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Disentangling Resilience, Agility and Leanness: Conceptual Development and Empirical Analysis

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Table of Contents

List of Tables

List of Figures

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Declaration

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Abstract

This PhD thesis extends the existing knowledge on resilience in the context of supply chain, specifically by: (1) disentangling resilience, leanness and agility and (2) investigating how resilience along with leanness and agility affects operational performance outcomes.

At the first phase, a literature review of practices underlying Lean, Agile and Resilient (LAR) was done, classifying them to the areas of overlap and non-overlap between LAR as regards the practices. Of the many practices identified for each of LAR, there are some that underlie just one of these three while others underlie two of them and even all three. To establish the practitioner need for this research, a survey combined with a focus group of various companies was conducted in the Forum of 2011 at Procter & Gamble, Brussels' office. The results confirm lack of clear distinction between practices that are part of lean, agile and resilience. Clarifying these concepts is crucial both from theoretical and practical aspects. Theoretically, when it comes to those practices which go under lean and agile, agile and resilience or even the three of LAR, when it comes to have them in statistical models researchers don't know where exactly these practices should be categorized. Practically, unclear boundaries between these concepts can make implementation of respective practices potentially problematic or confusing for managers.

At the second phase, the thesis aims at "disentangle resilience, leanness and agility". The survey carried out was done online in Germany due to the country's strong base in manufacturing. Through factor analysis, this part of the research approves the idea of literature that resilience has some practices that purely helps it, while it also has some practices that affect agility and resilience and agility, leanness and resilience. There are some differences in the boundaries of these categorizations between what literature mentions and what industrial managers believe in.

At the third phase, the thesis aims to investigate "how resilience along with leanness and agility affects performance outcomes". The aim is to empirically assess a set of hypotheses that follow not only from the literature, but also from the perceptions of practitioners about LAR resulted from phase two. The model is tested on a sample of Automotive Parts Suppliers (APS) in Iran as the largest automotive industry in the Middle East and 12th in the world, and specifically as an appropriate choice for a resilient-needed environment due to sanctions and volatility of the currency. A survey was used to obtain information and a structural equation model to analyse the data. The model quantitatively explains that while leanness is independent form resilience,

agility brings about resilience. On the other hand, the model tests the relations of leanness and resilience on flexibility, delivery, cost and time to recovery performance outcomes. The results show that higher level of resilience will lead to better delivery performance, better cost performance (i.e. helps cost reduction) and better time to recovery performance (i.e. helps time to recovery reduction). The results also show that its effect on flexibility performance is not significant.

Regarding leanness, the results confirm that lean positively affect delivery and flexibility performance. In addition, higher level of leanness will lead to better cost performance (i.e. helps cost reduction). The results also reject the hypothesis stating that higher level of leanness will lead to worse recovery performance, inferring that higher level of leanness leads to better time to recovery performance (i.e. helps time to recovery reduction).

Finally, there are different theoretical and managerial implications. Theoretically, this research disentangles resilience, agility and leanness. Then, it presents a model that resilience; leanness and agility are modelled not separately but besides each other and quantitatively it investigates how resilience along with leanness and agility affects performance outcomes. From managerial point of view, a need to understand what measures of the three concepts of LAR are related to each area between the three concepts has been answered so managers can prioritize their efforts and seek to balance their efforts across LAR. Overall, the conceptual model that stems from the SEM model gives a useful starting point for supply chain researchers regarding the three approaches in the supply chains.

List of abbreviations

ATO	Assemble to order
AVE	Average variance extracted
BCP	Business continuity planning
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CMV	Common method variance
CR	Composite reliability
DF	Degrees of freedom
HRM	Human resource management
JIT	Just in time
LAR	Lean, agile, resilient
MTO	Make to order
RMSEA	Root mean square of approximation
SC	Supply chain
SCM	Supply chain management
SCRES	Supply chain resilience
SCV	Supply chain vulnerability
SCRM	Supply chain risk management
SEM	Structural equation modeling
SME	small- and medium-sized enterprises
SPC	Statistical process
TPM	Total preventative maintenance
TPS	Toyota production system
TQM	Total quality management

Chapter 1: Introduction

Companies recognize the need to become more resilient since- as the market is constantly changing- threats are evolving, adapting, and changing as well (Pettit et al., 2011). According to Hamel and Valikangas (2003), resilience will prove to be the ultimate competitive advantage in an age of turbulence. Any supply chain has the risk that an unexpected disruption can occur, which can result in losing sales and market share and affect operational and financial performance outcomes. To decrease this risk, the supply chain must be ready to encounter the events with an efficient and effective response and recover to their original or even a better state. This is the essence of resilience (Panomoarov and Holcomb, 2009).

Resilience is a multidimensional and multidisciplinary concept (Panomoarov and Holcomb, 2009). Whilst firms need to understand resilience and know how they should achieve it, it does not mean that they should neglect being cost efficient in terms of lean and customer responsive in terms of agility. According to Carvalho et al. (2011, p. 152) *"The tradeoffs between lean, agile, resilient and green management paradigms are actual issues and may help supply chains to become more efficient, streamlined and sustainable. Leanness in a supply chain maximizes profits through cost reduction, while agility maximizes profits through providing exactly what the customer requires. Resilient supply chains may not be the lowest cost, but they are more capable of coping with the uncertain business environment".*

1.1 Academic research on resilience, leanness and agility

The result of the literature review shows the necessity of resilience and tries to somehow address the point of fit between resilience with leanness and agility both in terms of practices and performance outcomes. But here there are two gaps:

- The literature does not provide clear boundaries between resilient practices with lean and agile practices. Clarifying these concepts is crucial both from theoretical and practical aspects. Theoretically, when it comes to those practices which go under lean and agile, agile and resilience or even the three of LAR, when it comes to have them in statistical models researchers don't know where exactly these practices should be categorized. Practically, unclear boundaries between these concepts can make implementation of respective practices potentially problematic or confusing for managers.

The results of the literature review show that resilience, leanness and agility have some areas of overlap in terms of practices. But there also exists some non-overlapping areas that distinctively are related to resilience, agility or leanness. However, no previous research has been found to date that empirically assesses the fit between resilience with leanness and agility. There is some work for the combination for two of these three approaches such as the work of Aitkan et al. (2002), Towill and Christopher (2002) and Goldsby et al. (2006). Regarding the three approaches to date, all previous researches conceptually suggest this issue but there is no empirical evidence. Christopher and Rurtherford (2004) suggest creating supply chain resilience through agile Six Sigma. Konecka (2010) tries to consider lean and agile supply chain management concepts in the aspect of risk management, other studies such as the work of Carvalho et al., (2011); Machado and Duarte, (2010); Carbal et al., (2011) and Azvedo et al., (2011) all beginning to investigate the issue though none addressing it empirically.

- Secondly, in the highly competitive business climate (Kotzab et al., 2009), creating sustained competitive advantage of the firm is the key to success (Laseter and Gillis, 2012; Cao and Zhang, 2011). From Resource Based View lens, different researchers mention leanness, agility and resilience as capabilities that can offer firms different competitive advantages. Grant (2005, p. 138) mentions leanness as Toyata's capability, while Swafford et al. (2006); and Braunscheidel and Suresh (2009) state agility as the supply chain capability to respond in a speedy manner to a changing marketplace environment. In addition, Coutu (2002) and Stoltz (2004) consider resilience as a distinctive capability which is the key to producing results better than less resilient competitors. Putting all these together, no work to date could be found that empirically confirm how resilience along with leanness and agility affects performance outcomes. Again, there exists some work previously looked at that how lean and agile are affecting performance outcomes such as Narasimhan et al. (2006); and Hallgren and Olhager (2009) or how agility and resilience are affecting performance outcome such as Carvalho et al. (2012). Regarding the three, there is some work such as the work of Carvalho et al., (2011); and Azvedo et al., (2011, 2012) all beginning to develop conceptual models of the effects of lean, agile and resilience on performance outcomes though none addressing the issue empirically.

1.2 Research objectives and questions

As stated in Section 1.1, the literature review on leanness, agility and resilience shows two main gaps:

First, the literature doesn't provide clear boundaries between resilient practices with lean and agile practices. The importance of this gap can be stated from theoretical and practical aspects. The results of the literature review show that resilience, leanness and agility have some areas of overlap in terms of practices. But there also exists some non-overlapping areas that distinctively are related to resilience, agility or leanness. Theoretically, when it comes to those practices which go under lean and agile, agile and resilience or even the three of LAR, when it comes to have them in statistical models researchers don't know where exactly these practices should be categorized. Practically, unclear boundaries between these concepts can make implementation of respective practices potentially problematic or confusing for managers.

Second, as stated in Section 1.1, while different researchers mention leanness, agility and resilience as capabilities that can offer firms different competitive advantages form the Resource Based View lens, literature is still very poor in terms of empirical modelling and testing of how resilience along with leanness and agility can offer competitive advantages. The previous work all remained at the conceptual level though none addressed the issue empirically. Theoretically this gap is important since it is not enough to state that supply chains need to be resilient, lean and agile but more to develop statistical models that show how resilience along with leanness and agility affects performance outcomes and leads companies to gain competitive advantage. Practically, empirical testing of the models that shows how resilience along with leanness and agility affects performance outcomes gives useful guidance to supply chain managers whether they should see these approaches in opposition to each other or see them helping each other in improving performance outcomes.

This research is not about the leanness, agility and resilience in isolation, and is not aiming to critically view each of them in isolation. Enough has been written on the three approaches previously but the aim of this research is to study how these three can be seated together in today's supply chains. Nobody can deny the need for trying to be lean in terms of cost effectiveness, also being agile in terms of customer responsiveness but also the third element as being resilient in terms of being aware of risks and becoming ready to encounter them and pass them in the best way possible. As stated in summary in Section 1.1 above and will be discussed in extension in the literature review chapter, academic papers have started discussion around the issue that how for example leanness and agility can fit together, or how agility and resilience can be seated together in supply chains. Even discussions around how the three of the LAR can be fitted together have been started but all these remain conceptual and the literature still lacks any empirical analysis that could strongly explain how the relations are between LAR both in terms of practices and the effect on the performance outcomes.

The above discussion on the gaps and the importance of them is the origin of the research question defined for this research.

The research question is: "How does resilience fit with leanness and agility both in terms of practices and outcomes in the context of supply chain management?"

To seek an answer, two research objectives are defined:

- First objective: Disentangling resilience, leanness and agility.

- Second objective: Investigating how resilience impacts performance in the presence of practices for leanness as well as agility in the context of supply chain management.

The first research objective is targeting to fill the first gap discussed to provide clear boundaries between leanness, agility and resilience. The second objective is targeting to fill the second gap to provide not only conceptual model but also empirically validated one on how resilience along with leanness and agility affect performance outcomes.

1.3 Contribution of the present study

This study has important theoretical as well as managerial implications.

The existing literature lacks first of all, a clear distinction regarding measures related to resilience, agility and leanness. It tries to make a clear distinction between boundaries of these three approaches in supply chain management context through the first objective of this research "disentangling Resilience, agility and leanness". This is more crucial, when it comes to the measures where confusion exists about them in literature. This confusion is because there are some measures that according to the literature go under both leanness and agility and; agility and resilience or even the three of them. So when it comes to have them in statistical models researchers don't know where exactly these measures should be categorized. The first objective of this research tries to fill this gap.

While it is clearly concluded that which measures can be specifically categorized as resilience, agility and leanness, the research moves to the second objective which investigates how resilience along with leanness and agility affects performance outcomes. Regarding this part, it can be said that first, there has been no research found to date that quantitatively looks at resilience. Second, there has been no research to date that quantitatively looks at how resilience, agility and leanness can be modelled not solely but beside each other. Third, there has been no research to date that aims to investigate the effects of resilience along with leanness and agility on performance outcomes. Also in terms of performance outcomes, it should be stated that for the first time, time to recovery is considered as an outcome performance. So, supply chain performance needs to be measured in terms of not only flexibility, delivery and cost, but also time to recovery.

In addition, this research considers the managerial need for modelling how resilience along with leanness and agility affects performance outcomes. The conclusion of the survey and focus group, done in P&G in 2011, showed enough evidence that managers need to know how these three approaches of resilience, leanness and agility sit beside each other.

This research tries to fill this gap, first by disentangling leanness, agility and resilience where these three approaches make confusions.

Second, the SEM model gives useful guidance to supply chain managers regarding the three approaches in supply chains: resilience, leanness and agility. Quantitatively they can see how resilience along with leanness and agility affects performance outcomes.

What is more, this study is coming in the right time: currently there are volatile circumstances in the world, from sanctions to natural disasters. All these urge firms to pay more attention to resilience which also increases the academic interest in this issue. As a result, there is an audience eagerness to such theoretical and, managerial developments.

1.4 Structure and summary of the thesis

The Thesis structure is as follows:

- **Chapter 1: Introduction**

  The first chapter provides an introduction to the topic. The academic research is sketched. The gaps are identified. The research question and research objectives are defined clearly and finally the contributions of this study are described both in terms of theory and practice.

- **Chapter 2: Literature Review**

  This Chapter presents a literature review on the three main approaches of the supply chain management, which are also the main interests of this research: resilience, agility and leanness. This results in the first gap identified that there exist no clear boundaries between leanness, agility and resilience (LAR) in terms of practices calling for empirical research to disentangle resilience, leanness and agility.

  Then, the literature review goes on to review performance outcomes and how these three approaches and combinations of them affect performance outcomes. This results in the second identified gap that there exists no empirical research on how resilience along with leanness and agility affects performance outcomes resulted in a model development and related hypotheses.

  Finally, bridging between these two, a model and related hypotheses are developed.

  This chapter also reviews Resource Based View as a theory underlying this research.

- **Chapter 3: First quantitative study: Disentangling resilience, agility and leanness in the context of supply chain**

  This chapter goes through the first quantitative study with the objective of disentangling leanness, agility and resilience. The chapter presents the related survey designed for this part, choice of survey method (online), data collection (all industries in Germany) procedure and sampling consideration, measures taken to ensure survey quality and finally the analysis, resulted in clear constructs of LAR for the second objective of the study.

- **Chapter 4: Second quantitative study: How resilience along with leanness and agility affects performance outcomes?**

  This chapter goes through the second quantitative study with the objective of investigating how resilience along with leanness and agility affects performance outcomes. This part also presents the related survey, choice of survey method (mail survey), data collection procedure (Auto parts suppliers in Iran) and sampling consideration, measures taken to ensure survey quality and all other preparations related for running the final Structural Equation Model (SEM).

  In addition, this chapter presents the results of the structural equation modeling. First, all measurement models are tested for reliability and validity. While it is assured that all constructs are reliable and valid, the final structural equation model is tested. The results are all explained regarding the rejection or acceptance of all the hypotheses.

- **Chapter 5: Discussion and conclusion**

This chapter presents a review of the thesis. The results of the first quantitative study and the second quantitative study are discussed; all hypotheses of the structural equation model and their acceptance or rejection are discussed in details specially regarding the literature existed in the field. Then, the theoretical and managerial implications are drawn. Next, limitations of the research are stated and at the end directions for future research are suggested.

Chapter 2: Literature review

The gaps this research is trying to fill are not looking at the three approaches of LAR in isolation but looking at the combinations of these three in the literature is the main concern which this research tries to look at it critically and extract the gaps through it. There is huge literature review on leanness, agility and resilience but the concern here is that part of the literature which started combining these three approaches but there exists gaps there. These gaps are about the literature starting to consider LAR for supply chain but all remain conceptual. So, there is no empirical evidence on how leanness, agility and resilience can fit both in terms of practices and their effects on performance outcomes.

Therefore, this Chapter will present a literature review on the three main approaches of the supply chain management, which are also the main interest of this research: resilience, agility and leanness. Then, it will look at how combinations of these three approaches exist in literature which results in identifying the first gap and first objective of this research "disentangling resilience, leanness and agility". Then it will go to a review on performance outcomes and that how the three approaches and specifically the combinations of them have affected the performance outcomes. This will result in the second gap and the second objective of this research which is "investigating how resilience along with leanness and agility affect performance outcomes." Finally bridging between these two, a model and related hypotheses are developed. It is more than a decade that academics have been criticizing lean which leads to new approaches such as agility, then again shortages within agility that leads to more new and demanding approaches such as resilience. Therefore, this conclusion has been made that supply chain needs to be balanced between these three and needs these three, but no empirical evidence is presented yet and this point is the contribution of this research.

2.1 Resilience

2.1.1 Where resilience originates from

The Latin root of the word resilience is *"resilio",* which means to jump backwards. Merriam-Webster (2007) defines resilience as "*the tendency of a material to return to its original shape* *after the removal of a stress that has produced elastic strain".*

According to Ponomarov and Holcomb (2009) the study of resilience has its origin in development theory of social psychology and is an emerging theory on its own right. They state that resilience can be considered from different perspectives such as: ecological, social, psychological, economic, organizational and supply chain. These different perspectives are presented in Table 1.

Table 1- Different perspectives of resilience

Resilience perspectives	**Definition**	**Components, principles**
Social	the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure	
Psychological	The specific area of study that addresses resilience is called developmental psychopathology, an examination of developmental differences in people's response to stress and adversity.	Principles: Control (direction, regulation, and coordination of activities). Coherence (enhancing meaning, direction and understanding during the worst times; processes and procedures needed to reduce uncertainty). Connectedness (behavior to bend together; systematic coordination of efforts to avoid duplication and

		wastefulness of services).
Economic	The ability of a system to recover from a severe shock or stress	Types: Inherent: Ability under normal circumstances (e.g. the ability to substitute other inputs for those damaged by an external shock, or the ability of markets to reallocate resources in response to price signals). Adaptive: Ability in crisis situations due to ingenuity or extra effort (e.g. increasing input substitution possibilities in individual business operations, or strengthening the market by providing information to match suppliers with customers).
Organizational	The capacity to adjust and maintain desirable functions under challenging or straining conditions A dynamic capacity of organizational adaptability that grows and develops over time The ability to bounce back from disruptive events or hardship	

Ecological	Degree, manner, and pace of restoration of initial structure and function in an ecosystem after disturbance	Components: Elasticity: Rapidity of restoration of a stable state following disturbance Amplitude: The zone of deformation from which the system will return to its initial state Hysteresis: The extent to which the path of degradation under chronic disturbance, and a recovery when disturbance ceases, are not mirror-images of each other Malleability: Degree to which the steady state established after disturbance differs from the original steady-state Damping: The degree and manner by which the path of restoration is altered by any forces that change the normal restoring force
Supply chain risk management	The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining	Aspects: Agility, responsiveness Visibility Flexibility

	continuity of operations at the desired level of connectedness and control over structure and function.	Structure and knowledge Reduction of uncertainty, complexity, reengineering Collaboration Integration

As this research is in the field of supply chain management, it therefore is needed to see how resilience has been defined in this context and second how it is evolved in supply chain management.

2.1.2 Review on the Supply chain resilient literature and definition development

Christpoher and Peck (2004) present one of the earliest definitions of resilience in supply chain which is "*The ability of a system to return to its original state or to move to a new, more desirable state after being disturbed".* They identify four main factors for creating a resilient supply chain. These factors are supply chain reengineering, collaboration, agility and creating a supply chain management culture.

Sheffi and Rice (2005) define resilience as "*the ability to bounce back from a disruption*" which can be captured through creating redundancy and increasing flexibility. They see it as a strategic initiative. Rice and Caniato (2003) identify that redundancy is maintaining capacity to respond to disruptions in the supply network through investments in capital and capacity before the point of need.

> Panomarov and Holcomb (2009) define supply chain resilience as "*The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function"*(Panomarov and Holcomb, 2009, P. 131). Panomarov and Holcomb (2009) believe that resilience is a multidimensional and multidisciplinary concept routed in different disciplines as psychology, ecosystems, risk management and

supply chain management. They state that existing definitions of resilience are contradictory and confusing and that researchers are still trying to develop the unified theory of resilience. They mention that for justifying the need for resilient supply chains two things are needed: operational definition of resilience and an understanding of the key elements and capabilities which characterize it.

Another outstanding research on supply chain resilience is done by Wieland and Wallenburg (2012). In their paper they state that resilience is both a proactive capacity to "take action before it is a final necessity" and the reactive capacity to "recover after experiencing a crisis". It includes both the ability to prevent or resist being affected by an event and to "return to an acceptable level of performance in an acceptable period of time after being affected by an event". In their research they define resilience as the ability of a supply chain to cope with change.

To summarize, different definitions found in literature for resilience in the supply chain context are listed in Table 2.

Table 2- Resilience definitions in the supply chain context

Source	**Resilience definitions in the supply chain context**
Rice and Caniato (2003)	The ability to react to an unexpected disruption
Christopher and Peck (2004)	The ability to cope with the consequences of unavoidable risk events in order to return to its original operations or move to a new, more desirable state after being disturbed
Sheffi and Rice (2005)	The ability to bounce back from disruption
Azvedo et al. (2008)	The ability to cope with unexpected disturbances
Ponomarov and Holcomb (2009)	The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function

Berle et al. (2011)	The ability of the supply chain to handle a disruption without significant impact on the ability to serve the customer

Different definitions use the terms of “disturbance” and “disruption” while defining resilience. This calls for the definitions for these terms in order to have better understanding of resilience.

Supply chain disturbance is an unforeseeable event, which affects usual operation and stability of a company or a supply chain (Barroso et al., 2008). Supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain (Craighead et al., 2007). According to Greening and Rutherford (2011) disturbances are related to small impacts and do not change the chain structure whilst disruptions result in network irreversibility.

These definitions show that as research is moving forward, authors propose more specific definitions of the supply chain resilience. Rice and Caniato (2003) suggest a definition which focuses on the individual companies’ ability to react to unexpected events. Later, the focus is changed towards supply chain behaviour rather than individual companies.

Mensah and Merkuryev (2014) state supply chain resilience is a new area of study which still needs to be properly investigated. They believe there is still no concrete definition for supply chain resilience.

This research takes advantage of the definition of Sheffi and Rice (2005) for resilience as “The ability to bounce back from disruption”. This definition also supports the practices related to resilience in this research.

2.1.3 Supply chain resilience; background and evolution

According to Pettit et al. (2010), the first wide-spread study on supply chain resilience began in the United Kingdom, following transportation disruptions from fuel protests in 2000 and the outbreak of the Foot and Mouth Disease in early 2001. The UK’s industrial knowledge base on supply chain vulnerabilities was explored by that study in Cranfield University in 2003, leading to four main results:

(1) Supply chain vulnerability is an important business issue.

(2) Little research exists into supply chain vulnerability.

(3) Awareness of the subject is poor.

(4) A methodology is needed for managing supply chain vulnerability.

Christpoher and Peck (2004) identify four main factors for creating a resilient supply chain. These factors are supply chain reengineering, collaboration, agility and creating a supply chain management culture. Supply chain must be reengineered to consider all three concepts. Usually supply chains are designed based on cost and/or customer service. Resilience is usually neglected. Collaboration can be achieved through collaborative planning and supply chain intelligence. The aim of creating high level supply chain intelligence is greater visibility of upstream and downstream risk profiles and changes in them. While later agility will be expanded as one the practices that supply chain implement which leads them to improve their performance measures, in their model Christopher and Peck (2004) believe that agility helps resilience through visibility and velocity. They also mention supply chain risk management culture creation can be achieved by establishing supply chain continuity team, board level responsibility and leadership, and factor risk consideration into decision making. Factors which cause resilience are shown in Figure 1.

Figure 3- Mechanism of resilience [Source: Wieland and Wallenburg (2012)]

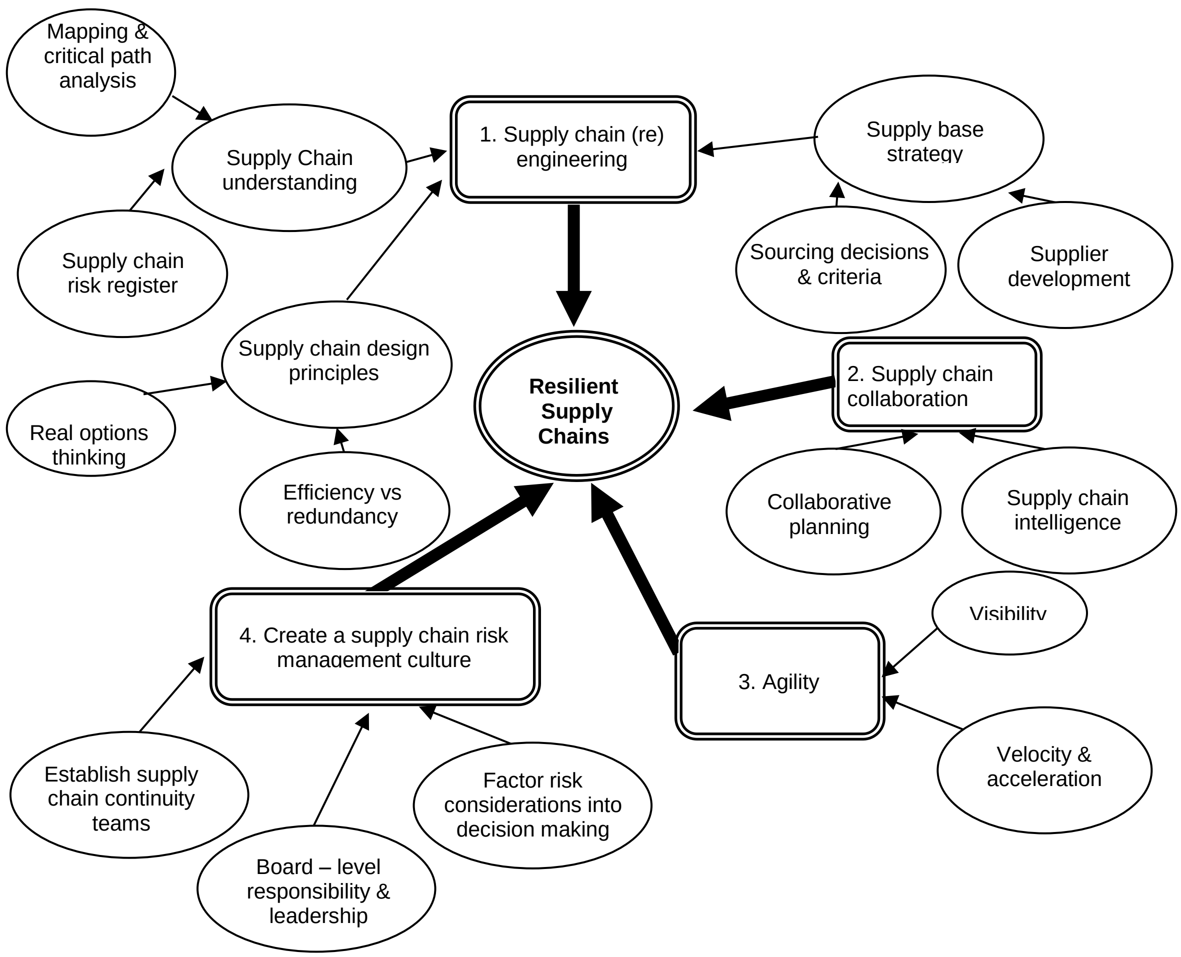

Figure 1. Resilient supply chain [Source: Christopher and Peck (2004)

Although their paper presents one of the first frameworks for supply chain resilience, however, it lacks empirical analysis.

According to Pettit et al (2010) in parallel to the Cranfield studies, researchers at the Massachusetts Institute of Technology (MIT) analysed many case studies of supply chain disruptions with a focus on identifying vulnerability characteristics and management responses such as flexibility, redundancy, security, and collaboration (Sheffi 2005).

Sheffi and Rice (2005) state that resilience; can be captured through creating redundancy and increasing flexibility. They see it as a strategic initiative. Rice and Caniato (2003) identify that redundancy is maintaining capacity to respond to disruptions in the supply network through investments in capital and capacity before point of need. This can be done through managing inventory, maintaining production lines or facilities in excess of capacity requirements, committing to contracts for material supply by buying capacity whether it is used or not, and maintaining a dedication transportation fleet. For flexibility, Sheffi and Rice (2005) define five facets for flexibility in relation with resilience. Actually to see how flexibility can be achieved the essential elements of any supply chain should be considered: material flows from suppliers through a conversion process, then through distribution channels. They are controlled by various systems while all are working with the context of corporate culture. Each of these five elements is a dimension of a potential flexibility:

1) Supply and procurement: if a company decides to work with one supplier, it should invest in a deep relationship. Alternatively, it can work with multiple suppliers which require a less deep relationship.

   2) Conversion flexibility: measures a company's ability to respond to a disruption. Here rapid response is viable through standard processes.

   3) Distribution and customer facing activities: distribution should be done through a fair allocation process so that long term relationships are damaged as little as possible.

   4) Control systems: they detect a disruption quickly. It should be done through: shipment visibility system with tracking and tracing capabilities, this enables, for example, late shipments to be notified to customers.

   5) The right culture: it is important not to underestimate the contribution of culture to an organization flexibility and resilience. One of the crucial ways to help resilience is empowering front line employees. Empowering front line employees can be done through learning from errors and fixing the root causes as well as many other processes which shape culture of quality.

Like the previous work of Christopher and Peck (2004) they offer their framework for resilient supply chain; however, that remains without empirical analysis.

One of the other remarkable papers about resilience is presented by Panomarov and Holcomb (2009) who believe that the dynamic integration of logistic capabilities enables supply chain resilience which leads to sustainable competitive advantage. Their proposed model for supply chain resilience addresses the relationship between logistic capabilities and supply chain resilience.

As they state in their paper, Supply chain resilience is relatively a new research area and their conceptual model is just one of the possible views. Their research still lacks any empirical analysis.

Pettit et al. (2010) also conduct an exploratory research and offer a supply chain resilient framework which recognizes the need to balance managerial capabilities with the inherent vulnerabilities of the supply chain design and its environment. They also identified 14 unique capabilities which increase supply chain resilience. These capabilities include: flexibility in sourcing, flexibility in order fulfillment, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organization, market position, security and financial strength.

As stated in their paper, one of their major limitations is that their research lacks empirical analysis of their framework similar to the previous studies. All frameworks are suggested but still no empirical analysis on the issue is found which put the validation of the frameworks under question.

According to Pettit et al. (2010) the concept of resilience in supply chain combines these previous tenets (Section 2.1.1) with studies of supply chain vulnerability. Svensson (2002) defines supply chain vulnerability as *"unexpected deviations from the norm and their negative consequences"*. According to Craighead et al. (2007) and Sheffi (2005) vulnerability can be measured mathematically in terms of "risk", a combination of the likelihood of an event and its potential severity. Both these definitions have foundations in "supply chain risk management" (SCRM). Therefore, it is needed to review SCRM and more specifically the concept of risk itself.

Juttner et al. (2003) define SCRM as "*the identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain risk members, to reduce supply chain vulnerability*" (Juttner et al., 2003, p. 201).

According to Normman and Jansson (2004), a more standard definition of risk is "*the chance, in quantitative terms, of a defined hazard occurring. It, therefore, combines a probabilistic measure of the occurrence of the primary event(s) with a measure of the consequences of that/those event(s)"* (The Royal Society, 1992, p. 4). So risk is a quality that reflects both the range of possible outcomes and the distribution of respective probabilities for each of the outcomes. This quantitative definition can be expressed as: Risk= Probability of the event * Business impact (severity).

Juttner et al. (2002) state that risk should be differentiated from risk sources and risk consequences or impacts. They categorize risk sources related to supply chain into three groups of internal, external and network related risks. They believe that internal risk sources range from labour (strikes) or production (e.g. machine failure) to IT system uncertainties. They count political, natural, social, industry/market risks as external sources of risk. Network related risks arise from interaction between organizations within the supply chain e.g. insufficient cooperation.

Risk impacts are the focused supply chain outcomes variables like cost and quality. Sodhi and Tang (2012) state in their book that it is helpful to think of "risk" as issues ranging from underlying causes to actual risk events to impacts. In the occurrence of a risk event, causes are before the risk event while the impact is felt after the occurrence of such an event. They consider three types of risks motivated by the supply chain organizations as: supply risks, process risks, demand risks and corporate level risks.

The next step after categorizing risks is how to manage them. According to The Royal Society (1992, p. 3*) "risk management is the making of decisions regarding risks and their subsequent implementation, and flows from risk estimation and risk evaluation"*.

According to Pettit et al. (2010) in practice, risk management entails examining all possible outcomes of a project or process, then weighing the potential returns against the potential risks of the investment. Risk assessment is a critical step in the risk management process. As shown in Fig. 2, it is achieved based on the assessed probability of an event and the estimated severity if the event occurs. Risk management is unable to characterize low-probability, high-consequence (LP/HC) events adequately and this can be considered as its greatest weakness. In addition, the traditional risk assessment approach is unable to deal with unforeseeable events. Pettit et al. (2010) conclude that the concept of supply chain resilience can fill these gaps, resulted in supply chains which are enabled to survive from unforeseen disruptions.

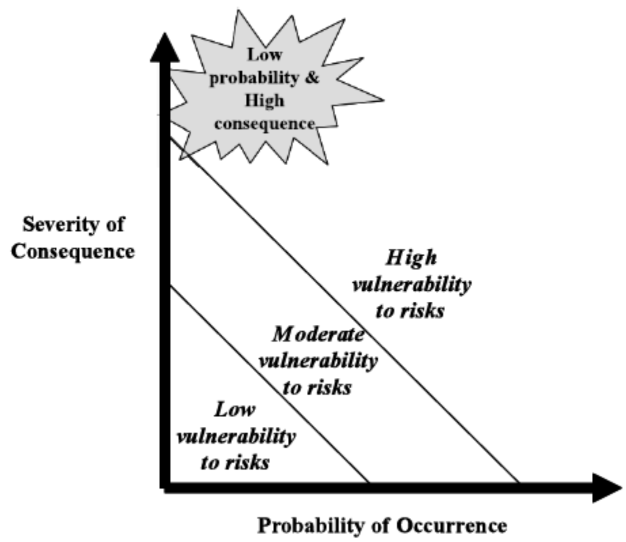

Figure 2-Traditional risk assessment [Source: Pettit et al. (2010)]

As Hanifan (2007) states the ability to predict and manage supply chain risk does not grow at the same pace as supply chain extension and reach. Traditional risk assessments usually measuring a few variables such as probability and magnitude of impact can no longer protect against sophisticated supply chain disruptions. Traditional risk assessments lack both the nuance and scope to deal with a modern supply chain, as well as the ability to accurately determine the financial consequences of various vulnerabilities which include the cost of recovery, opportunity costs and the future cost to mitigate. He states that traditional approaches generally focus on two risk parameters including probability and magnitude. Therefore, what is the chance of a particular disruption and what is its impact on its business? But there exist some important points to be missed: can the risk be detected easily or not? How long does it take for a disruption to be noticed and what are the possible impacts of that lag of time?

Back to the review on papers on resilience, the next one is Wieland and Wallenburg (2012) who state in their paper that for coping with change and departing from an unstable state, the nature of interaction with the environment needs to be either reactive or proactive. A reactive strategy meets environmental change with a corresponding organization action, while the proactive one is based on forecasting and prevention. They believe the former strategy is agility and the latter is robustness. They conclude that resilience is formed by agility and robustness. Their mechanism of resilience is presented in Figure 3.

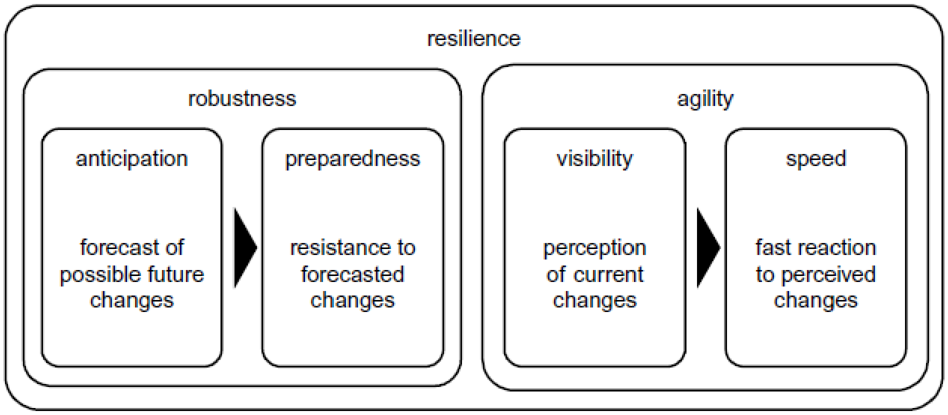

Figure 3- Mechanism of resilience [Source: Wieland and Wallenburg (2012)]

While they did an empirical analysis for their suggested framework, their work has some limitation. As stated in their paper, all participants are from German-speaking countries; therefore, generalizability can be a problem. And as any other survey research, for some constructs, a broader operationalization could have been possible.

Summary of key literature on resilience and their contribution to the issue are listed in Table 3.

