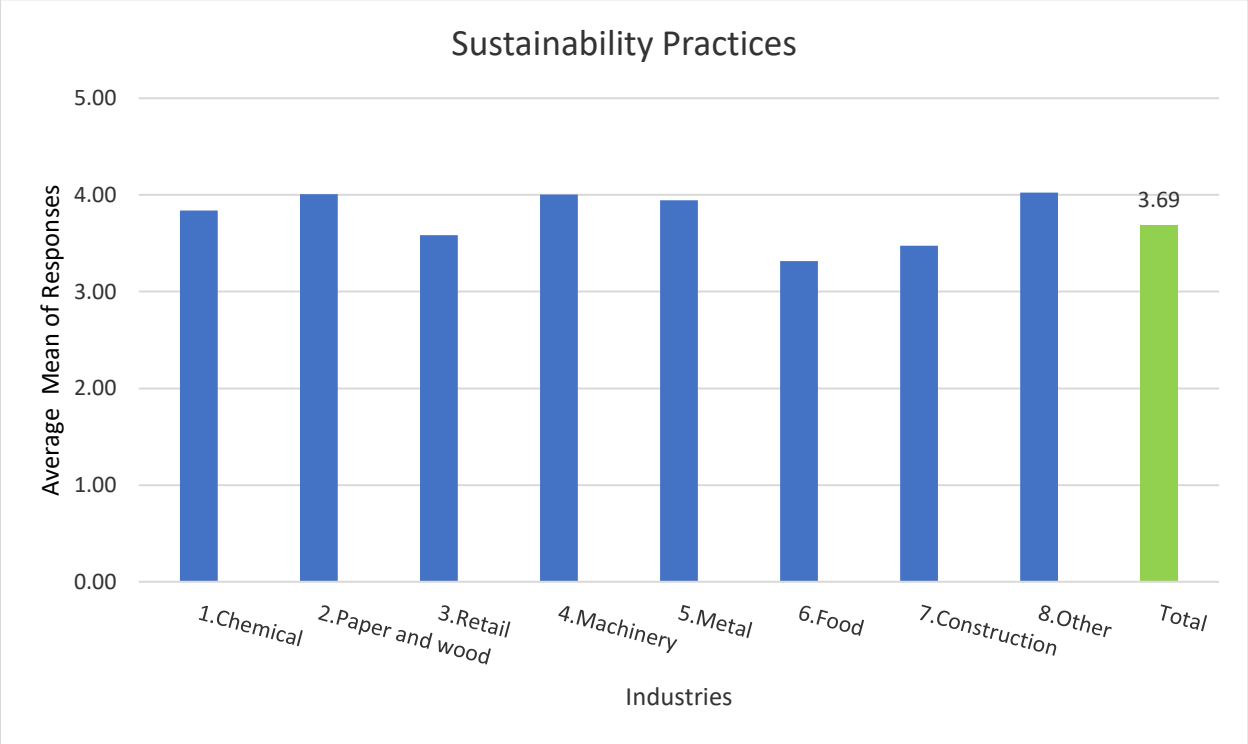


Table 2: Descriptive table by component group – Data Analytics

Component	Attributes	Mean	Std. Deviation
Data Analytics	DA 1	2.82	1.127
	DA 2	3.29	1.154
	DA 3	2.76	1.150
	DA 4	2.32	1.025
	DA 5	2.59	1.065
	DA 6	2.80	.993
	DA 7	2.51	1.003
	DA 8	2.67	.975
	DA 9	2.17	.954

The Table 2,3,4,5 represent the mean value, standard deviation of the respondents by industry. The responses related to data analytics are presented in table 2. The question asked companies to rate how they utilize data analysis in their operations. Storing large amounts of data had the highest mean (3.29) and standard deviation (1.154). This implies that although the responses were spread over the widest range, they also indicated higher levels of use on this item compared to the other. Conversely, using data analytics to discover explanatory and predictive patterns had the narrowest range of responses with standard deviation of 0.954 and was used the least with the lowest mean rating of 2.17. All items were positively skewed except Storing large amounts of data which was negatively skewed. Overall, there are no significant issues with the normality of the data for the data analytics scale.

Table 3: Descriptive table by component – Sustainability practices

Component	Attributes	Mean	Std. Deviation
Sustainability Practices	SP 1	3.22	1.005
	SP 2	3.77	1.163
	SP 3	3.57	1.249
	SP 4	3.49	1.223
	SP 5	4.05	1.017
	SP 6	4.03	.937

The responses related to sustainability practices are presented in table 3. The question asked companies to rate sustainability practices in their procurement practices. Supplier audits and selection incorporate sustainability compliance had the highest mean (4.05) and standard deviation (1.017). This indicates that, respondent companies' practices sustainability compliance in supplier audit and selection as their sustainability practices.

Table 4: Descriptive table by component group – Risk Management

Component	Attributes	Mean	Std. Deviation
Risk Management	RM1	3.89	.778
	RM2	3.75	.758
	RM3	3.74	.803
	RM4	3.80	.749

With a mean over 3.7 in all of the attributes it can be said that all the measures, availability of products, risk of late deliveries, quality and price list are considered highly important for the procurement risk management.

Table 5: Descriptive table by component group - Resilience

Component	Attributes	Mean	Std. Deviation
Resilience	Res1	3.82	.689
	Res2	3.28	.792
	Res 3	3.52	.770
	Res4	3.45	.837

4.1 Factor analysis

Factor analysis is conducted to identify variables that are composites of observed variables. Table 6 summarizes the results of factor analysis. Various studies have concluded that factor loadings should be greater than 0.5 to achieve the best results (Truong & McColl, 2011; Hulland, 1999), but this can be varied based on theoretically assumed relationship. For this study, all the items that were lower than 0.5 were excluded for further analysis.

The Kaiser-Meyer-Olkin (KMO) test was used to determine both the sample adequacy of the items used in the factor analysis and the model adequacy. According to Kaiser (1974), the minimum acceptable value of KMO is 0.5. All of the KMO values obtained during the test were greater than 0,5, indicating that both the sample and the model were adequate. The lowest KMO value is 0.673. To test reliability of the factors, the Cronbach alpha values were examined. It should be noted that a reliability coefficient of.70 or higher is considered acceptable (Hair et al., 1998).

Factor analysis for data analytics identified one factor with values ranging from .713 to .846. According to Osborne, Costello, and Kellow (2008), communalities greater than 0.4 are acceptable. The communalities here are over 0 .5 Since the Kaiser-Meyer-Olkin test (KMO) is .909 and the Cronbach's alpha 0,922, all the variables (items) were kept for further analysis.

For risk management practices, items with low factor loading were removed. Currency risk, supplier bankruptcy, workforce, product safety risks, brand image related issue and information related questions were removed as the factor loading was not within the acceptable range. The KMO is 0.793 and Cronbach's alpha is 0,753. Because removing additional items did not result in an increase in Cronbach's alpha, the remaining items were retained, even if the communalities remained close to 0,4 on one item.

For sustainability practices factors having values greater than .65 was taken into account and the rest are removed due to having low factor loadings as those will have lesser impact on the variables. Use of responsibility register of suppliers, product specific clearance, appointment of third-party evaluator for supplier compliance, CSR reporting, sustainability requirement mentioned in purchasing contract, lifecycle analysis with environmental impact indicators, concrete sustainable target by procurement team were not taken into account for further analysis as they did not meet the required level of loading values. Having Cronbach's alpha value 0.854 and KMO .845. And finally, to measure resilience, the questions were associated with how easily and quickly the companies can bring about the necessary changes and adopt to it, whether they can quickly respond to supply chain disruption and level of situational awareness in the companies. From the high factor loading, ranges from 0,724to 0.828, it is established that the questions were relevant and adequate in measuring resilience. KMO reading is .771 which represents sampling adequacy and Cornbrash's Alpha .800 indicating that the items have a high degree of internal consistency.

Table 6: Summary of exploratory analysis, validity, and reliability

Construct	Items	Factor loading	Communalities	Variance extracted (%)	KMO	Cronbach´s Alpha (α)
Data Analytics	DA 1	.795	.632	61.89	.909	.922
	DA 2	.793	.628			
	DA 3	.835	.698			
	DA 4	.826	.683			
	DA 5	.764	.583			
	DA 6	.846	.716			
	DA 7	.751	.565			
	DA 8	.713	.509			
	DA 9	.747	.557			
Risk Management	RM1	0,826	.683	57.87%	.673	.753
	RM2	0,825	.681			
	RM3	0,712	.444			
	RM4	0,666	.507			
Sustainability	SP 1	0,848	.718	58.32%	.845	0.854
	SP 2	0,836	.698			
	SP 3	0,788	.621			
	SP 4	0,776	.602			
	SP 5	0,656	.431			
	SP 6	0,655	.429			
Resilience	Res1	0,828	.686	63.071%	.771	0.800
	Res2	0,812	.659			
	Res 3	0,808	.653			
	Res4	0,724	.525			

4.2 Correlation and Regression Analysis:

A correlation matrix was used to determine the relationships between the variables. Independent variables were compared to dependent variables, and the R-squared (R^2) coefficient was calculated. The chosen dependent variable showed positive correlation with all the independent variables with different percentage of dependency. Positive result shows that the independent variables have impact on dependent variable. The R-squared (R^2) coefficient explains the strength of the relationship between the independent and dependent variable in percentage terms. The greater the R-squared (R^2) value, the stronger the relationship between the independent variables and the dependent variable. The p-value is used to determine whether a result is statistically significant. The coefficient β is compared to the p-value. A statistically significant result will establish the variables' influence. higher values of means higher influence of the independent variable on the dependent variable.

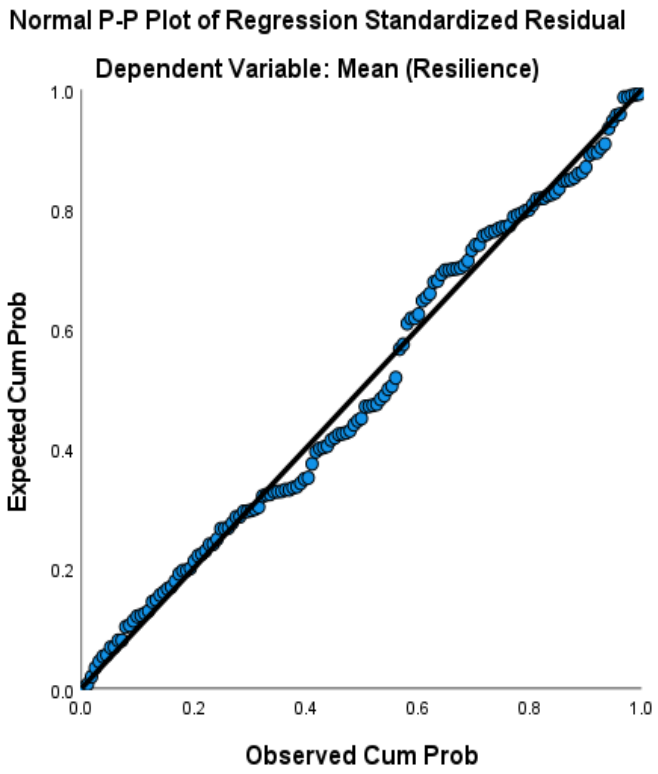
In this study, based on correlation it can be said that, out of three of the independent variables, Sustainability practices has the least but significant impact on the dependent variable resilience at 0.24 level. The other two variables, data analytics and risk management capability, also positively influence resilience at 0.29 and 0.37 level according to Pearson correlation.