Table 3- Summary of key literature on resilience (conceptual models for resilience)

Reference	**Summary**
Hamel and Valikangas (2003)	A macro view of resilience (labelled as 'strategic' resilience) Identify four challenges including cognitive, strategic, political and ideological challenges that firms face in moving from complacency to resilience and suggest possible remedies
Rice and Caniato (2003)	A hybrid flexibility/redundancy approach for increasing supply chain resilience
Christopher and Peck (2004)	Agility, collaboration, risk management culture and reengineering as antecedents of achieving resilience in the supply chain
Sheffi and Rice (2005)	Achieving resilience via redundancy and flexibility

Ponomarov and Holcomb (2009)	Dynamic integration of logistic capabilities enables supply chain resilience which leads to sustainable competitive advantage. Their proposed model for supply chain resilience addresses the relationship between logistic capabilities and supply chain resilience.
Pettit et al. (2010)	Suggest a framework to define resilience in terms of measurable variables mentioning that their framework needs to be empirically validated.
Demmer et al. (2011)	Identify key antecedents of resilience in large enterprises and use a case study to examine whether these strategies are applicable for small- and medium-sized enterprises (SMEs).
Juttner and Maklan (2011)	Conceptualise supply chain resilience (SCRES) and explores its relationship with the related concepts of SCRM and SCV
Blackhurst et al. (2011)	Propose a supply resilience framework that contains the elements that may contribute to increase resilience (denominated as resilience enablers) and elements that may contribute to reduce resilience (denominated as resilience reducers).
Carvalho et al. (2011)	Explore the divergences and commitments between the lean, agile, resilient and green paradigms while investigating the effect of paradigms' practices within supply chain attributes.
Speigler et al. (2012)	Explore the resilience of supply chains from a systems dynamics perspective

As stated previously, the research question here is how resilience fit with leanness and agility both in terms of practices and outcomes. As a result of the above review on the papers of resilience, it can be concluded that even resilience itself still is not developed and validated completely, nor the question of this research which is its relation with leanness and agility. All researchers have suggested frameworks for resilience while most of them remained without empirical validation. The next step in the literature review is looking for practices related to resilience.

2.1.4 Supply Chain resilience; related practices

Extent literature related to resilience was reviewed in order to extract all practices which are related to resilience. These practices are all presented in Table 4.

Table 4- Practices related to resilience extracted from literature

Practices related to resilience	Literature mentioning the practices
Alternative modes of Transportation	Pettit et al. (2010); Sheffi (2005); Sheffi and Rice (2005); Christopher and Rutherford (2004); Ponomarov and Holcomb (2009); Fiksel (2003)
Business continuity	Sheffi and Rice (2005); Christopher and Peck (2004);Zsidisin et al. (2005); Craighead et al. (2007)
Contingency plans	Juttner et al. (2003); Tang (2006); Kleindorfer and Saad (2005); Craighead et al. (2007); Peck (2006);
Detection systems in place to detect any supply chain disruption	Pettit et al. (2010); Sheffi and Rice (2005); Ponomarov and Holcomb (2009)
Decentralization of physical assets in multiple locations of assets	Pettit et al. (2010); Sheffi and Rice (2005); Bartos and Balmford (2011); Manuj and Mentzer (2008 a)
Security	Pettit et al.(2010); Sheffi (2005); Tang (2006)
Establishing communication lines	Juttner (2005);Ta et al. (2009); Christopher and Peck (2004)

Redundant supplier	Sheffi and Rice (2005); Rice and Caniato (2003); Bartos and Balmford (2011); Xu (2008)
Flexible manufacturing equipment to produce different products with the same facilities	Pettit et al.(2010); Sheffi and Rice (2005); Rice and Caniato 2003; Peck 2006; Bartos and Balmford (2011); Xu (2008); Ponomarov and Holcomb (2009)
Excess capacity	Pettit et al. (2010); Sheffi and Rice (2005) ; Rathic et al. (2008); Peck (2006); Christopher and Rutherford (2004); Ponomarov and Holcomb (2009)
Visibility	Pettit et al. (2010); Christopher and Peck (2004)
cross functional workforce	Pettit et al. (2010); Sheffi and Rice (2005); Rice and Caniato (2003); Bartos and Balmford (2011); Peck (2006)
Collaboration	Pettit et al. (2010); Christopher and Peck (2004); Sheffi and Rice (2005); Peck (2006); Ponomarov and Holcomb (2009)

This research should go to review how resilience is linked to leanness and agility here, in order to answer its research question; however, first it is needed to review leanness and agility, and then move to how these three approaches in supply chain are linked together in literature.

2.2 Agility

The concept of agility was first introduced in a report from the Iacocca Institute at Lehigh

University in 1991. The report explained that how US corporations should move forward to become a manufacturing leader again (Nagel and Dove, 1991).

While agility has been defined in different contexts such as manufacturing, here agility in the context of supply chain is the main concern.

Christopher and Peck (2004) define supply chain agility as the ability to respond quickly to unpredictable changes in demand or supply. From their point of view, the key to an agile response is the presence of agile partners in upstream and downstream of the focal firm. Christopher and Peck (2004) define the two key characteristics of agile supply chain as visibility (the ability to see from one end of the pipeline to the other) and velocity (distance over time). Also, the acceleration is important. It is defined how rapidly a supply chain can react to changes in demand. There are three ways for improving velocity and acceleration:

- Streamlined processes: they have been engineered to reduce the number of stages or activities involved. They are designed to perform these activities in parallel rather than in series and electronically rather than paper based.
- Reduction in in-bound lead-times: one of the criteria for supplier choosing is the ability to respond quickly in terms of delivery and cope with short-term changes in volume. Here, shared information can be helpful in achieving agility.
- Reducing time of none value- adding activities within the pipelines

Papers related to agility can be mainly divided into two streams. The first category focuses on agility practices and the second group concentrates on how agility affects performance outcomes. These papers have different definitions for agility. Table 5 summarizes the key literature on agility related to both groups and the definitions that are used in these papers for agility.

Table 5- Key literature on agility and the definitions used

Paper focus	Key Literature on Agility	Definition	Performance Dimension	Associated Practices
Agile	Gunasekaran	*"Capability to survive*		Flexible people

practices	and Yusuf (2002)	*and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services"*.		& technology, strategic planning & objectives, market focus
	Swafford et al. (2006)	*"Capability of an organization to adapt or react to marketplace changes or to seize/exploit market opportunities with speed and quickness"*.		Procurement, sourcing flexibility, manufacturing flexibility, distribution, logistics flexibility
	Braunscheidel and Suresh (2009)	*"Supply chain's capability to respond in a speedy manner to a changing marketplace environment"*.		Joint planning, customer responsiveness, visibility, demand, response
Agility and performance	Sharifi and Zhang (2001)	*"Ability to sense, respond to, and exploit anticipated or unexpected changes in the business environment"*.	Delivery responsiveness, delivery speed, product model flexibility (customization), product	Advanced soft & hard technologies, internal networks, worker empowerment,

			introduction flexibility, volume flexibility	concurrent teams
	Prince and Kay (2003)	*"Capabilities of an enterprise to reconfigure itself in response to sudden changes in ways that are cost effective, timely, robust and of broad scope"*.	Delivery speed, product introduction speed; stable unit cost, changeover flexibility	Information & communication technologies, computer controlled manufacturing, Modular facilities
	Brown And Bessant (2003)	*"Ability to respond quickly and effectively to changes in market demand"*.	Proactive & reactive flexibility, delivery speed, design quality (customization), cost efficiency	JIT, TQM, customer linkages, supplier alliances & information sharing, wide range of skill training, advanced information & manufacturing
	Vasques Bustelo et al. (2007)	*"Capability to change market requirement, maximize customer service level, minimize the cost of goods"*.	Cost, quality, delivery, environment, flexibility, Service	Agile HR, agile technologies, value chain integration, knowledge

				management, concurrent engineering

As seen above, different researchers define agility in different ways. This research takes advantage of the one from Swafford et al. (2006). They define agility as "*the supply chain's capability to adapt or respond in a speedy manner to a changing marketplace environment*". This definition also supports the practices related to agility in this research.

According to Hoek (2000), agility in the supply chain is linked to customer sensitivity, virtual integration, process integration and network integration (illustrated in Fig. 4).

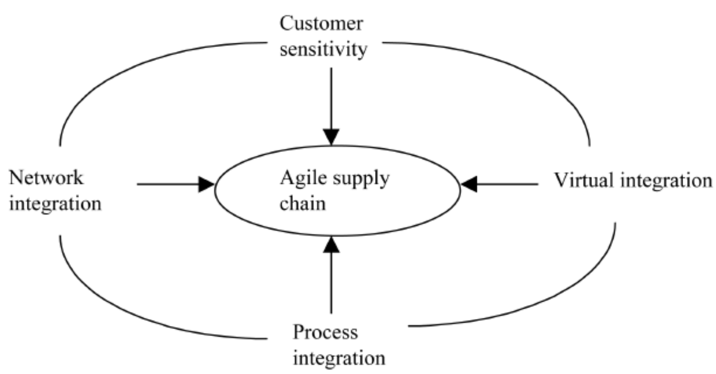

Figure 4- Elements of an agile supply chain [Source: Hoek (2000)]

Additionally, characteristics of agile supply chain according to Van der Vorst et al. (2001) are being:

-Market sensitive: the supply chain is capable of reading the real demand and responding to it.
-Virtual: using information technology between buyers and suppliers to share the data
-Process integrated: collaborative working between buyers and suppliers such as joint product development, common systems and shared information
-Network based: relationships with partners must be managed in a network, committed to more agile relationships with final customers.

Hoek (2000) cites two important practices for agile supply chain are postponement and information decoupling. Postponement is about delaying activities in the supply chain until customer orders are received. According to Hoek (2000), postponement helps the following items:

-The customization of product and services (customized and localized assembly)

-The use of customer order information throughout the supply chain (linking supply chain operations to the customer order)

-The cross functional effort involved in assembling products in the distribution channel closer to customer (linking manufacturing and distribution, potentially even design products through redesigning products around modularity and commonality).

-The crucial role of supplier networks in postponement (generic modules and parts are needed before customized assembly)

According to Hoek (2000), information decoupling concentrates on the flow of the information in the supply chain rather than the physical flow of goods. Integrating the flow of information helps to have better responsiveness, process and network integration.

2.2.1 Agility, flexibility and responsiveness

Swafford et al. (2006) states that flexibility is an important antecedent of supply chain agility. Also, Braunscheidel and Suresh (2009) mention flexibility is associated with competency which is internally focused while agility is associated with capability which is externally focused. Competencies is defined as "what an organization can do particularly well" according to (Andrews, 1987), while capability is "appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment" according to Teece et al., (1997). Chiang et al. (2011) concludes that a system can be flexible without being agile, while an agile system is definitely flexible.

Bernardes and Hanna (2009) define responsiveness as the actions or behaviour of a system using a series of capabilities to address changes triggered by stimuli. They conclude that flexibility refers to specific internal mechanisms within the broader system, which may be used to contribute to overall system responsiveness. So flexibility is having the availability of choices which may be used to respond the changes. It is an attribute of the system while responsiveness is an outcome of using that. Table 6 summarizes the scope and definition related to agility, flexibility and responsiveness.

Table 6- Summary of conceptualization of flexibility, agility and responsiveness [Source: Bernardes and Hanna (2009)]

Original Perspective	**Flexibility**	**Agility**	**Responsiveness**
Scope	- Operating Characteristic -Inherent system property	-Business level organizing paradigm - Approach to organizing the system	- Business level performance capability system behavior or outcome
Definition	Ability of a system to change status within an existing configuration (of pre-established parameters)	Ability of the system to rapidly reconfigure (with a new parameter set)	Propensity for purposeful and timely behavior change in the presence of modulating stimuli

Also, Reichhart and Holweg (2007) define responsiveness as "*the speed with which the system can adjust its output within the available range of the four external flexibility types: product, mix, volume and delivery, in response to an external stimulus, e.g. a customer order*." According to their paper, velocity, adaptability, and flexibility are responsible for the system responsiveness.

The next step in the literature review is looking for practices related to agility.

2.2.2 Supply Chain agility; related practices

Extent literature related to agility was reviewed in order to extract all practices which are related to agility. These practices are all shown in Table 7.

Table 7- Practices related to agility extracted from literature

Practices related to agility	Lit. mentioned practices
Computer based technologies	Power (2001); Gunasekaran (1998); Prince and Kay (2003)
High customization capability	Braunscheidel and Suresh (2009); Hallgren and Olhager (2009); Hoek et al. (2001); Swafford et al. (2006); Holweg (2005)
Introducing new products quickly	Hallgren and Olhager (2009); Sharifi and Zhang (2001); Lee (1998)
Responding quickly to rapidly changing situation somewhere in the supply chain	Sharif and Zahng (1999); Gould (1997); Hormozi (2001)
Integrating different functions in the company	Narasimhan et al. (2006); Machado and Duarte (2010); Aitken et al. (2002)
Redundant supplier	Lee (2004); Lou et al. (2002); Cheng and Ye (2011)
Flexible manufacturing equipment to produce different products with the same facilities	Swafford et al. (2006); Sharifi and Zhang (2001); Goldsby et al. (2006); Christopher and Towill (2001); Ramesh (2005); Aitken et al. (2005); Christopher and Towill (2000); Goldsby et al. (2006)
Excess capacity	Swafford et al. (2006); Bruce et al. (2004)
Visibility	Braunscheidel and Suresh (2009); Christopher and peck (2004); Aitken et al. (2002)
Just in time (JIT)	Power (2001); Narasimhan et al. (2006); Brown (2003)
Concurrent engineering	Vázquez-Bustelo et al. (2007); Gunasekaran (1998); Choi and Hartley (1996); Yusuf et

	al. (1999); Booth (1996)
Knowledge management	Vázquez-Bustelo et al. (2007); Jin Hai et al. (2003); Booth (1996)
Total quality management (TQM)	Power (2001); Narasimhan et al.(2006); Yusuf et al. (1999)
Implementing new technologies	Power (2001); Vázquez-Bustelo et al. (2007); Narasimhan et al. (2006)
Reducing process downtime between product changeovers	Sharifi and Zhang (1999); Swafford et al. (2006)
cross functional workforce	Vázquez-Bustelo et al. (2007); Sharif and Zhang (2001); Ramesh (2005); Narasimhan et al. (2006)
Collaboration	Sharifi and Zhang (2001); Yusuf and Adeleye (2002); Cao and Dowlatshahi (2005)

2.3 Leanness

Lean is often viewed as a process or simply another strategy whereas it should be seen as a philosophy (Ransom, 2008). As a philosophy it is a way of thinking whereas tactics or processes are mechanisms to activate these thoughts (Bhasin and Burcher, 2005).

2.3.1 Definition

According to Hallgren and Olhager (2009), JIT system- initially known as Toyota Production System (TPS) - was the precursor of lean manufacturing. JIT/TPS/lean was developed in 1980, by Taiichi Ohno, Shigeo Shingo and Yasuhiro Monden. Later lean manufacturing was used for the practices carried out within Toyota.

Taiichi Ohno, the architect of Toyota Production System (TPS) believes the crucial factor for any company's success is elimination of waste (Goldsby et al., 2006). Goldsby et al. (2006)

mention the list developed by Ohno, including seven basic forms of wastes as follows:

- Defects in production
- Overproduction
- Inventories
- Unnecessary processing
- Unnecessary movement of people
- Unnecessary transport of goods
- Waiting by employees

In recent studies waste is categorized into obvious wastes and less obvious wastes (Narasimhan et al., 2006). Obvious wastes are unneeded processes, executive setup times, unreliable machines and reworks. Less obvious wastes associated with variability. They can be subdivided into variability in process times, delivery times, yield rates, staffing levels and demand rates, which all create buffering costs.

According to Shah and Ward (2003), lean manufacturing is a collection of practices that work together with the aim to create a streamlined, high quality system that produces finished products in relation to the customer's demand rate with little or no waste.

According to Goldsby et al. (2006), the potential of lean principles has been embraced by many practitioners and researchers and they were expanded into logistics, product development, and purchasing. In the follow up of Woamck and Joens' (1996) book, conceptualision of lean operations was extended to the broader enterprise. The lean enterprise identifies the value inherent in specific products, identifies the value stream for each product, supports the flow of value, lets the customer pull value from the producer, and pursues perfection. According to Goldsby et al. (2006), "*It is through this holistic, enterprise-wide approach to lean implementation that the theory extends beyond functional strategy to a broader supply chain strategy*". Machado and Duarte (2010) state that to create a lean supply chain it is necessary to examine each process and identify unnecessary resources, which can be measured in terms of cost, time and inventory. According to Konecka (2010), the emergence of lean supply chains is a result of the relationships between the quality and the costs. These are the key factors which affect the competitiveness along with other factors such as time, price, speed, customer satisfaction, productivity diversity and technology. The existing activities within Supply Chain

Management (SCM) aim at the reduction in cost by using lean management. When the demand is easily predictable in markets, and therefore plans and schedules can be prepared on basis of demand forecasts and are realized exactly, lean supply chains are advantageous.

Papers related to leanness can be mainly divided into two streams. The first category focuses on lean practices and the second group concentrates on how leanness affects performance outcomes. These papers have different definition for leanness. Table 8 summarizes the key literature on leanness related to both groups and the definitions that are used in these papers for leanness.

Table 8- Key literature on leanness and the definitions used

Paper Focus	Key Literature on Leanness	Definition	Performance Dimension	Associated Practices
	Bhasin and Brucher (2006)	*"A philosophy that when implemented reduces the time from customer order to delivery by eliminating sources of waste".*		Technical & cultural requirements: 12 & 13 measures respectively
	Shah and Ward (2007)	Lean production is an integrated socio-technical system whose *"main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability".*		Three underlying constructs: supplier, customer & internally related
Lean and performance	Shah and ward (2003)	*"Collection of practices that work together synergistically to create a streamlined, high quality system that produces finished products at the pace*	Cost efficiency, conformance quality, delivery reliability,	JIT, TPM, TQM, HRM (22 sub-practices)

		of customer demand with little or no waste".	product mix flexibility	
	Hopp and Spearman (2004)	*"Production that is accomplished with minimal buffering costs"*.	Low buffering cost, low variability in process times, delivery times, yield rates staffing levels, demand rates, etc.	Pull production, eliminate obvious waste, swapping inexpensive buffers for expensive ones, variability reduction, continuous improvement
	Treville and Antonikas (2006)	*"Integrated manufacturing system intended to maximize capacity utilization and minimize buffer inventories through minimizing system variability"*.	Conformance quality, delivery reliability, processing time	JIT manufacturing, TQM, TPM, Kaizen, design for manufacturing & assembly, supplier management, human resource training and involvement
	Fullerton and Wempe (2009)	*"Response to the demand of high quality products with varying production requirements, and often require deliveries in small lot sizes with short lead times"*.	Non-financial manufacturing performance measures (11 measures)	Shop-floor involvement, setup time reduction, cellular manufacturing, quality improvement

	Eroglu and Hofer (2011)	*"Strategy or philosophy that relies on a set of practices (e.g. Kanban, total quality management, etc.) to minimize waste (e.g. excess inventories, scrap, rework, etc.) in order to improve firm performance (Womack et al., 1990).*	firm financial performance: return on sales (ROS) and return on assets (ROA)	Inventory leanness

As seen above, different researchers define leanness in different ways while it was mostly defined in manufacturing. Uz-Zaman and Ahsan (2014) define lean supply chain as "the identification of all types of waste in the value stream of the supply chain and take steps to eliminate them and minimize lead time".

This research takes advantage of the Eroglu and Hofer (2011) definition and defines lean as a philosophy relies on a set of practices (e.g. JIT, total quality management, etc.) to minimize waste in order to improve firm performance (Womack et al., 1990). This definition also supports the practices related to lean in this research.

2.3.2 Lean Requirements

Bhasin and Burcher (2005) categorize the lean requirements to technical and cultural requirements. They name continuous improvements, cellular manufacturing, Kanban, single minute exchange of dies, supplier development, supplier base reduction and TPM as technical requirements. They also state that while lean is concerned with reducing wastes in all levels it is also about the change in the culture of the organization.

According to Shah and Ward (2003) JIT, Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM) are practices associated with lean manufacturing. Shah and Ward (2007) define three underlying constructs of lean production which were identified as supplier related, customer related and internally related.

Hopp and Spearman (2004) in their paper state while lean is concerned with driving out waste, it represents a more fundamental framework for enhancing efficiency. Their suggestions for lean implementation are: eliminating obvious wastes, swapping buffers, reducing variability and continuing improvement. Later, Treville and Antonikas (2006) consider lean production job designs in their paper. They believe that lean is achieved over time through a combination of synergistic and mutually reinforcing practices including JIT, TPM, TQM, Design for manufacturing and assembly (DFMA) and supplier management.

2.3.3 Lean enterprise objectives and strategic implications

Bhasin and Burcher (2005) state a decade ago the lean production concept was viewed as a counter- intuitive alternative to traditional manufacturing models proposed by researchers such as Womack et al (1990). Lavelle (2000) proposes reducing costs and shorter lead times ranked the highest amongst the quoted objectives.

Bergstorm (1994) states one weakness of lean is it is unable to accommodate the variations or reduction in demand for finished products. Emiliani (2003) suggests that the focus of lean needs to switch to the supply chain, product development, administration and behaviour. Also, Katayama et al. (1996) recommend that lean production is incapable of responding to large oscillation in aggregate demand volumes. In addition, Parnell (2005) states that instead of consideration of lean as a means to achieve additional margins, it should focus on being more responsive to demand. In conclusion, besides all advantages, there are some lacks which urge firms to move beyond lean and for concepts such as agility and resilience.

2.3.4 Supply chain leanness, related practices

In order to be able to answer the research question, it is needed to extract all practices from lean literature. These practices are all presented in Table 9.

Table 9- Practices related to lean extracted from literature

Practices related to lean	Lit. mentioned practices

Total preventative maintenance (TPM)	Shah and Ward (2003); Shah and Ward (2007); Treville and Antonakis (2005); Bhasin and Burcher (2006); Basu (2009; p. 27)
Statistical process control (SPC)	Shah and Ward (2007); Narasimhan et al. (2006)
Cellular manufacturing	Fullerton and Wempe (2008); Bhasin and Burcher (2006); Simpson and Power (2005)
Producing outputs with minimum resource requirements	Sanchez et al. (2001); Goldsby et al. (2006); Van der vorst et al. (2001)
Just in time (JIT)	Shah and Ward (2003); Narasimhan et al. (2006); Jayaram et al. (2008); Sanchez et al. (2001); Shah and Ward (2007); Treville and Antonakis (2005); konecka (2010); Narasimhan et al. (2006); Basu (2009; p. 26)
Concurrent engineering	Jayaram et al. (2008); Hayes and Pisano (1994)
Knowledge management	Melton (2005); Bicheno and Holweg (2009; p. 15)
Total quality management (TQM)	Shah and Ward (2003); Narasimhan et al. (2006); Sanchez et al. (2001); Treville & Antonakis (2005); Konecka (2010); Fullerton and Wempe (2008); (Basu 2009; p. 33)
Implementing new technologies	Shah and Ward (2003); Narasimhan et al. (2006)
Reducing process downtime between	Shah and Ward (2007); Shah and Ward (2003); Fullerton and Wempe (2008); Baso

product changeovers	(2009; p.2)
cross functional workforce	Shah and Ward (2003); Sanchez et al. (2001); Treville and Antonakis (2005); Narasimhan et al. (2006)
Collaboration	(Ivezic) 1999; Simpson and Power (2005); Bicheno and Holweg (2009; p. 14)

Now that resilience, leanness and agility have been reviewed for definition and practices, the next step is to look at literature and see how these three approaches are linked in the supply chain literature.

2.4 How leanness, agility and resilience are linked in supply chain literature

Going back to the research question "How does resilience fit with leanness and agility both in terms of practices and outcomes in the context of supply chain management" , it is now the time to go to the core part of the literature review which is how these three approaches have been linked in literature and what are the important criticism. Resilience, leanness, and agility have been reviewed in the previous sections but the core element of this research is that how these three approaches are linked together.

2.4.1 Leanness and agility

Inman et al. (2011), Hallgren and Olhager (2009) and Krishnamurthy and Yuach (2007) state that lean and agile coexistence in to three categories:

- Lean is an antecedent of agility. Many researchers, as mentioned in Table 8, believe that agile manufacturing is the next logical step, or a natural development, from lean manufacturing. According to Sarkis (2001), agile manufacturing is flexible manufacturing system added to lean manufacturing. Narasimhan et al. (2006) report their result of their study, suggesting that leanness is precursor to agility.

- Lean and agile are mutually supportive concepts. Leanness has been described by many researchers, as mentioned in Table 8, as a concept which is compatible, complementary, and mutually supportive with agile manufacturing. Elements for agility include; the ability to produce large or small batches with minimum setups, cross trained flexible workforce, reduced process lead times and costs, fully empowered employee, and JIT purchasing and flexible setups. There are elements of lean manufacturing especially within JIT that confirm these two concepts can be supportive.
- Lean and agile are different and the concept of leagility emerged (Naylor et al., 1999; Mason-Jones et al., 2000; Hoek, 2000; Aitken et al., 2002; Bruce et al., 2004; Krishnamurthy & Yauch, 2007). According to Hoek (2000), the aim of 'leagility' is combining waste elimination or efficiency with customer responsiveness within the same supply chain. In the lean part, there is Make-To-Stock (MTS) operation while in agile part it is Make-To-Order (MTO) operations. Table 10 summarizes the views related to the relationships between leanness and agility.

Table 10- Three views of the relationship between lean and agile manufacturing [Source: Inman et al. (2011)]

Relationship between Lean/Agile	**Source**	**Summary**
Lean and agile as mutually exclusive concepts	Harrison (1997)	Expresses doubts that lean and agile are compatible while emphasizing that agile implies more resources not fewer
	Goldsby et al. (2006)	Note that lean and agile are often pitted as opposing paradigms.
	Gunasekaran et al. (2008)	Clear dividing lines can be drawn between the two; agile manufacturing focuses on speed and flexibility and not cost.
	Vazquez- Bustelo et al. (2007)	Lean manufacturing subordinates responsiveness (service) to efficiency and productivity (cost).

	Christopher and Towill (2001)	Lean market winner is cost.
	Zhang and Sharifi (2007); Mason Jones et al. (2000)	Agile market winners are speed, flexibility and responsiveness to changes, i.e. service level.
	Vazquez- Bustelo et al. (2007); Naylor et al. (1999)	Lean manufacturing is appropriate when market conditions are basically stable, demand is smooth and standard products are produced and agile manufacturing is appropriate when the environment is more turbulent and more product variety is present.
Lean and agile as mutually supportive concepts	Katayama and Bennett (1999); Krishnamurthy and Yauch (2007)	Mutually supportive concepts
	Krishnamurthy and Yauch (2007)	Results in benefits not accessible when the concepts are used in isolation.
	Kidd (1994)	Compatible concepts
	Naylor et al. (1999)	Complementary concepts
	Gunasekaran et al. (2008); Ramesh and Devadesan (2007); Goldsby et al. (2006); Mccullen and Towill (2001)	Elements cited as necessary for agile performance include elements of lean manufacturing. Specifically Just-In-Time manufacturing.
Lean as antecedents to agility	Narasimhan et al. (2006)	The predominant view in the literature is that lean manufacturing is a performance/practice state that is antecedent to agile manufacturing.
	Jin-Hai et al. (2003); Hormozi (2001)	Agility is the latest step in the evolution from mass production to Just-in- Time to lean to agile.
	Goldman and Nagel (1993)	Agile manufacturing assimilates the full range of flexible production technologies, along with the lessons learned from TQM, JIT, and lean production.

	Gunasekaran et al. (2008); Vazquez- Bustelo et al. (2007); Sharifi and Zhang (2001); Sharifi and Zhang (2000)	Agile manufacturing can be achieved by utilizing and integrating elements of existing systems and methods that are already developed and in use.
	Sarkis (2001)	Agile manufacturing equals flexible manufacturing system plus lean manufacturing.
	Mccullen and Towill (2001)	Agile manufacturing can subsume the paradigm of lean production.
	Gunasekaran et al. (2008); Hormozi (2001); Maskell (2001); Gunasekaran (1999); Robertson and Jones (1999); Booth (1996)	Agile manufacturing is the next logical step or a natural development from the concept of lean manufacturing.

2.4.2 Agility and resilience

In their work Christopher and Peck (2004) state that resilience implies agility and name agility as one of the factors that helps supply chain become resilient. Lenort and Wicher (2012) state agility can be considered as a capability for resilience. Also, Ponomarov and Holcomb (2009) mention agility as a formative element of resilience. Besides, Wieland and Wallenburg (2012) state resilience is formed by two dimensions. The first one is agility which is reactive and the second one is robustness, which is proactive.

On the other hand, in their conceptual frame work model, Carvalho et al. (2012) present agility and resilience as two constructs that both help supply chain performance and as a result supply chain competitiveness.

2.4.3 Resilience, leanness and agility

Different management approaches have been adopted for supply chain management. The lean supply chain is based on cost reduction, focused on the improvement of processes through the elimination of all wastes. The agile supply chain intends to create ability to respond rapidly to unpredictable changes in markets both in terms of variety and volume (Agarwal et al., 2006). However, when supply chain encounters disruptions caused by sudden and unforeseen events, the lean supply chain seems to be more fragile.

Carvalho et al. (2011), present a table (Table 11) in their paper making a comparison between leanness, agility and resilience in supply chain management.

Table 11- Comparison between leanness, agility and resilience [Source: Carvalho et al. (2011)]

	Lean	**Agile**	**Resilient**
Purpose	Focus on cost reduction and flexibility, for already available products , through continues elimination of waste or non-value added activities across the chain	Understands customer requirements by interfacing with customers and the market and being adaptable to future changes	System ability to return to its original state or to a new, more desirable one after experiencing a disturbance and avoiding the occurrence of failure modes
Manufacturing focus	Maintains a high average utilization rate Uses JIT practices , pulling the goods through the system based on the demand	Has the ability to respond quickly to varying customer needs, deploys excess buffer capacity to respond to market requirements	The emphasis is on flexibility (minimal batch sizes and capacity redundancies)
Alliances (with suppliers and customers)	May participate in traditional alliances such as partnerships and joint ventures at the operational level	Exploits a dynamic type of alliance known as "virtual organization" for product design	Supply chain partners join an alliance network to develop security practices and share knowledge
Organizational	Uses a statistic organizational structure	Creates virtual organizations with	Create a supply chain

structure	with few levels in the hierarchy	partners that vary with different product offering that change frequently	risk management culture
Approach to choosing supplier	Supplier attributes involve low cost and high quality	Supplier attributes involve speed, flexibility, and quality	Flexible sourcing
Inventory strategy	Generates high turns and minimizes the inventory through the chains	Make decisions in response to customer demands	Strategic emergency stock in potential critical points
Lead time focus	Shortens lead-time as long as it does not increase the cost	Invest aggressively to reduce lead time	Reduce lead time
Product design strategy	Maximizes performance and minimizes cost	Design product to meet individual customer needs	postponement
Product variety	Low	High	High
Market	Serves only the current market segments, with a predictable demand	Acquire new competencies, develops new product lines, and opens up new markets with a volatile demand	Have the capabilities to act on and anticipate changes in markets and overcome demand risk

Melnyk (2007) believes that lean supply chains become more fragile, without buffers in the format of extra capacity, lead time and inventory. Lack of extra resources makes coping with unplanned events impossible. Juttner (2005) recommends that firms should try to be lean but not too lean since the risks increase dramatically. Faisal et al. (2006) note that leaner and more integrated supply chains have more uncertainties, dynamics and accidents. In a lean supply chain, decreasing inventory as a waste increases the impact of supply chain disruption (Chopra and Sodhi, 2004). Konecka (2010) specifies that the more efficient operations are connected with the higher risk, because of high attention to cost. Therefore, coping with unforeseen events are more difficult.

According to Towill (2005), agility without resilience can create an overexposed organization that emphasizes openness, and speed so much, that severe shocks and disruptions can severely damage its performance, even threaten its survival. Konecka (2010) states that agility, is the best way to satisfy more demanding clients. This is due to a lower risk of unsatisfying of the customers, lost orders and too slow responses. However, it has its own risks as it requires the free spaces to provide flexible operations and it reduces productivity. Furthermore, Konecka (2010) argues that each strategy in supply chain has its own benefits and drawbacks. These facts call for more research on compatibility basis.

According to Carvalho et al. (2011, p. 152) *"The trade-offs between lean, agile, resilient and green (LARG) management paradigms are actual issues and may help supply chains to become more efficient, streamlined and sustainable. Leanness in a supply chain maximizes profits through cost reduction, while agility maximizes profits through providing exactly what the customer requires. Resilient supply chains may not be the lowest cost, but they are more capable of coping with the uncertain business environment*." Table 12 summarizes the previous research on Lean, Agile and Resilient (LAR).

Table 12- Previous research which covers the three concepts of LAR

Authors	Main contributions
Christopher and Rutherford (2004)	Provide a literature review on supply chain (SC) Six Sigma. It focuses on how resilient SC might be managed by the application of Six Sigma procedures.
Konecka (2010)	Considers lean and agile supply chain management concepts in the aspect of risk management.
Carvalho et al. (2011)	Explore the divergences and commitments between the lean, agile, resilient and green paradigms while investigating the effect of paradigms' practices within supply chain

	attributes.
Machado and Duarte (2010)	Intend to find if (and how) LAR paradigms have been under researchers' attention.
Carbal et al. (2011)	Present and discuss an information model for a SCM platform to support current integrated LARG (lean/ agile/ resilient/green) paradigms.
Azvedo et al. (2011)	Propose a conceptual model for a lean, agile, resilience and green SC, with the purpose of improving their operational, economic and environmental performance. In this attempt a set of SC management practices, which were named LARG practices, and several performance measures are suggested.
Figueira et al. (2012)	Present a conceptual framework that allows integrating ergonomic and safety design principles during the different implementation phases of lean, agile, resilient and green practices.

Based on this part of the literature review, it could be concluded that there isn't a clear portrait of how these three approaches of LAR have been connected together. Academic papers mentioned in the above Table 12 have started stating the need for linking these three approaches but are unable to present clear boundaries between them. All models presented in these papers are still in the conceptual level.

The practices related to leanness, agility and resilience are extracted in Tables 4, 7 and 9 before. Looking through these three Tables, it is clear that some of these practices are purely linked to leanness, agility or resilience, while there are some practices that are linked to leanness and agility both, resilience and agility both; and the three of resilience, leanness and agility. Therefore, this conclusion was achieved that there are some overlapping and non-overlapping practices between resilience with leanness and agility. This result is shown in Table 13.

Table 13- Results of literature review regarding overlapping and non-overlapping measures between resilience with leanness and agility

Practice	Lit. mentioned for Resilience	Lit. mentioned for Agile	Lit. mentioned for lean
Alternative modes of Transportation	Pettit et al. (2010); Sheffi (2005); Sheffi and Rice (2005); Christopher and Rutherford (2004); Ponomarov and Holcomb (2009); Fiksel (2003)		
Business continuity	Sheffi and Rice (2005); Christopher and Peck (2004);Zsidisin et al. (2005); Craighead et al. (2007)		
Contingency plans	Juttner et al. (2003); Tang (2006); Kleindorfer and Saad (2005); Craighead et al. (2007); Peck (2006);		
Detection systems in place to detect any supply chain disruption	Pettit et al. (2010); Sheffi and Rice (2005); Ponomarov and Holcomb (2009)		
Decentralization of physical assets in multiple locations of	Pettit et al. (2010); Sheffi and Rice (2005); Bartos and Balmford (2011);		

assets	Manuj and Mentzer (2008 a)		
Security	Pettit et al.(2010); Sheffi (2005); Tang (2006)		
Establishing communication lines	Juttner (2005);Ta et al. (2009); Christopher and Peck (2004)		
Computer based technologies		Power (2001); Gunasekaran (1998); Prince and Kay (2003)	
High customization capability		Braunscheidel and Suresh (2009); Hallgren and Olhager (2009); Hoek et al. (2001); Swafford et al. (2006); Holweg (2005)	
Introducing new products quickly		Hallgren and Olhager (2009); Sharifi and Zhang (2001); Lee (1998)	
Responding quickly to rapidly changing situation somewhere in the supply chain		Sharif and Zahng (1999); Gould (1997); Hormozi (2001)	
Integrating different functions in the company		Narasimhan et al. (2006); Machado and Duarte (2010); Aitken et al. (2002)	
Total preventative			Shah and Ward

maintenance (TPM)			(2003); Shah and Ward (2007); Treville and Antonakis (2005); Bhasin and Burcher (2006); Basu (2009; p. 27)
Statistical process control (SPC)			Shah and Ward (2007); Narasimhan et al. (2006)
Cellular manufacturing			Fullerton and Wempe (2008); Bhasin and Burcher (2006); Simpson and Power (2005)
Producing outputs with minimum resource requirements			Sanchez et al. (2001); Goldsby et al. (2006); Van der vorst et al. (2001)
Redundant supplier	Sheffi and Rice (2005); Rice and Caniato (2003); Bartos and Balmford (2011); Xu (2008)	Lee (2004); Lou et al. (2002); Cheng and Ye (2011)	
Flexible manufacturing equipment to produce different products with the same facilities	Pettit et al.(2010); Sheffi and Rice (2005); Rice and Caniato 2003; Peck 2006; Bartos and Balmford (2011); Xu (2008); Ponomarov and Holcomb (2009)	Swafford et al. (2006); Sharifi and Zhang (2001); Goldsby et al. (2006); Christopher and Towill (2001); Ramesh (2005); Aitken et al. (2005); Christopher and Towill (2000); Goldsby	

		et al. (2006)	
Excess capacity	Pettit et al. (2010); Sheffi and Rice (2005) ; Rathic et al. (2008); Peck (2006); Christopher and Rutherford (2004); Ponomarov and Holcomb (2009)	Swafford et al. (2006); Bruce et al. (2004)	
Visibility	Pettit et al. (2010); Christopher and Peck (2004)	Braunscheidel and Suresh (2009); Christopher and peck (2004); Aitken et al. (2002)	
Just in time (JIT)		Power (2001); Narasimhan et al. (2006); Brown (2003)	Shah and Ward (2003); Narasimhan et al. (2006); Jayaram et al. (2008); Sanchez et al. (2001); Shah and Ward (2007); Treville and Antonakis (2005); konecka (2010); Narasimhan et al. (2006); Basu (2009; p. 26)
Concurrent engineering		Vázquez-Bustelo et al. (2007); Gunasekaran (1998); Choi and Hartley (1996); Yusuf et al. (1999); Booth (1996)	Jayaram et al. (2008); Hayes and Pisano (1994)

Knowledge management		Vázquez-Bustelo et al. (2007); Jin Hai et al. (2003); Booth (1996)	Melton (2005); Bicheno and Holweg (2009; p. 15)
Total quality management (TQM)		Power (2001); Narasimhan et al.(2006); Yusuf et al. (1999)	Shah and Ward (2003); Narasimhan et al. (2006); Sanchez et al. (2001); Treville & Antonakis (2005); Konecka (2010); Fullerton and Wempe (2008); (Basu 2009; p. 33)
Implementing new technologies		Power (2001); Vázquez-Bustelo et al. (2007); Narasimhan et al. (2006)	Shah and Ward (2003); Narasimhan et al. (2006)
Reducing process downtime between product changeovers		Sharifi and Zhang (1999); Swafford et al. (2006)	Shah and Ward (2007); Shah and Ward (2003); Fullerton and Wempe (2008); Baso (2009; p.2)
cross functional workforce	Pettit et al. (2010); Sheffi and Rice (2005); Rice and Caniato (2003); Bartos and Balmford (2011); Peck (2006)	Vázquez-Bustelo et al. (2007); Sharif and Zhang (2001); Ramesh (2005); Narasimhan et al. (2006)	Shah and Ward (2003); Sanchez et al. (2001); Treville and Antonakis (2005); Narasimhan et al. (2006)
Collaboration	Pettit et al. (2010); Christopher and Peck (2004); Sheffi and Rice (2005); Peck	Sharifi and Zhang (2001); Yusuf and Adeleye (2002); Cao and Dowlatshahi (2005)	(Ivezic) 1999; Simpson and Power (2005); Bicheno and Holweg (2009; p. 14)

	(2006); Ponomarov and Holcomb (2009)		

The literature review shows that there are some overlapping and non-overlapping practices across leanness, agility and resilience (Table 13). Therefore, there exists some confusion in literature regarding what exactly resilience is, what exactly agility is and what exactly leanness is especially when it comes to those practices which are both connected to leanness and agility; agility and resilience; and leanness, agility and resilience according to the literature. A summary of literature review is presented in Table 14.