As all the correlations listed above are significant, and therefore are included in the subsequent regression analysis. The regression analysis was used to test the hypotheses and analyze the correlational relationships. To test the hypotheses, a single linear regression was used. All three of the hypotheses derived from the literature were confirmed. Table 8 shows details of the statistical analysis of the tested hypotheses, including unstandardized and standardized coefficients, t-value, R, R squared, and F-value.

Table 7: Pearson's correlation matrix for relations

Correlations					
		Mean (Data Analytics)	Mean (Resilience)	Mean (Risk Management)	Mean (Sustainability Practices)
Mean (Data Analytics)	Pearson Correlation	1			
Mean (Resilience)	Pearson Correlation	.289**			
	Sig. (2-tailed)	.000			
Mean (Risk Management)	Pearson Correlation	.370**	.323**		
	Sig. (2-tailed)	.000	.000		
Mean (Sustainability Practices)	Pearson Correlation	.243**	.492**	.356**	
	Sig. (2-tailed)	.003	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).					

Figure 8: Normal distribution in graph



Residuals lie close to the diagonal line, which represents the ideal normal distribution. So, from here it can be derived that the data is normally distributed.

Table 8: Model summary table - strength of the relationship

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.533[a]	.284	.269	.52303	1.783
a. Predictors: (Constant), Mean (SusP), Mean (DA), Mean (RM)					
b. Dependent Variable: Mean (Resilience)					

Adjusted R^2 represents that 26.9% of the variance in dependent variable is explained by independent variable. In this case, 26.9% of all the variability of resilience can be explained by the data analytics, sustainability and risk management practices when

taken as a group significantly. The Durbin-Watson test result shows a value of 1.783 which indicates slight positive co-relation among residuals.

Table 9: Analysis of variance for statistical significance

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.518	3	5.173	18.909	.001[b]
	Residual	39.119	143	.274		
	Total	54.637	146			
a. Dependent Variable: Mean (Resilience)						
b. Predictors: (Constant), Mean (Sustainability Practices), Mean (Data Analytics), Mean (Risk Management)						

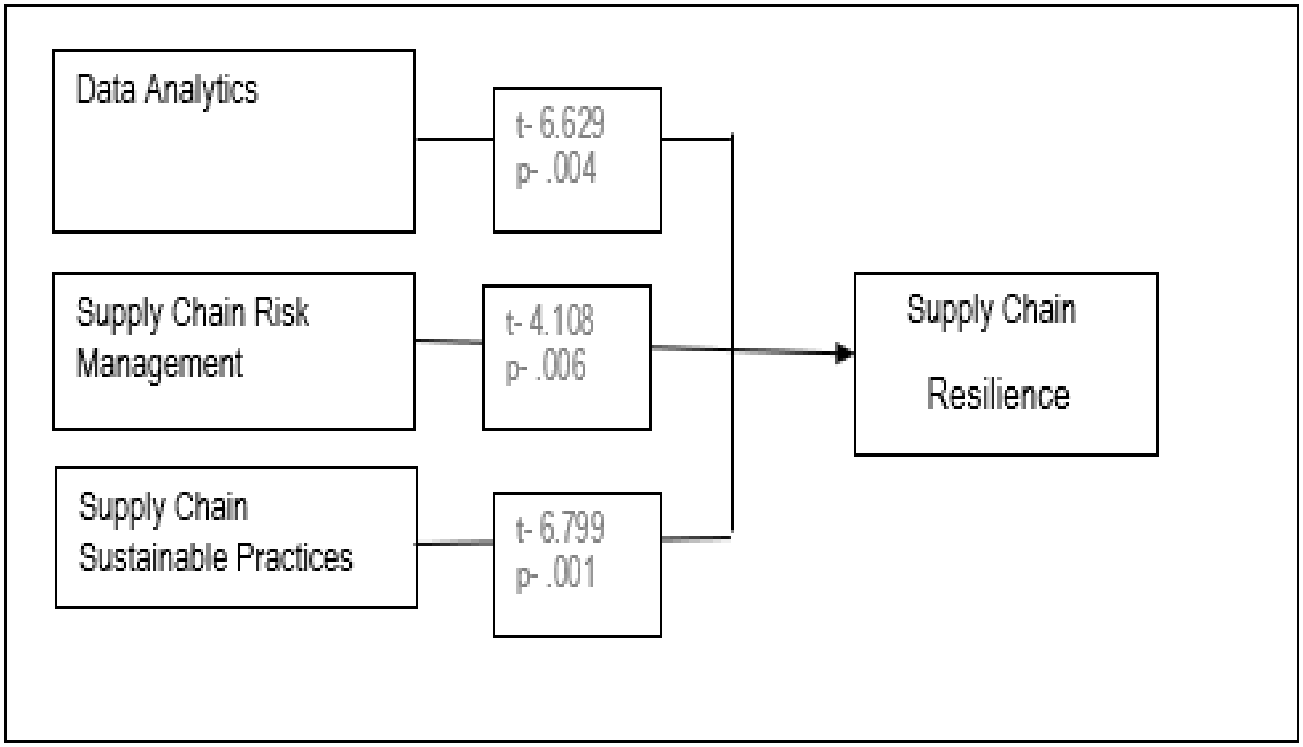
The ANOVA table indicates whether the model is significant or not. To be significant, a model's predictor variables must be good predictors of the outcome variable. It is determined by the model's significance value. Because the significant value is less than alpha 0.05 in this case, it can be concluded that the model is significant; Fc (3,146=18.91, p<.001, R^2= .284). In other words, independent variables data analytics, sustainability and risk management practices significantly impact the dependent variable resilience.

Table 10: Coefficients- Strength of the effect independent variable ton the dependent variable

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig. (p value)
	B	Std. Error	Beta		
Mean (Data Analytics)	.214	.059	.289	3.629	.004
Mean (Risk Management)	.235	.057	.323	4.108	.006
Mean (Sustainability Practices)	.514	.076	.492	6.799	.001

From the coefficient table it can be interpreted that Sustainability Practices significantly impact the level of resilience with having p-value of 0.001 and B 0.432. Since, sustainability significantly influences resilience, it can be said that increase in one unit of sustainability practices can positively impact the resilience by 43%. The p-value of data analytics is ≈ .004 which is also statistically significant. This result can be interpreted as data analytics is responsible for increased resilience at 21%. The third variable risk management practices also shows significant impact on resilience having a value of .006 which is smaller than standard acceptable p-value < .05. Its impact on resilience is 23.5%.

Figure 7: The conceptual model with t and p value



4.3 Hypothesis Testing

Hypothesis 1: Data analytics (Technological capabilities) has positive relation with supply chain resilience.

The effect of data analytics on resilience was investigated using regression analysis, where DA is an independent variable and resilience is a dependent variable. The correlation between the two variables is positive, with R accounting for 0.289 and the $p < .05$. So, the hypothesis is accepted.

Hypothesis 2: If a company improves its risk management capacity, then it improves supply chain resilience as a result.

Better risk management capacity seems to have a positive influence on the resilience of a company. H2 is supported as coefficient β is 0,235 and the result is statistically significant with $p < 0.05$.

Hypothesis 3: Better Sustainability practices leads to higher resilience capacity.

The effect of sustainability practices on resilience was analyzed in the third hypothesis. The relationship is strong as R= .323. The coefficient is also significant at p=001 < .05, so the hypothesis is accepted. The t-value accounted for 6,799. F-value (16.880) shows the strong significance of the model.

4.4 Reliability and Validity

Reliability and validity are two measures to evaluate the quality of a research. Reliability is a term that refers to the consistency with which a method measure something. If the same result can be obtained consistently when the same methods and conditions are used, the measurement is considered reliable. Generally, a longer survey with more measures has a higher level of reliability than a shorter survey with fewer measures. Cronbach's alpha is used to determine the reliability of the measures in this study, with values greater than 0,80 indicating a reliable measure, values between 0,70 and 0,80 indicating a good measure, and values between 0,60 and 0,70 indicating a not-so-good measure but still acceptable. Cronbach's alpha values for each factor in the factor analysis were reported separately (Table 6). Cronbach values for each measure are between 0.753 – 0.922 which are from a reliable level to very good level.

Table 11: Cronbach's alpha values of factor analysis:

Measure	Cronbach's alpha	KMO
Data analytics	0.922	.909
Risk management	0.753	.673
Sustainability	0.854	.845.
Resiliency	0.800	.771

How well the findings contribute to the resolving of the research question is reported by the validity. Criteria and contrast related validity analyze if the theories and concepts are suitable for the study and if the measures are formed correctly and if questions measure what the study intend those to measure. In this study, the questions and concepts that were used in survey were carefully developed based on literature review and from previous study. The validity of the measures and concepts in this study was determined using factor analysis (the detailed result can be found in table # in this chapter). Recommended KMO (Kaiser-Meyer-Olkin) values is between 0 and 1 which indicates the sampling is adequate. All the values above .05 represents acceptable factorial simplicity (Kaiser, 1974). The value less than .5 is an indication that sampling is not adequate. In this study all the KMO values are above .6 which is an indication of adequate sample size. Communalities of all the variables above .30 represents an acceptable level. Factor loadings that were below .30 were rejected.

5. Discussion and conclusion

The final chapter of this thesis discusses the main findings of the research, answers the research question, and reflects on the study's results and limitations. Furthermore, the theoretical and practical-managerial contributions are outlined, and suggestions for future research are made.'

5.1 What factors influence supply chain resilience?

The resilience issue is critical because it focuses on managing risks associated with unexpected events and ensuring company sustainability under unstable environmental conditions caused by economic, social, technical, and physical climate change. This section presents the answers to the research questions that were established at the start of the study, along with the hypotheses that were developed to precisely answer the question. The main research question is What factors influence supply chain resilience?

The answer to the research question is supported by the literature review as well as the findings from the quantitative study. As per the research data analytics, sustainability practices, and risk management capabilities of a company are factors that positively influence resilience. According to the empirical findings, it can be concluded that the factors that were examined for the study have a positive effect on resilience, but the impact of each varies. According to this study sustainability and risk management deemed as the most influential factor toward resilience.