Table 14- Practices related to resilience, agility and leanness

Practices	Related to resilience	Related to leanness	Related to agility
Business Continuity (BC) team	x		
Contingency plans made	x		
Decentralization of physical assets in multiple locations	x		
Detection systems in place to detect any supply chain disruption	x		
Establishing communication line in case of a disruption in the supply chain	x		
Security against deliberate intrusion	x		
Alternative modes of transportation in the supply chain	x		
Total preventative maintenance (TPM)		x	
Statistical process control (SPC)		x	
Cellular manufacturing		x	
Producing outputs with minimum resources		x	
Integrating different functions in the company			x
Computer based technologies to manage manufacturing processes.			x

Customizing the final product for individual end-customers			x
Responding quickly to rapidly changing situation somewhere in the supply chain			x
Time-to-market, i.e., introducing new products quickly			x
Reducing process downtime between product changeovers		x	x
TQM		x	x
Implementing new technologies		x	x
Concurrent engineering for overlapping activities in product design to achieve simultaneous development.		x	x
Knowledge management		x	x
Just In Time (JIT)		x	x
Flexible manufacturing equipment to produce different products with the same facilities	x		x
Visibility – knowing the status of operating assets and the environment within the supply chain	x		x
Excess capacity in the supply chain to absorb sudden increases in demand	x		x
Redundant suppliers for the same part with these suppliers being capable to substitute each other	x		x
Collaboration with suppliers (Ability to work effectively with suppliers for mutual benefit)	x	x	x
Cross-functional workforce	x	x	x

So this research is done in two phases. In the first phase the focus is on “disentangling resilience, agility and leanness”, for which an empirical study was designed.

While it can be empirically assessed which practices are related to resilience, which practices are related to agility and which practices are related to lean, this research will flow to its second phase which will investigate “how resilience along with leanness and agility affects operational performance outcomes”. For this aim, a review on the performance outcomes in the context of supply chain management is a necessity.

2.5 Performance outcomes

The second phase of this research focuses on “how resilience along with leanness and agility affects operational performance outcomes”. As stated before, in the highly competitive business climate (Kotzab et al., 2009), creating sustained competitive advantage of the firm is the key to success (Laseter and Gillis, 2012; Cao and Zhang, 2011). From Resource Based View lens (will be explained in Section 3.1), different researchers mention leanness, agility and resilience as capabilities that can offer firms different competitive advantages (Grant, 2005; Braunscheidel and Suresh, 2009; Coutu, 2002; Stoltz, 2004). Putting all these together, no work to date could be found that empirically confirm how resilience along with leanness and agility affects performance outcomes. There exists some work previously looked at that how lean and agile are affecting performance outcomes such as Narasimhan et al. (2006) and Hallgren and Olhager (2009) or how agility and resilience affect performance outcome such as Carvalho et al. (2012). Regarding the three, there is some work such as the work of Carvalho et al., (2011); and Azvedo et al., (2011, 2012) all beginning to develop a conceptual model of lean, agile and resilience though none addresses the issue empirically. For this phase, a literature review on performance outcomes is performed.

When a procedure or a model is undertaken, some measure of its performance is presented and analysed (Beamon, 1999). Chan (2003) states performance measurement describes the information on activities with respect to meeting customer expectations and strategic objectives. According to Gunasekaran et al. (2001), it is necessary to assess performance for effectiveness and efficiency. According to Neely et al. (2005), there exist three definitions:

- Performance measurement: the process of quantifying the efficiency and effectiveness of action.
- Performance measure: a metric used to quantify the efficiency and/or effectiveness of an action.
- Performance measurement system: the set of metrics used to quantify both the efficiency and effectiveness of actions.

According to Wong (2009), performance measurement is crucial to better supply chain management. There are several metrics in the literature for measuring the performance of a supply chain. In this section an attempt is made to summarize some of the most appropriate performance measures of SC.

Lin and Ho (2010) suggest financial and non-financial measures. Askariazad and Wanous (2009) prioritize SC performance measures according to their importance in the evaluation of value-added activities (supply, manufacturing, logistics, marketing & sales, and support activities). Aramyan et al. (2009) suggest their performance measurement system composed by efficiency, flexibility, responsiveness and quality. Gunasekaran et al. (2004) develop a framework for supply chain performance measurement. Their paper, provides a detailed 'measurement and metrics classification' and uses a survey aiming at assessing importance within each metric group. Chan (2003) proposes qualitative and quantitative measures. The qualitative measures include customer satisfaction, flexibility, effective risk management and information and material flow integration. The quantitative measures try to evaluate the performance in terms of strategic planning, order planning, suppliers, production and delivery. Beamon (1999) focuses on the main metrics such as time, resource utilization, output and flexibility and tries to develop more detailed performance measures in the new enterprise environment. Bagchi (1996) defines the metrics of a SC in four categories including time, quality, cost, efficiency and diagnostic measure and uses them to compare the competitiveness of selected companies. Neely et al., (1995) provide categories of performance measures including time, quality, flexibility and cost. According to Stewart and Hobin (2001), Robert S. Kaplan and David P. Norton introduced the balanced scorecard, a set of measures that allow for a holistic, integrated view of business performance in 1992. "The score-card is originally created to supplement traditional financial measures with criteria measuring performance from three additional perspectives: those of customers, internal business processes, and learning and growth" (Stewart and Hobin, 2001, P. 39).

As can be concluded, different measurement systems have been suggested and used to evaluate supply chain performance but there exists some criticism. Gunasekaran and Kobu (2007) highlight the confusion as to the classification of metrics in literature and lacking complete coverage of all the performance measures. Gunasekaran et al. (2001) state that performance measurement systems are not usually adjusted to SC real necessities, they fail to support continuing improvement and they lack systematic thinking. Chan and Qi (2003) note that mostly performance measurement systems focus on cost and do not concentrate on the maximization of the value added to the end customer. Lamber and Pohlen (2001) state that supply chain performance measurement systems don't provide information on how well the key business processes have been performed or how the SC has met customer needs. Finally, different studies state that almost no performance measurement systems are adjusted to the actual supply chain necessities (Gunasekaran et al., 2001; Hoek, 2001).

Many authors have explored which performance metric should be used. According to Gunasekaran et al. (2001), it is necessary to identify which measurement metrics really matter to the business, while they believe it is not a notable number of metrics to be used that counts, since performance measurements can be better addressed using only a few good metrics.

While many authors mention which performance measures are the key metrics for leanness and agility and test their relation statistically (Narasimhan et al., 2006; Hallgren and Olhager 2009; Shah and Ward, 2003), literature still is very limited regarding performance measures and the relation of them with resilience. No empirical research was found regarding how resilience affects performance outcomes.

For this study which covers resilience, leanness and agility, a thorough literature review was done on the papers including these concepts and their effect on the performance. The literature review of performance measures affected by LAR is summarized in Table 15.

Table 15- Performance measures affected by LAR

Performance outcomes	**Lit. mentioned performance measure affected by Lean**	**Lit. mentioned performance measure affected by Agile**	**Lit. mentioned performance measure affected by Resilience ***
Cost	Eroglu and Hofer (2011); Hallgren and Olhager (2009); Shah and Ward (2003); Cua et al. (2001); Prince and Kay (2003)	Narasimhan etal. (2006); Vázquez-Bustelo et al. (2007); Hallgren and Olhager (2009)	Manuj and Mentzer (2008b); Carvalho and Machado (2009); Haimes (2006); Fiksel (2003)

Delivery	Eroglu and Hofer (2011); Hallgren and Olhager (2009); Cua et al. (2001)	Narasimhan et al. (2006); Inman et al. (2011); Hallgren and Olhager (2009); Vázquez-Bustelo et al. (2007)	Manuj and Mentzer (2008b)
Flexibility	Eroglu and Hofer (2011); Hallgren and Olhager (2009)	Narasimhan et al. (2006); Inman et al. (2011); Hallgren and Olhager (2009); Vázquez-Bustelo et al. (2007)	Fiksel (2006)
Time to recovery*	Zsidisin et al. (2005); Konecka (2010)	Christopher and Peck (2004); Lee (2004)	Sodhi and Tang (2012); Carvalho and Machado (2009); Haimes (2006)

* None of the studies are empirical.

So for this study cost, delivery and flexibility are used as stated in the work of Narasimhan et al. (2006), Hallgren and Olhager (2009), Azvedo et al. (2011) and Carvalho et al. (2011). For the first time in this research, measures related to time to recovery have been added as a performance construct for resilience which include: Time to detect undesirable risk event in the plant or supply side in a timely manner; Time to design a solution when an undesirable event occurs in the supply chain; Time to deploy a solution when an undesirable event occurs in the plant or supply side in a timely manner; and time to recover from risk incidents or disruptions and to return to normal operational state rapidly. These measures are taken by Sodhi and Tang (2012, Chapter 5, p. 11).

Following measures are extracted through a thorough literature review, which have been identified to be suitable for this research:

1- Cost: according to Chan (2003), the profit of an enterprise is directly affected by the cost of its operations. As a result, many people understand its importance and influence to the whole performance. Different authors such as Gunasekaran et al. (2001), Chan (2003) and Neely et al. (2005) mention the following measures for cost:

- Distribution cost: includes the transportation and handling costs, safety stock cost, and duty.
- Manufacturing cost: includes labour, maintenance and re-work costs. Also, there are purchased materials, equipment charges and the supplier's margin.
- Inventory cost: includes the work-in-process and finished goods inventories.

2- Flexibility: 'flexibility is about the ability or the adaptability of the company to respond to diversity or change' (Chan, 2003, P. 539). Gunasekaran et al. (2001), Chan (2003) and Neely et al. (2005) categorize measure of flexibility into:

- Volume flexibility: demand volume may change and organizations need to respond quickly and efficiently to either increases or decreases in aggregate demand levels.
- Mix flexibility: measures the number and variety of products, which can be produced without incurring high costs or large changes in performance outcomes.
- Delivery flexibility: is the ability to move planned delivery dates forward to accommodate rush orders or special orders.
- New product flexibility: the ease with which new products can be introduced to the system. Time or costs are involved in creating a new product. Also, the quality must be controlled for new product.

3- Delivery: Gunasekaran et al. (2001), Chan (2003), Neely et al. (2005) and Wagner and Bode (2008) mention the following measures for delivery:

- On time delivery: measures the product delivery performance. It can be represented by the percentage of orders delivered on or before the due date (Beamon, 1999)
- Delivery dependability: meeting quoted or anticipated delivery quantities on a consistent basis.
- Fill rate: percentage of demand filled from available stock (Kleijnen and Smits,

2003)

- Customer response time: the amount of time between an order and its corresponding delivery

4- Time to recovery: Dalziel and McManus (2004) state that in order to see any progress in organizations in becoming resilient, metric for measuring resilience is needed. Manuj and Mentzer (2008b) state that performance measures should be developed to assess the success and the failure of risk management related issues which resilience can be included as well. Sodhi and Tang (2012, Chapter 5, p. 11) mentioned in their book "Managing Supply Chain risk" that reducing response lead time to a risk incident includes D1, D2 and D3. D1 is the time to design one or more solutions. D2 is selecting one solution in response to the incident. D3 is the time to deploy the solution. After that the time it takes to restore the operations is the recovery time. Following measures can be considered as measures to evaluate time to recovery:

- Time to detect undesirable risk event in the plant or supply side in a timely manner
- Time to design a solution when an undesirable event occurs in the supply chain
- Time to deploy a solution when an undesirable event occurs in the plant or supply side in a timely manner
- Time to recover from risk incidents or disruptions and to return to normal operational state rapidly

The summary of the performance outcomes resulted from the literature review is presented in Table 16.

Table 16- Measures for performance outcomes

Operational performance outcomes	**Measure**	**Explanation**	**Source**
Cost	Distribution cost per	Transportation and	Chan (2003); Beamon (1999); Gunasekaran et al. (2001);

	unit	handling costs	Gunasekaran and Kobu (2007); Shepherd and Gunter (2006)
	Manufacturing cost per unit	Labour, maintenance and Re-work costs	Chan (2003), Shepherd and Gunter (2006); Beamon (1999); Vázquez-Bustelo et al. (2007); Hallgren and Olhager (2009); Shah and Ward (2003); Narasimhan et al. (2006)
	Inventory cost per unit	Work-in-process and finished goods inventories, Inventory obsolescence	Chan (2003); Gunasekaran and Kobu (2007); Shepherd and Gunter (2006); beamon (1999); Gunasekaran (2001)
Delivery	Orders delivered at the right time as a percentage of total orders	On time delivery (percentage of orders delivered on or before the due date)	Fullerton and Wempe (2008); Hallgren and Olhager (2009); Narasimhan et al. (2006); Li et al. (2005)
	Fill rate	The proportion of orders that can be filled immediately	Chan (2003), Gunasekaran and Kobu (2007); Shepherd and Gunter (2006); Agarwal and Shankar (2002)
	Order cycle time of customer	Customer response time: the amount of time between an order and its corresponding delivery. It includes the reaction time, manufacturing time, and transportation time.	Shepherd and Gunter (2006); Gunasekaran et al. (2001); Beamon (1999); Morash (2001); Chan (2003)
	Orders with the right quantity as a percentage of total	Delivery dependability (meeting quoted or anticipated delivery	Chan (2003); Wagner and Bode (2008)

	orders	quantities on a consistent basis)	
Flexibility	Percentage change possible in demand volume of specific products without incurring high incremental costs	Volume flexibility: demand volume may change and organizations need to respond quickly and efficiently to either increases or decreases in aggregate demand levels	Chan (2003); Shepherd and Gunter (2006); Beamon (1999); Vázquez-Bustelo et al. (2007); Narasimhan et al. (2006)
	Number of products from this supply chain without incurring high costs	Mix flexibility: the number and variety of products, which can be produced without incurring high costs or large changes in performance outcomes	Chan (2003); Gunasekaran and kobu (2007); Shepherd and Gunter (2006); Beamon (1999)
	Number of new products introduced in response to customer demand without incurring high incremental costs	New product flexibility	Chan (2003); Shepherd and Gunter (2006); Beamon (1999)
	Percentage change possible in customer lead time in response to changes in delivery schedule without incurring high incremental costs	Delivery flexibility: the ability to move planned delivery dates forward to accommodate rush orders or special orders.	Gunasekaran et al. (2001); Chan (2003); Neely et al. (2005)
Time to	Time to detect undesirable risk event		Sodhi and Tang (2012, Chapter 5, P. 11); Bruneau et al. 2003;

recovery	in the plant or supply side in a timely manner		Dalziell and McManus (2004)
	Time to design a solution when an undesirable event occurs in the supply chain		Sodhi and Tang (2012, Chapter 5, P. 11); Bruneau et al. (2003); Dalziell and McManus (2004)
	Time to deploy a solution when an undesirable event occurred in the plant or supply side in a timely manner		Sodhi and Tang (2012, Chapter 5, P. 11); Bruneau et al. (2003); Dalziell and McManus (2004)
	Time to recover from risk incidents or disruptions and to return to normal operational state rapidly		Sodhi and Tang (2012, Chapter 5, P. 11), Bruneau et al. (2003); Dalziell and McManus (2004)

2.6 Resource based view; theory underlying this research

Resource Based View (RBV) is a theory that has been widely applied in management research. The RBV is a theoretical perspective which describes, explains and predicts how firms can achieve sustainable competitive advantage through acquisition and control over resources (Rungtusanatham et al., 2003). According to Barney (2001), RBV is generally used to explain the factors affecting resource utilisation of firms in order to improve their competitive advantage and firm performance RBV is also a popular theory in SCM research (Cao and Zhang, 2011).

2.6.1 Foundation of RBV

The main concepts of RBV include the firms' resources, capabilities, and strategic assets (Barney, 1991). The foundation of RBV argues that the performance of the firms depends on the strategic resources. These resources include core competencies (Javidan, 1998; Prahalad and Hamel, 1990), dynamic capabilities (Teece et al., 1997) and absorptive capacity (Cohen and Levinthal, 1990).

Core competencies are the key characteristics of the main products of the firm. Core competencies are also considered as a collective learning across functions within an organisation (Prahalad and Hamel, 1990). According to Kroes and Ghosh (2010), these core competencies of the firm are the critical factor of competitive advantage. According to Lowson (2002), competencies are fundamental knowledge owned by the firm such as knowledge, know-how, experience, innovation and unique information, and competitive advantage can be resulted from focusing upon key competencies. He mentions that key competencies are those things in which the firm specializes or does well.

The framework of dynamic capability focuses on how and where firms create and capture capabilities from their resources (Teece et al., 1997). Eisenhardt and Martin (2000) believe that competitiveness of the firm can be derived from their capability to utilise their resources in the changing environment.

Absorptive capacity is the ability of the firm to utilise resources to achieve efficiency and knowledge creation (Malhotra et al., 2005; Cohen and Levinthal, 1990). It includes assimilation, transformation, acquisition, and exploitation. According to Malhotra et al. (2005), absorptive capacity is another key to enhance competitive advantage of the firms.

2.6.2 RBV and sustained competitive advantage

In RBV, firms combine their resources in a unique manner to establish a competitive advantage over their competitors (Barney, 1991). Resources are the basic units of analysis and include physical and financial assets as well as employees' skills and organizational (social) processes (Hart, 1995). A person, machine, raw material, and knowledge are examples of resources. A resource, or set of resources, can be used to create competitive advantage (Lowson, 2002). When resources are combined, they lead to the formation of competencies and capabilities (Prahalad and Hamel, 1990). Capabilities are complex bundles of individual skills, assets and accumulated knowledge exercised through organizational processes which make firms able to co-ordinate activities and make use of their resources (Day, 1994; Olavarrieta, 1997; Helfat, 2003).

Resources can be tangible (e.g. equipment) and intangible (e.g. Process knowledge) assets (Grant, 1991), that make production and delivery of goods and services easier. Firms seek to gain and exert different levels of control over resources that can provide a competitive advantage over competitors (Rungtusanatham et al., 2003).

Barney (1991) mentions five characteristics of resources that would let firms to attain a sustainable competitive advantage. A resource should be:

- Valuable: it improves efficiency and effectiveness of the firm.
- Rare: a firm can exploit it to the disadvantage of its competitors by exerting control over it.
- Imperfectly imitable: it prevents competitors developing it in-house easily.
- Imperfectly mobile: it discourages the ex-post competition that would offset the advantages of maintaining control of the resource.
- Sustainable: so competitors cannot identify different but strategically equivalent resources.

Furthermore, Lowson (2002) identifies that in resource based view companies are conceptualized as a collection of resources, rather than holding purely market positions. According to Barney (1991), the resource based view examines how certain assets and capabilities lay a foundation for competitive advantage and superior performance.

The major points of RBV can be summarized as follows according to Rungtusanatham et al. (2003):

- Each firm seeks to gain, control and bundle resources with capabilities for competition.
- Resources are tangible and intangible assets.
- Capabilities are organizational routines or mechanisms that enable the firm to gain and deploy resources in order to make production and delivery easier.
- Resources and capabilities are valuable, rare, imperfectly mobile, not imitable, and not sustainable, so they can provide a sustainable competitive advantage.

“The essence of the resource-based view is its focus on the individual resources, competencies and capabilities of the organization, rather than on a market-based strategy that may have commonalities with others in the industry” (Lowson, 2002, 2003). The resource based view focuses on these internal resources which are generated and cannot be purchased externally. Organizations are bundles and clusters of resources (Olavarrieta, 1997) and managers must develop these in individual ways. RBV declares that competitive advantages of firms are obtained by accumulating internal resources and capabilities that are rare, valuable and difficult to imitate (Barney 1991). So the most important objectives for firms which apply RBV are to identify their capabilities and develop them further (Day, 1994). Capabilities are often difficult to identify because of their dynamics and complexity. According to Grant (1991), while some capabilities can be identified using the standard functional approach, the most important capabilities usually arise from an integration of the individual functional capabilities. Therefore, the RBV approach is developed one step further by Teece et al. (1997) who formulates dynamic capability perspectives.

In conclusion, RBV has a primary focus on explaining the impact of firms’ strategic resources, core competencies and capabilities on the performance, economic rents and sustained competitive advantage of the firm (Barney, 1991; Grant, 1991). In addition, according to Cousins and Menguc (2006), RBV argues that firms possessing strategic resources will have more potential to benefit from opportunities and mitigate the impacts of threats in the business circumstances rather than those who possess only marginal resources. Such resources have to be non-substitutable and non-imitable as well as scarce among the competitors of the firms.

2.6.3 Extended RBV

According to Barney (1991), in RBV resources are important but possession alone does not create much benefit. To achieve the higher level of competitive advantage, firms must not only possess but also utilise such resources (Rubin, 1973). Mahoney and Pandian (1992) also argue that resources are not the reason firms possess competitive advantage, but rather the capabilities to maximise the utilisation of the resource in a unique way are more important. There is evidence of the gaps between *resource possession* and *resource exploitation* (Priem and Butler, 2001; Barney and Arikan, 2001). According to Priem and Butler

(2001), RBV literature is criticised that the knowledge of where, when and how resources may be useful to the firm still remains a "*black box*". To open this black box, the concept of *dynamic capability* is introduced by Teece et al. (1997, p. 516) as "*the firm's ability to integrate, build and reconfigure internal and external competences to rapidly address changing environments*". These arguments then offer the avenue of the research on the process of resource configuration in dynamics markets (Eisenhardt and Martin, 2000). Teece et al. (1997) state that the competitive environment today is changing more quickly than ever before and that conventional resource based view does not completely address this issue. According to them, the term "dynamic" refers to the capacity to renew competencies so as to achieve congruence with the changing environment. The term "capabilities" refers to the role of management to control all those elements which keep competencies relevant and effective. Eisenhardt and Martin (2000) state that in environments that are moderately dynamic, dynamic capabilities appear much like the traditional idea of routines where they are stable processes that rely extensively on existing knowledge with outcomes which are predictable. The framework of RBV can be illustrated in Fig. 5.

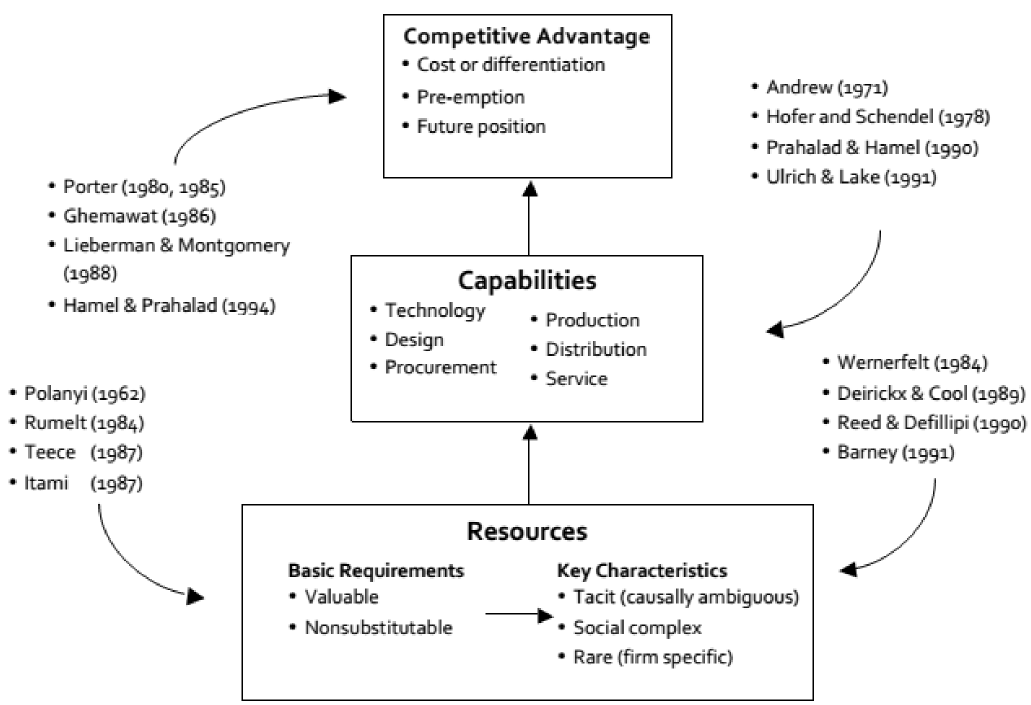

Figure 5- Framework of the RBV (Hart, 1995)

2.6.4 Relevance of RBV to this research

Different researchers mention lean, agile and resilience as capabilities that can offer firms different competitive advantages. According to Jorgensen et al. (2007), being successfully and sustainably lean involves more than just using tools and methods and efforts; it should be looked as lean capability development. "*Toyota's manufacturing capability – its system of "lean production" – integrates capabilities relating to the manufacture of components and subassemblies, supply-chain management, production scheduling, assembly, quality control procedures, systems for managing innovation and continuous improvement, and inventory control*" (Grant, 2005, P.138). Swafford et al. (2006) define agility as the supply chain's capability to respond in a speedy manner to a changing marketplace environment. Braunscheidel and Suresh (2009) also define agility as the company's capability, both internally and in conjunction with its key suppliers and customers, in order to adapt or respond quickly to the marketplace changes. Coutu (2002) mentions resilience as a critical capability for success. Additionally, Stoltz (2004) considers resilience as a distinctive organizational capability which is the key to producing results better than less resilient competitors. This research is based on the integration of these capabilities that lead to competitive advantages. The Resource Based View (RBV) of the firm provides important insights for understanding how competitive advantages within firms are created (Ponomarov and Holcomb, 2009).

Here it is needed to review the research question and the research objectives defined for this research:

RQ: How does resilience fit with leanness and agility both in terms of practices and outcomes in the context of supply chain management?

And the research objectives:

- Disentangling resilience, leanness and agility
- Investigating how resilience impacts performance in the presence of practices for leanness as well as agility in the context of supply chain management.

As stated above, according to the literature, leanness, agility and resilience are critical capabilities to success of the supply chains. In the research question for this research, the effects of these three approaches on the performance outcomes are investigated. Therefore, on one side there are capabilities, on the other side, performance outcomes as competitive advantages. The theory bridging these two sides appropriately is the Resourced based view.

Some existing literature discusses how leanness and agility as supply chain capabilities lead to competitive advantages. Positive effect of lean on cost, flexibility and delivery are discussed in Eroglu and Hofer (2001), and Hallgren and Olhager (2009). Also Narasimhan et al. (2006), Inman et al (2011), and Hallgren and Olhager (2009) confirm positive relations between agility with flexibility, delivery and cost performance. In time of uncertainty, however, supply chain resilience comes into play. It is a premise of this research that is a missing link to sustainable competitive advantages.

According to Mentzer and Kahn (1996) and Juttner et al. (2007), an integrative aspect finds its theoretical justification in the recent stream of literature on demand-supply integration. This is also supported by the fact that no single capability alone, however strong it is, is sufficient for achieving competitive advantages. So, capabilities should be combined appropriately rather than stand-alone abilities.

2.7 Conceptual model and the hypotheses

As previously stated, this research is done in two phases. In the first phase, the focus is on "disentangling resilience, agility and leanness". While it can be empirically assessed which practices are related to resilience, which practices are related to agility and which practices are related to lean, this research will flow to its second phase which investigates "how resilience along with leanness and agility affects operational performance outcomes". For this part, a survey is designed and the data are collected from Iran Auto industry. Through a complete literature review, the following sets of hypotheses are developed.

Regarding agility and resilience, some researchers such as Christopher and Peck (2004) believe that many organizations are at risk because their response time to demand changes or supply disruptions are too long and since agility is the ability to respond rapidly to unpredictable changes in demand or supply, the more agile an organization is, the less response time to changes is expected, therefore the organization is more resilient. They present a framework for resilience and state agility as one of the four factors that directly helps resilience. Also, Pettit et al. mention that in order to counteract vulnerabilities, supply chain can develop capabilities including agility that assure long-term survival. In addition, Panomarov and Holcomb (2009) state agility as a formative element of resilience. In conclusion, agile supply chain leads to more rapid response to changed conditions therefore leads to more resilience. So the first hypothesis can be postulated as follows:

H1: higher level of agility will have a positive impact on resilience.

Regarding resilience, no research could be found that empirically check the effects of resilience on cost, quality, delivery, flexibility and time to recovery. Due to this reason, these measures are not well defined for resilience. Looking at the results achieved from literature review (Table 13) practices which affect resilience include business continuity team, contingency plans made, decentralization of physical assets in multiple locations, detection systems in place to detect any supply disruption, establishing communication line in case of a disruption in the supply chain, security, alternative modes of transportation in the supply chain, flexible manufacturing equipment, visibility, excess capacity, redundant suppliers, collaboration with suppliers and cross-functional workforce. According to different literature, each of these practices affects some of the supply chain performance outcomes and therefore can be helpful in making the related hypotheses for this part of the research. According to Carvalho et al. (2012), redundancy of suppliers and alternative modes of transportation in resilient supply chains supports low cost and quicker response to demand in a turbulent business environment. Flexible manufacturing equipment which lets producing different products with the same facilities results in simpler planning, scheduling and lower set ups and holding costs. Therefore, regarding resilience and its effect on cost, the following hypothesis can be postulated:

H2a: Higher level of resilience will have a positive impact on cost performance.

Regarding the effect of resilience on flexibility performance, cross functional workforce improves the ability to cope with bottlenecks in processes and changes in due dates, therefore, affect customer lead time in response to changes in delivery schedule as a measure of flexibility performance (Juttner et al., 2007). Also, many of the related practices of resilience resulted from literature mentioned in the above paragraph such as redundant suppliers, alternative modes of transportation, excess capacity, and collaboration with suppliers can lead to better flexibility performance while there is a change in demand volume or delivery date (Carvalho et al., 2012). Therefore, regarding resilience and its effect on flexibility, the following hypothesis can be postulated:

H2b: Higher level of resilience will have a positive impact on flexibility performance.

Regarding the effect of resilience on delivery performance, according to Carvalho et al. (2012), collaboration with suppliers improves on time delivery percentage. Also, according to Rice and Caniato (2003) and Sheffi and Rice (2005), redundancies such as multiple suppliers and safety stocks can help resilient supply chains to have better delivery performance. These help supply chain to deliver orders with the right quantity at the right time even when a disruption occurs (Thun and Hoening, 2011). Therefore, regarding resilience and its effect on delivery, the following hypothesis can be postulated:

H2c: Higher level of resilience will have a positive impact on delivery performance.

Regarding the effect of resilience on time to recovery performance, practices such as business continuity team, contingency plans made, decentralization of physical assets in multiple locations, detection systems in place to detect any supply disruption, establishing communication line in case of a disruption in the supply chain, and alternative modes of transportation in the supply chain all help supply chains to decrease “time to detect undesirable risk event”, “time to design a solution” and finally “time to deploy a solution”. When an undesirable event occurs, it therefore helps time to recover from risk incidents or disruptions and to return to normal operational state or even a better one rapidly. Consequently, regarding resilience and its effect on time to recovery performance, the following hypothesis can be postulated:

H2d: Higher level of resilience will have a positive impact on time to recovery performance.

Regarding hypotheses for performance outcomes, for leanness, researchers have confirmed positive link of leanness with cost, flexibility and delivery performance (Eroglu and Hofer, 2011; Hallgren and Olhager, 2009). Going back to practices related to lean achieved from literature review in Table 12, TPM, TQM, and JIT could be named as three important practices related to lean. Cuo et al. (2001) in their paper investigate how these three affect performance in terms of cost, delivery and flexibility. According to Yusuf (2002), the ultimate goal of lean is to increase productivity and reduce cost by deleting all kinds of waste including inventory. Therefore, the following hypothesis can be postulated:

H3a: Higher level of leanness will have a positive impact on cost performance.

Regarding the effect of lean on delivery performance, Shah and Ward (2003) consider the effect of lean bundles (JIT, TPM, TQM and HRM) on the performance outcomes such as manufacturing cycle time and customer lead time and they confirm that lean bundles are associated with higher performance in terms of manufacturing cycle time (delivery) and customer lead time (flexibility). Therefore, it can be postulated that:

H3b: Higher level of leanness will have a positive impact on delivery performance.

In terms of the effect of leanness on flexibility performance, except Shah and Ward (2003) research mentioned above, who conclude that customer lead time as a factor of flexibility performance, can be improved by lean bundles, Narasimhan et al. (2006) also state that leanness can improve new product flexibility and process flexibility. Bhasin (2007) believes that lean offers greater production flexibility. JIT production improves customer response time, shorter setup time reduces the time required to change machines to work on different parts and also allows for smaller lot sizes. With lot sizes decreased, inventory levels are lowered and finally production flexibility increases (Fullerton and Mc Watters, 2000). Therefore, it can be postulated that:

H3c: Higher level of leanness will have a positive impact on flexibility performance.

A main gap in the literature appears to be in terms of the relation between leanness and time to recovery measures. Melnyk (2007) believes that lean supply chains become more fragile without buffers in the format of extra capacity, lead time and inventory. According to Zsidisin et al. (2005), lean systems become more fragile and cannot cope with unplanned variances because of the lack of resilience and robustness. From the review of the literature, following hypothesis can be postulated:

H3d: Higher level of leanness will have a negative impact on recovery performance.

Regarding agility, researchers such as Narasimhan et al. (2006), Inman et al. (2011), Hallgren and Olhager (2009) and Vázquez-Bustelo et al. (2007) confirm positive relations between agility with flexibility, delivery and cost performance. Agility is associated with a firm's ability to survive and prosper in a competitive environment that always is changing. It is not only a matter of flexibility and responsiveness in outcomes, but also offers high quality products at low cost with better service and delivery conditions (Vázquez-Bustelo et al., 2007). Agility needs minimum total lead time defined as the time taken from a customer raising a request for a product or service until it is delivered. Effective engineering of cycle time reduction leads to significant bottom line improvements in manufacturing costs (Aitken et al., 2000). Also, Narasimhan et al. (2006) in their paper state that agility leads to performance improvements in responsiveness, shorter product lead time and cost. Therefore, the following hypothesis can be postulated:

H4a: Higher level of agility will have a positive impact on cost performance.

Regarding the effect of agility on delivery, Swafford et al. (2006) conclude from their results that supply chain agility is achieved through the interaction among organizational processes that improves responsiveness and delivery. In addition, Different practices related to agility resulted from the literature review (Table 12) such as customization, visibility , excess capacity and redundant suppliers all help for the delivery of right quantity of the orders in the right time. Therefore, the following hypothesis can be postulated:

H4b: Higher level of agility will have a positive impact on delivery performance.

Regarding the effect of agility on flexibility performance, it can be said that agile supply chain is ready to encounter changes and its special characteristic is being responsive to these changes. Different practices related to agility resulted from the literature review (Table 11) such as customization, or excess capacity in order to absorb sudden increases in demand let agile supply chain to handle changes possible in demand volume or in customer lead time. Therefore, as other researchers state in their work such as Narasmihan et al. (2006) and Halgren and Olhager (2009), the following hypothesis can be postulated that:

H4c: Higher level of agility will have a positive impact on flexibility performance.

Regarding the relation of agility and time to recovery, Christopher and Peck (2004) state that agility is essential to react quickly to unforeseen events. Similarly, Lee (2004) presents methods to overcome both short- and long-term changes based on agility, adaptability and alignment. As such, it could be implied that agility could affect time to recovery performance positively. From the review of the literature, following hypothesis needs to be tested:

H4d: Higher level of agility will have a positive impact on time to recovery performance.

These hypotheses are shown in Figure 6.