To deal with the everchanging business environment it is important to understand the need for adapt to change and to have a system that deals with the change in a quick and effective manner. One useful way is to have updated resources and to have the ability to utilize and adjust those resources toward the disruption is critical to a firm's resilience. Thus, developing capabilities is crucial (Ambulkar, Blackhurst & Grawe, 2014). This study supports the claims made by Christopher and Lee (2004) and Brandon-Jones et al. (2014) that supply chain visibility, as a prerequisite for resilience, can improve supply chain management by reducing interventions and facilitating

decision making. Additionally, one way to enhance demand and supply visibility is to strengthen data analytics capabilities (Srinivasan & Swink, 2017). This study tested the relationship between data analytics and supply chain resilience empirically. The ability to process raw data provides access to the most recent and complete insight, which leads to improved organizational performance and, ultimately, provides competitive advantage (Dubey et al., 2019).

As discussed in literature review resilience is critical for developing of capabilities and sustainable competitive advantage (Ponomarov and Holcomb 2009). Sustainability practices in supply chain function has been identified as a crucial factor in achieving resilience. A greater understanding of sustainable practices in a supply chain enables more informed decision-making and reduces the risks faced by both individual organizations and the overall network. Sustainable sourcing, production and distribution strategies can cope with market demand at an efficient manner. Moreover, it is noted that a resilient supply chain's environmental and social performance was essentially unaffected by disturbances (Fahimnia & Jabbarzadeh, 2016).

Supply chain risk management is a resilience capability that enhances resilience, which in turn aids in mitigating the effects of disruptions (El Baz and Ruel, 2020). Many business leaders see risk as a negative and risk management as a value-preserving mechanism. Rather, businesses can begin to view risk as a strategic component for increasing resilience, as well as an opportunity to create value for the organization when managed effectively. It is necessary to identify risks and then transform processes to assist in managing and mitigating those risks. Simba et al. (2017) demonstrate how a lack of an effective risk management system has a direct negative effect on resilience. Absence of or failure to adhere to risk management tool guidelines harmed the firm's ability to meet market supply demand for that particular product.To manage price, quality, delivery, and product availability risk, it is often necessary to restructure processes such as the initial due diligence phase of vendor selection and vendor off-boarding. Companies can use risk sensing to assess the likelihood of future disruptions, whether anticipated or unexpected. Effective risk management functions as a performance improvement tool, enabling businesses to manage disruptions more effectively through improved management of both external and internal risks (Blos, Wee and Yang, 2012). Failure to mitigate risks effectively results in profit loss.

Supply chains will continue to be vulnerable, uncertain, and complex as a result of the turbulent, rapidly changing nature of the global business economy. Developing a resilient supply chain capable of managing potential risks and disruptions has become a focal point of Supply chain Risk management research. Thus, supply chain resilience will continue to grow in popularity as more researchers and practitioners dedicate their attention to this critical subject (Hohenstein, Feisel & Hartmann, 2015). This research focused on finding the factors that impacts resilience the most and to what extend the identified factors affect the resilience of a supply chain. According to the study, no single factor can significantly increase a firm's resilience instantly. It is a synergistic relationship of several factors which when implemented as a part of company's overall strategy (Malindretos & Binioris, 2014). With developed capabilities not only internal but also external disruptions can be dealt with efficiently without having to entire breakdown of the supply chain system.

5.2 Managerial recommendations

This study makes several important implications for supply chain managers who operate in an extremely uncertain business environment. Given the numerous benefits of having a resilient supply chain - economic, social, and environmental - managers should investigate ways to achieve this. According to this study, one of those capabilities is data analytics. To improve information processing capability, managers may consider the long-term benefits of having updated information systems in the context of their own businesses before deciding whether to invest. Capability for data analytics enables organizations to adapt more effectively to change (Dubey et al, 2019).

The findings of the study may encourage firms to adopt supply chain risk management initiatives or enhance existing practices in response to the potential benefits to supply chain resilience. Firms should prioritize developing efficient and up-to-date risk identification measures, as they affect all other supply chain risk management processes.

Furthermore, firms should develop interconnected supply chain risk management practices in order to increase their supply chain robustness and resilience. Furthermore, in order to implement supply chain sustainability, multiple criteria must be taken into account. Implementing supply chain sustainability is efficient sustainable supply chain management should cover entire life cycle of a product which involves the entire supply chain. Although improved supply chain resilience sometimes results in higher cost, it is a good practice for getting long term benefits such as competitive advantages, handling of disruption etc.

5.3 Limitations and suggestion for future research

This thesis and its findings are limited in several aspects. First, the use of a sample size of 147 companies. Although the results from the analysis of the data from this sample give a glimpse into the factors that influence supply chain resilience they cannot be easily generalized. Furthermore, the sample was also limited in geographical scope. Only Finnish companies were analyzed which means the findings may only apply to the Finnish context. As such, future research could analyze the factors affecting supply chain resilience using bigger samples and other geographical contexts in other to support these findings and/or improve generalizability.

Second, due to time constraints, the scope of this study was limited to just 3 factors of resilience. According to the literature, several other factors such as performance and processes, digitalization technologies, information sharing etc. also influence resilience. Hence, to get a bigger picture of the relationships between these proposed factors and supply chain resilience, future research should look to analyze more factors. Third, this study was not conducted on the industry level, however, there could be industry-specific differences in the importance of each factor. To address this, future studies could use multi-group analyses to examine if the factors affecting companies' supply chain resilience vary based on the industry they belong to.

Finally, several other questions remain that provide avenues for research such as: How can the factors themselves be implemented/improved by a company? Which factors are most important and should be given priority? To answer these questions

qualitative methods like case studies may be required to get an in-depth understanding of how these factors influence resilience in practice. For example, a case study tracking an individual company resilience before and after developing one factors may provide a different perspective.

References

Ali, A., Mahfouz, A. and Arisha, A. (2017). Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Management: An International Journal*, 22(1), pp.16–39.

ALTAY, N. and RAMIREZ, A. (2010). IMPACT OF DISASTERS ON FIRMS IN DIFFERENT SECTORS: IMPLICATIONS FOR SUPPLY CHAINS. *Journal of Supply Chain Management*, 46(4), pp.59–80.

Ambulkar, S., Blackhurst, J. and Grawe, S. (2014). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management*, 33-34(1), pp.111–122.

Baryannis, G., Validi, S., Dani, S. and Antoniou, G. (2018). Supply chain risk management and artificial intelligence: state of the art and future research directions. *International Journal of Production Research*, [online] 57(7), pp.1–24. Available at: https://pure.hud.ac.uk/en/publications/supply-chain-risk-management-and-artificial-intelligence-state-of.

Belhadi, A., Kamble, S., Gunasekaran, A., Ndubisi, N.O., Venkatesh, M. and Jabbou, C.J.C. (2020). Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries. *Technological Forecasting and Social Change*, [online] p.120447. Available at: https://www.sciencedirect.com/science/article/pii/S0040162520312737?via%3Dihub.

Bell, E., Bryman, A. and Harley, B. (2015). *Business Research Methods*. 5th ed. Oxford: Oxford University Press.

Bi, Z. and Cochran, D. (2014). Big data analytics with applications. *Journal of Management Analytics*, 1(4), pp.249–265.

Blos, M.F., Wee, H.M. and Yang, W.-H. (2012). Supply Chain Risk Management: Resilience and Business Continuity. Handbook on Decision Making, pp.219–236.

Boone, T., Ganeshan, R., Jain, A. and Sanders, N.R. (2019). Forecasting sales in the supply chain: Consumer analytics in the big data era. *International Journal of Forecasting*, 35(1), pp.170–180.

Brandon-Jones, E., Squire, B., Autry, C. and Petersen, K.J. (2014). A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. *Journal of Supply Chain Management*, p.n/a-n/a.

Brinch, M., Stentoft, J., Jensen, J.K. and Rajkumar, C. (2018). Practitioners understanding of big data and its applications in supply chain management. *The International Journal of Logistics Management*, 29(2), pp.555–574.

Brush, T. and Artz, K.W. (1999). Toward a contingent resource-based theory: The impact of informationasymmetry on the value of capabilities. *Strategic Management Journal*, Vol 20(), pp.223–25.

Brusset, X. and Teller, C. (2017). Supply chain capabilities, risks, and resilience. *International Journal of Production Economics*, 184, pp.59–68.

Burgess, K., Singh, P.J. and Koroglu, R. (2006). Supply chain management: a structured literature review and implications for future research. *International Journal of Operations & Production Management*, 26(7), pp.703–729.

Carter, E.E. (1972). What are the risks in risk analysis? *Harvard Business Review*, Vol. 50(No. 4), p.pp. 72-82.

Carter, H., Hertz, D.B. and Thomas, H. (1984). Risk Analysis and Its Applications. *The Journal of the Operational Research Society*, 35(5), p.453.

Chae, B. (Kevin), Olson, D. and Sheu, C. (2013). The impact of supply chain analytics on operational performance: a resource-based view. *International Journal of Production Research*, 52(16), pp.4695–4710.

Choi, T.Y. and Hong, Y. (2002). Unveiling the structure of supply networks: case studies in Honda, Acura, and DaimlerChrysler. *Journal of Operations Management*, 20(5), pp.469–493.

Christopher, M. and Lee, H. (2004). Mitigating supply chain risk through improved confidence. *International Journal of Physical Distribution & Logistics Management*, 34(5), pp.388–396.

Christopher, M. and Peck, H. (2004). Building the Resilient Supply Chain. *The International Journal of Logistics Management*, [online] 15(2), pp.1–14. Available at: https://core.ac.uk/download/pdf/138417.pdf?repositoryId=23.

Coso.org. (2019). *COSO Enterprise Risk Management — Integrated Framework*. [online] Available at: https://www.coso.org/Pages/erm-integratedframework.aspx.

Day, J.M. (2013). Fostering emergent resilience: the complex adaptive supply network of disaster relief. *International Journal of Production Research*, 52(7), pp.1970–1988.

Dubey, R., Altay, N., Gunasekaran, A., Blome, C., Papadopoulos, T. and Childe, S.J. (2018). Supply chain agility, adaptability and alignment. *International Journal of Operations & Production Management*, 38(1), pp.129–148.

Dubey, R., Gunasekaran, A., Childe, S.J., Fosso Wamba, S., Roubaud, D. and Foropon, C. (2019). Empirical investigation of data analytics capability and organizational flexibility as complements to supply chain resilience. *International Journal of Production Research*, pp.1–19.

El Baz, J. and Ruel, S. (2020). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. International Journal of Production Economics.

Fabrigar, L.R., Wegener, D.T., MacCallum, R.C. and Strahan, E.J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, [online] 4(3), pp.272–299. Available at: http://ww.w.statpower.net/Content/312/Handout/Fabrigar1999.pdf [Accessed 17 Mar. 2019].

Fahimnia, B. and Jabbarzadeh, A. (2016). Marrying supply chain sustainability and resilience: A match made in heaven. *Transportation Research Part E: Logistics and Transportation Review*, 91, pp.306–324.

Fosso Wamba, S., Gunasekaran, A., Papadopoulos, T. and Ngai, E. (2018). Big data analytics in logistics and supply chain management. *The International Journal of Logistics Management*, 29(2), pp.478–484.