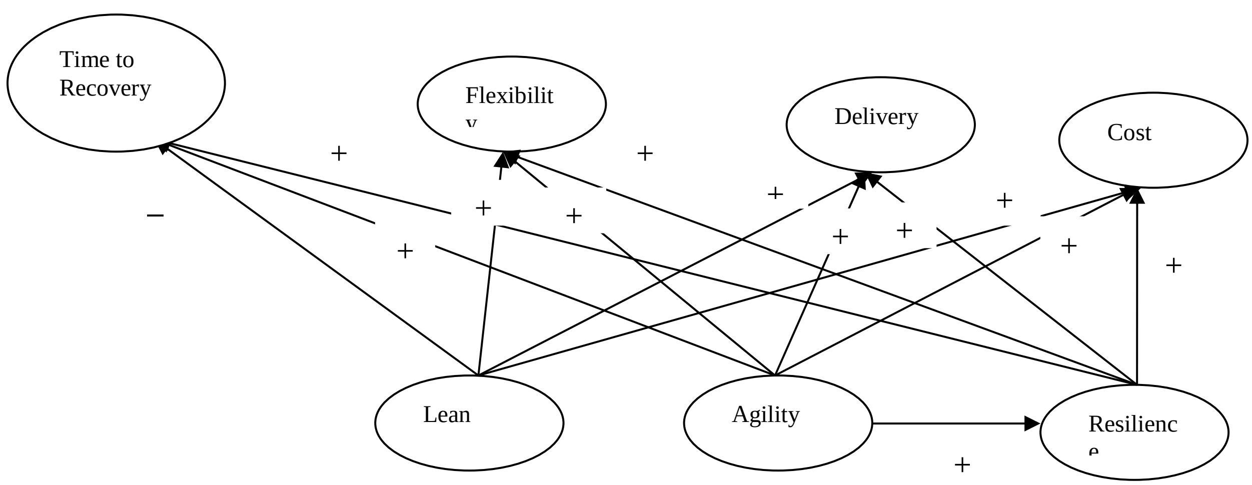

Figure 6- Primary research model

2.8 Industry relevance

In early stages of this research, in parallel with the literature review and developing research questions, there was an opportunity to conduct a short survey and a discussion at the Procter and Gamble's (P&G) Brussels' office, in March 2011, to establish the practitioner need for this research. This was under the topic of "Seeking Cost Efficiency, Customer Responsiveness and Business Continuity" in their internal forum. The theme was "Tomorrow's Supply Networks: Agility and Full Asset Utilization". Approximately 40 managers were questioned in the session, 77.8 %of them were from P&G's supply chain.

Managers from these companies were asked whether Lean, Agile and Business continuity practices were in place in their supply chain. In that point, since still the boundaries of the research were developing, the term Business continuity was used as one of the core ideas related to resilience. Leanness and agility are developed concepts in the area of supply chain both in research and practice, while resilience is a newer concept which still has lots of dark points which are needed to be clarified both in research and practice. Since business continuity term is more familiar term in industry and managers may have started working on developing business continuity teams and plans, this term was used in this phase of the research.

The managers were asked about:

- Any past practices of lean, agile and business continuity
- Whether the practices were done with upstream and downstream supply chain partners
- Whether or not target benefits were achieved
- Whether or not those benefits were sustainable over time.
- Whether their company has formal ways to look across these three practices
- Whether they agree that their company seeks ways to improve all three simultaneously

According to descriptive data presented in Tables 15-18, the majority of managers believed that they had at least one company-wide initiative of LAR in the last three years with their upstream and downstream partners and they were successful and sustainable in terms of their goals.

With regard to having any practices of Lean, Agile and Business continuity in the last three years, the majority believed they had at least one company-wide initiative or at least one division-wide initiative according to Table 17.

Table 17- Managers' pole on having lean, agile and business continuity practices in the last three years (N=40)

Issue/Question	At least one company-wide initiative	At least one division-wide initiative	No significant initiative	Not applicable
Lean	44.4%	33.3%	5.4%	16.7%
Agile	66.7%	22.2%	5.6%	5.6%
Business continuity planning	47.1%	23.5%	17.6%	11.8%

With regards to working with upstream and downstream supply chain partners in each initiative, most managers believed they worked with both upstream and downstream partners according to Table 18.

Table 18- Managers' poll on working with upstream or downstream partners on each of the lean, agile and business continuity practices (N=40)

Issue/Question	Worked with upstream partners only	Worked with downstream partners only	Worked with both upstream and downstream	In-house initiative only; did not work with upstream or downstream partners	Not applicable
Lean	15%	20%	55%	0%	10%
Agile	12%	23.6%	55%	0%	9.4%
Business continuity planning	26.3%	10.5%	36.6%	5.3%	21.1%

According to Table 19 most managers believed that they were effectively successful in achieving goals in all three practices and the results of the three practices were effectively sustainable.

Table 19- Managers' poll on success and sustainability of the results of lean, agile and business continuity practices (N=40)

Issue/Question	Highly effective	Effective	Somewhat effective	Not effective	Not applicable
Successful in lean	5.6%	72.2%	11.1%	0%	11.1%
Successful in agile	5.6%	61.1%	22.2%	0%	11.1%
Successful in business continuity planning	26.3%	36.8%	10.5%	0%	26.3%
Sustainability of the results of lean	5.3%	47.4%	26.3%	10.5%	10.5%
Sustainability of the results of agile	0%	66.7%	22.2%	5.6%	5.6%
Sustainability of the results of business continuity planning	15.8%	36.8%	15.8%	5.3%	26.3%

According to Table 20 most of them agreed that their companies had formal ways to look across the three practices and that they were seeking ways for improving all the three practices at the same time.

Table 20- Managers' poll on having formal ways to look across the three practices in their company and seeking ways to improve them

Issue/Question	Strongly disagree	disagree	Neither agree nor disagree	agree	Strongly agree

Respondents' belief about having formal ways to look across the three practices in their company	5.9%	29.4%	17.6%	41.2%	5.9%
Respondents' belief of their company seeking ways to improve the three practices	9.5%	19%	4.8%	57.1%	9.5%

The results suggest that although there is agreement that the supply chain has to be improved in terms of Lean, Agile as well as Business continuity and the companies concerned do carry out practices in each of these, striking a balance remains. The main outcome as regards this paper was that there was lack of clear boundaries between the three efforts as regards specific practices.

While they specified that their companies had formal ways to look across LAR and that they were seeking ways for improving LAR at the same time, they mentioned following challenges in seeking the right balance between the three practices:

- Lean and agile practices were implemented and coordinated by the same teams but Business Continuity Planning (BCP) was done by a team from a totally different organization
- Lean and agile practices were daily operations but BCP was done as a project.
- There was no program leader across practices corresponding to Lean, Agile or Resilient.

There was a perception that the companies needed to improve all three fronts. Some reasons for not achieving the right balance between the three practices can be summarized as follows:

- It is not clear yet how to do it. Bottlenecks and challenges such as different metrics exist.
- The context is dynamic. Balance would keep changing which means if it is found, it will again move and there is a need to find it again.

- Operational and organizational constraints such as BC are annual projects while lean and agile are ongoing ones.
- There are different perceptions of lean, agile and BCP. In the discussion following the survey, some managers believed that unclear boundaries between these concepts could make implementation of respective practices potentially problematic or confusing when multiple practices were carried out in the same time.

In conclusion, they believed that unclear boundaries between these concepts could make implementation of respective practices potentially problematic or confusing when multiple practices were carried out in the same time.

This conclusion is in line with the literature review performed on the academic papers and is an evidence that before any other issue, first it is needed that resilience, leanness and agility are disentangled for more clearance not only conceptually as done until now but also empirically for a stronger evidence.

2.9 Gap in the literature

The literature appears to have a twofold gap: (1) the concepts of lean, agile, and resilience overlap as per Table 12, and (2) the literature suggests that lean, agile and resilience all impact performance. As such, to make progress on the research question, i.e., how resilience impacts performance in the presence of practices for leanness as well as agility in the context of supply chain management, it is needed first to disentangle the three concepts from each other. Moreover, different researchers have conceived lean, agile and resilience slightly differently, so it makes sense to disentangle them with empirical testing. Secondly, it is needed to refine the primary model (Figure 6) obtained from the literature to a narrower conceptual model that can be a better starting point for researchers. The primary model (Figure 6) is not fully empirically tested either as many of the links are conceptual so there is need for empirical testing as well.

In conclusion, the results of these survey and discussion as an early stage research, in line with the results of the literature review show that there is a need for clarifying the three concepts of resilience, leanness and agility in the first step. In the next chapter, it will be explained that how this research is designed in order to answer the two research objectives: first, disentangling resilience, leanness and agility and second, investigating how resilience along with leanness and agility affects performance outcomes.

2.10 Epistemological position

According to Walliman (2006) and Snape and Spencer (2003), epistemology is concerned with what can be regarded as legitimate knowledge and how it can be acquired. There exist two approaches to acquire knowledge in the study of social science which are empiricism and rationalism. Gaining knowledge by sensory experience which is followed by inductive reasoning is empiricism and acquiring knowledge by deductive reasoning is rationalism.

The researcher's epistemological position plays an important role when designing their research. The reason is that different philosophical positions include different assumptions and each can affect the researchers' view of the world differently (Easterby-Smith et al., 2008). Holden and Lynch (2004, p. 397) state that "Methodological choice should be consequential to the researcher's philosophical stance and the social science phenomenon to be investigated" Therefore, it can be inferred that the research methodology selected and used follows the philosophical stance of the researcher.

While there are several epistemological positions in the study of social science, according to Neuman (2006), two fundamentally different viewpoints in the social science are positivism and interpretivism. According to Caldwell (1994), the positivist approach believes that the authentic knowledge is the outcome of actual experience and it can be derived only through scientific methods.

Positivism is a branch of foundatationalism, which is considered to be the oldest western philosophy. The two branches of foundatationalism are rationalism and empiricism each being represented by Descartes and John Locke respectively (Phillips and Burbules, 2000). Descartes identified the foundation of his knowledge by his ability to reason; he believed that knowledge was true if it could not be rationally doubted and that if something seemed indubitably true, then it must be true. Locke on the other hand believed that the secure foundation of knowledge was experience, which is gained through the human senses of sight, hearing, touch, etc. (Phillips and Burbules, 2000). Positivism is an extension of empiricism, and as such it can be understood why researchers who adopt the positivist approach rely heavily on quantitative methods. Positivists believe that the social world is external to the researcher and that the properties of this external world should be measured objectively (Easterby-Smith et al. 2002, p. 28). The positivists conduct research in a deductive manner by developing a theory or hypothesis, based on existing knowledge, and then collect quantitative data to test the theory or hypothesis. It should also be stated that there exists criticism to positivist's view. According to Phillips and Burbules (2000, pp. 14-25), while positivists believe that knowledge claims can only be based on what is observed; however, it has been shown that observation cannot be neutral. That is the researchers' experiences in the past can affect their understanding of what they observe. Next, a theory cannot be unequivocally claimed to be true based on the observed evidence because there could be many other theories to describe the observed events. In addition, the problem of induction is the longest standing issue for the positivist. The problem is that how much evidence is there to support a theory; one cannot be completely sure that there is no evidence as yet undiscovered to refute the theory.

Interpretivist approach rejects the existence of any general social scientific law since they believe the evidence about the social action is embedded in the context in which it occurs, so it cannot be studied in isolation (Neuman, 2010). According to Gray (2009), interpretivists argue that the nature of a social reality is different from the nature of natural reality. According to Sayer (2000), there is no regularity within the social world, so it is meaningless to claim a general law.

However, advocates of positivism argue that the social phenomena are observable, so they can be the focus of any objective research (Neuman 2010). Therefore, a positivist explanation of this sense is valid if it meets three criteria: the explanation should not have a logical contradiction. It should be consistent with the observed phenomena and finally it should be replicable.

Finally, this study follows the positivist school of thought. According to this school, it is possible to identify a set of laws and causal explanations that together can explain a stable pattern that exists in the social world (Neuman, 2010). So it can be concluded that the knowledge gaining process starts with gathering facts and quantifying concepts. As Brannick and Coghlan (2007) state these concepts are required to be linked through propositions and/or hypotheses and then these hypotheses are required to be tested by empirical observations. Therefore, the present study also developed its sets of hypotheses which will be tested with empirical data in the next chapters.

Chapter 3: First quantitative study: Disentangling resilience, agility and leanness in the context of supply chain

The result of literature review shows not enough clarity between resilience with leanness and agility in the context of supply chain. So the first quantitative study will target to disentangle resilience, agility and leanness in the context of supply chain. Then, the next step will be the second quantitative study with the aim of understanding how resilience along with leanness and agility affects performance outcomes.

The literature review shows confusion regarding the three approaches of resilience, agility and leanness. The challenge is unclear boundaries between the three concepts and vague portrait of categorization of measures covering each of them. The detailed literature review identifies the main practices of the three approaches of leanness, agility and resilience and specifies the overlapping and non-overlapping areas between them (Table 13). The result of the literature review shows that there is some work such as Azvedo et al. (2012) which try to solve this confusion; however, the issue remains to be settled empirically. This confusion specifically is problematic regarding the practices/ practices which according to literature are both linked to resilience and agility; agility and leanness; and even resilience, leanness and agility. Therefore, the first phase of this research is about disentangling resilience, agility and leanness by designing a survey study.

3.1 Overview and structure of the questionnaire

The questionnaire starts with a short opening statement sharing some basic background information such as:

- Origin of the research which is academic study for Cass Business School
- The area of the research and short explanation about it which is disentangling resilience, agility and leanness in supply chain context.
- Some general guidelines such as the time needed for answering the questionnaire.
- Confidentiality and insurance about the ethical aspects
- An offer to answer any question that might arise

- An offer to make the results available

The second part includes questions with regards to demographic information such as number of employees, average annual sale, and position and years of experience of the respondent. The main part of the questionnaire consists of practices/practices regarding resilience, leanness and agility. ***Managers were asked to which extent they think implementing these measures as practices would help their organization become lean, agile and resilient.***

As it is concluded in the literature review stage, there is lack of clarity pertaining to distinctions between LAR at the level of specific operational practices. The belief is that the previous developed scales related to leanness and agility cannot be used directly since all are suffering from this lack of clarity between practices which are linked to leanness or agility. This issue is more complicated when it comes to the practices that some are in the overlapping areas between LAR. For example Narasimhan et al. (2006) in their paper analyse that agile performers statistically dominate lean performers in implementation of many practices including JIT flow, while many other researchers such as Shah and Ward (2003) categorize JIT as a lean practice. This complication exists about many other practices too resulted from our literature review (Table 13). As stated before, the literature review shows confusion regarding the three approaches of LAR and the challenge is unclear boundaries between the three concepts and vague portrait of categorization of measures related to each of them. This confusion specifically is problematic regarding the practices/practices which according to literature are both linked to, resilience and agility; agility and leanness; and even resilience, leanness and agility.

The next point needed to be mentioned here is that there also exists confusion regarding some items used here such as JIT. Some researchers such as Inman et al. (2011) use them as multi-dimensional factors while there are others such as Shah and Ward (2007) bringing it as an item from the 10 items they defined lean by them in their research. This is while the multi-dimension of JIT scale in Inman's work includes lots of questions double –barrelled (Inman et al., 2011, P: 352) which makes using their scale impossible. In addition, it should be kept in mind that while the primary goal of this research is clarifying LAR, the final and main goal of it is how LAR affects performance outcomes, i.e. a statistical model that can justify how LAR affects performance outcomes. Defining LAR with multi-dimensional scales could include hundreds of questions, impossible for any survey study and later in the analysis stage, specifically while the respondents are all managers with lots of time limitations. Finally, seeing this research as the first research to have an empirical look at the three approaches of LAR, which is passing all previous conceptual works previously done in the field, could justify being fair enough to see this work as the starting point with some of its limitations.

The third point is about the unit of analysis. This issue is a complicated issue in most of the research in supply chain management field. These complications exist even in very good papers such as Swafford et al. (2006) published in JOM which talks about supply chain agility but the unit of analysis is manufacturing firm:

Swafford et al. (2006, p. 172) state that '*'we hypothesize that the key antecedents of a firm's supply chain agility are the inherent flexibility dimensions within each of the three supply chain processes. We choose to address an organization's internal supply chain, rather than its extended supply chain, which includes the firm's suppliers' and customers' supply chain processes. While possessing agility over a firm's extended supply chain is desirable, a firm has less control over its external processes compared to its own. Also, from a practical viewpoint, it would be difficult if not impossible to investigate the agility of every process in an organization's extended supply chain. By focusing on the key processes in a firm's internal supply chain, we have sought to keep this study more tractable, while gaining an understanding of the antecedents of a firm's supply chain agility that are within the firm's domain of control''.* But their work is clearly criticized by Braunscheidel and Suresh (2009, p. 126) who state in their paper that *"it would indeed be meaningful, and practical to focus on the immediate supply chain neighborhood of the firm."* Braunscheidel and Suresh (2009) define their unit of analysis as the firm, internally, and in conjunction with its key suppliers and customers. Also Shah and Ward (2007) in their paper for developing lean framework consider lean as internally related, customer related and supplier related concept. Therefore, as this research also investigates how resilience, leanness and agility fit in the context of supply chain, the unit of analysis is defined as the firm internally and in conjunction with its key suppliers and customers. The belief is that leanness, agility and resilience cannot be just considered in the firm individually, but in the form and in conjunction with its suppliers and customers which are the real essence of supply chain.

As Braunscheidel and Suresh (2009) state, the scope of the analysis should be the supply chain level.

3.2 Questionnaire measures

The questionnaire includes nine questions for the demographic questions and 28 questions related to practices related to resilience, agility and leanness. These are presented in Table 21.

Table 21- Disentangling resilience, agility and leanness, questionnaire measures

		Extent to which this initiative helps in becoming more … (-2: highly negative effect, +2: highly positive effect)		
		Lean	**Agile**	**Resilient**
1	Total preventative maintenance (TPM)			
2	TQM			
3	JIT			
4	Statistical process control (SPC)			
5	Cellular manufacturing			
6	Producing outputs with minimum resources			
7	Integrating different functions in the company			
8	Computer based technologies to manage manufacturing processes			
9	Customizing the final product for individual end-customers			
10	Responding quickly to rapidly changing situation somewhere in the supply chain			
11	Reducing process downtime between product changeovers			
12	Flexible manufacturing equipment to produce different products with the same facilities			
13	Cross-functional workforce			
14	Alternative modes of transportation in the supply chain			
15	Decentralization of physical assets in multiple locations			
16	Security against deliberate intrusion			

17	Redundant suppliers for the same part with these suppliers being capable to substitute each other			
18	Business Continuity (BC) team			
19	Contingency plans made			
20	Establishing communication line in case of a disruption in the supply chain			
21	Visibility			
22	Detection systems in place to detect any supply chain disruption			
23	Excess capacity in the supply chain to absorb sudden increases in demand			
24	Implement new technologies			
25	Concurrent engineering for overlapping activities in product design to achieve simultaneous development			
26	Knowledge management, by creating an organization that encourages experimentation of innovative ideas to allow extensive dissemination of knowledge throughout the organization			
27	Time-to-market, i.e., introducing new products quickly			
28	Collaboration with suppliers: Ability to work effectively with suppliers for mutual benefit			

3.3 Pre testing the instrument

Initially the questionnaire was translated from English into German by a native German speaker; it was then translated back into English by a native English speaker to guarantee translation equivalence (Salciuviene et al., 2005; Craig and Douglas, 2005).

Initial survey instrument was reviewed for content validity by a panel of academic and practitioner experts in the related area for content, clarity and understanding after it was translated into German. Reviews were undertaken by academics familiar with the constructs employed in the research. Additionally, this survey was pre-tested with five supply chain managers in Germany. Table 22 shows the major changes made after pre-testing:

Table 22- Points of pre-testing of the questionniare designed for data collection in Germany

Before pre-test	**After pre-test**
Fully integrated enterprise with each functional aspect of the manufacturing design, production and marketing of a product being performed across different organizations.	Integration of different company functions
Speed or quickness to carry out operations in the shortest possible time in response to rapidly changing situation somewhere in the supply chain	Responding quickly to rapidly changing situation somewhere in the supply chain
Currency for annual sales level: USD	Currency for annual sales level: EUR
Scale from -3 to +3	Scale from -2 to +2 for easiness of use (-2: very little; -1: little; 0: no effect; +1: much; +2: very much)
Question checked for not being double-barrelled such as Cross trained or cross functional workforce	Cross functional workforce

These were done in order to improve clarity and identify and resolve any unfamiliar or misunderstood wording. After all reviews, the survey instrument was modified accordingly. The final questionnaire is attached in Appendix 1.

3.4 Sampling

Germany is chosen for data collection because of the country's strong base in manufacturing. Manufacturing, Supply Chain, Sourcing/strategic sourcing and Marketing/Customer relations managers are targeted because it was concluded they are most appropriate ones with their particular knowledge related to supply chain practices. The data base used for German companies was Sachon Germany supplies which is freely available and includes many companies with up-to-date information. It includes all sectors presented in Table 23.

Table 23- Different sectors included in the data base

Mining	Tools and precision tools
Oil products and gases	Quarry products and building materials
Iron and steel	Fine, sanitary and technical ceramics
Drawing plant and rolling mill products	Glass
Foundry	Woodworking, furniture and functional furnishings
Metal forming	Chemistry, pharmacy, cosmetics
Steel, light metal, container and pipeline construction	Plastics processing, plastic products
Nonferrous metals and nonferrous metal products	Pulp and paper
Mechanical and plant engineering	Paper processing, printing and publishing companies
Aircraft and spacecraft	Leather and furs
Automobiles and two-wheeled vehicles	Footwear
Railway engineering	Bags, cases, briefcases and folders, etuis
Shipbuilding and ocean engineering	Rubber products
Electrical and electronics industry	Textiles, textile products
Optics and fine mechanics	Clothing
Metal goods and furnishings	Jewellery and silverware, clocks
Sport and leisure	Musical instruments
Model making, toys and stationery, decoration articles	Food, beverage and luxury food industry
Environmental, waste disposal and recycling technology	Agriculture and forestry, horticulture
Biotechnology	Business to business trade

The five industries including Consulting engineers, Engineering firms, Construction, Arts and handicrafts and Industrial services of the database were excluded since they were deemed not to have a typical supply chain and logistics that the other sectors included and they might cause bias in the results.

3.5 Survey technique and operational procedure

The survey carried out for this part of research is done online in Germany with the survey tool "Qualtrics", which enables researchers to confidentially and quickly distribute and manage surveys in a cost-and time saving manner. The survey was sent as an attached email survey.

Advantages of online surveys compared to postal questionnaire survey which acted as motivations to do this part of the research via online survey are low cost, fast response rate, more geographical coverage and fewer unanswered questions (Bryman, 2008). On the other hand, disadvantages of online surveys compared to postal questionnaire survey according to Bryman (2008) are low response rate and the issue that populations are restricted to online one. However, this cannot be a problem here since Germany is a developed country with almost everybody, especially every company, having access to the Internet and email as a basis for doing business.

3.5.1 Data collection

First, emails were sent to email addresses extracted from the database asking managers whether they would like to participate in the research, regarding answering the questionnaire. 503 people stated that they would like to participate, to whom the questionnaire was sent by email. Three reminders for following up were sent excluding those who had already responded. The first reminder was sent after one week, the second one after two weeks and the third one after 4 weeks. 185 questionnaires where answered. By deletion of mostly blank questionnaires and uncompleted ones, 126 questionnaires were usable.

3.5.2 Response rate

Regarding the response rate, Bryman and Bell (2011) identify the following formula:

$$Response\ rate = \frac{(Number\ of\ Usable\ questionniares)x100}{(Total\ sample - unsuitable\ or\ un - contactable\ members\ of\ the\ sample)}$$

Here, assuming that all interested actually saw the survey, it can be estimated as:

(126) x 100 / (503– 59) = 28.37 %

3.6 Steps to improve the response rates to questionnaires

For improving the response rate of the surveys, following steps were taken into consideration according to De Vaus (2002):

1- Providing a good cover letter including the following items: the questionnaires start with a short opening statement identifying the origin of the research (academic study from Cass Business School), the research area, an explanation of how the respondents were selected, anonymity, confidentiality and insurance about the ethical aspects, approximate time for completion, an offer to answer any question that might arise, an offer to make the results available and thanking the respondents in advance for taking part in the research. A cover letter was designed in accordance with the guidelines mentioned in the book "Surveys in Social Research" by De Vaus (2002, P.135) and can be referred in questionnaire attached in Appendix 1.

2- Follow up through Dillman's method: as explained previously in section 3.5.1. Follow up procedure was done to increase the response rates.

3.7 Sample characteristics

Sample characteristics regarding the industry sectors participated in the survey are summarized in Table 24.

Table 24- Sample characteristics, industry sector

Industry sector	Manufacturing	55.3%
	energy and water supply	1.2%
	wholesale and retail trade	4.3%
	mining and quarrying	0.6%

	post and telecommunications	1.2%
	real estate, renting and business activities	0.6%
	public administration and defense	0.6%
	health and social work	2.5%
	other community, social and personal service activities	1.9%
	Others	31.7%

With regards to Table 24, the question might appear that how some managers from the sectors such as Real estate can answer questions related to leanness and agility. It should be considered that these managers could be from manufacturing sector but selling their products to different business activities, categorizing themselves in those specific categorizations. The second point is that managers are not asked about how much they are successful in implementing these practices in their organization, but instead, they are asked to which extent they think implementing these practices can help their organization in becoming lean, agile and resilient. So, basically it is more about the concept rather than rating their organization.

Sample characteristics regarding the areas of the respondents are presented in Table 25.

Table 25- Sample characteristics, area of respondent

Area of the respondent	Production	27.9%
	Supply Chain	29.7%
	sourcing/strategic sourcing	10.3%
	Marketing/ customer relations	14.5%
	Other	17.6%

Sample characteristics regarding the years of experience of the respondents at the position are presented in Table 26.

Table 26- Sample characteristics, years of experience at the position

Years of experience at the position	less than 5 years	30.5%
	more than 10 years	56.7%
	between 5 and 10 years	12.8%

Sample characteristics regarding the years which the respondents have been working with the company at the position are presented in Table 27.

Table 27- Sample characteristics, years working with the company at the position

Years working with the company at the position	less than 5 years	36.6%
	more than 10 years	52.4%
	between 5 and 10 years	11.0%

Sample characteristics regarding the number of the employees at the location are presented in Table 28.

Table 28- Sample characteristics, number of employees at the location

Number of employees	fewer than 100	51.2 %
	100-249	10.4%
	250-499	12.8%

at the location	500-999	20.1%
	more than 1000	5.5%

Sample characteristics regarding the average annual sale are presented in Table 29.

Table 29- Sample characteristics, average annual sale

Average annual sale	less than € 10 Million	46.3%
	€ 10-50 Million	16.7%
	€ 51-100 Million	9.9%
	€ 101-250 Million	8.6%
	€ 251-500 Million	4.9%
	more than € 500 Million	13.6%

Sample characteristic regarding the plant age are presented in Table 30.

Table 30- Sample characteristics, plant age

Plant age	less than 10 years	32.3%
	more than 20 years	59.0%
	between 10 and 20 years	8.7%

Sample characteristics regarding the number of the plants are presented in Table 31.

Table 31- Sample characteristics, number of plants

Number of plants	fewer than 3plants	58.1%
	more than 6 plants	31.9%
	between 3 and 6 plants	10.0%

3.8 Survey quality: survey errors and treatments

The steps taken to reduce the various survey errors in order to produce high quality research are as follows:

3.8.1 Sampling and non-coverage error

Sampling error is the error that arises when only a subset of the population is included in a sample survey (Weisberg, 2005, P. 225). Usually it can be reduced by having large and random sample from the population of interest. Non-coverage error happens when certain members of the population are not included in the sample frame. One of the approaches to minimize the non-coverage error is using multiple frames into the same study (Weisberg, 2005, P.205). If complete and up-to-date lists of populations are available, this error will be reduced.

In order to decrease these errors, for the first quantitative study, the data base used for German companies was 'Sachon Germany supplies'. The most important factors for choosing this database was that email addresses were exportable; that is the database was reliable and represented a huge amount of German companies in every region as well as all industries and small as well as big companies. It was freely available and included many companies with up to date information. Sampling was done completely randomly, and it was tried to get the highest possible response rate by having follow-up procedure.

3.8.2 Non-response error

No matter how carefully a sample is selected, some members of the sample simply do not respond to the survey questions. But there are methods for improving response rate mentioned by researchers such as Dillman (Dillman, 1978, 1991). Dillman's follow up method has been used as explained in data collection section previously. Also, the questionnaires were made to appear easy and less time consuming to complete, encouraging the respondents by explaining the purpose of the research briefly and considering a reward (informing respondents that if they would like to have the results, they will be sent after the analysis is done).

Another point suggested is to make sure that those who responded aren't different from those who didn’t especially when the response rates are low. It will be assessed by comparing respondents to non-respondents on key demographic characteristic (Filion, 1976). Lambert and Harrington (1990) describe a common approach to assessment which is comparing the first and second waves of responses and assuming that non-response bias does not exist if no differences exist on the survey variables. Following this common approach, respondents will be categorized on responding to either the initial requests are classified as early respondents. Those responding to the follow up requests will be classified as late respondents, being considered a surrogate for non-respondents (Armstrong and Overton, 1977). Using this method, responses of the first 30 received surveys will be compared to responses of the last 30 surveys. T-tests can be performed using annual revenue, number of employees along with three randomly selected measures or using one way Anova (Shah and Ward, 2007; Swafford et al., 2006; Narasimhan et al., 2006; Inman et al., 2011; Braunscheidel and Suresh, 2009).

For the first quantitative study, early and late respondents were compared considering the assumption that the data from late respondents were representative of non-respondents (Armstrong and Overton, 1977). According to Swafford et al. (2006), responses of the first 30 received surveys were compared to responses of the last 30 received surveys. T-tests were performed on key demographic characteristics such as number of employees and annual sale. Results indicate no significant difference between early and late responses so it can be concluded that non-response bias is not present.

3.8.3 Measurement error

It can be characterized as the difference between value of a variable provided by a respondent and the truth (but unknown) value of that variable (Statistical policy office, 2001). This error is originated from the questionnaire, by the respondent; or is attributed to the mode of data collection. One of the ways for reducing this error is questionnaire pre-testing which according to Presser et al., (2004) is the only way to evaluate in advance whether a questionnaire causes problems for respondents. Additionally, according to Seidler (1974) choosing informants involved the first concrete strategy to reduce measurement error. Measurement error caused by respondents occurs when respondents do not respond to specific questions. It could also be the result of social desirability which is over reporting of admirable attitudes and behaviours and underreporting those that were not socially reported (Krosnick, 1999), although according to Dillman's (1987), this is less felt in self- administered questionnaire.

In this study, measurement error was decreased by pre-testing the questionnaire. Regarding respondents, it has been tried to contact the people who had the knowledge to fill out the questionnaire. It was tried to control social desirability by emphasizing the anonymous nature of the research in the cover letter of the questionnaire.

Overall, measurement error can be systematic or random, that is, error that causes a constant bias in the measurements of all indicators such as common method variance (explained in Section 4.8.4) or error that influences only specific items and can be attributed to many unrelated factors. So, every observed measurement (Om) is composed from the true score (Ts), as well as systematic error (Se) and random error (Re): Om = Ts + Se + Re.

These errors can impact on a study's reliability and validity. Reliability is influenced by random error while validity is influenced by both systematic and random error.

3.8.4 Validity and reliability

The issues of validity and reliability of the questionnaires will be tested during the analysis phase after the completion of the data collection.

- **Content validity:** This issue does not have formal statistical test; however, it can be augmented by a thorough literature review, linkage to theory and review of the initial survey instrument by a panel of experts comprising both academics and practitioners (Braunscheidel and Suresh, 2009). This issue was managed by undertaking an extensive literature review at the start of the research. Also, the pre-test procedure helped reduce this issue as well.
- **Convergent validity:** Convergent validity represents how well the measures relate to each other with respect to a common concept, and is exhibited by having sig. factor loadings of measures on hypothesized constructs (Anderson and Gerbing, 1988b). The ability of items in a scale to converge or load together as a single construct is measured by examining individual loadings for each block of indicators. Each indicator should share more variance with the component score than with the error variance. It will be

assessed by examining the individual loadings of each scale item onto its latent variables. There are different thresholds in literature defined for convergent validity. Some such as Swafford et al. (2006) state that the standardized loadings should be greater than 0.707 implying that the indicators share more variance with their respective latent variable than with error variance. There are others such as Inman et al. (2011) stating that items with loading under 0.5 should be deleted in the CFA. Item measures with insignificant factor loadings will be removed from the scale if content validity will not be scarified (Swafford et al., 2006)

- **Reliability:** According to Filed (2009, P.673), "*reliability means that a measure or questionnaire should consistently reflect the construct that it is measuring*". One way to interpret it is considering other things being equal; a person should get the same score on a questionnaire if they complete it at two different points in time. The other is that individual items (or set of items) should produce results consistent with overall questionnaire. Cronbach's Alpha is the most common measure of scale reliability. The minimum value of 0.7 is considered acceptable for existing scales and a value of 0.6 is deemed appropriate for newly developed scales.

3.9 Data analysis

Confirmatory Factor Analysis (CFA) with maximum likelihood estimation was undertaken using AMOS Version 19 for analyzing the data. Also, for some parts SPSS 19 was used.

3.9.1 Data analysis overview

"Factor analysis is a method for investigating whether a number of variables of interest Y1, Y2, : : :, Yl, are linearly related to a smaller number of unobservable factors F1, F2, : : :, Fk" (Tryfos, 1997). The fact that the factors are not observable disqualifies regression. According to Harrington (2009) steps for creating a confirmatory factor analysis model includes specifying the model, defining observable and latent variables. Prior research is crucial to specify a CFA model. Observed variables are those items that are directly observed, such as a response to a question. Latent variables are those underlying unobserved constructs of interest.

There is another technique called Exploratory Factor Analysis (EFA) which is used to identify the underlying factors or latent variables for a set of variables. It is usually considered a data driven approach to identify a smaller number of underlying factors as latent variables. Unlike EFA and CFA, it requires pre-specification of all aspects of the model to be tested and is more theory-driven than data-driven. Here, in the survey, respondents were asked to rate how much practices, which as a result of the literature review were linked to lean, are actually linked to lean (these practices could be from the category which all the literature agree is just connected to lean, could be from the category that some literature state they are both connected to lean and agile and finally could be even from the category that the literature state that are connected to leanness, agility and resilience). Respondents were again asked to rate how much practices, as a result of the literature review were linked to agility, are actually linked to agility (these practices could be from the category that all literature agree that they are just connected to agility, could be from the category that some literature state that they are connected to agility, some other state they are connected to lean, could be from the category that some literature believe they are connected to agility, some other believe they are connected to resilience, and finally could be from the category that some literature link them to agility, some to leanness and some to resilience). Top rate respondents were again asked how much practices, which were really connected to resilience, were actually linked to resilience (both from non-overlapping and overlapping areas). Since each measure and its relation to lean, agile and resilience at least referred to three sources in literature, there were enough theoretical evidence to run three CFAs and three CFA model for leanness, agility and resilience.

Here, three CFA models were performed. The first model is a CFA for resilience based on the measures which were taken from literature review. The second model is a CFA model for agility and the third one is for lean.

According to Field (2009, p. 628), factor analysis is used to understand the structure of a set of variables. The objective of the CFA is to test whether the model fits the data. There are several estimation methods to test the fit. The most common one is Maximum Likelihood (ML) which is used here as well. According to Harrington (2009), there is different goodness of fit indices; each of them provides different information about the model fit. So, researchers usually report different fit indices. Fit indices are divided into three groups: absolute fit indices, parsimony correlation indices and comparative fit indices.

Majority of experts (Schumacker and Lomax, 2004; Kline, 2005; McDonald and Ho, 2002; Garson, 2009; Harrimgton, 2009) suggest the following measures, which I will report in my analysis:

1) **Chi-square** (X^2 or "CMIN" in AMOS) with degrees of freedom (DF) and significance (p) level: This is an absolute fit index which tests whether the model fits exactly in the population. AMOS outputs model chi-square as "CMIN". Ideally, the chi-square value should not be significant if there is a good model fit. If a model's chi-square ≤ .05, the researcher's model is rejected. There are multiple limitations for Chi-Square: it is dependent on sample size and will almost always be significant with large samples. Given the known sensitivity of this statistic to the sample size, however, use of X^2 provides little guidance in determining the extent to which the model does not fit; thus, it is more beneficial to rely on the other fit indexes as well as other statistics regarding validity and reliability. According to Byrne (2010, p. 77), one of the first fit statistics to address this problem is Chi-square/degrees of freedom.

2) **Chi-square/degrees of freedom** (relative chi-square or normal or normed chi-square): AMOS lists relative chi-square as CMIN/DF. This is the chi-square fit index divided by degrees of freedom, in an attempt to make it less dependent on sample size. Carmines and McIver (1981) state that relative chi-square should be in the ≤ 2.0 or ≤ 3.0 range for an acceptable model, while Ullman (2001) says ≤ 2.0 or less reflects good fit and Kline (2005) considers 3.0 as the threshold.

3) **CFI** (Comparative Fit Index): the CFI which is a comparative fit index evaluates the fit of the model relative to a more restricted nested baseline model. That is it compares the covariance matrix predicted by the model to the observed covariance matrix, and compares the null model (covariance matrix of 0's) with the observed covariance matrix, to gauge the percent of lack of fit which is accounted for by going from the null model to the researcher's model. According to Byrne (2010, p. 79), CFI indicates if the model fits the data well in the sense that the hypothesized model adequately describes the sample data. According to Fan et al. (1999), the CFI also similar to RMSEA is not sensitive to sample size. The CFI varies from 0 to 1: a CFI close to 1 indicates a very good fit. Again there are multiple guidelines available for acceptable model fit but it is already good if ≥ .90, according to (Kline, 2005, p.140), indicating that 90% of the co-variation in the data can be reproduced by the given model.

4) **RMSEA** (Root Mean Square of Approximation) or "discrepancy per degree of freedom" with

90% confidence intervals: This is a parsimony correlation index. The RMSEA tests the extent to which the model fits reasonably well in the population. It is sensitive to model complexity but it is relatively insensitive to sample size. According to Byrne (2010, p. 80), it takes into account the error of approximation in the population and asks the question “how well would the model, with unknown but optimally chosen parameter values, fit the population covariance matrix if it were available?” Different researchers state different thresholds for RMSEA. Schumacker and Lomax (2004) state that there is good model fit if RMSEA is less than or equal to .05 and adequate fit if RMSEA is less than or equal to .08. Browne and Cudeck (1993) state that RMSEA less than 0.10 is acceptable. According to Byrne (2010, P. 81), Confidence of intervals should be stated to assess the precision of RMSEA estimates. AMOS reports RMSEA with 90% confidence intervals (LO 90 and HI 90).

3.9.2 Data screening and preparation

Harrington (2009, p. 61) states that as part of preparing data for analysis, it is necessary to look for missing data. There are some recommendations for handling missing data, one of them is imputation, i.e. using computer software to replace missing values with plausible guesses or estimates of what a response might have been. So, I used imputation for the missing data and then went for the next step of running analysis.

3.9.3 Normality

According to Kline (2005), every variable with skew index absolute value greater than 3 and kurtosis index absolute values greater than 10 are of concern. This analysis was done in SPSS 19 for this part of the research. All measures were checked via descriptive analysis for skewness and Kurtosis and the results show that all of them are within the acceptable range.

3.10 Conducting the CFA

Three CFA models were run in AMOS 19 for each of the approaches of resilience, agility and leanness.

3.10.1 CFA model for resilience

The CFA model for resilience includes all measures which from literature it is concluded that affect resilience. These measures are all shown in Table 32.

Table 32- Measures used for resilience CFA model

Num.	Practice	Variable label in AMOS
1	Flexible manufacturing equipment to produce different products with the same facilities	felx.man
2	Cross-functional workforce	workforce
3	Alternative modes of transportation in the supply chain	alter.trans
4	Decentralization of physical assets in multiple locations	decent
5	Security against deliberate intrusion	security
6	Redundant suppliers for the same part with these suppliers being capable to substitute each other	red.sup
7	Business Continuity (BC) team	BC
8	Contingency plans made	contin.plan
9	Establishing communication line in case of a disruption in the supply chain	com.line
10	Visibility	visibi
11	Detection systems in place to detect any supply chain disruption	detec.sys
12	Excess capacity in the supply chain to absorb sudden increases in demand	exces.cap
13	Collaboration with suppliers: Ability to work effectively with suppliers for mutual benefit,	coll.supp

For the reliability test SPSS 19 was used to calculate Cronbach's Alpha. The result is presented in Table 33.

Table 33- Reliability statistics test for the first resilience CFA model

Cronbach's Alpha	.857
Cronbach's Alpha Based on Standardized Items	.860
N of Items	13

The table of Item-total statistics was considered carefully in order to see how Cronbach's Alpha can be improved. But since Cronbach's Alpha was already above .7, also there would be a small change in the result by deleting some variables; all variables were kept for content validity.

For achieving factor loadings and testing convergent validity, a CFA was run by AMOS 19; the model is shown in Figure 7.

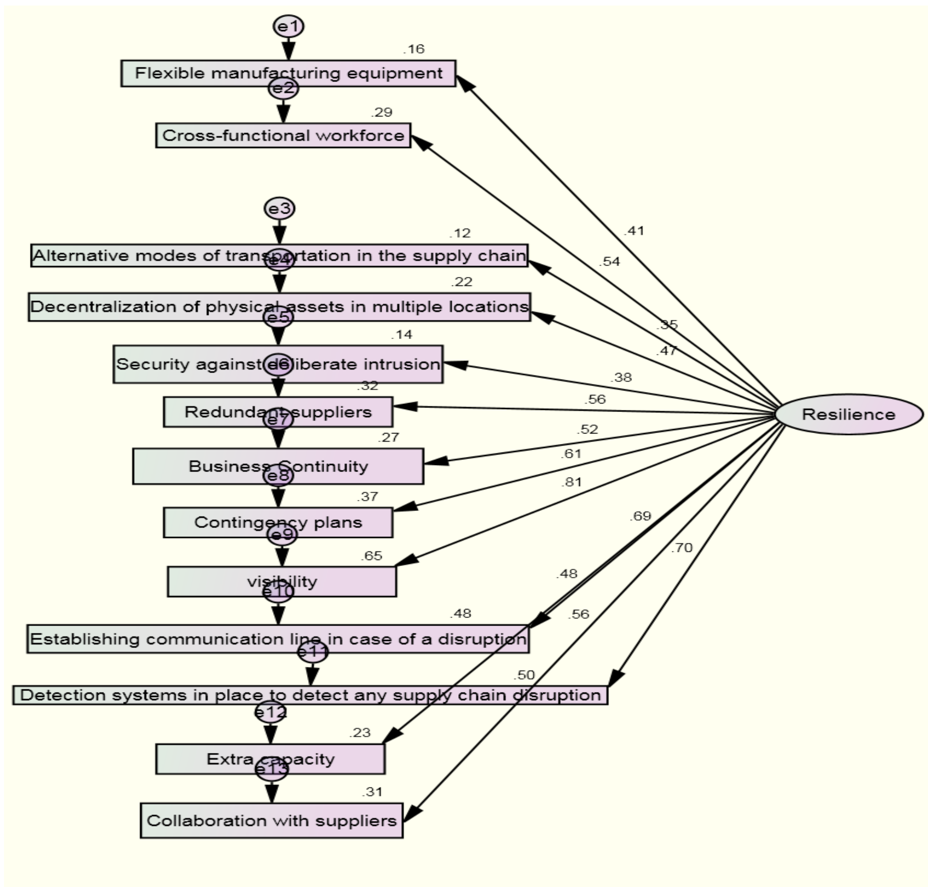

Figure 7- First CFA model for resilience [Source: AMOS 19 software]

This CFA resulted in Chi-square of 167.69 with 65 degrees of freedom (P=.000). The chi-square value should not be significant in an ideal model with a good model fit. But given the known sensitivity of this statistic to the sample size, however, use of X^2 provides little guidance in determining the extent to which the model does not fit; thus, it is more beneficial to rely on the other fit indexes as well as other statistics regarding validity and reliability. Fit indices are presented in Table 34. CMIN/DF is in its acceptable range (CMIN/DF<3). CFI is .838 which should be >.9 and RMSEA is .095 which is in its acceptable range (RMSEA <0.1). The fit indices are shown in Table 34.

Table 34- Fit indices for the first CFA model for resilience

Fit index	
CMIN/DF	2.580
CFI	.838
RMSEA	.095

The regression weights are shown in Table 35. This table shows that all factors significantly load on resilience since all P values are significant.

Table 35- P values of factors' load on resilience for the first CFA model for resilience

			P
felx.man	<---	Resilience	
workforce	<---	Resilience	***
alter.trans	<---	Resilience	***
decent	<---	Resilience	***
security	<---	Resilience	***
red.sup	<---	Resilience	***
BC	<---	Resilience	***
contin.plan	<---	Resilience	***
visibi	<---	Resilience	***
com.line	<---	Resilience	***
detec.sys	<---	Resilience	***
exces.cap	<---	Resilience	***
coll.supp	<---	Resilience	***

***The probability is less than 0.001.

For convergent validity, the table of standardized regression weights as presented in Table 36 was considered carefully. Measures with standardized regression weights less than .50 should be deleted for achieving convergent validity.

Table 36- Standardized regression weights for the first CFA model for resilience

			Estimate
felx.man	<---	Resilience	.406

			Estimate
workforce	<---	Resilience	.536
alter.trans	<---	Resilience	.345
decent	<---	Resilience	.467
security	<---	Resilience	.375
red.sup	<---	Resilience	.562
BC	<---	Resilience	.518
contin.plan	<---	Resilience	.608
visibi	<---	Resilience	.809
com.line	<---	Resilience	.694
detec.sys	<---	Resilience	.705
exces.cap	<---	Resilience	.477
coll.supp	<---	Resilience	.560

First "Alternative modes of transportation", then "Security", then "Flexible manufacturing equipment to produce different products with the same facilities" are deleted in a one by one process in order to get convergent validity. After deletion of the mentioned items, the new model is presented in Figure 8.

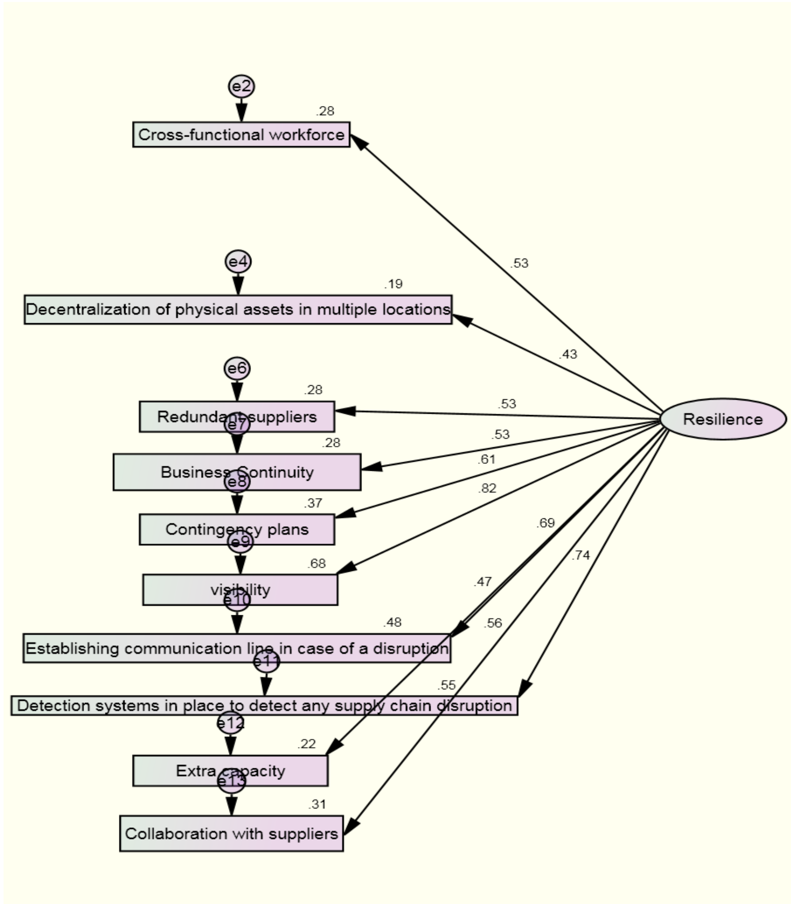

Figure 8- Final CFA model for resilience [Source: AMOS 19 software]

The new model result in Chi-square of 62.512 with 35 degrees of freedom (p=.003). The new fit indices are shown in Table 37, as it can be seen all are in the acceptable range (CMIN/DF<3, RMSEA<.1, CFI>.9).

Table 37- Fit indices for the final CFA model for resilience

Fit index	
CMIN/DF	1.786
CFI	.945
RMSEA	.067

Table 38 shows that all measures are significantly related to resilience.

Table 38- P values of factors' load on resilience for the final CFA model for resilience

			P
workforce	<---	Resilience	
decent	<---	Resilience	***
red.sup	<---	Resilience	***
BC	<---	Resilience	***
contin.plan	<---	Resilience	***
visibi	<---	Resilience	***
com.line	<---	Resilience	***
detec.sys	<---	Resilience	***
exces.cap	<---	Resilience	***
coll.supp	<---	Resilience	***

***The probability is less than 0.001.

Table 39 shows that convergent validity of the model is also supported since now all standardized regression weights are above .50.

Table 39- Standardized regression weights for the final CFA model for resilience

			Estimate
workforce	<---	Resilience	.528
decent	<---	Resilience	.432
red.sup	<---	Resilience	.531
BC	<---	Resilience	.526
contin.plan	<---	Resilience	.607
visibi	<---	Resilience	.824
com.line	<---	Resilience	.691
detec.sys	<---	Resilience	.740
exces.cap	<---	Resilience	.466
coll.supp	<---	Resilience	.558

3.10.2 CFA model for agility

The CFA model for agility includes all measures which, from literature it was concluded, affect agility. All these measures are presented in Table 40.

Table 40- Measures used for agility CFA model

Num.	Practice	Variable label in AMOS
1	TQM	TQM
2	JIT	JIT
3	integrating different functions in the company	integ
4	Computer based technologies to managing manufacturing processes.	com.tech
5	Customizing the final product for individual end-customers	custom
6	Responding quickly to rapidly changing situation somewhere in the supply chain	respons.rap
7	Reducing process downtime between product changeovers	quick.chan
8	Flexible manufacturing equipment to produce different products with the same facilities	felx.man
9	Cross-functional workforce	workforce
10	Redundant suppliers for the same part with these suppliers being capable to substitute each other	red.sup
11	Visibility	visibi
12	Excess capacity in the supply chain to absorb sudden increases in demand	exces.cap
13	Capability to implement new technologies in your product	new.tech
14	Concurrent engineering for overlapping activities in product design to achieve simultaneous development.	con.eng
15	Knowledge management	kn.mgt
16	Time-to-market, i.e., introducing new products quickly	time.mar
17	Collaboration with suppliers: Ability to work effectively with suppliers for mutual benefit,	coll.supp

For testing reliability, SPSS 19 was used. The result is presented in Table 41.

Table 41- Reliability test for the first agile CFA

Cronbach's Alpha	.856
Cronbach's Alpha Based on Standardized Items	.860
N of Items	17

The table of Item-total statistics was considered carefully in order to see how Cronbach's Alpha can be improved. But since Cronbach's Alpha was already above .7, also there would be a small change in the result by deleting some variables; all variables were kept for content validity.

For achieving factor loadings and testing convergent validity, a CFA was run by AMOS 19; the model is shown in Figure 9.

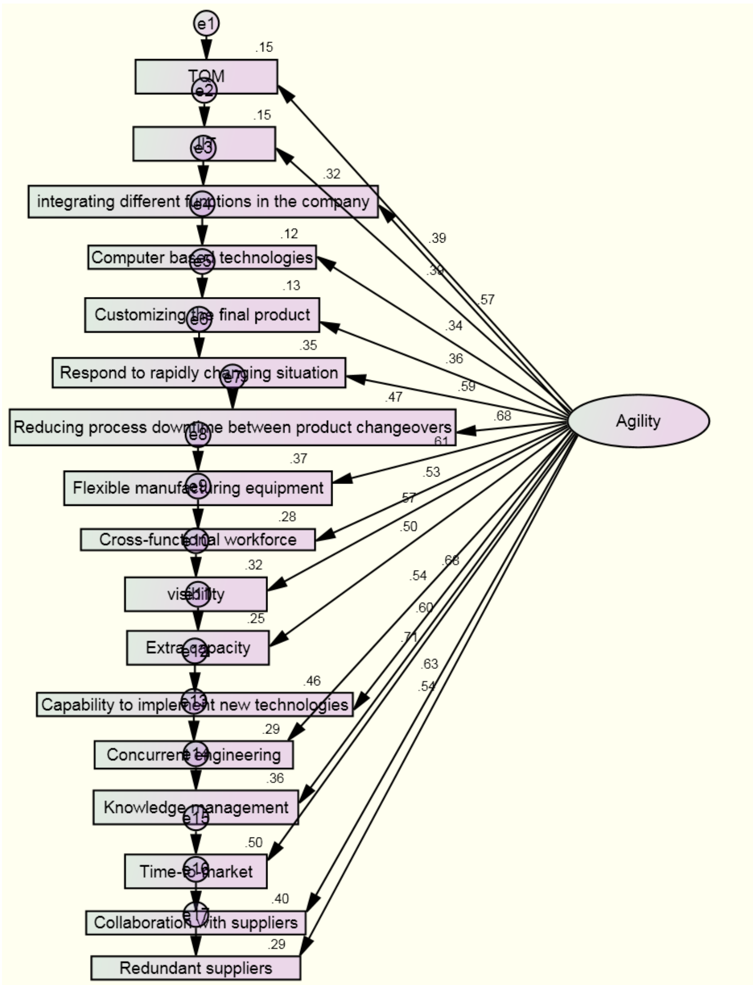

Figure 9- First CFA model for agility [Source: AMOS 19 software]

This CFA resulted in a Chi-square of 256.77 with degrees of freedom 119 (p =.00). Results of the fit indices for the first CFA model for agility are presented in Table 42.

Table 42- Fit indices for the first CFA model for agility

Fit index	
CMIN/DF	2.158
CFI	.840
RMSEA	.082

CMIN/DF is in its acceptable range, also RMSEA is less than .1 and CFI is equal to .840.

Table 43 shows the p values, while it can be concluded that all items load significantly on agility.

Table 43- P values of factors' load on agility for the first CFA model for agility

			P
TQM	<---	Agility	
JIT	<---	Agility	***
integ	<---	Agility	***
com.tech	<---	Agility	***
custom	<---	Agility	***
respons.rap	<---	Agility	***
quick.chan	<---	Agility	***
felx.man	<---	Agility	***
workforce	<---	Agility	***
visibi	<---	Agility	***
exces.cap	<---	Agility	***
new.tech	<---	Agility	***
con.eng	<---	Agility	***
kn.mgt	<---	Agility	***
time.mar	<---	Agility	***
coll.supp	<---	Agility	***
red.sup	<---	Agility	***

***The probability is less than 0.001.

Table 44 shows the standardized regression weights for the first CFA model for agility. Measures with standardized regression weights less than .50 should be deleted for achieving convergent validity.

Table 44- Standardized regression weights for the first CFA model for agility

			Estimate
TQM	<---	Agility	.386
JIT	<---	Agility	.388
integ	<---	Agility	.570
com.tech	<---	Agility	.340
custom	<---	Agility	.362
respons.rap	<---	Agility	.593
quick.chan	<---	Agility	.683
felx.man	<---	Agility	.611
workforce	<---	Agility	.531
visibi	<---	Agility	.568
exces.cap	<---	Agility	.495
new.tech	<---	Agility	.679
con.eng	<---	Agility	.540
kn.mgt	<---	Agility	.600
time.mar	<---	Agility	.711
coll.supp	<---	Agility	.634
red.sup	<---	Agility	.536

It can be concluded that for convergent validity "Computer based technology" needs to be deleted since it is below .50. Then "Customization", "TQM" and finally "JIT" are deleted. The new model is presented in Figure 10.

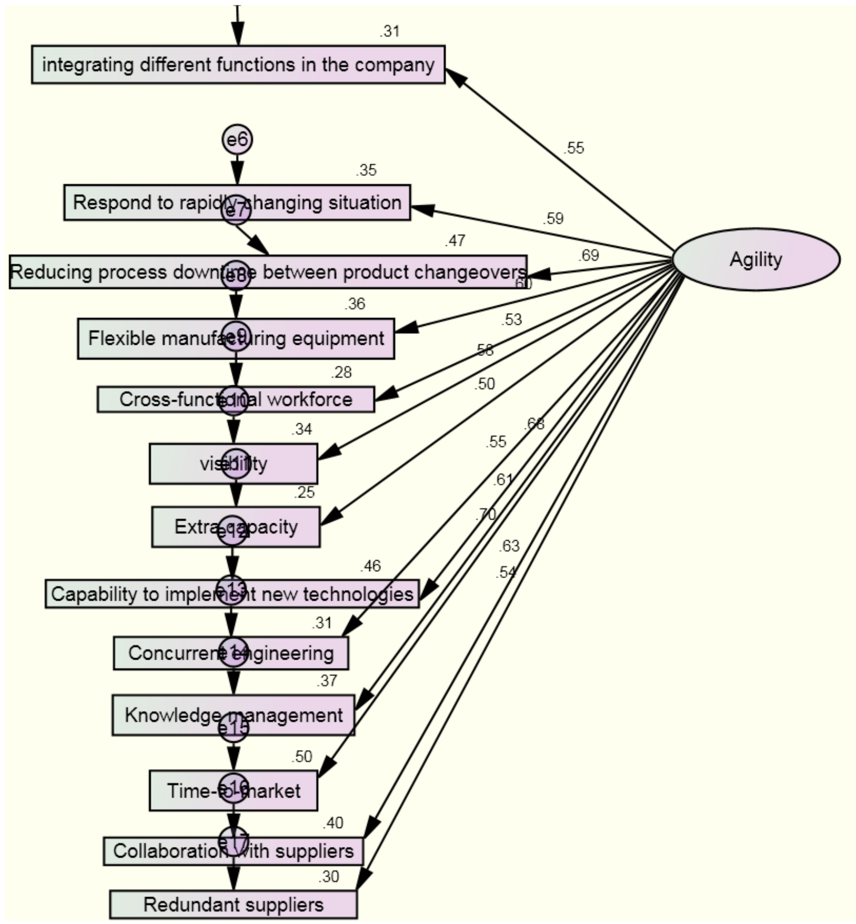

Figure 10- Final CFA model for agility [Source: AMOS 19 software]

The new model resulted in the Chi-square of 143.386 with 65 degrees of freedom (p=.000). Fit indices are presented in Table 45 while giving enough evidence of good model fit.

Table 45- Fit indices for the final CFA model for agility

Fit index	
CMIN/DF	2.206
CFI	.891
RMSEA	.083

Table 46 shows that all items in the final model significantly load on agility.

Table 46- P values of factors' load on agility for the final CFA model for agility

			P
integ	<---	Agility	
respons.rap	<---	Agility	***
quick.chan	<---	Agility	***
felx.man	<---	Agility	***
workforce	<---	Agility	***
visibi	<---	Agility	***
exces.cap	<---	Agility	***
new.tech	<---	Agility	***
con.eng	<---	Agility	***
kn.mgt	<---	Agility	***
time.mar	<---	Agility	***
coll.supp	<---	Agility	***
red.sup	<---	Agility	***

***The probability is less than 0.001.

In addition, Table 47 shows that convergent validity is supported since now all standardized regression weights are above .50.

Table 47- Standardized regression weights for the final CFA model for agility

			Estimate
integ	<---	Agility	.554
respons.rap	<---	Agility	.594
quick.chan	<---	Agility	.689
felx.man	<---	Agility	.600
workforce	<---	Agility	.531
visibi	<---	Agility	.582
exces.cap	<---	Agility	.500
new.tech	<---	Agility	.677
con.eng	<---	Agility	.553
kn.mgt	<---	Agility	.606
time.mar	<---	Agility	.704
coll.supp	<---	Agility	.631
red.sup	<---	Agility	.545

3.10.3 CFA model for lean

The questionnaire for lean includes all items which, from literature it was concluded, affect leanness. These measures are presented in Table 48.

Table 48- Measures used for lean CFA model

Num.	Initiative/Practice	Variable label in AMOS
1	TPM	TPM
2	TQM	TQM
3	JIT	JIT
4	Statistical process control	SPC
5	Cellular manufacturing	cel.man
6	Producing outputs with minimum resources	effi
7	Reducing process downtime between product changeovers	quick.chan
8	Cross-functional workforce	workforce
9	Implementing new technologies	new.tech
10	Concurrent engineering for overlapping activities in product design to achieve simultaneous development.	con.eng
11	Knowledge management	kn.mgt
12	Collaboration with suppliers: Ability to work effectively with suppliers for mutual benefit	coll.supp

For the reliability test, again SPSS 19 was used to calculate cronbach's Alpha. The result is presented in Table 49.

Table 49- Reliability test for the first CFA model for lean

Cronbach's Alpha	.818
Cronbach's Alpha Based on Standardized Items	.820
N of Items	12

The table of Item-total statistics was considered carefully in order to see how Cronbach's Alpha can be improved. But since Cronbach's Alpha was already above .7, also there would be a small change in the result by deleting some variables; all variables were kept for content validity.

For achieving factor loadings and testing the convergent validity, AMOS 19 was used resulted in the model presented in Figure 11.

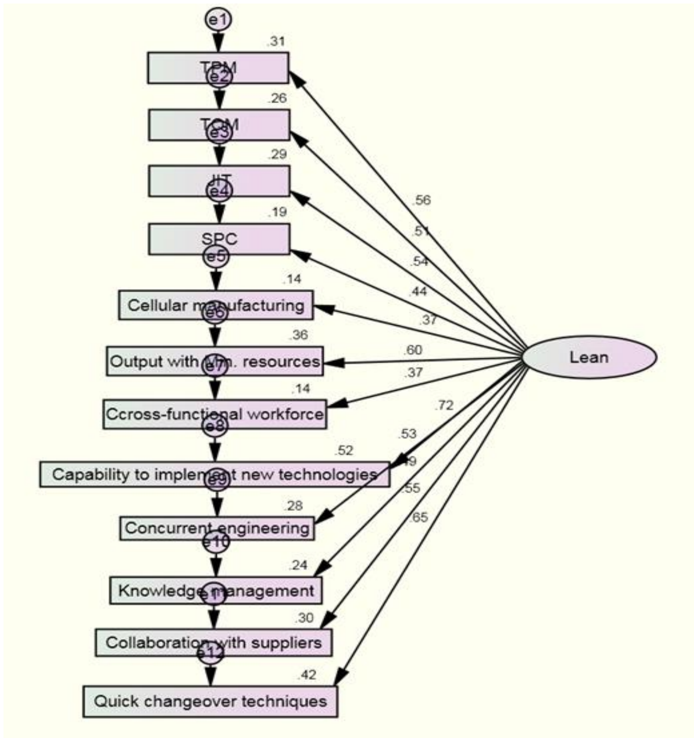

Figure 11- First CFA model for lean [Source: AMOS 19 software]

The CFA model results in Chi-square of 129.54 with 54 degrees of freedom (p=.000). Fit indices for the first CFA model for leanness are presented in Table 50.

Table 50- Fit indices for the first CFA model for lean

Fit index	
CMIN/DF	2.399
CFI	.842
RMSEA	.090

Table 51 shows that all the related factors significantly load on lean.

Table 51- P values of factors' load on lean for the first CFA model for lean

			P
JIT	<---	lean	***
SPC	<---	lean	***
effi	<---	lean	***
quick.chan	<---	lean	***
new.tech	<---	lean	***
con.eng	<---	lean	***
kn.mgt	<---	lean	***
coll.supp	<---	lean	***
TQM	<---	lean	***
TPM	<---	lean	
cel.man	<---	lean	***
workforce	<---	lean	***

***The probability is less than 0.001.

For convergent validity and factor loadings, the table of standardized regression weights (Table 52) is considered.

Table 52- Standardized regression weights for the first CFA model for lean

			Estimate
TPM	<---	Lean	.555
TQM	<---	Lean	.511
JIT	<---	Lean	.540
SPC	<---	Lean	.442
cel.man	<---	Lean	.368
output.with.min.res	<---	Lean	.598
workforce	<---	Lean	.370
new.tech	<---	Lean	.721
con.eng	<---	Lean	.533
kn.mgt	<---	Lean	.491
coll.supp	<---	Lean	.550
quick.chan	<---	Lean	.650

Regarding convergent validity factor, loadings with amounts less than .5 should be deleted. “Cellular manufacturing”, “Cross-functional workforce”, “SPC”, and “knowledge management” are deleted in a one by one process. The final model is presented in Figure 12. There is not a certain framework in previous literature regarding lean that all researchers agree with it. For instance, Shah and Ward (2003) bring cellular manufacturing as an item of the JIT construct while they don't bring SPC as a lean practice in their model. In their next paper (2007), "defining and developing measures of lean production" they bring cellular manufacturing as an item for the factor named flow. Hallgren and Olhager (2009) have their scale for lean without including SPC.

Here, also the conclusion of this research is that lean is mostly defined by measures shown in Fig. 12. These measures are first taken from literature, but also they emerge as lean measures in this empirical analysis.

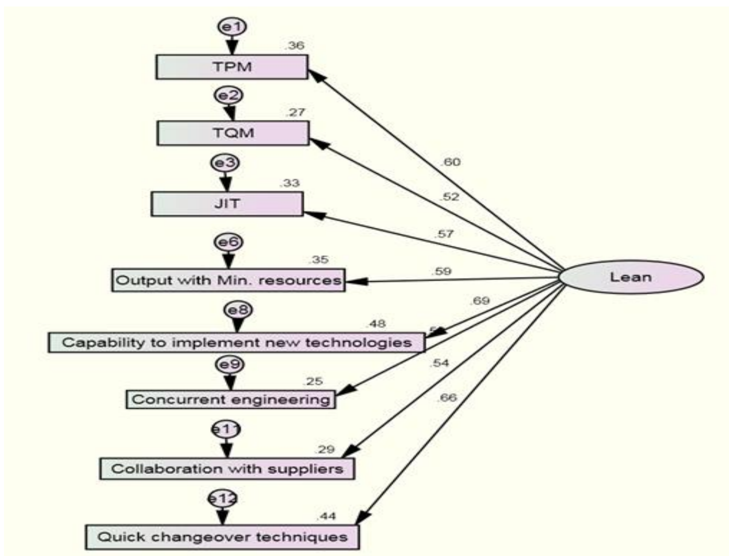

Figure 12- Final CFA model for lean [Source from AMOS 19 software]

The new model results in Chi-square of 36.519 with degrees of freedom of 20 (p=.013). Now fit indices improve and are all in their acceptable range and presented in Table 53.

Table 53- Fit indices for the final CFA model for lean

Fit index	
CMIN/DF	1.826
CFI	.948
RMSEA	.069

Table 54 shows that all factors significantly load on leanness.

Table 54- P values of factors' load on lean for the final CFA model for lean

			Estimate	P
TPM	<---	Lean	1.000	
TQM	<---	Lean	.909	***
JIT	<---	Lean	1.100	***
output.with.min.res	<---	Lean	1.152	***
new.tech	<---	Lean	.993	***
con.eng	<---	Lean	.901	***
coll.supp	<---	Lean	.806	***
quick.chan	<---	Lean	1.081	***

***The probability is less than 0.001.

Table 55 shows that convergent validity of the final model is supported since all factor loadings are above .5.

Table 55- Standardized regression weights for the final CFA model for lean

			Estimate
TPM	<---	Lean	.596
TQM	<---	Lean	.517
JIT	<---	Lean	.573
output.with.min.res	<---	Lean	.594
new.tech	<---	Lean	.692
con.eng	<---	Lean	.505
coll.supp	<---	Lean	.538
quick.chan	<---	Lean	.664

3.11 Results and discussion for the first quantitative study

The results of significant standardized regression weights of measures on leanness, agility and resilience after reliability and validity tests are presented in Table 56.

Table 56- Summary of significant standardized regression weights for final CFA models for resilience, agility and leanness

Practices	**Related to resilience**	**Related to agile**	**Related to lean**
Business Continuity (BC) team	.526		
Contingency plans made	.607		
Detection systems in place to detect	.740		

any supply chain disruption			
Establishing communication line in case of a disruption in the supply chain	.691		
Decentralization of physical assets in multiple locations	.432		
Total preventative maintenance (TPM)			.596
Producing outputs with minimum resources			.594
TQM			.517
Just In Time (JIT)			.573
Integrating different functions in the company		.554	
Responding quickly to rapidly changing situation somewhere in the supply chain		.594	
Time-to-market, i.e., introducing new products quickly		.704	
Flexible manufacturing equipment to produce different products with the same facilities		.600	
Knowledge management		.606	
Excess capacity in the supply chain to absorb sudden increases in demand	.466	.500	
Capability to implement new technologies		.677	.692
Concurrent engineering for overlapping activities in product design to achieve simultaneous development.		.553	.505
Reducing process downtime between product changeovers		.689	.664
Redundant suppliers for the same part with these suppliers being capable to substitute each other	.531	.545	
Cross-functional workforce	.528	.531	
Visibility – knowing the status of operating assets and the environment within the supply chain	.824	.582	
Collaboration with suppliers (Ability to work effectively with suppliers for mutual benefit)	.558	.631	.538

3.12 Conclusion and contribution to the second quantitative study

If all the CFA results for lean, agile and resilience are considered, it can be concluded that:

- "Business continuity team", "Contingency plans made", "Detection systems in place to detect any supply chain disruption", "Decentralization of physical assets in multiple locations" and "Establishing communication line in case of a disruption in the supply chain" are measures that significantly affect "resilience". These results are in line with what the literature review showed previously regarding these measures.
- "TPM", "JIT", "TQM" and "Producing outputs with minimum resources" are measures that significantly affect "leanness". Regarding JIT and TQM, in some papers they were related to both leanness and agility, while this empirical research shows these measures are related to leanness.
- "Integrating different functions in the company", "Responding rapidly to changing situation somewhere in the supply chain", "Introducing new products quickly", "Flexible manufacturing equipment to produce different products with the same facilities", and "Knowledge management" are measures that significantly affect "agility". Knowledge management was mentioned by literature to be linked to both leanness and agility, while this empirical research shows that this measure is significantly linked to agility.
- "Excess capacity", "Redundant suppliers", "Cross functional workforce" and "Visibility" are measures that affect significantly both "resilience" and "agility". Cross functional workforce was linked to the three approaches of resilience, leanness and agility in literature review while this empirical research shows that it is significantly lined to agility and leanness.
- "Implementing new technologies", "Concurrent engineering" and "Reducing process downtime between changeovers" are measures that affect significantly both "leanness" and "agility". These results are in line with what the literature review showed previously regarding these measures.
- "Collaboration with suppliers" affects significantly the three approaches of "resilience", "leanness" and "agility". This result is in line with what the literature review showed previously regarding this measure.

Hallgren and Olhager (2009) in their paper look at lean and agile manufacturing and their effects on performance outcomes. *"When looking at the characteristics associated with lean and agile, there is some overlap of some characteristics that are viewed as ingredients in both lean and agile Manufacturing…To develop measures of leanness and agility of a manufacturing system, the very basics of the concept need to be disentangled (Narasimhan et al., 2006). We are therefore looking for characteristics that can be associated with one but not with the other, and focus on leanness and agility as operations capabilities related to practices and routines"* (Hallgren and Olhager 2009, P. 978). In line with their research, while we are going to look that how resilience along with leanness and agility affects performance outcomes, it is needed to focus on the practices that significantly only affect resilience, agility and leanness.

While there is a criticism on the work of Hallgren and Olhager (2009) that the measures used as the pure measures for leanness and agility have some conflicts with the previous literature, in this research it has been tried to first disentangle the three concepts of LAR clearly, and then select the practices that significantly only affect resilience, leanness and agility.

Measures which significantly affect only leanness, agility and resilience are presented in Table 57.

Table 57- Practices that significantly only affect resilience, agility and leanness

Practices	**Related to resilience**	**Related to agility**	**Related to leanness**
Business Continuity (BC) team	x		
Contingency plans made	x		
Detection systems in place to detect any supply chain disruption	x		
Establishing communication line in case of a disruption in	x		

the supply chain			
Decentralization of physical assets in multiple locations	x		
Total preventative maintenance (TPM)			x
Produce outputs with minimum resources			x
Just In Time (JIT)			x
TQM			x
Integrating different functions in the company		x	
Responding rapidly to changing situation somewhere in the supply chain		x	
Introducing new products quickly		x	
Flexible manufacturing equipment to produce different products with the same facilities		x	
Knowledge management		x	

Now that resilience, agility and leanness are disentangled regarding the confusion existing in literature, this research can proceed to the second phase to see how resilience along with leanness and agility can affect performance outcome.

Chapter 4: Second quantitative study: How resilience along with leanness and agility affects performance outcomes?

4.1 Overview and structure of the questionnaire

Companies recognize the need to become more resilient since as the market is constantly changing, threats are evolving, adapting, and changing as well (Pettit et al., 2011). According to Hamel and Valikangas (2003) resilience will prove to be the ultimate competitive advantage in an age of turbulence. At the same time companies recognize they cannot ignore cost efficiency or customer-responsiveness. Carvalho et al. (2011) suggest that the simultaneous deployment of lean, agile and resilient practices have positive effects on supply chain competitiveness. They add that a supply chain that can be lean, agile and resilient means that:

- it reduces all kinds of wastes
- it provides a quick response to changes in customer's preferences
- it employs mechanisms to react instantaneously to unexpected events

So managers need to know how resilience along with leanness and agility affect the operational performance outcomes so they can use these implications in their decision making.

Regarding resilience, there is no work to date to empirically confirm how resilience along with leanness and agility affects operational performance outcomes. There are some clues within the literature, such as Azvedo et al. (2011) where conceptual models of leanness, agility and resilience were beginning to be developed though none of these studies addressing the issue empirically.

The objective of this chapter is then to investigate how resilience along with leanness and agility affects operational performance outcomes.

4.2 Model development and hypothesis

Going back to the model and hypotheses developed in 2.6, following sets of hypotheses need to be tested:

H1: higher level of agility will have a positive impact on resilience.

H2a: Higher level of resilience will have a positive impact on cost performance.
H2b: Higher level of resilience will have a positive impact on flexibility performance.
H2c: Higher level of resilience will have a positive impact on delivery performance.
H2d: Higher level of resilience will have a positive impact on time to recovery performance.

H3a: Higher level of leanness will have a positive impact on cost performance.
H3b: Higher level of leanness will have a positive impact on delivery performance
H3c: Higher level of leanness will have a positive impact on flexibility performance.
H3d: Higher level of leanness will have a negative impact on recovery performance.