Germain, R., Claycomb, C. and Dröge, C. (2007). Supply chain variability, organizational structure, and performance: The moderating effect of demand unpredictability. *Journal of Operations Management*, [online] 26(5), pp.557–570. Available at: https://www.sciencedirect.com/science/article/pii/S0272696307001398.

Hafezalkotob, A. and Zamani, S. (2018). A multi-product green supply chain under government supervision with price and demand uncertainty. *Journal of Industrial Engineering International*, 15(1), pp.193–206.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998). *Multivariate data analysis*. Upper Saddle River, Nj: Prentice-Hall.

Handfield, R., Jeong, S. and Choi, T. (2019). Emerging procurement technology: data analytics and cognitive analytics. *International Journal of Physical Distribution & Logistics Management*, 49(10), pp.972–1002.

Hofmann, E. and Rutschmann, E. (2018). Big data analytics and demand forecasting in supply chains: a conceptual analysis. *The International Journal of Logistics Management*, 29(2), pp.739–766.

Hofmann, E., Sternberg, H., Chen, H., Pflaum, A. and Prockl, G. (2019). Supply chain management and Industry 4.0: conducting research in the digital age. *International Journal of Physical Distribution & Logistics Management*, 49(10), pp.945–955.

Hohenstein, N.-O., Feisel, E., Hartmann, E. and Giunipero, L. (2015). Research on the phenomenon of supply chain resilience. *International Journal of Physical Distribution & Logistics Management*, 45(1/2), pp.90–117.

Ivanov, D. and Dolgui, A. (2020). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, pp.1–14.

Jean, R.-J. “Bryan”, Kim, D. and Sinkovics, R.R. (2012). Drivers and Performance Outcomes of Supplier Innovation Generation in Customer-Supplier Relationships: The Role of Power-Dependence. *Decision Sciences*, 43(6), pp.1003–1038.

Kaiser, H.F. (1974). *Analysis of factorial simplicity*. Psychometrika, pp.31–36.

Khorasani, S.T. and Almasifard, M. (2017). An Inventory Model with Quantity Discount Offer Policy for Perishable Goods in the Two-Level Supply Chain. *International Journal of Engineering and Technology*, 9(4), pp.2828–2834.

Kusrini, E. and Primadasa, R. (2018). *Sustainable Performance Measurement Using Sustainable Value Stream Mapping: A Case Study On One Of Palm Oil Companies In Indonesia*.

Lamba, K. and Singh, S.P. (2017). Big data in operations and supply chain management: current trends and future perspectives. *Production Planning & Control*, 28(11-12), pp.877–890.

Lavastre, O., Gunasekaran, A. and Spalanzani, A. (2012). Supply chain risk management in French companies. *Decision Support Systems*, 52(4), pp.828–838.

Lechler, S., Canzaniello, A., Roßmann, B., von der Gracht, H.A. and Hartmann, E. (2019). Real-time data processing in supply chain management: revealing the uncertainty dilemma. *International Journal of Physical Distribution & Logistics Management*, 49(10), pp.1003–1019.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T.S. and Subba Rao, S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. *Omega*, 34(2), pp.107–124.

Linnenluecke, M.K. (2015). Resilience in Business and Management Research: A Review of Influential Publications and a Research Agenda. *International Journal of Management Reviews*, 19(1), pp.4–30.

Malindretos, G. and Binioris, S. (2014). Supply Chain Resilience and Sustainability. *Investment Research and Analysis Journal*, 5.

Mangan, J. and Christopher, M. (2005). Management development and the supply chain manager of the future. *The International Journal of Logistics Management*, 16(2), pp.178–191.

Manhart, P. (2017). Supply chain risk management: capabilities and performance. *Graduate Theses and Dissertations*. [online] Available at: https://lib.dr.iastate.edu/etd/16934 [Accessed 19 Jun. 2021].

Negri, M., Cagno, E., Colicchia, C. and Sarkis, J. (2021). Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda. *Business Strategy and the Environment*.

Osborne, J.W., Costello, A.B. and Kellow, J.T. (2008). Best Practices in Exploratory Factor Analysis. *SAGE Publishing*, pp.205–213.

Oxford University Press (1989). *The Oxford English dictionary.* Oxford: Clarendon Press ; Oxford.

Paulraj, A., Chen, I.J. and Lado, A.A. (2012). An Empirical Taxonomy of Supply Chain Management Practices. *Journal of Business Logistics*, 33(3), pp.227–244.

Pettit, T.J., Croxton, K.L. and Fiksel, J. (2013). Ensuring Supply Chain Resilience: Development and Implementation of an Assessment Tool. *Journal of Business Logistics*, [online] 34(1), pp.46–76. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/jbl.12009.

Pettit, T.J., Fiksel, J. and Croxton, K.L. (2010). ENSURING SUPPLY CHAIN RESILIENCE: DEVELOPMENT OF A CONCEPTUAL FRAMEWORK. *Journal of Business Logistics*, 31(1), pp.1–21.

Ponomarov, S.Y. and Holcomb, M.C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management*, 20(1), pp.124–143.

Rao, S. and Goldsby, T.J. (2009). Supply chain risks: a review and typology. *The International Journal of Logistics Management*, 20(1), pp.97–123.

RAVICHANDRAN, T., LERTWONGSATIEN, C. and LERTWONGSATIEN, C. (2005). Effect of Information Systems Resources and Capabilities on Firm Performance: A Resource-Based Perspective. *Journal of Management Information Systems*, 21(4), pp.237–276.