H4a: Higher level of agility will have a positive impact on cost performance.
H4b: Higher level of agility will have a positive impact on delivery performance.
H4c: Higher level of agility will have a positive impact on flexibility performance.
H4d: Higher level of agility will have a positive impact on time to recovery performance.

The primary research model developed in section 2.7 is presented again in Fig. 13 for convenience. Recall that most links are conceptual and that the motivation here is to start with this conceptual model using empirical analysis to a more refined structural model that can be a better starting point for researchers. From the first phase of this research, disentangled constructs of leanness, agility and resilience have been developed without any confusion that previously existed in literature.

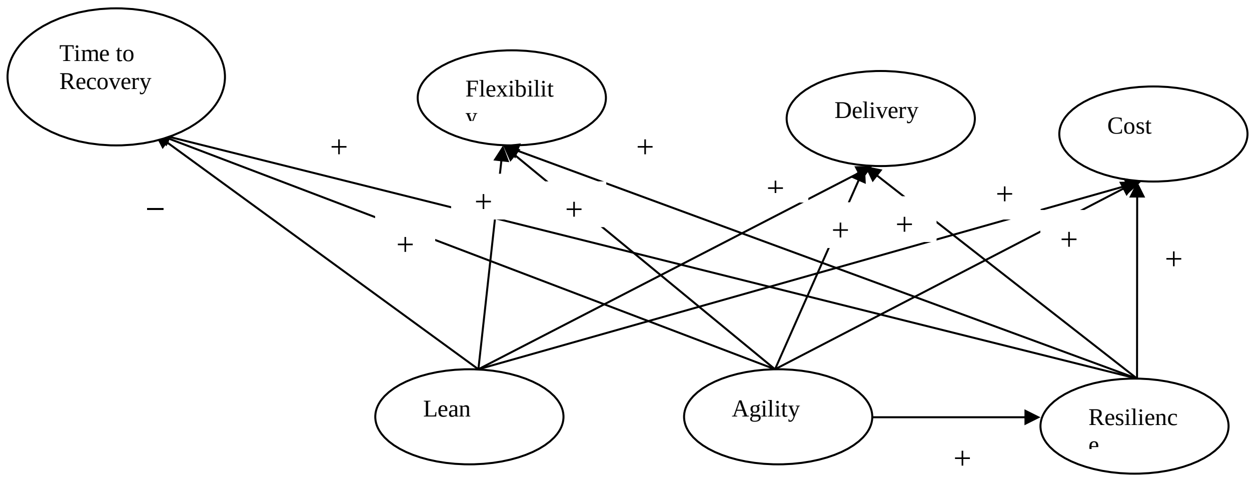

Figure 13- Primary research model

4.3 Questionnaire measures

For this phase a questionnaire was designed following literature review. It was drafted in English targeting managers of Tier 1 suppliers of auto companies in Iran. The details of why this industry and why this country was selected for this survey are explained in section 4.5 describing the sampling issues. The questionnaire begins with a cover letter. Taking Fowler's (2009) guidance for ethical issues in survey research into consideration, the following issues were tried to be covered. For informing the respondents, it was mentioned in the cover letter of the questionnaire that this is an academic research for a PhD thesis in Cass Business School. Also the issue of confidentiality was mentioned. An accurate and reasonable description of the purposes of the research was also explained. In addition, cooperation was completely voluntary and participants were offered to receive the result of the research after the analysis phase. The second part includes questions with regards to demographic information such as; number of employees, average annual sale, position and years of experience of the respondent.

4.3.1 Independent variables

The third part of the questionnaire consisted of 14 questions regarding resilience, leanness and agility. ***Managers were asked to indicate the extent to which their organization has been successful implementing these practices across the supply chain (including the plant(s), customers, suppliers) in comparison with similar tier 1 suppliers***. The measures (statements) were in the form of 7- point Likert scales while 1 indicates very low/not at all, 4 indicates average and 7 indicates very high/best-in-class. These practices regarding resilience, leanness and agility which were the independent variables are shown in Table 57.

Table 58- Questions regarding lean, agile, resilient practices

constructs	**Measures**	
Resilience	Decentralization of physical assets in multiple locations	R1
	Business Continuity (BC) team	R2
	Contingency plans made	R3
	Establishing communication line in case of a disruption in the supply chain	R4
	Detection systems in place to detect any supply chain disruption	R5
Lean	Total preventative maintenance (TPM)	L1
	Just In Time (JIT)	L2
	Producing outputs with minimum resources	L3
	TQM	L4
Agility	Integrating different functions in the company	A1
	Responding rapidly to changing situation somewhere in the supply chain	A2
	Flexible manufacturing equipment to produce different products with the same facilities	A3
	Knowledge management	A4
	Introducing new products quickly	A5

4.3.2 Dependent variable: Operational performance outcomes

The fourth part includes 17 measures related operational performance outcomes related to cost, flexibility, delivery and time to recovery. ***Managers were asked to rate their company's***

performance on these performance measures across their supply chain (including the plant(s) customers, suppliers) in comparison with similar tier 1 suppliers. The measures (statements) were in the form of 7- point Likert scales while 1 indicates very poor, 4 indicates average and 7, indicates best-in-class. There are several metrics in the literature for measuring the performance of a supply chain (SC). Based on the literature review performance measures as presented in Table 59 were considered.

Table 59- Performance measures extracted from literature

Operational performance outcomes	Measures	
Cost	Distribution cost per unit	C1
	Manufacturing cost per unit	C2
	Inventory cost per unit	C3
Delivery	Fill rate	D1
	Orders with the right quantity as a percentage of total orders	D2
	Order cycle time of customer	D3
	Orders delivered at the right time as a percentage of total orders	D4
Flexibility	Percentage change possible in demand volume of specific products without incurring high incremental costs	F1
	Percentage change possible in customer lead time in response to changes in delivery schedule without incurring high incremental costs	F2
	Number of new products introduced in response to customer demand without incurring high incremental costs	F3
	Number of products from this supply chain without	F4

	incurring high costs	
Time to recovery	Time to detect undesirable risk event in a timely manner	T1
	Time to design a solution when an undesirable event occurs	T2
	Time to deploy a solution when an undesirable event occurred in a timely manner	T3
	Time to recover from risk incidents or disruptions and to return to normal operational state rapidly	T4

4.4 Pre testing the questionnaire

The original questionnaire was first designed and refined in English. Next, to enhance conceptual and translation equivalence (Douglas and Craig, 1983), the questionnaire was translated into Persian, and then translated back into English by another person, both being professional translators, fluent in both languages. Difference between the original and the back translated versions were then reconciled. Initially face-to-face interviews where used to pre-test the questionnaire with five managers of Auto Parts Suppliers (APS) in Iran, to ensure the comprehensibility of the translated questionnaire.

According to Krosnick (1999), the following two ways for effective pre-testing were considered:

- Behavior coding: the questionnaire completion was monitored and any problem in understanding was noted. Questions which show most deviations were candidates for modifications.
- Cognitive pre-testing: the researcher asks some respondents to think aloud while completing the questionnaire. This was helpful to see how items are comprehended and answered, so possible sources of confusion and misunderstandings could be identified.

There were few changes. First of all the ranges for average annual sale have been changed to what managers believed is closer and more relevant to Iranian Auto industry. Second, for the area of respondent, sourcing/strategic sourcing has been changed to Quality Assurance/ Quality

Control (QA/QC) which from managers' point of view was more relevant.

4.5 Sampling

The sample is being taken across Automotive Parts Suppliers (APS) in Iran. Auto industry was selected since this is the field in which the lean approach was developed. According to Economist Intelligence Unit (2010), Iran has the largest automotive industry in the Middle East, and the automotive industry is the second-largest in Iran (after oil and gas). Iran is selected due to several reasons:

- Firstly, research emanating from this country is rare.
- Secondly, Iran's internationally oriented fast growing economy represents an underdeveloped but rapidly emerging market, yet there is little known about this country (Mafi and Carr, 1990).
- Thirdly, the unique economic conditions of the automotive market, e.g. the absence of any foreign automotive manufacturers in Iran, has created a distinctive situation in which many of the Automotive Parts Suppliers (APS) have developed the capacity and capabilities that enables them to simultaneously work with different automotive manufacturers in Iran.
- Due to recent sanctions, unstable currency, etc. the industry should make itself not only lean in terms of cost efficient and agile in terms of customer responsive, but also consider the resilience issues in order to survive.
- Iran is the 12th largest automaker in the world (The International Organization of Motor Vehicle Manufacturers (OICA), 2011). The 2011 production statistics is shown in Table 60.

Table 60- 2011 production statistics (countries/cars)

Country	Cars	Commercial vehicles	Total	% change
Argentina	577,233	251,538	828,771	15.7%

Country	**Cars**	**Commercial vehicles**	**Total**	**% change**
Australia	189,503	34,690	224,193	-8.1%
Austria	130,343	22,162	152,505	45.2%
Belgium	562,386	0	562,386	1.3%
Brazil	**2,534,534**	**871,616**	**3,406,150**	**0.7%**
Canada	990,483	1,144,410	2,134,893	3.2%
China	**14,485,326**	**3,933,550**	**18,418,876**	**0.8%**
Czech Rep.	1,191,968	7,866	1,199,834	11.5%
Egypt	53,072	28,659	81,731	-30.0%
Finland	2,540	0	2,540	-61.9%
France	**1,931,030**	**363,859**	**2,294,889**	**2.9%**
Germany	**5,871,918**	**439,400**	**6,311,318**	**6.9%**
Hungary	200,000	2,800	202,800	-4.1%
India	**3,053,871**	**882,577**	**3,936,448**	**10.7%**
Indonesia	561,863	276,085	837,948	19.3%
Iran	**1,413,276**	**235,229**	**1,648,505**	**3.1%**
Italy	485,606	304,742	790,348	-5.7%
Japan	**7,158,525**	**1,240,129**	**8,398,654**	**-12.8%**
Malaysia	496,440	43,610	540,050	-4.9%
Mexico	**1,657,080**	**1,022,957**	**2,680,037**	**14.4%**
Netherlands	40,772	32,379	73,151	-22.3%
Poland	740,000	97,132	837,132	-3.7%

Country	**Cars**	**Commercial vehicles**	**Total**	**% change**
Portugal	141,779	50,463	192,242	21.1%
Romania	310,243	24,989	335,232	-4.5%
Russia	**1,738,163**	**249,873**	**1,988,036**	**41.7%**
Serbia	15,050	740	15,790	-12.4%
Slovakia	639,763	0	639,763	13.9%
Slovenia	168,955	5,164	174,119	-17.6%
South Africa	312,265	220,280	532,545	12.8%
South Korea	**4,221,617**	**435,477**	**4,657,094**	**9.0%**
Spain	**1,819,453**	**534,229**	**2,353,682**	**-1.4%**
Sweden	188,969	0	188,969	-13.0%
Taiwan	288,523	54,773	343,296	13.1%
Thailand	549,770	928,690	1,478,460	-10.1%
Turkey	639,734	549,397	1,189,131	8.6%
Ukraine	97,585	7,069	104,654	25.9%
UK	1,343,810	120,189	1,463,999	5.1%
USA	**2,966,133**	**5,687,427**	**8,653,560**	**11.5%**
Uzbekistan	146,300	33,260	179,560	14.5%
Others	368,615	127,215	495,830	2.2%
Total	59,929,016	20,163,824	80,092,840	3.2%

Currently, there are around 25 automotive manufacturers in Iran, but the two leading domestic producers—Iran Khodro and Saipa—have a combined market share of over 90% (Economist Intelligence Unit, 2010).

Foreign firms are also involved in the Iranian automotive industry as joint ventures with local companies. These usually are based on assembling imported vehicles from completely knocked down (CKD) kits, including; PSA, Peugeot Citroën and Renault from France, Toyota and Nissan from Japan, Volkswagen, Mercedes-Benz and BMW from Germany, Hyundai and Kia Motors from South Korea, and Chery from China. These collaborations were mostly stopped because of the sanction. It can be said that the industry faces serious challenges as this sector, like other sectors in the country, encounters the after-math of international sanctions (Economist Intelligence Unit, 2010).

There are about 609 firms which are producing parts for the two main Auto companies.

4.6 Survey technique and operational procedure

4.6.1 Data collection

Data collection, whilst often difficult, was even more complex in Iran due to the following reasons:

- The time frame selected for the data collection was a time when the whole country is under severe sanctions due to its nuclear programs. As such, most Automotive Parts Suppliers (APS) are encountering serious economic problems. Therefore, asking them to cooperate in an academic study requires tact and support.
- There is no network, or organization, which can directly contact all the suppliers in auto industry. Therefore, I needed to use my personal contacts to make these links.

Regarding these issues the following ways were tried for getting a higher response rate:

- A list of the manufacturing and operation managers has been taken from Iranian Auto Parts Manufacturers Association (IAPMA). The list included 609 suppliers name, address and contact address. However, this list was not updated. So all the contact addresses which had a formal website, were checked through their website so another up-to-dated list was created including 130 updated and validated addresses. The questionnaire was sent to these 130 updated addresses, following a reminder after 3 weeks. The cover letter of the questionnaire was personalized by the job title and the name of the targeted manager to increase the response rate. The questionnaire was sent with pre-addressed postage-paid envelopes.

- As mentioned previously the two leading domestic producers—Iran Khodro and Saipa—have a combined market share of over 90%. So an effective way was involving these two companies in the research in order to make contact with suppliers. Saipa has Sazehgostar Saipa Co. (SGS) as its head supplier of its automotive parts and Iran Khodro, has Supplying Automotive Parts Co. (SAPCO) as its head supplier of its automotive parts. The research was presented via a one hour presentation for SGS and SAPCO related departments, with the aim of making them interested in the research topic and motivated assist the author in connecting her to the APSs for the data collection. Also, as mentioned on the cover letter of the questionnaire, companies have been told that if they are interested in the results, they will be sent to them after the analysis of the data is done. A recently published book by SAPCO including 331 APS with their complete contact addresses became available as the second list of the contact information of APSs in Iran. Training departments of SGS and SAPCO started sending the questionnaires to the companies for which their contact addresses were taken from the SAPCO list. The questionnaires were sent by an email to the related managers asking them to participate in the study. Follow up telephone calls were made to non-respondents. Since I previously worked in SGS as supply expert of mechanical parts for nearly two years, I followed the data collection process in close collaboration with the related departments.

Due to the types of questions covered in this survey Managing Directors, Vice Presidents, Manufacturing/Operation, Marketing/Customer relations, and Quality assurance/Quality control managers are targeted because it was concluded that they are the most appropriate ones with their particular knowledge related to supply chain practices and their supply chain performances. Different researchers previously in their work select similar key respondents. Braunscheidel and Suresh (2009) select Managing Directors, Vice Presidents, Manufacturing/Operation and supply chain managers in their survey related to supply chain agility while stating that for the types of questions covered in their survey, high-ranking respondents with sufficient level of seniority tend to be more reliable information than their subordinate rank. It was felt that these were managers with enough seniority to know about their companies' upstream and downstream integration and performance. Similar to their work, in this research Managing Directors, Vice Presidents, Manufacturing/Operation, Marketing/Customer relations and Sourcing, and Strategic sourcing managers were first selected as the key respondents to answer this survey. In the pre-testing phase of the questionnaire explained in Section 4.4 and during the discussions with the team of managers to pre-test the survey and refinements, it was concluded that Sourcing and Strategic sourcing managers should be changed to Quality Assurance and Quality control managers which from managers' point of view was more relevant to the firms in Iran. As the detail analysis is presented in Section 4.7 later for the sample characteristics, about %52 of the respondents were president/VP, while about %58 of them were working with the company at the position for more than 10 years and while about %50 of them have more than 10 years of experience at the position. These all show that they are reliable source for answering the survey regarding the practices and performance of their companies. The selection of the key respondents is also consistent with many past survey-based research studies in supply chain management.

The unit of analysis is Automotive Parts Supplier (APS) and its interfaces with suppliers and customers. Similar to Shah and Ward (2007), it is not just the APS internally, but seeing it with its linkages to its suppliers and customers (here Iran Khodro and Saipa, the two main Automotive manufacturers) from a supply chain view point.

4.6.2 Response rate

Follow-ups were undertaken through emails, fax and phone calls for achieving higher response rate. 609 questionnaires were sent out. 165 were received while 151 were usable.

Regarding the response rate, according to the formula presented in section 3.5.2, it can be estimated as:

(151) x 100 / (609- 14) = 25.37 %

In previous studies in related areas published in Journal of Operations Management the sample size the following response rates can be quantified: the sample size of 115 with response rate of 19% (Swafford et al., 2006) and 96 with response rate of 7.9% (Inman et al., 2011).

Manufacturing managers are the main source for supply chain management related data, being very busy; they do not usually find time for answering the questionnaires so it is difficult to achieve high response rates to surveys (Inman et al., 2011). Malhotra and Grover (1998) recommend rule-of-thumb baseline minimum of 20% for empirical studies. Although some researchers such as Fowler (2009) subscribes to the philosophy that there is no generally accepted minimum response rate.

In this research the response rate of %25.38 is a considerable one in operations research.

4.7 Sample characteristics

Due to the types of questions covered in this survey Managing Directors, Vice Presidents, Manufacturing/Operation, Marketing/Customer relations, and Quality assurance/Quality control managers were targeted since high-ranking respondents, with sufficient level of seniority, tend to be more reliable sources of information (Braunscheidel and Suresh, 2009). As such, the sample included senior managers.

Sample characteristics regarding the area of respondents are presented in Table 61.

Table 61- Sample characteristics, area of respondent

Area of the respondent	Production	8.6%
	Supply Chain	15.9%
	Planning/quality	57.6%
	Marketing/ customer relations	17.9%

Sample characteristics regarding the years of experience of the respondents at the position are presented in Table 62.

Table 62- Sample characteristics, years of experience at the position

Years of experience at the position	less than 5 year	26.2%
	more than 10 years	49.7%
	between 5 and 10 years	24.2%

Sample characteristics regarding the years respondents have been working with the company at the position are presented in Table 63.

Table 63- Sample characteristics, years working with the company at the position

Years working with the company at the position	less than 5 year	27.8%
	more than 10 years	58.3%
	between 5 and 10 years	13.9%

Sample characteristics regarding the number of employees at the location are presented in Table 64.

Table 64- Sample characteristics, number of employees at the location

Number of employees at the location	less than 100	37.7 %
	100-249	27.2%
	250-499	17.9%
	500-999	9.9%
	more than 1000	7.3%

Sample characteristics regarding the annual sale are presented in Table 65.

Table 65- Sample characteristics, average annual sale

Average annual sale	less than $ 2 Million	23.1%
	$ 2-4 Million	21.7%
	$ 4-8 Million	22.4%
	more than $ 8 Million	32.9%

Sample characteristics regarding the plant age is presented in Table 66.

Table 66- Sample characteristics, plant age

Plant age	less than 10 years	3.5%
	more than 20 years	89.4%
	between 10 and 20 years	8.7%

Sample characteristics regarding the number of plants are presented in Table 67.

Table 67- Sample characteristics, number of plants

Number of plants	fewer than 3plants	58.1%
	more than 6 plants	31.9%
	between 3 and 6 plants	7%

4.8 Survey quality: survey errors and treatments

While survey errors were theoretically explained in Section 3.8, here I explain how these errors are treated for the second phase of the research and the second questionnaire.

4.8.1 Sampling and non-coverage error

Being explained in 3.8.1 for this part of study, the only available lists for Auto Parts Suppliers

(APS) in Iran are provided by Iranian Auto Parts Manufacturers Association (IAPMA) and Supplying Automotive Parts Co. (SAPCO). Regarding the first list, it includes 609 suppliers' names and addresses and contact addresses. However, this list was not updated. So, all the contact addresses which had a formal website were checked through their website and another up-to-dated list was created including 130 updated and validated addresses. In order to reduce the non-coverage bias, the second list which is a recently published book by SAPCO including 331 APSs with their complete contact addresses is used. The data collection is designed to get the highest response rate possible, with follow-up procedure.

4.8.2 Non-response error

Being explained in section 3.8.2, in this part of my research, early and late respondents were compared considering the assumption that the data from late respondents are representative of non-respondents (Armstrong and Overton, 1977). According to Swafford et al. (2006) responses of the first 30 received surveys were compared to responses of the last 30 received surveys. T-tests were performed on key demographic characteristics such as number of employees and annual sale. Results indicate no significant difference between early and late responses, so it can be concluded that non-response bias is not present.

4.8.3 Measurement error

Being explained in 3.8.3 in this study, measurement error was decreased by pre-testing the questionnaire with five supply chain managers and four academics who were asked to review the questionnaire for readability, ambiguity, and completeness (Dillman, 1991). Regarding respondents, it has been tried to contact the people who have the knowledge to fill out the questionnaire. Those managers with sufficient level of seniority who tend to be more reliable sources of information were contacted (Braunscheidel and Suresh, 2009). It was tried to control social desirability by emphasizing the anonymous nature of the research in the cover letter of the questionnaire. Finally, different reliability measures such as Cronbach's Alpha and construct reliability and different validity measures such as AVE and Convergent validity checks were considered while testing measurement model as the first phase of Structural Equation Model

(SEM). All are reported in section 4.1 in detail.

4.8.4 Common method variance

When data for the independent and dependent variables are collected from single informants, common method bias may lead to inflated estimates of the relationships between the variables (Podsakoff and Organ, 1986; Christmann, 2004).

According to Podsakoff et al. (2003) Common method variance (CMV) is the variance that is attributable to the measurement method rather than to the constructs the measures represent. According to Chang et al. (2010), it can result in the artificial inflation of correlations in cases where a single informant accounts for both predictor and criterion measures.

As Podsakoff and Organ (1986) and Christmann (2004) recommend, Harman's one factor test will use post hoc to examine the extent of the potential bias. As prescribed by Harman's test, all variables will be entered into a principal component factor analysis.

According to Podsakoff and Organ (1986), substantial common method variance is signalled by the emergence of either a single factor or one general factor that explains a majority of the total variance.

There are both procedural and statistical remedies for this issue.

- Procedural remedies: According to Podsakoff et al. (2003), the two ways to control this bias are (a) ex-ante, through the design of the study's procedures, and/or (b) ex-post, by means of statistical controls. In the ex- ante phase, following suggestions from Krosnick (1999) and Bryman and Bell (2003), during questionnaire design I was very careful with defining ambiguous terms, avoid vague concepts, keep questions specific and concise, avoid double barreled questions and avoid complicated syntax. Pretests were done with five supply chain managers and four academics who were asked to review the questionnaire for readability, ambiguity, and completeness in order to achieve the stated goals. Also respondents were assured of confidentiality and anonymity of the data.
- Statistical remedies: According to Harman (1967), Harman's single factor test is a common technique to assess common method variance. According to Andersson and Bateman (1967), this tests whether or not CMV exists in a data set by loading all the study's variables into and exploratory factor analysis EFA and examining the un-rotated

factor solution. If a single common factor emerges, it indicates the CMV exists. The basic assumption is that if a substantial amount of CMV is present, either a single factor will emerge from FA or one general factor will account for the majority of the covariance among the measures. (Podsakoff and Organ, 1986). SO, an EFA was applied to all 29 measurement variables (Figure 14). The test indicates that no single factor of such magnitude emerges that can indicate CMV.

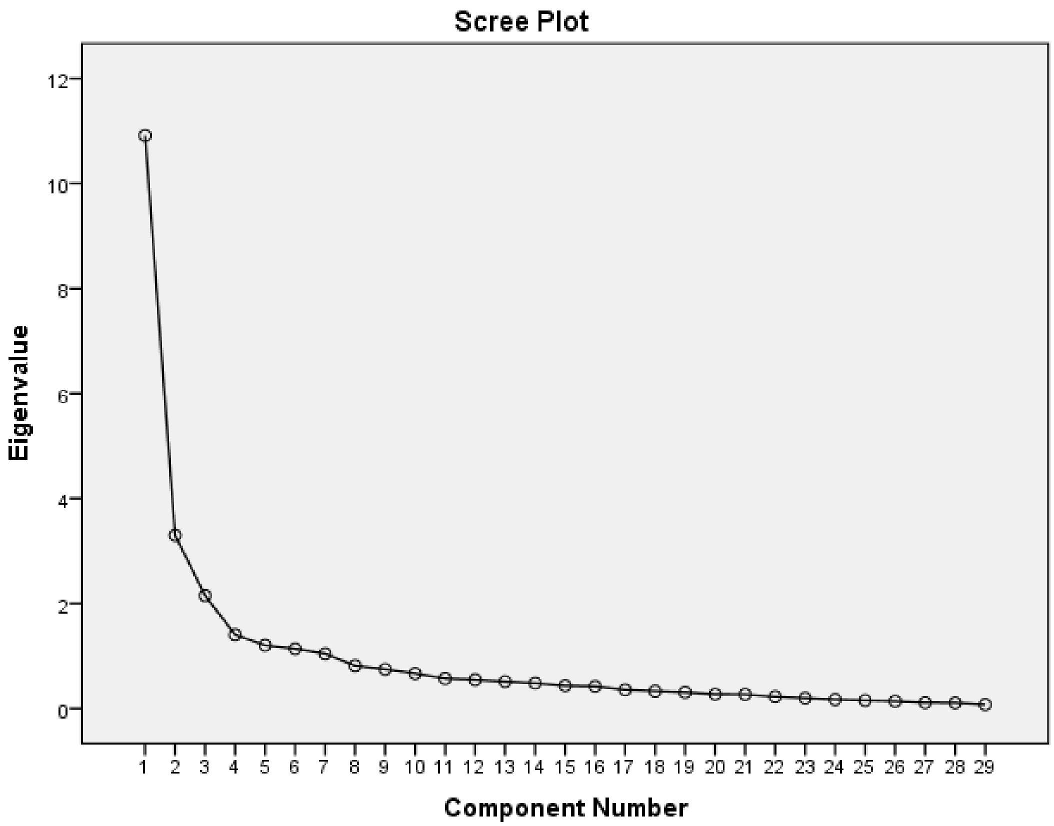

Figure 14- Scree plot testing for CMV [Source: SPSS 19]

In this test a principal component factor analysis was performed with all variables in the model. The results of the factor analysis (Table 68) reveal that 7 factors explain 72.89% of the variance of the variables with 37.63% by the first extracted factor. So there doesn't exist any evidence that a single factor emerged or that any factor explains most of the variance. Therefore, it can be concluded that CMV is not a problem in this study.

Table 68- Total variance expalined

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.914	37.634	37.634	10.914	37.634	37.634
2	3.298	11.371	49.005	3.298	11.371	49.005
3	2.148	7.406	56.411	2.148	7.406	56.411
4	1.403	4.839	61.251	1.403	4.839	61.251
5	1.202	4.143	65.394	1.202	4.143	65.394
6	1.135	3.913	69.307	1.135	3.913	69.307
7	1.040	3.588	72.894	1.040	3.588	72.894

Extraction Method: Principal Component Analysis.

According to Podsakoff et al. (2003), Harman's single factor test is one of the most widely used techniques that have been used by researchers to address the CMV. But more recently some researchers using this technique have used CFA as a more sophisticated test of the hypothesis that a single factor can account for all of the variance in their data (Podsakoff et al., 2003). As Chang et al. (2010) strongly suggest, providing robustness in the CMV test results a second statistical test was adopted in this study. In order to perform this test, all 29 variables were loaded into one CFA with fit indices of χ^2 (df= 278) = 557.145, CFI= .879, RMSEA= .082. Comparing these results against χ^2 (df= 62) = 118.41, CFI= .939, RMSEA= .078 for the measurement model yields a $\Delta\chi_2$ of 438.735 with df= 216, p<.001. Hence it can be concluded that one latent factor does not account for all marked variables (Podsakoff et al (2003); therefore, supporting the assumption that CMV is not a problem in this study.

4.9 Data analysis overview and SEM assumptions

A structural equation modelling (SEM) analysis, with maximum likelihood estimation, was undertaken using AMOS (version 19.0) in this part of study. Additionally for some minor analyses, SPSS version 19.0 and Excel MS Office 2007 have been used.

"A structural equation model can be defined as: a hypothesis of a specific pattern of relations

among a set of measured variables (MVs) and latent variables (LVs)" (Shah and Goldstein, 2005, p.166). It was founded in the conference entitled "*Structural Equation Models in the Social Sciences*" where Jöreskog (1973), Keesling (1973) and Wiley (1973) presented their framework that combines factor analysis and path analysis.

There are also two approaches co-varianced SEM VS PLS-SEM. According to Gefen (2000) covariance-based SEM uses model fitting to compare the co-variance structure fit of the researcher's model to a best possible fit covariance structure. It tests a priori specified model against population estimates drives from the sample. Covariance–based SEM techniques emphasize the overall fit of the entire observed covariance matrix with the hypothesized covariance model. PLS is design to explain variance, as a result is more suitable for predictive applications and theory building. Specifically it is suited for small data sample analysis for the data that doesn't necessarily show the multivariate normal distribution required by covariance-based SEM. Covariance based SEM applies second order derivatives such as maximum likelihood ML functions to maximise the parameter estimates.

According to Gefen (2000), comparative analysis between SEM with PLS and Regression is presented in Table 69.

Table 69- Comparative analysis between techniques [Source: Gefen (2000)]

Issue	Lisrel	PLS	Linear Regression
Objective of overall analysis	Show that the null hypothesis of the entire proposed model is plausible, while rejecting path-specific null hypotheses of no effect.	Reject a set of path-specific null hypotheses of no effect.	Reject a set of path-specific null hypotheses of no effect.
Objective of variance analysis required theory	Overall model fit such as insignificant Chi-	Variances explanation (high R-square)	Variance explanation (high R-Square)

based	square or high AGFI Required sound theory base. Supports confirmatory research	Does not necessarily require sound theory base. Supports both exploratory and confirmatory research.	Does not necessarily require sound theory base. Supports both exploratory and confirmatory research.
Assumed distribution	Multivariate normal, if estimation is through ML. Deviations from multivariate normal are supported with other estimation techniques.	Relatively robust to deviations from a multivariate distribution.	Relatively robust to deviations from a multivariate distribution with established methods of handling non-multivariate distributions.
Required minimal sample size	At least 100-150 cases.	At least 10 times the number of items in the most complex construct	Supports smaller sample sizes, although a sample of at least 30 is required.

According to Bagozzi and Yi (2012), SEM is different from other techniques in several ways:

- SEM allows an estimation of a series of separate, interdependent and causal relationships at the same time.
- Measurement errors and random errors can be included in the model, as well as removing potential for estimation.
- SEM can deal with multicollinearity effectively.

Bagozzi and yi (2012) summarize benefits of SEM:

- Provides integrative functions like an umbrella of methods under leading programs
- Helps researchers to be more precise while specifying the hypotheses and operationalization of constructs.

- Guides exploratory and confirmatory research in a manner that combines self-insight and modelling skills with theory.
- Is useful in experimental and survey research, including cross sectional studies.

Also as stated by Shah and Goldstein (2006), SEM has become one of the preferred statistical methods that researchers in the area of SCM have used.

There are different packages for analysing SEM, I chose Amos, and it provides the user with AMOS Graphic and AMOS basic for equation statements. According to Byrne (2001), most researchers will opt for the Amos graphic approach. It is user friendly, it is very flexible in making changes to the model, and it is consistent with SPSS which I was using for part of my analysis.

Garson (2009) suggests following assumptions for covariance-based SEM:

- Adequate sample size: according to Kline (2011), the sample size in SEM can be categorised into three levels: small (sample < 100), medium (100 < sample < 200), and large (sample > 200). In previous studies in related areas published in Journal of Operations Management the following sample size and response rates can be referred: the sample size of 115 with response rate of 19% (Swafford et al., 2006) and 96 with response rate of 7.9% (Inman et al., 2011). This research could get the sample size of 151 with the response rate of %25.38.
- Here ordinal variables (Liker scales 1-7) are used in this study. These are typically treated as interval in SEM studies. Garson 2009 discusses that as long as Likert scales are more than 4, they can be treated as interval data without problems.
- Multivariate normality: According to Ullman (2006), in SEM the most commonly employed techniques for estimating models assume multivariate normality. As a rule of thumb data may be assumed to be normal if skewness and kurtosis are within the range of ±1, while there are others such as Schumacker and Lomax (2004), Gefen (2009), who widen this range to ±1.5 or even 2. All measures were checked via descriptive analysis for skewness and Kurtosis and the results show that all of them are in within the acceptable range.
- Multicollinearity: According to Field (2009, p. 223), “*multicollinearity exists when there is a strong correlation between two or more predictors in a regression model*”.

According to Weston (2006), "*Multicollinearity refers to situations where measured variables are so highly related that they are essentially redundant*". For SEM researchers this is a problem since they use related measures as indicators of a construct and sometimes these measure are too highly related for certain statistical operations to function properly. To examine the problem of collinearity, a series of bi-variant correlation tests (Pearson) were done for all pairs of items belonging to different constructs. According to Tabachnick and Fidell (2007), the correlation value of .9 or higher is usually a signal of significant collinearity problem. In all pairs bi-variant correlation was below .9 suggesting that collinearity is not a problem for this study.

According to Gefen (2000), the SEM model contains two models; the measurement model and the structural model. The measurement model defines the constructs (latent variables) that the model will use and assign observed variables to each. The structural model defines the causal relationship among the latent variables. The process in SEM models according to Hair et al. (2010, p. 654) is as presented in Figure 15.

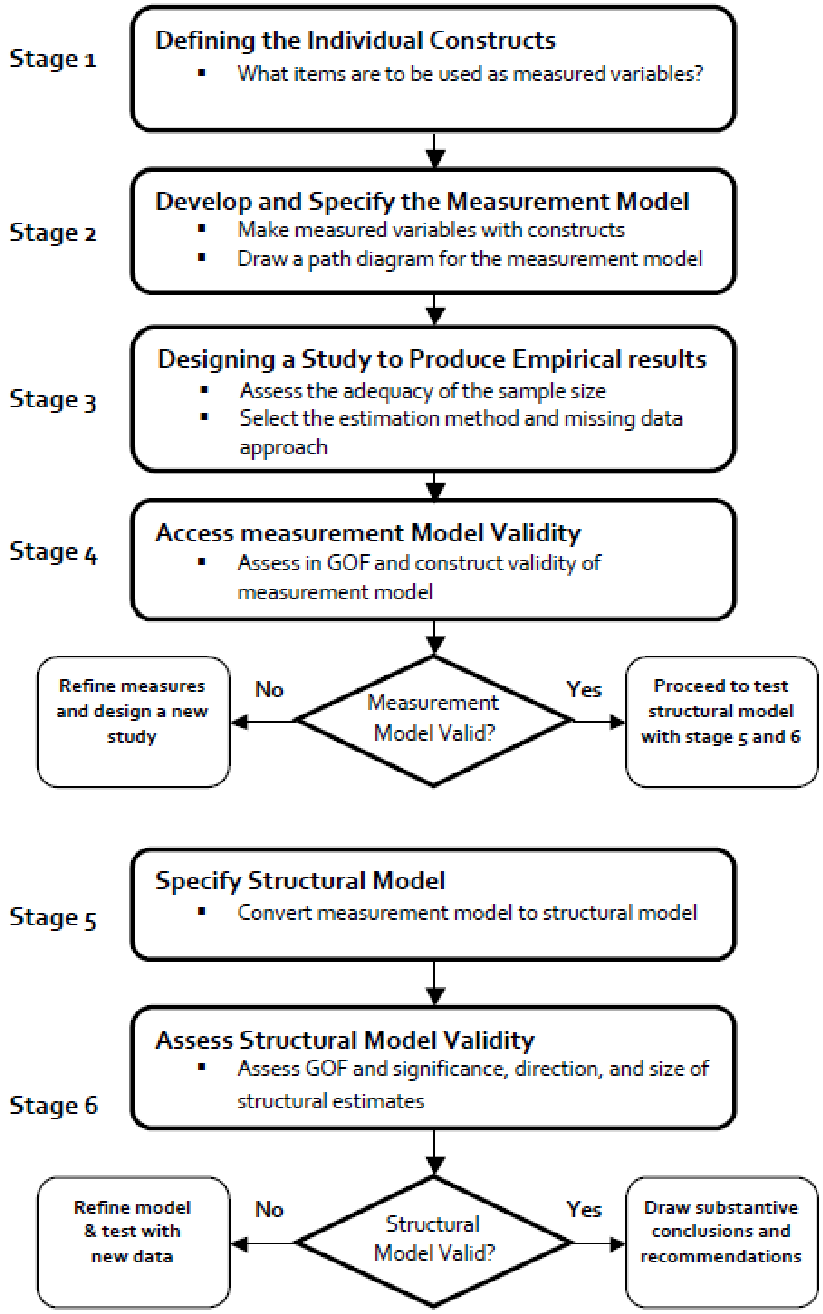

Figure 15- Process in structural equation models [Source: Hair et al. (2010, P. 654)]

4.10 Results of second quantitative study: Measurement model and structural model

165 questionnaires were received from 609 which were sent out while 151 of them were usable. The data were entered in SPSS with lots of care about accuracy of the data entry. Data were checked for the range edits to ensure that only the possible codes available for each question are used. Also each respondent was checked that his/her answers were not entered in the data entry matrix twice, or on the other hand it was not omitted. Harrington (2099, p. 61) states that as part of preparing data for analysis it is necessary to look for missing data. There are some recommendations for handling missing data, one of them is imputation, i.e. using computer software to replace missing values with plausible guesses or estimates of what a response might have been. So, imputation of the data was done and then I went for the next step of running analysis.

4.10.1 Measurement model

A two-step model testing was performed. So, first step is the measurement model tested for fit. The logic behind this process according to Jbreskog and Sorbom (1993, p. 113) is that "*The testing of the structural model, i.e., the testing of the initially specified theory, may be meaningless unless it is first established that the measurement model holds"*.

According to Anderson and Gerbing (1988b), confirmatory factor analysis should be used to test the measurement model before estimating the structural model. According to Weston (2006), CFA tests whether the indicators load on specific latent variables as is suggested in the model. Such a measurement model is evaluated like any other SEM model, using goodness of fit measures (discussed in the next paragraphs). Assuring that the model is valid, I then proceed to the next step, which is the SEM model estimation.

For the validation of my measurement model, series of CFAs where performed for each construct. According to Narasimhan et al. (2006), independent CFAs for each of the constructs can be performed. This was also done in the work of Swafford et al. (2006) to achieve higher statistical power in testing. Various fit measures were checked for achieving goodness of fit. Moreover, extra calculations were done in SPSS and Excel in order to calculate construct reliability and variance extracted. According to Garson (2009), these statistics based on structure loadings can be used to assess the extent to which a variable is measured well by its indicators.

There exist different fit indices and SEM experts have different ideas about reporting which of them is most proper for an SEM report, but as mentioned in many work such as Kline (2005), Garson (2009), Blunch (2011, P. 110) and Weston (2006), I will report the following fit indices for reliability and validity of the constructs:

1- Chi-square: explained in 3.9.1
2- Chi Square/Degrees of freedom: explained in 3.9.1
3- CFI: explained in 3.9.1
4- RMSEA: explained in 3.9.1
5- Average Variance extracted: AVE measures "*the amount of variance captured by a construct in relation to the variance due to random measurement error*" (Gaur et al., 2011). According to Fornell and Larcker (1981), AVE should be greater than .5 in order to confirm the convergent validity. It is calculated from following formula:

$$\text{AVE}= \frac{\sum_{i=1}^{n} \lambda_i^2}{\sum_{i=1}^{n} \lambda_i^2 + \sum_{i=1}^{n} e_i}$$

Where λ_i is the standardised factor loading for item *i*, and e_i is the error variance term.

6- Construct reliability: According to Manly (1990), Construct reliability is the internal consistency of the items representing a construct. The most common approach used to examine CR is Cronbach's Alpha explained previously in 3.8.4. Fornell and Larcker (1981) also suggest Composite reliability of construct as an alternative in testing reliability. It can be calculated from:

$$\text{Composite Reliability (CR)} = \frac{\left(\sum_{i=1}^{n} \lambda_i\right)^2}{\left(\sum_{i=1}^{n} \lambda_i\right)^2 + \left(\sum_{i=1}^{n} e_i\right)}$$

Where λ_i is the standardised factor loading for item i and e_i is the error variance term. According to Gerbing and Anderson (1988b), composite reliability is supported if the reliability estimate is .7 or higher.

Finally, as Swafford et al. (2006) state in their paper, discriminant validity should be tested, which is how well an item measure relates to its hypothesized construct versus other constructs in the model. Discriminant validity should be tested with a series of pair-wise chi square tests of the difference between two models involving two constructs. In the first model the covariance between the two constructs is fixed to 1, while the second model allows the covariance to be computed freely. According to Narasimhan et al. (2006), a statistically significant difference in chi square values for the two models demonstrates the distinction between the constructs.

In the previous chapter, the constructs are well defined, so the next step is testing validity and reliability of the constructs with the above mentioned indices.

4.10.1.1 Measurement model for resilience

For resilience, resulted from the previous research, measures of “Decentralization of physical assets in multiple locations”, “Business continuity team”, “Contingency plans made”, “establishing communication lines in case of a disruption” and “Detection systems in place to detect any supply chain disruption” were entered to a CFA. These measures are presented in Table 70.

Table 70- Measure for resilience construct for the SEM model

constructs	Measures	Label in SPSS	Variable name in SPSS
	Decentralization of physical assets in multiple locations	R1	decent

Resilience	Business Continuity (BC) team	R2	BC
	Contingency plans made	R3	contin.plan
	Establishing communication line in case of a disruption in the supply chain	R4	com.line
	Detection systems in place to detect any supply chain disruption	R5	detec.sys

The CFA model is presented in Figure 16.

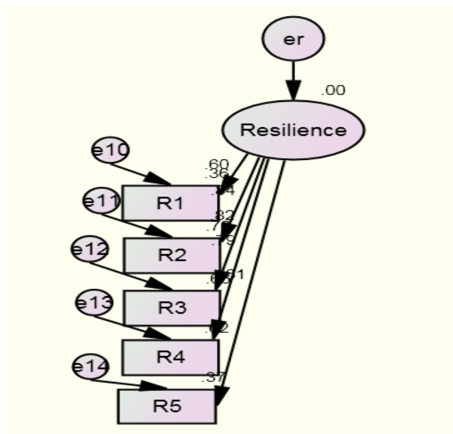

Figure 16- Resilience construct and its items with standardized loading [Source: AMOS 19 software]

The Chi-square with five degrees of freedom is 12.631 (Probability level=.027). The chi-square value should not be significant in an ideal model with a good model fit. But given the known sensitivity of this statistic to the sample size, however, use of X^2 provides little guidance in determining the extent to which the model does not fit; thus, it is more beneficial to rely on the other fit indexes as well as other statistics regarding validity and reliability. The fit indices are presented in Table 71. CMIN/DF is 2.526 which are smaller than threshold of 3. RMSEA is .101 CFI is great as it is >0.9.

Table 71- Fit indices for the resilient construct for the SEM model

Fit index	

CMIN/DF	2.526
CFI	.976
RMSEA	.101

From Table 72 it can be concluded that all these for items are significantly related to resilience.

Table 72- P values of factors' load on resilience for the resilient construct for the SEM model

			P
decent	<---	Resilience	
BC	<---	Resilience	***
contin.plan	<---	Resilience	***
com.line	<---	Resilience	***
detec.sys	<---	Resilience	***

***The probability is less than 0.001

From Table 73, it can be concluded that all standardized regression weights for the items related to Resilience scale are above .5 showing enough evidence of convergent validity.

Table 73- Standardized regression weights for the resilient construct for the SEM model

			Estimate
decent	<---	Resilience	.601
BC	<---	Resilience	.835
contin.plan	<---	Resilience	.815
com.line	<---	Resilience	.787
detec.sys	<---	Resilience	.610

Since fit indices were not appropriately in the acceptable range (critical RMSEA), by looking at Modification indices MI that Amos presents, it can be concluded that the largest changes will be because of covariance between e13 and e14. This shows that "establishing communication lines" and "Detection systems in place" are correlated. According to Byrne (2010, p. 108) "*Large MIs argue for the presence of factor cross loadings and error covariance*". According to Blunch

(2008, P. 141) a modification index is attached to a fixed parameter, and states by how much the Chi Square value will be reduced if the parameter is set free. Item of "Detection systems in place to detect any supply chain disruption" is deleted in this stage. The new CFA model is shown in Figure 17.

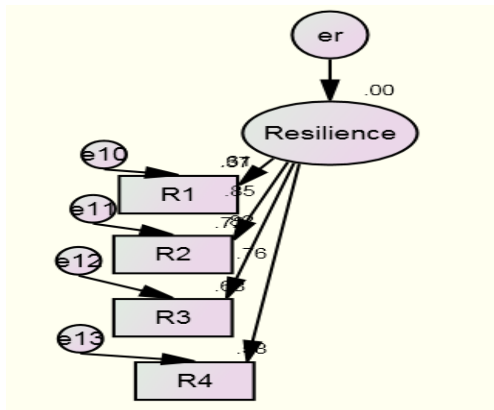

Figure 17- Final measurement model for resilient construct

The Chi-square with two degrees of freedom is 4.607 (Probability level=1). The chi-square value should not be significant in an ideal model with a good model fit. The fit indices are presented in Table 74. CMIN/DF is 2.309 which are smaller than threshold of 3. RMSEA is .093 which is smaller than threshold 0.1 and CFI is great as it >.9. All the fit indices result in goodness of fit of the measurement model for resilience.

Table 74- Fit indices for the final resilient construct for the SEM model

Fit index	
CMIN/DF	2.309
CFI	.991
RMSEA	.093

From Table 75, it can be concluded that all these for items are significantly related to resilience.

Table 75- P values of factors' load on resilience for the final resilient construct for the SEM model

			P
decent	<---	Resilience	
BC	<---	Resilience	***
contin.plan	<---	Resilience	***
com.line	<---	Resilience	***

***The probability is less than 0.001.

From Table 76, it can be concluded that all standardized regression weights for the items related to Resilience scale are above .5 showing enough evidence of convergent validity.

Table 76- Standardized regression weights for the final resilient construct

			Estimate
decent	<---	Resilience	.608
BC	<---	Resilience	.848
contin.plan	<---	Resilience	.823
com.line	<---	Resilience	.759

Also AVE was calculated using AMOS 19 and EXCEL software and was equal to .52 which is above the threshold of .5. Finally, Cronbach's Alpha was calculated in SPSS 19 and was equal to .844. The composite reliability being calculated using AMOS 19 and Excel was equal to .84. Both of these measures are in the acceptable range and are above .7 resulting in a good reliability.

4.10.1.2 Measurement model for agility

For agility, resulted from previous research, measures of "Integrating different functions in the company", "Responding rapidly to changing situations somewhere in the supply chain", "Flexible manufacturing equipment", "Knowledge management" and "Introducing new products quickly" were entered to a CFA. These measures are presented in Table 77.

Table 77- Measures for agile construct for the SEM model

constructs	Measures	Label in SPSS	Variable name in SPSS
Agility	Integrating different functions in the company	A1	integ
	Responding rapidly to changing situation somewhere in the supply chain	A2	respons.rap
	Flexible manufacturing equipment to produce different products with the same facilities	A3	felx.man
	Knowledge management	A4	kn.mgt
	Introducing new products quickly	A5	time.mar

The CFA model for agile construct is presented in Figure 18.

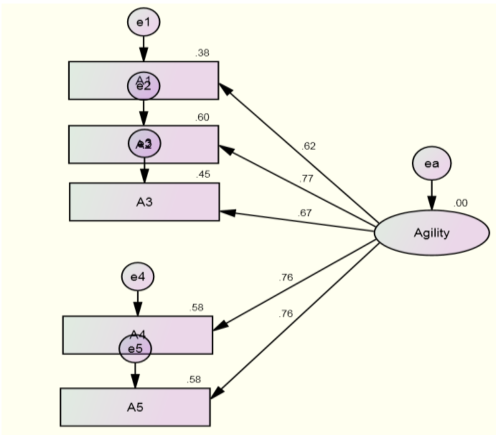

Figure 18- Agile construct for the SEM model [Source: AMOS 19]

The Chi-Square with 5 degrees of freedom is 7.386 (P=.193). Other fit indices are presented in Table 78. CMIN/DF is 1.447 which is excellent, CFI is .991 which also is excellent and RMSEA is .056. All evidences now support for a very goodness of fit.

Table 78- Fit indices for the agile construct for the SEM model

Fit index	
CMIN/DF	1.447
CFI	.991
RMSEA	.056

Table 79 shows that all items are significantly related to agility.

Table 79- P values of factors' load on agility for the agile construct for the SEM model

			P
integ	<---	Agility	
respons.rap	<---	Agility	***
felx.man	<---	Agility	***
kn.mgt	<---	Agility	***
time.mar	<---	Agility	***

***The probability is less than 0.001.

Table 80 shows that all factor loadings are in the accepted range and present good support for convergent validity.

Table 80- Standardized regression weights for the agile construct for the SEM model

			Estimate
integ	<---	Agility	.620
respons.rap	<---	Agility	.775
felx.man	<---	Agility	.673
kn.mgt	<---	Agility	.761
time.mar	<---	Agility	.763

Also, AVE was calculated using AMOS 19 and EXCEL and was equal to .59 which is above the threshold of 0.5. Also, Cronbach's Alpha was calculated in SPSS 19 and was equal to .794. The composite reliability was calculated using AMOS 19 and Excel and was equal to .847. Both of these measures are in the acceptable range and are above .7 resulting in a good reliability for the agile construct.

4.10.1.3 Measurement model for leanness

For leanness, resulted from the previous research, measures of "TPM", "JIT", "Producing outputs with minimum resources" and "TQM" were entered to a CFA. These measures are presented in Table 81.

Table 81- Measures for the lean construct for the SEM

constructs	Measures	Label in SPSS	Variable name in SPSS
Lean	Total preventative maintenance (TPM)	L1	TPM
	Just In Time (JIT)	L2	JIT
	TQM	L4	TQM
	Producing outputs with minimum resources	L3	effi

The CFA model is as presented in Figure 19.

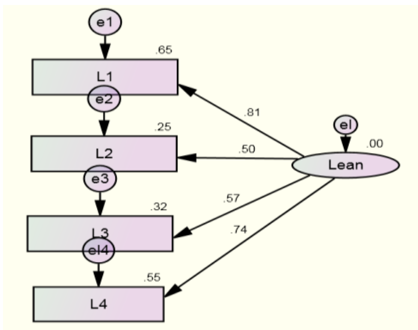

Figure 19- Lean construct for the SEM model [Source: Amos 19 software]

The model resulted in Chi-square of 2.73 with degrees of freedom of 2 (P=.2). Other fit indices are presented in Table 82. CMIN/DF is 1.363, CFI is .995 and RMSEA is .049. All are in their acceptable ranges and result in goodness of fit.

Table 82- Fit indices for the lean construct for the SEM model

Fit index	
CMIN/DF	1.363
CFI	.995
RMSEA	.049

Table 83 shows that all the items are significantly related to the construct.

Table 83- P values of factors' load on lean for the lean construct for the SEM model

	P
TPM <--- Lean	
JIT <--- Lean	***
effi <--- Lean	***
TQM <--- Lean	***

***The probability is less than 0.001.

Table 84 presents all factor loadings giving enough evidence for good convergent validity since all the factor loadings are above 0.5.

Table 84- Standardized regression weights for the lean construct for the SEM model

	Estimate
TPM <--- Lean	.804
JIT <--- Lean	.498
effi <--- Lean	.572
TQM <--- Lean	.741

AVE was calculated using AMOS 19 and EXCEL and was equal to .44. Deletion of JIT can improve the AVE to .508, but in this stage since the standardized regression weight of it is in the acceptable range, it is kept for retaining content validity (Swafford et al., 2006). Also, Cronbach's Alpha was calculated in SPSS 19 and was equal to .731. The composite reliability being calculated using AMOS 19 and Excel was equal to .754. Both of these measures are in the acceptable range and are above .7 resulting in a good reliability.

As explained in Section 4.1, according to Narasimhan et al. (2006) and Swafford et al. (2006), for discriminant validity three combinations of the three constructs were taken into consideration. For each of them, two models were considered. In the first model, the covariance between the two constructs was fixed to one. In the second model, the covariance was left free. Consequently, a χ^2 - difference test on the paired models (Anderson and Gerbing 1988a) was performed. For resilience and lean $\Delta\chi 2_{(df=1)}$ was 5.023, for resilience and agile it was 5.276 and for lean and agile it was 4.471. These results indicated that the critical value ($\Delta\chi 2_{(df=1)}$ = 3.84) was exceeded in all three cases, indicating enough distinction of the constructs.

In conclusion, the measurement model validation process for resilience, agile and lean constructs goes on very smoothly. This is as it was expected since previously all confusions existed in literature were solved by designing the first phase of this research with the aim of disentangling resilience, agility and leanness.

4.10.2 Performance measurement model

Based on the literature review (Section 2.5) performance measures presented in Table 85 are considered for performance constructs. There are cost, delivery, flexibility and time to recovery.

Table 85- Performance measures related to performance constructs based on literature review

Operational performance outcomes	Measures	Label in SPSS	Variable name in SPSS
Cost	Distribution cost per unit	C1	dis.cost
	Manufacturing cost per unit	C2	man.cost
	Inventory cost per unit	C3	invent.cost
Delivery	Fill rate	D1	fill.ra
	Orders with the right quantity as a percentage of total orders	D2	right.quan
	Order cycle time of customer	D3	cycle.time
	Orders delivered at the right time as a percentage of total orders	D4	right.tim
Flexibility	Percentage change possible in demand volume of specific products without incurring high incremental costs	F1	change.dem

	Percentage change possible in customer lead time in response to changes in delivery schedule without incurring high incremental costs	F2	chang.leadt
	Number of new products introduced in response to customer demand without incurring high incremental costs	F3	new.pro
	Number of products from this supply chain without incurring high costs	F4	mix.flex
Time to recovery	Time to detect undesirable risk event in a timely manner	T1	time.detect
	Time to design a solution when an undesirable event occurs	T2	time.des
	Time to deploy a solution when an undesirable event occurred in a timely manner	T3	time.dep
	Time to recover from risk incidents or disruptions and to return to normal operational state rapidly	T4	time.rec

A CFA for performance measures was done in a single CFA model as done previously in some distinguished papers such as Narasimhan et al. (2006). This model is presented in Figure 20.

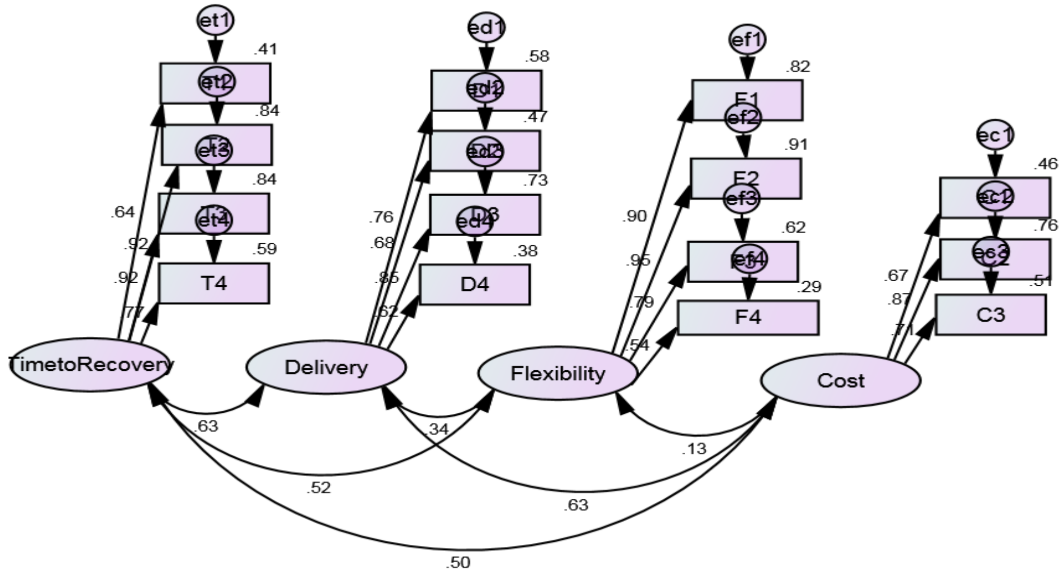

Figure 20- First measurement model for the performance constructs

The chi-square is 273.834 with the 84 degrees of freedom (p=.000). As stated before, this index is known because of its sensitivity to the sample size, however, use of X^2 provides little guidance in determining the extent to which the model does not fit; therefore, it is more beneficial to rely on the other fit indexes as well as other statistics regarding validity and reliability. The CMIN/DF (X^2/degrees of freedom) is 3.260, CFI is .867. RMSEA is .123 which are all signalling that the model should be improved for getting better fit indices. This goodness of fit measures is reported in Table 86.

Table 86- Fit indices for the first measurement model for the performance constructs

Fit index	
CMIN/DF	3.260
CFI	.867
RMSEA	.123

Table 87 shows that all indicators are related significantly to the performance constructs.

Table 87- P values of factors' load on performance for the first CFA model for the performance constructs

			P
invent.cost	<---	Cost	
man.cost	<---	Cost	***
dis.cost	<---	Cost	***
new.pro	<---	Flexibility	
chang.leadt	<---	Flexibility	***
change.dem	<---	Flexibility	***
right.tim	<---	Delivery	
cycle.time	<---	Delivery	***
right.quan	<---	Delivery	***
fill.ra	<---	Delivery	***
time.rec	<---	TimetoRecovery	
time.dep	<---	TimetoRecovery	***
time.des	<---	TimetoRecovery	***
time.detect	<---	TimetoRecovery	***
mix.flex	<---	Flexibility	***

***The probability is less than 0.001.

Table 88 shows that all those factor loadings are above .5 giving enough evidence for convergent validity.

Table 88- Standardized regression weights for the first measurement model for the performance constructs

			Estimate
invent.cost	<---	Cost	.713
man.cost	<---	Cost	.872
dis.cost	<---	Cost	.675
new.pro	<---	Flexibility	.790
chang.leadt	<---	Flexibility	.952
change.dem	<---	Flexibility	.904
right.tim	<---	Delivery	.615
cycle.time	<---	Delivery	.852
right.quan	<---	Delivery	.685
fill.ra	<---	Delivery	.764
time.rec	<---	TimetoRecovery	.767
time.dep	<---	TimetoRecovery	.916
time.des	<---	TimetoRecovery	.919
time.detect	<---	TimetoRecovery	.639
mix.flex	<---	Flexibility	.540

Since fit indices were not in the acceptable range, by looking at Modification indices (MI) that AMOS presents, it can be concluded that the largest changes will be because of D4 and F4. eD4 shows high co-variance both with eD2 and Flexibility. eF4 shows high co-variance by eF3 and eT1. So these items (D4, F4) should be deleted one by one. According to Byrne (2010, p. 108), "*Large MIs argue for the presence of factor cross loadings and error covariance".* According to Blunch (2008, P. 141) a modification index is attached to a fixed parameter, and states by how much the Chi Square value will be reduced if the parameter is set free. Next to the modification indices (M.I.), the expected change in parameter values (Par Change) are presented. Table 89 shows the modification indices for the first measurement model for the performance constructs.

Table 89- Modification indices (covariance) for the first measurement model for the performance constructs [Source: AMOS 19 software]

			M.I.	Par Change
ef4	<-->	Cost	4.715	.154
ef4	<-->	TimetoRecovery	5.033	.148
et1	<-->	Delivery	10.185	.119
et1	<-->	Flexibility	8.750	-.218
et1	<-->	ef4	23.654	.416
ed1	<-->	Flexibility	9.838	-.217
ed1	<-->	et1	8.992	.172
ed2	<-->	TimetoRecovery	8.378	-.122
ed2	<-->	et1	7.484	.150
ed2	<-->	et2	5.828	-.088
ed3	<-->	Delivery	4.189	-.065
ed3	<-->	TimetoRecovery	8.289	.124
ed4	<-->	Flexibility	23.893	.354
ed4	<-->	TimetoRecovery	4.117	-.094
ed4	<-->	ed2	22.716	.256
ed4	<-->	ed3	5.948	-.132
ef1	<-->	ef4	4.278	-.166
ef2	<-->	ef4	6.454	-.169
ef2	<-->	et1	11.611	-.164
ef2	<-->	ed1	8.923	-.135
ef3	<-->	TimetoRecovery	4.503	.110
ef3	<-->	ef4	35.172	.562
ef3	<-->	et1	5.274	.155
ec3	<-->	ef4	5.521	.198

After deletion, the new measurement model for performance outcomes is presented in Figure 21.

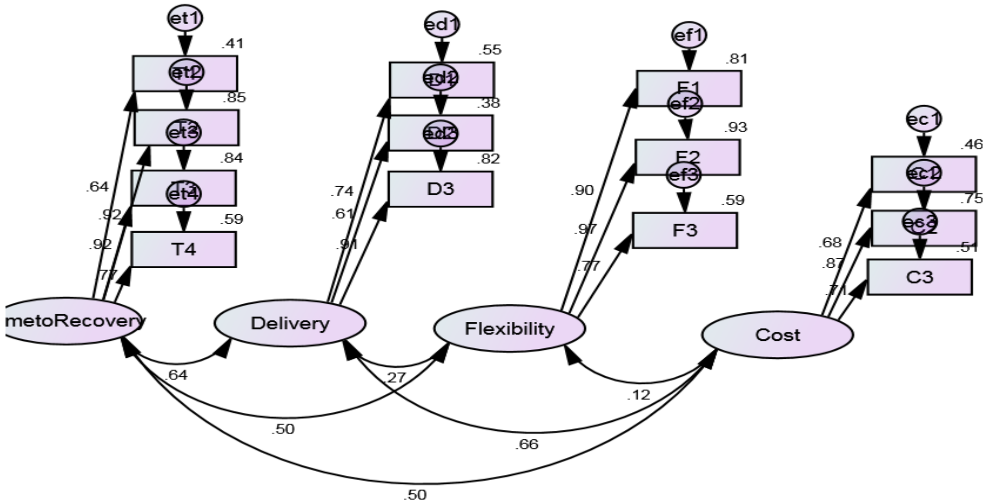

Figure 21- Revised measurement model for the performance constructs [Source: AMOS 19 software]

Chi-square is equal to 116.43 with the degrees of freedom of 59 (P=.000). CMIN/DF has improved to 1.973. CFI has improved to .952 and RMSEA to .081. The deletion of D4 improved all fit indices and now the fit indices are all in acceptable range showing enough evidence of goodness of fit. The fit indices are all presented in Table 90.

Table 90- Fit indices for the revised measurement model for the performance constructs

Fit index	
CMIN/DF	1.973
CFI	.952
RMSEA	.081

Table 91 shows that all items are significantly related to their scale.

Table 91- P values of factors' load on performance for the revised measurement model for the performance variables

	P
invent.cost <--- Cost	

			P
man.cost	<---	Cost	***
dis.cost	<---	Cost	***
new.pro	<---	Flexibility	
chang.leadt	<---	Flexibility	***
change.dem	<---	Flexibility	***
cycle.time	<---	Delivery	
right.quan	<---	Delivery	***
fill.ra	<---	Delivery	***
time.rec	<---	TimetoRecovery	
time.dep	<---	TimetoRecovery	***
time.des	<---	TimetoRecovery	***
time.detect	<---	TimetoRecovery	***

***The probability is less than 0.001.

Table 92, presents all new factor loadings which are all above .5 giving good evidence for convergent validity.

Table 92- Standardized regression weights for the revised measurement model for the performance constructs

			Estimate
invent.cost	<---	Cost	.715
man.cost	<---	Cost	.869
dis.cost	<---	Cost	.676
new.pro	<---	Flexibility	.770
chang.leadt	<---	Flexibility	.966
change.dem	<---	Flexibility	.902
cycle.time	<---	Delivery	.905
right.quan	<---	Delivery	.613
fill.ra	<---	Delivery	.742
time.rec	<---	TimetoRecovery	.767
time.dep	<---	TimetoRecovery	.916
time.des	<---	TimetoRecovery	.919
time.detect	<---	TimetoRecovery	.639

Once the measurement models were statistically validated and assessed, their causal relationships can be tested in the structural model.

4.11 SEM results: Testing the structural model

According to Gefen (2000, p.30), *"The structural model estimates the assumed causal and covariance linear relationships among the exogenous and endogenous latent constructs. SEM also estimates the shared measurement error for the constructs."* According to Weston 2006, Equations in the structural portion of the model specify the hypothesized relationships among latent variables. In the next sections, results are being presented- Regression weights or path estimates- together with some necessary fit indexes:

- Chi Square (CMIN) with degrees of freedom and significance (P) level
- Chi-Square divided by degrees of freedom (CMIN/DF)
- CFI
- RMSEA with 90% confidence intervals

The main goal of this research is to develop and test the model that explains how resilience along with leanness and agility affects performance outcomes in the context of supply chain. While the Primary model presented in Fig. 13 was tested in addition to many other different models, the final research model is presented in Figure 22.

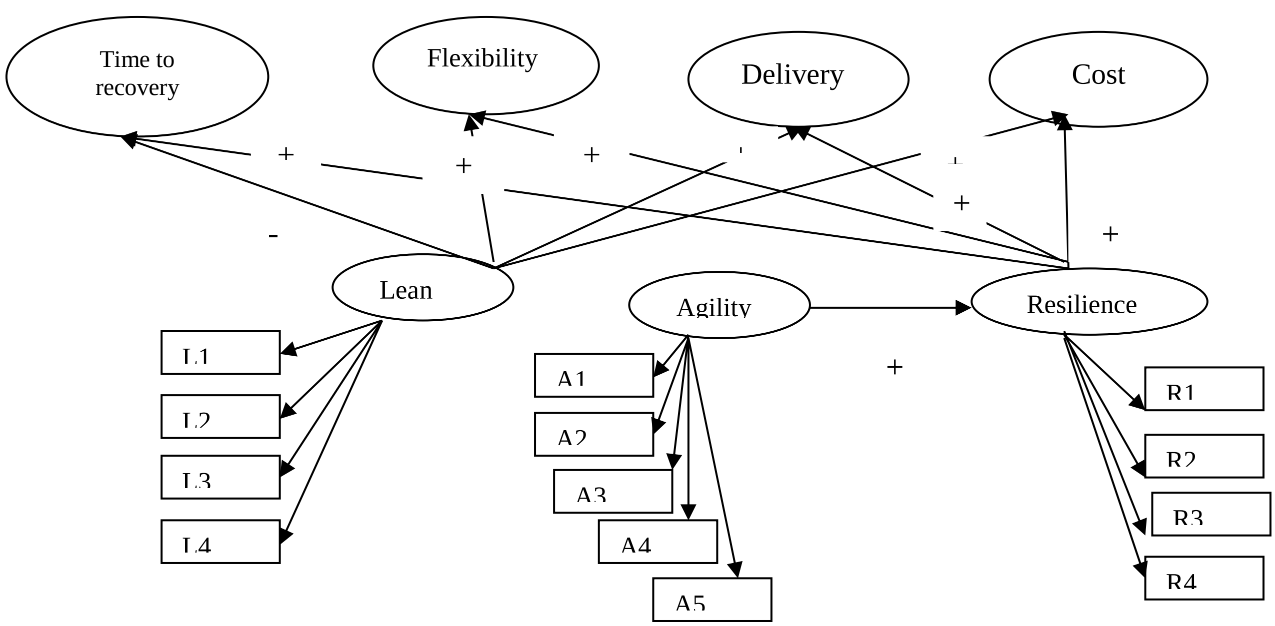

Figure 22- Final research model

In Figure 23 the final SEM model which was run by AMOS 19 is presented.

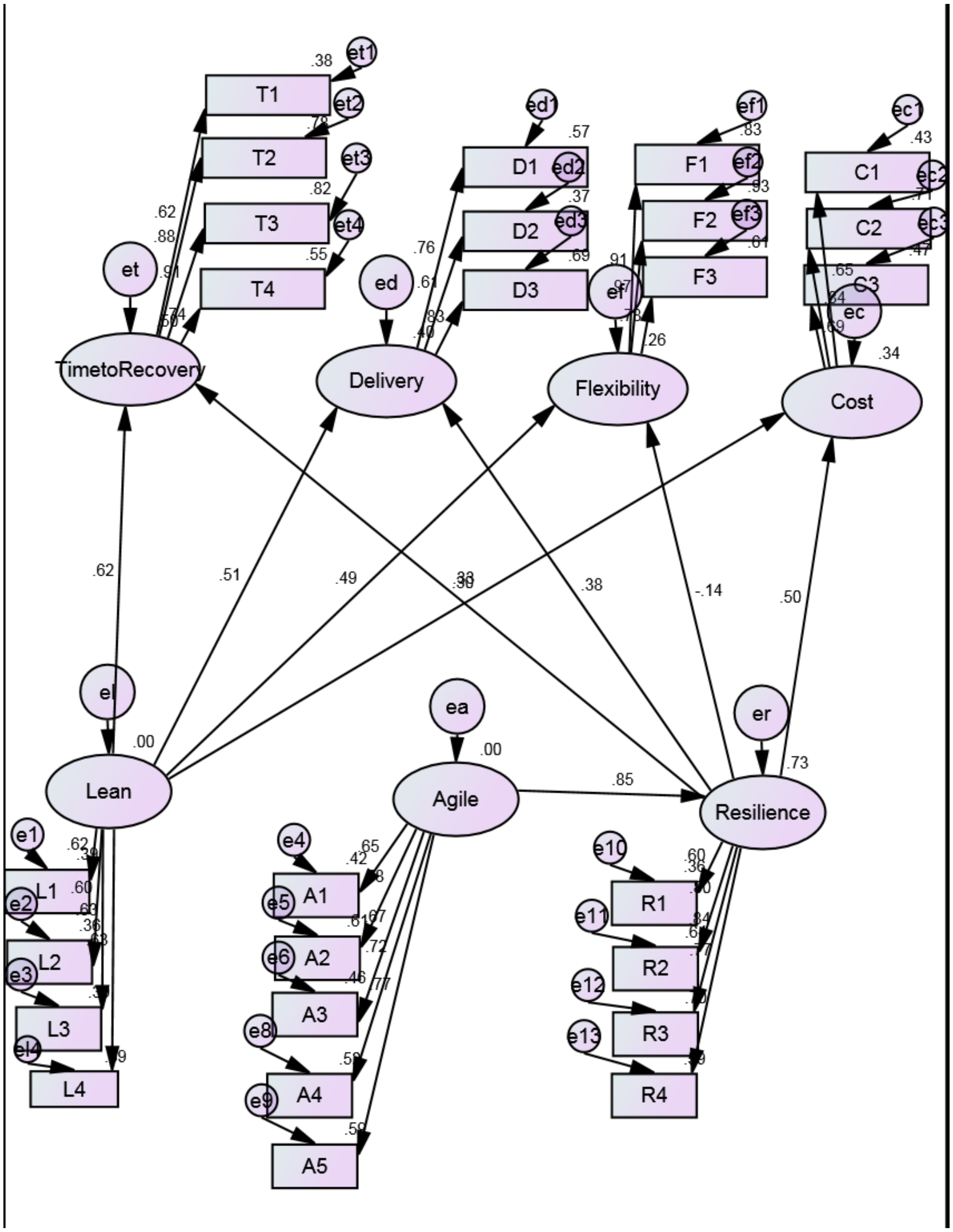

Figure 23- Final structural model [Source: AMOS 19 software]

Chi-Square of 748.463 with 290 degrees of freedom is achieved (p=.000). Other fit indices are presented in Table 93. CMIN/DF equals to 2.58. CFI is .81 and RMSEA is .10. It should be noted that according to Weston et al. (2006), debates exist among statisticians regarding acceptable fit. Marsh et al. (2004) also indicate that sample size, model complexity and degrees of misspecification affect appropriate cutoff values. This body of research has shown that inappropriately applying more stringent cutoff criteria could result in the incorrect rejection of acceptable models when sample size is smaller than 500. And models are not complex. From Weston et al (2006) point of view, RMSEA less than .10 is acceptable for these cases. Also, according to Blunch (2008, P. 144), CFI indices below .80 should be taken seriously. Therefore, the fit indices are in acceptable range confirming that the model fits the data. The fit indices for the structural model are shown in Table 93.

Table 93- Fit indices for the structural model

Fit index	
CMIN/DF	2.58
CFI	.81
RMSEA	.10

Table 94 shows that all paths are significant at the level of .05. The only exception is the effect of resilience on flexibility which is not significant.

Table 94- P values of factors' load on constructs for the structural model

			P
Resilience	<---	Agile	***
TimetoRecovery	<---	Lean	***
Delivery	<---	Lean	***
Flexibility	<---	Lean	***
Cost	<---	Lean	.003
Cost	<---	Resilience	***
Flexibility	<---	Resilience	.083
Delivery	<---	Resilience	***
TimetoRecovery	<---	Resilience	***
TPM	<---	Lean	
JIT	<---	Lean	***

			P
effi	<---	Lean	***
TQM	<---	Lean	***
integ	<---	Agile	
respons.rap	<---	Agile	***
felx.man	<---	Agile	***
kn.mgt	<---	Agile	***
time.mar	<---	Agile	***
decent	<---	Resilience	
BC	<---	Resilience	***
contin.plan	<---	Resilience	***
com.line	<---	Resilience	***
time.rec	<---	TimetoRecovery	***
time.dep	<---	TimetoRecovery	***
time.des	<---	TimetoRecovery	***
time.detect	<---	TimetoRecovery	
cycle.time	<---	Delivery	***
right.quan	<---	Delivery	***
fill.ra	<---	Delivery	
new.pro	<---	Flexibility	***
chang.leadt	<---	Flexibility	***
change.dem	<---	Flexibility	
invent.cost	<---	Cost	***
man.cost	<---	Cost	***
dis.cost	<---	Cost	

***The probability is less than 0.001.

From Table 95, the regression weights can be extracted. There is a strong positive relation between agility and resilience (standardized path coefficient .854) and it is statistically significant (P= ***). This confirms the hypothesis that agility leads to resilience.

Table 95- Standardized regression weights for the structural model

			Estimate
Resilience	<---	Agile	.854
TimetoRecovery	<---	Lean	.625
Delivery	<---	Lean	.507
Flexibility	<---	Lean	.492
Cost	<---	Lean	.305
Cost	<---	Resilience	.500

			Estimate
Flexibility	<---	Resilience	-.142
Delivery	<---	Resilience	.375
TimetoRecovery	<---	Resilience	.332
TPM	<---	Lean	.625
JIT	<---	Lean	.602
effi	<---	Lean	.626
TQM	<---	Lean	.628
integ	<---	Agile	.648
respons.rap	<---	Agile	.778
felx.man	<---	Agile	.675
kn.mgt	<---	Agile	.722
time.mar	<---	Agile	.768
decent	<---	Resilience	.599
BC	<---	Resilience	.798
contin.plan	<---	Resilience	.836
com.line	<---	Resilience	.765
time.rec	<---	TimetoRecovery	.740
time.dep	<---	TimetoRecovery	.906
time.des	<---	TimetoRecovery	.880
time.detect	<---	TimetoRecovery	.620
cycle.time	<---	Delivery	.828
right.quan	<---	Delivery	.609
fill.ra	<---	Delivery	.756
new.pro	<---	Flexibility	.781
chang.leadt	<---	Flexibility	.966
change.dem	<---	Flexibility	.912
invent.cost	<---	Cost	.687
man.cost	<---	Cost	.844
dis.cost	<---	Cost	.653

The results show that leanness helps time to recovery performance (i.e. it decreases time to recovery). It was hypothesized that leanness has a negative effect on time to recovery performance which means the more leaner the supply chains, the more time to recovery they will have in time of disruptions. However, the data analysis shows actually lean helps time to recovery performance. The analysis shows that leanness has positive effects on delivery and flexibility performance outcomes confirming the related hypotheses. Furthermore, this model also confirms that lean helps cost performance outcomes (i.e. it decreases costs) and the related hypothesis is confirmed.