Rha, J.S. (2020). Trends of Research on Supply Chain Resilience: A Systematic Review Using Network Analysis. *Sustainability*, 12(11), p.4343.

Rice, J. and Caniato, F. (2003). *Building a SECURE A N D RESPONSE OPPORTUNITY EVOLUTION RELATIONSHIP BALANCE*. [online] . Available at: http://web.mit.edu/scresponse/repository/Rice_SCResp_Article_SCMR.pdf [Accessed 19 Jun. 2021].

Richey, R.G., Morgan, T.R., Lindsey-Hall, K. and Adams, F.G. (2016). A global exploration of Big Data in the supply chain. *International Journal of Physical Distribution & Logistics Management*, 46(8), pp.710–739.

Ritchie, B. and Clare, B. (2009). Encyclopedia of Information Science and Technology, Second Edition. *Encyclopedia of information science and technology*. [online] Available at: https://www.igi-global.com/book/encyclopedia-information-science-technology-second/362 [Accessed 15 Nov. 2019].

Sanders, N.R. (2016). How to Use Big Data to Drive Your Supply Chain. *California Management Review*, 58(3), pp.26–48.

Saunders, M., Lewis, P. and Thornhill, A. (2012). *Research methods for business students*. 6th ed. Harlow, Essex, England: Pearson Education Limited.

Saunders, M., Lewis, P. and Thornhill, A. (2016). *Research Methods for Business Students.* 7th ed. Pearson.

Sharma, M.M. (2013). A Study on the Concept of Green Supply Chain Management. *Journal of Supply Chain Management Systems*, Vol. 2(1), pp.1–7.

Simba, S., Niemann, W., Kotzé, T. and Agigi, A. (2017). Supply chain risk management processes for resilience: A study of South African grocery manufacturers. Journal of Transport and Supply Chain Management, 11.

Singh Jain, A.D., Mehta, I., Mitra, J. and Agrawal, S. (2017). Application of Big Data in Supply Chain Management. *Materials Today: Proceedings*, [online] 4(2), pp.1106–1115. Available at: https://www.sciencedirect.com/science/article/pii/S2214785317301268 [Accessed 24 Mar. 2019].

Singh Srai, J. and Gregory, M. (2008). A supply network configuration perspective on international supply chain development. *International Journal of Operations & Production Management*, 28(5), pp.386–411.

Srinivasan, R. and Swink, M. (2017). An Investigation of Visibility and Flexibility as Complements to Supply Chain Analytics: An Organizational Information Processing Theory Perspective. *Production and Operations Management*, 27(10), pp.1849–1867.

Stank, T., Esper, T., Goldsby, T.J., Zinn, W. and Autry, C. (2019). Toward a Digitally Dominant Paradigm for twenty-first century supply chain scholarship. *International Journal of Physical Distribution & Logistics Management*, 49(10), pp.956–971.

Sternberg, H. and Lantz, B. (2018). Using crowdsourced data to analyze transport crime. *International Journal of Logistics Research and Applications*, 21(2), pp.133–147.

Stoltz, P.G. (2004). Building resilience for uncertain times. *leader to leader*, Winter 2004(31), pp.16–20.

SUPPLY CHAIN VULNERABILITY Executive Report On Behalf of: Department for Transport, Local Government and the Regions Department of Trade and Industry Home Office. (2002).

Tang, C.S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics*, 103(2), pp.451–488.

Vogus, T.J. and Sutcliffe, K.M. (2007). Organizational resilience: Towards a theory and research agenda. *2007 IEEE International Conference on Systems, Man and Cybernetics*. [online] Available at: https://ieeexplore.ieee.org/document/4414160/.

Wagner, S.M. and Bode, C. (2009). Dominant Risks and Risk Management Practices in Supply Chains. *International Series in Operations Research & Management Science*, pp.271–290.

Wang, G., Gunasekaran, A., Ngai, E.W.T. and Papadopoulos, T. (2016). Big data analytics in logistics and supply chain management: Certain investigations for research and applications. *International Journal of Production Economics*, [online] 176, pp.98–110. Available at: https://www.sciencedirect.com/science/article/pii/S0925527316300056.

Wu, F., Yeniyurt, S., Kim, D. and Cavusgil, S.T. (2006). The impact of information technology on supply chain capabilities and firm performance: A resource-based view. *Industrial Marketing Management*, 35(4), pp.493–504.

Yossi, S. and Rice Jr, B. (2005). A Supply Chain View of the Resilient Enterprise. *MIT Sloan Management Review*, pp.41–48.

Zavala-Alcívar, A., Verdecho, M.-J. and Alfaro-Saiz, J.-J. (2020). A Conceptual Framework to Manage Resilience and Increase Sustainability in the Supply Chain. *Sustainability*, 12(16), p.6300.

Zhao, L., Huo, B., Sun, L. and Zhao, X. (2013). The impact of supply chain risk on supply chain integration and company performance: a global investigation. *Supply Chain Management: An International Journal*, 18(2), pp.115–131.

Zhu, Q., Krikke, H. and Caniëls, M.C.J. (2017). Integrated supply chain risk management: a systematic review. *The International Journal of Logistics Management*, 28(4), pp.1123–1141.

Itgovernance.co.uk. (2016). An Introduction to Business Resilience | IT Governance UK. [online] Available at: https://www.itgovernance.co.uk/business-resilience.

youmatter.world. (2020). Resilience Definition: What Is It, Meaning, Examples And Areas Of Use. [online] Available at: https://youmatter.world/en/definition/definitions-resilience-definition-meaning-examples/.