Moving to the effects of resilience on performance outcomes, the model confirms that resilience helps time to recovery performance of the supply chains. The hypothesis regarding that resilience helps cost performance is also confirmed and this relation is statistically significant (P=***). The analysis also confirms that resilience has a significant effect on devilry performance outcome and this effect is positive. In addition, the analysis shows that the effect of resilience on flexibility performance outcome is not significant.

Chapter 5: Discussion and Conclusion

This chapter starts with a review of the thesis. The results of the first quantitative study and the second quantitative study are discussed and the theoretical and managerial implications are drawn. Next, limitations of the research are stated and at the end directions for future research are suggested.

5.1 Thesis review

The need to become more resilient is recognized by companies since as the market is changing constantly the threats are evolving and changing as well. Therefore, as stated in literature resilience will prove to be the ultimate advantage in an age of turbulence. Whilst firms need to understand resilience and know how they should achieve it, they also need to be aware of cost efficiency in terms of lean and customer responsiveness in terms of agile. As mentioned in literature, the tradeoffs between lean, agile and resilience are actual issues in the supply chains. Therefore, this research investigates how resilience fits with leanness and agility in terms of practices and performance outcomes in the context of supply chain management.

A comprehensive literature review was performed on the underlying practices of resilience, agility and leanness (LAR). Of the many practices identified for each of LAR, there are some that underlie just one of these three while others underlie two of them and even all three. This shows confusion existed in literature regarding practices related to leanness, agility and resilience. In the second phase of the literature review, the effects of LAR on performance were investigated. The results of this phase shows that while the effects of lean and agile on performance outcomes have been investigated both in isolation and combination, there is no empirical research on the effect of resilience and specifically combinations of LAR on performance and all previous research remained in the conceptual level.

Therefore, the literature review on leanness, agility and resilience shows two main gaps:

First, the literature doesn’t provide clear boundaries between resilient practices with lean and agile practices. The importance of this gap can be stated from theoretical and practical aspects. The results of the literature review show that resilience, leanness and agility have some areas of overlap in terms of practices. But there also exists some non-overlapping areas that distinctively are related to resilience, agility or leanness. Theoretically, when it comes to those practices which go under lean and agile, agile and resilience or even the three of LAR, when it comes to have them in statistical models researchers don't know where exactly these practices should be categorized. Practically, unclear boundaries between these concepts can make implementation of respective practices potentially problematic or confusing for managers.

Second, while different researchers mention leanness, agility and resilience as capabilities that can offer firms different competitive advantages form the Resource Based View lens, literature is still very poor in terms of empirical modelling and testing of how resilience along with leanness and agility can offer competitive advantages. The previous work is all remained at the conceptual level though none addressing the issue empirically. Theoretically this gap is important since it is not enough to state that supply chains need to be resilient, lean and agile but more to develop statistical models that show how resilience along with leanness and agility affects performance outcomes and leads companies to gain competitive advantage. Practically, empirical testing of the models that show how resilience along with leanness and agility affects performance outcomes gives useful guidance to supply chain managers whether they should see these approaches in opposition to each other or see them helping each other in improving performance outcomes.

The above discussion on the gaps and the importance of them is the origin of the research question defined for this research.

The research question is: How does resilience fit with leanness and agility both in terms of practices and outcomes in the context of supply chain management?

To seek an answer, two research objectives are defined:

- First objective: Disentangling resilience, leanness and agility.

- Second objective: Investigating how resilience impacts performance in the presence of practices for leanness as well as agility in the context of supply chain management.

In the next step, a short survey combined with a discussion after that, were conducted in the forum in 2011 at Procter & Gamble, Brussels' office in order to establish the practitioners' need for this research. There, managers were asked some questions regarding LAR in their companies, specifically they were asked if their companies had formal ways to look across these three practices and whether their companies sought ways to improve all three simultaneously. They specified that their companies had formal ways to look across the LAR, and that they were seeking ways for improving LAR at the same time but in the discussion following the survey they stated that they were unsuccessful in seeking the right balance between LAR. From different reasons they discussed, one was being not clear of the essence of LAR, i.e. different perception exists for these approaches which makes implementation of the respective practices problematic or confusing when multiple practices are carried out at the same time. Therefore, after the literature review, these results related to the preliminary stage of the research also confirm the gap extracted from literature.

In conclusion, the results of these survey and discussion as an early stage of the research, in line with the results of the literature review show that there is a need for clarifying the three concepts of resilience, leanness and agility in the first step. In the next chapter, it will be explained that how this research is designed in order to answer the two research objectives: first, disentangling resilience, leanness and agility and second, investigating how resilience along with leanness and agility affects performance outcomes.

In the next step, the first quantitative study was designed with the aim of "disentangling resilience, leanness and agility". The designed survey was carried out online in Germany due to the country's strong base in manufacturing. Through sets of factor analysis, this study approves the idea presented in literature that resilience has some practices that purely help it while it also has some practices that affect agility and resilience and even leanness, agility and resilience. There were some differences found in the boundaries of these categorizations between what was concluded from literature and what industrial managers believe.

At the next phase, the second quantitative study was designed with the aim of "investigating how resilience along with leanness and agility affects performance outcomes". The designed survey was carried out in Iran auto industry among auto parts suppliers. The country was selected as the largest auto industry in the middle east and 12^{th} in the world, and specifically as an appropriate choice of a resilience-needed environment due to the sanctions and volatility of the currency. The aim was to assess a set of hypotheses that follow not only from literature but also from the perception of practitioners about LAR resulted from the previous step. A Structural Equation

Model (SEM) was developed and tested. It explains that while leanness is independent from resilience, agility brings about resilience. It also tests the effects of leanness and resilience on flexibility, delivery, cost and time to recovery as performance outcomes. Figure 24 provides an overview of the thesis.

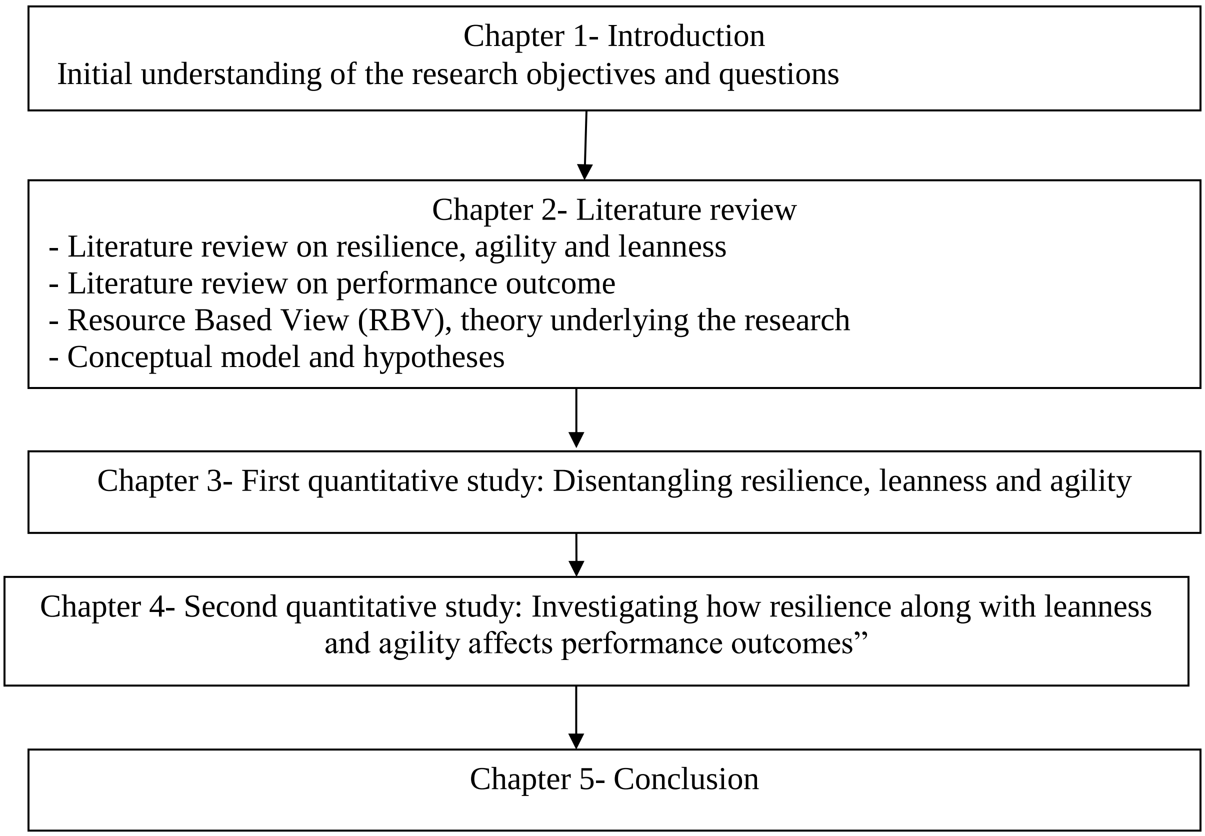

Figure 24- Overview of the thesis

5.2 First quantitative study “disentangling resilience, leanness and agility”

The extent literature review in Chapter two, could categorize supply chain practices to those which are purely related to resilience, agility and leanness. It also shows some practices which are both related to agility and resilience, leanness and agility; and finally some practices which are related to the three of the concepts of leanness, agility and resilience. These categorizations are presented in Table 96.

Table 96- Practices related to resilience, agility and leanness according to literature

Practices	Related to resilience	Related to leanness	Related to agility
Business Continuity (BC) team	x		
Contingency plans made	x		
Decentralization of physical assets in multiple locations	x		
Detection systems in place to detect any supply chain disruption	x		
Establishing communication line in case of a disruption in the supply chain	x		
Security against deliberate intrusion	x		
Alternative modes of transportation in the supply chain	x		
Total preventative maintenance (TPM)		x	
Statistical process control (SPC)		x	
Cellular manufacturing		x	
Producing outputs with minimum resources		x	
Integrating different functions in the company			x
Computer based technologies to manage manufacturing processes.			x
Customizing the final product for individual end-customers			x
Responding quickly to rapidly changing situation somewhere in the supply chain			x
Time-to-market, i.e., introducing new products quickly			x
Reducing process downtime between product changeovers		x	x
TQM		x	x
Implementing new technologies		x	x

Concurrent engineering for overlapping activities in product design to achieve simultaneous development.		x	x
Knowledge management		x	x
Just In Time (JIT)		x	x
Flexible manufacturing equipment to produce different products with the same facilities	x		x
Visibility – knowing the status of operating assets and the environment within the supply chain	x		x
Excess capacity in the supply chain to absorb sudden increases in demand	x		x
Redundant suppliers for the same part with these suppliers being capable to substitute each other	x		x
Collaboration with suppliers (Ability to work effectively with suppliers for mutual benefit)	x	x	x
Cross-functional workforce	x	x	x

The aim of the first quantitative study was to clarify the boundaries between the three concepts of resilience, agility and leanness (LAR), specifically in the areas of overlaps and non-overlaps. A survey was designed which its main parts were practices regarding LAR. Managers were asked to which extent they think implementation of the practices would help organizations become, lean, agile and resilient.

5.2.1 Main results of the first quantitative study

The aim of the first quantitative study was to clarify the boundaries between the three concepts of resilience, agility and leanness (LAR), specifically in the areas of overlaps and non-overlaps. The results of the analysis confirmed the idea presented in literature that there are some areas of overlaps and non-overlaps between LAR. But there were some differences found in the boundaries of these categorizations between what was concluded from literature and what industrial managers believe.

With the survey study done in Germany, all the significant relations between practices and LAR could be quantified. These results are shown in Table 97.

Table 97- Summary of significant standardized regression weights for final CFA models for resilience, agility and leanness

Practices/initiatives	Related to resilience	Related to agile	Related to lean
Business Continuity (BC) team	.526		
Contingency plans made	.607		
Detection systems in place to detect any supply chain disruption	.740		
Establishing communication line in case of a disruption in the supply chain	.691		
Decentralization of physical assets in multiple locations	.432		
Total preventative maintenance (TPM)			.596
Producing outputs with minimum resources			.594
TQM			.517
Just In Time (JIT)			.573
Integrating different functions in the company		.554	
Responding quickly to rapidly changing situation somewhere in the supply chain		.594	
Time-to-market, i.e., introducing new products quickly		.704	
Flexible manufacturing equipment to produce different products with the same facilities		.600	
Knowledge management		.606	
Excess capacity in the supply chain to absorb sudden increases in demand	.466	.500	
Capability to implement new technologies		.677	.692
Concurrent engineering for overlapping activities in product design to achieve simultaneous development.		.553	.505
Reducing process downtime between product changeovers		.689	.664
Redundant suppliers for the same part with these suppliers being capable to substitute each other	.531	.545	

Cross-functional workforce	.528	.531	
Visibility – knowing the status of operating assets and the environment within the supply chain	.824	.582	
Collaboration with suppliers (Ability to work effectively with suppliers for mutual benefit)	.558	.631	.538

5.2.2 Discussion of the results of the first quantitative study

From comparison of Table 96 and Table 97- Categorizing practices according to literature with quantified relations based on the survey study, it can be discussed that:

- "Business continuity team", "Contingency plans made", "Detection systems in place to detect any supply chain disruption", "Decentralization of physical assets in multiple locations" and "Establishing communication line in case of a disruption in the supply chain" are measures that significantly affect "resilience". These results are in line with what the literature review showed previously regarding these measures.
- "TPM", "JIT", "TQM" and "Producing outputs with minimum resources" are measures that significantly affect "leanness". Regarding JIT in some papers (Narasimhan et al. (2006); Brown (2003); Power (2001)) they were related to both leanness and agility, while this empirical research shows this measure is more related to leanness. About TQM, also, Narasimhan et al. (2006), Power (2001) and Yusuf et al. (1999) categorize it as a practice which both related to leanness and agility while again this empirical research conclude it as a practice which significantly helps leanness. Looking at Table 11 the detailed literature review also shows that most researchers in their papers categorize these two practices as lean practice while the second group of researchers linking them to leanness and agility are in minority. Still this empirical research shows that most practitioners in line with most researchers see TQM and JIT as two significant practices related to lean.
- "Integrating different functions in the company", "Responding rapidly to changing situation somewhere in the supply chain", "Introducing new products quickly", "Flexible manufacturing equipment to produce different products with the same facilities", and "Knowledge management" are measures that significantly affect "agility". Knowledge

management was mentioned by literature (Table 13) to be linked to both leanness and agility, while this empirical research shows that this measure is significantly linked to agility. Still this empirical research shows that most practitioners in line with most researchers see knowledge management as a significant practice related to agility.

- "Excess capacity", "Redundant suppliers", "Cross functional workforce" and "Visibility" are measures that affect significantly both "resilience" and "agility". Cross functional workforce was linked to the three approaches of resilience, leanness and agility in literature review (Table 13) while this empirical research shows that is significantly linked to agility and leanness.
- "Implementing new technologies", "Concurrent engineering" and "Reducing process downtime between changeovers" are measures that significantly affect both "leanness" and "agility". These results are in line with what the literature review (Table 11) showed previously regarding these measures.
- "Collaboration with suppliers" significantly affects the three approaches of "resilience", "leanness" and "agility". This result is in line with what the literature review showed previously (Table 13) regarding this measure.

The first objective of this research was disentangling leanness, agility and resilience. As stated above, this research tried to make a clear distinction between boundaries of LAR in the context of supply chain empirically. This is more helpful when it comes to the items about which confusion exists in literature.

Through the above discussion and table of the results for study one, it can be concluded that pure lean can be addressed by practices including TPM, JIT, Producing outputs with minimum resources and TQM. Pure agility can be addressed by integrating different functions in the company, responding rapidly to changing situation somewhere in the supply chain, flexible manufacturing equipment to produce different products with the same facilities, knowledge management and introducing products quickly. Pure resilience can be addressed by decentralization of multiple assets in multiple locations, business continuity team, contingency plans made, establishing communication lines in case of a disruption and detection systems in place to detect any supply chain disruption.

After that resilience, agility and leanness were disentangled clearly, they were entered into the statistical model in the next phase in order to investigate how resilience along with leanness and agility affects performance outcomes.

5.3 Second quantitative study "investigating how resilience along with leanness and agility affects performance outcomes"

As stated before, the literature appears to have a twofold gap: (1) the concepts of lean, agile, and resilience overlap as per Table 13, and (2) the literature suggesting that lean, agile and resilience all impact performance. As such, to make progress on the research question, i.e. how resilience impacts performance in the presence of practices for leanness as well as agility in the context of supply chain management, it was needed first to disentangle the three concepts from each other. Moreover, different researchers have conceived lean, agile and resilience slightly differently so it makes sense to disentangle them with empirical testing which was done in the first quantitative study. Secondly, it was needed to refine the primary model (Figure 25) obtained from the literature to a narrower conceptual model that can be a better starting point for researchers. The primary model (Figure 25) is not fully empirically tested either as many of the links are conceptual so there is a need for empirical testing as well.

Going back to the model and hypotheses developed in 2.7, following sets of hypotheses need to be tested:

H1: higher level of agility will have a positive impact on resilience.

H2a: Higher level of resilience will have a positive impact on cost performance.
H2b: Higher level of resilience will have a positive impact on flexibility performance.
H2c: Higher level of resilience will have a positive impact on delivery performance.
H2d: Higher level of resilience will have a positive impact on time to recovery performance.

H3a: Higher level of leanness will have a positive impact on cost performance.
H3b: Higher level of leanness will have a positive impact on delivery performance

H3c: Higher level of leanness will have a positive impact on flexibility performance.
H3d: Higher level of leanness will have a negative impact on recovery performance.

H4a: Higher level of agility will have a positive impact on cost performance.
H4b: Higher level of agility will have a positive impact on delivery performance.
H4c: Higher level of agility will have a positive impact on flexibility performance.
H4d: Higher level of agility will have a positive impact on time to recovery performance.

The model developed as primary model is presented in Fig. 25.

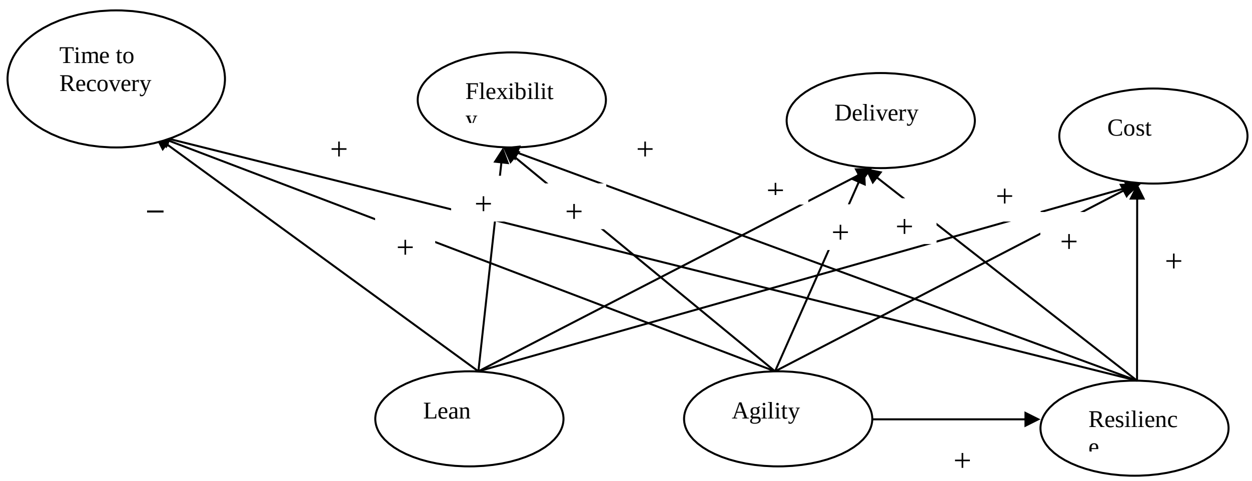

Figure 25- Primary research model

Therefore, for testing this model and hypotheses, a survey was designed including independent variables and dependent variables. For independent variables (LAR practices), managers were asked to indicate the extent to which their organization has been successfully implementing these practices across the supply chain in comparison with similar tier 1 suppliers. For dependent variables (performance outcomes), managers were asked to rate their companies performance across their supply chain in comparison with similar tier 1 suppliers.

5.3.1 Main results of the second quantitative study

Primary model presented in Fig. 25 was tested to many other different models; the final research model is presented in Fig. 26.

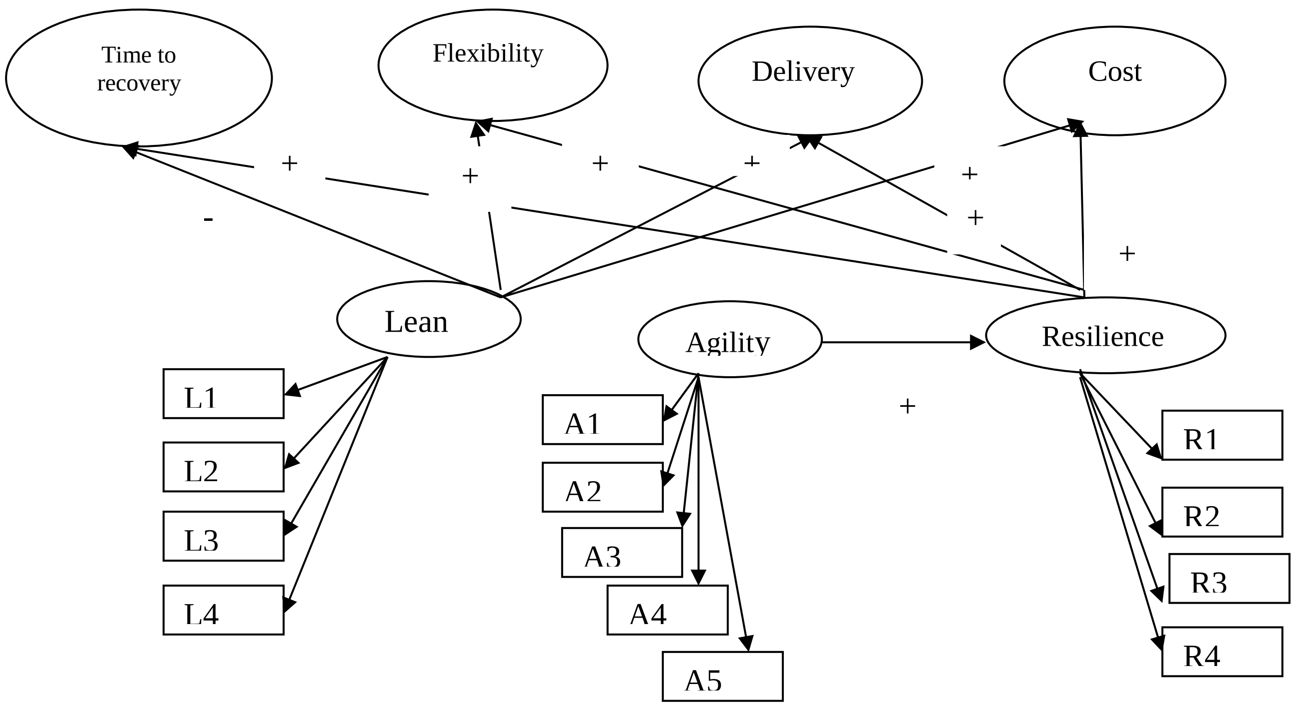

Figure 26- Final research model

In Table 98 all hypotheses related to the model presented in Fig. 26 are presented and that if the model and analysis confirm their acceptance or rejection. All the hypotheses were accepted and confirmed by the model analysis while there were two which have been rejected.

Table 98- Results of the hypotheses testing

	Hypothesis	
Resilience <--- Agile	*Higher level of agility will have a positive impact on resilience.*	accepted
cost <--- Resilience	*Higher level of resilience will have a positive impact on*	accepted

	Hypothesis	
	cost performance.	
Flexibility <--- Resilience	*Higher level of resilience will have a positive impact on flexibility performance.*	rejected
Delivery <--- Resilience	*Higher level of resilience will have a positive impact on delivery performance.*	accepted
Recovery <--- Resilience	*Higher level of resilience will have a positive impact on time to recovery performance.*	accepted
Recovery <--- Lean	*Higher level of leanness will have a negative impact on time to recovery performance.*	rejected
Delivery <--- Lean	*Higher level of leanness will have a positive impact on delivery performance*	accepted
Flexibility <--- Lean	*Higher level of leanness will have a positive impact on flexibility performance.*	accepted
cost <--- Lean	*Higher level of leanness will have a negative impact on cost performance.*	accepted

5.3.2 Discussion of the results of the second quantitative study

Regarding the relationship between agility and resilience, as it was mentioned in the literature review chapter; there exist two schools of thoughts. The first group believe that agility brings about resilience such as Christopher and Peck (2004), Pettit et al. (2010) and Panomarov and Holcomb (2009). While there is the second group such as Carvalho et al. (2012) who present agility and resilience as two independent elements. This research hypothesized the relation of agility and resilience based on the first group of thoughts, i.e. agility brings about resilience. The model and the related analysis show the acceptance of this hypothesis. So now, it can be concluded with enough quantitative evidence that agility is not completely independent from resilience and as Panomarov and Holcomb (2009) state agility is a formative element of resilience.

Regarding resilience, no research could be found that empirically investigates the effects of resilience on cost, delivery, flexibility and time to recovery performance. Christopher and Peck (2004) conclude that resilience will change performance in terms of cost related measures but this should be researched by other authors in future. While Pettit et al. (2010) undertook an initial attempt at translating resilience into a framework to create useful managerial tool which can improve performance, they highlighted that their work needs empirical validation. This research shows quantitatively that resilience has a significant and positive effect on delivery performance outcome. This is in line with what has been mentioned in the work such as Manuj and Mentzer (2008b). This research also shows that resilience has a significant and positive effect on time to recovery performance, i.e. it helps supply chain to have shorter time to recover in case of disruptions. This is also in line with literature which all state this issue while none of them tests it quantitatively. In addition, this research confirms that resilience has a significant and positive effect on cost performance, i.e. it helps cost reduction. While no research up to now looks at this relation quantitatively there were some literature stating this positive relation such as Fiksel (2003) and Carvalho and Machado (2009). Therefore, regarding the relation between resilience and flexibility performance, this research concludes that this relation is not significant. While again no previous research could be found that quantitatively considers and test this relation, there was some literature very slightly stating that resilience improves flexibility performance such as Fiksel (2003). In this research, it can be interpreted regarding how flexibility performance measures have been defined. The flexibility performance was defined by items such as “Percentage change possible in demand volume of specific products without incurring high incremental costs”, “Percentage change possible in customer lead time in response to changes in delivery schedule without incurring high incremental costs” and “Number of new products introduced in response to customer demand without incurring high incremental costs”.

Regarding leanness and its effects on performance outcomes, there was some previous literature which investigated the effects of lean on delivery, flexibility and cost. But there is no research up to now that quantitatively tests the relation of leanness on time to recovery as a performance outcome. The result of this research presents that lean has a significant and positive effect on cost performance, i.e. it decreases cost. This research also confirms that lean positively affects delivery and flexibility performance. These results are in line with Hallgren and Olhager (2009), and Narasimhan et al. (2006) which both suggest positive and significant effects of lean on delivery, flexibility and cost reduction. When it comes to the relation between leanness and time to recovery performance, some literature such as Melnyk (2007) and Zsidisin et al. (2005) state that leanness should result in worse time to recovery performance, i.e. it causes longer time to recovery. This model shows that leanness actually helps time to recovery performance, i.e. it reduces time to recovery. The only evidence could be found to support this finding was the paper of Oliver and Olcatt (2013). In their work, they describe how suppliers, customers and competitors of five Japanese companies affected by the earthquake were mobilised and deployed so that production could quickly be resumed. They conclude that the Japanese background in leanness actually helped them for quicker recovery and therefore reduced time to recovery.

In conclusion, this study here suggests that resilience should be viewed, in parallel with lean efforts, to actually improve operational outcomes such as cost, delivery, etc., not just time for recovery. It does so through agility practices. Thus, this research has provided a new conceptual model linking lean, agile and resilience practices to performance.

5.4 Theoretical implications

As stated already, the existing research lacks first of all a clear distinction regarding items related to resilience, agility and leanness. It was tried to make a clear distinction between boundaries of these three approaches in supply chain management through the first phase of this research "disentangling resilience, agility and leanness". This is more crucial when it comes to the items about which confusion exists in literature. This confusion is because there are some measures that according to literature go under leanness and agility, agility and resilience and even the three of them. So, when it comes to have them in statistical models, researchers don't know where exactly these measures should be categorized. The first phase of this research tries to fill this gap.

While it was clearly shown that which measures can be specifically categorized as resilience, agility and leanness, the research moves to the second phase which investigates how resilience along with leanness and agility affects performance outcomes. Regarding this part, it can be said that first no research has been found to date that quantitatively looks at resilience. Second, there has been no research to date that quantitatively looks at how resilience, agility and leanness can be modelled not solely but beside each other. Third, there has been no research to date that aims to investigate the effects of resilience along with leanness and agility on performance outcomes. Also, in terms of performance outcomes it should be stated that for the first time “time to recovery” is considered as a performance outcome in a quantitative model for supply chain. So supply chain needs to be measured not only in terms of flexibility, delivery and cost performance but also in terms of time to recovery.

The research here suggests that resilience should be viewed, in parallel with lean efforts, to actually improve operational outcomes such as cost, delivery, etc., not just time for recovery. It does so through agility practices so researchers can appreciate it. Thus, this research has provided a new conceptual model linking lean, agile and resilience practices to performance.

Therefore, this study is the first in SCM literature that focuses on how LAR really fit in terms of both practice and performance outcomes and tries to pass the limitations exist in previous literature, which are first lack of clarity between the boundaries of LAR, i.e. the confusion exists in practices regarding these three approaches; and second lack of any empirically validated model on LAR and their effects on performance outcomes. While recently many conceptual papers can be found that address the issue that supply chains need to focus on leanness, agility and resilience hand in hand, but no empirically validated model could be found. Therefore the contribution of this research to SCM literature is shedding light on first, the confusion exists in practices related to LAR through the first empirical study and second, the gap of nonexistence of any empirically validated model of the effects of LAR on performance outcomes.

5.5 Managerial implications

Currently there are volatile circumstances in the world, from sanctions to natural disasters. All these urge firms to pay more attention to resilience which also increases the academic interests in this issue. Whilst firms need to understand resilience and know how they should achieve it, it doesn’t mean that they should neglect being cost efficient in terms of lean and customer responsive in terms of agile. As Calrvalho et al. (2011) state, the trade-off between leanness, agility and resilience are actual issues and may help supply chain to become more efficient, customer responsive and resilient. In the very early stages of this research in a discussion with supply chain managers in a forum in P&G, they stated that their companies have formal ways to look across the three approaches and that they are seeking ways to improve them at the same time but still they are incapable. It can be concluded that while a good robust framework which can help managers to have LAR in their supply chains is a necessity, there is a lack in academic papers until now that can present this framework to supply chain managers. Therefore, this research first tries to present a clear empirically validated portrait regarding practices related to LAR, clarify their overlaps and non-overlaps, and present a good guideline to managers of what really leanness, agility and resilience are; far from the confusion which exists now in SCM literature which makes implementation of these three approaches difficult for managers. Then, it presents a comprehensive model, which is empirically validated, despite of other studies having existed until now which all remained in the conceptual level. This model clearly shows that how these three approaches can be related to each other, one important guideline that according to this study, agility improves resilience. It also clearly gives guidance to them that rather than seeing leanness and resilience as two enemies, they should see these two approaches helping each other in achieving high performance both in cost and time to recovery performance. Also, managers can take advantage of the new performance outcome introduced in this research as "time to recovery". It makes them aware that except cost, delivery, flexibility or other routine performance outcomes, they should now monitor their supply chains in terms of time to recovery as a performance outcome too.

In conclusion, managers can benefit this research in two important contributions: first, as discussed in the discussion group conducted in P&G in 2011, managers believe that their companies are seeking ways to improve the three concepts of LAR. They stated unclear boundaries between these three concepts as a factor that makes the implementation of respective practices potentially problematic or confusing when multiple practices are carried out in the same time. This research tries to fill this gap by disentangling leanness, agility and resilience where these three approaches were making confusions. Second, the final structural model (Figure 23), gives useful guidance to supply chain managers. Rather than seeing lean and resilience practices in opposition to each other, they should see both helping performance outcomes including time to recovery. Moreover, they should see agility practices as directly improving resilience.

5.6 Conclusion

The core idea underlying this research is to identify how resilience fits with leanness and agility in the context of supply chain. This general objective was broken down into two specific research questions targeting at:

1- Disentangling resilience, agility and leanness.

This study explains and empirically verifies that resilience, leanness and agility have some areas of overlaps in terms of practices and practice. But there also exists some non-overlapping areas that distinctively are related to resilience, agility and leanness. To date, all previous research conceptually suggests this but since there was no empirical evidence previously, this confusion exists in literature. This study aims to shed light on this confusion.

2- Investigating how resilience along with agility and leanness affects performance outcomes.

This study explains and empirically verifies that how resilience along with agility and leanness affects performance outcomes. While the effect of combinations of two of them could be found in literature, no previous research can be found that quantitatively assesses how resilience along with leanness and agility affects performance outcomes. This study aims to shed light on this gap.

In conclusion, this research doesn't go directly to use previous scales for leanness, agility and resilience. Regarding the confusion existing in literature, the first phase of this research focuses on disentangling resilience, agility and leanness. So, the constructs for LAR are not suffering from the confusion existed previously in literature.

In addition, for the first time and in contrast with the literature which all remained on the conceptual level by presenting conceptual models for having a combination of these three approaches and how they affect performance outcomes; this research tests a structural equation model including the three approaches.

Finally, in this research, leanness, agility and resilience are investigated to test whether their respective practices and performance outcomes differ. Discriminating constructs for leanness and agility and resilience were found, i.e. leanness, agility and resilience do indeed foster some distinctly different capabilities. It is evident the impact on performance measures shows both some similarities and some differences. This study suggests that resilience should be viewed, in parallel with lean efforts, to actually improve performance outcomes such as cost, delivery, etc., not just time for recovery. It does so through agility practices. The major differences in performance outcomes are related to flexibility and time to recovery performance such that lean doesn't have a negative impact on time to recovery performance. This means that leanness should be viewed in parallel to resilience, i.e. it helps to shorten time to recovery. Also, regarding the relation between resilience and flexibility performance, this research concluded that this relation is not significant.

5.7 Limitations and directions for future research

For the very preliminary stage of this research which was a short survey following a discussion on LAR done in P&G in 2011, it should be stated that norms of validity and reliability were not applied. In the very first stages of this research the confusion related to LAR was found in the literature, so in P&G Forum, there was an opportunity to discuss the issues found in literature with managers. It was not a structured survey; it was done through voting systems and then a discussion. This process was all done for clarifying research questions and testing are they really the questions of managers in the industrial world as well. While this preliminary stage was very helpful, it was not a structured survey as the first and second study.

For the first phase of this research which was done with the goal of disentangling resilience, leanness and agility, a survey was done asking managers from different industries in Germany. A major limitation as of many other survey studies is the issue of generalizability from a single country. While the wide ranges of industries were included in sampling, one avenue for future is to replicate this study in other different countries. In this part of the study, however, managers were asked about the concept, i.e. what really they thought resilience, agility and leanness were rather than what really they did in their companies.

For the second phase of this research which was done with the goal of understanding how resilience along with agility and leanness affects performance outcomes, a survey was done in Iran auto industry and managers were asked about the practice and performance outcomes of their companies. Regarding the issue of generalizability, an interesting avenue is researching other countries encountering huge turbulent circumstances like the sanctions which Iran is encountering now, to see if the results will be the same or not. Are there any cultural moderating roles existing there? Also, it would be interesting to investigate other industries to see if the type of industry plays a specific role in the model. Another avenue for future research is to investigate if selecting LAR is dependent on the strategy selected by different companies.

Finally in both studies, several practices which are associated to leanness, agility or resilience were identified; however, there might be other practices that can be related to each of these three approaches. In addition, the findings are limited to the specific research design that was used. Single respondents were selected to collect the data. While multiple respondents are usually suggested to validate the data obtained; however, it is very difficult to get multiple informants to agree to participate.

As previously stated, this is the first research to have an empirical look at the three approaches of resilience, leanness and agility which has passed all previous conceptual work previously done in this field. Therefore, it is fair to point out that this work should be seen as the starting point that investigates the effects of resilience along with leanness and agility on performance outcomes in the context of supply chain. The empirical study of LAR is in its infancy, and moving it forward requires reliable and valid empirical models, which this study can be a starting helpful point.

Appendices

Appendix1: Survey for the first quantitative study: Disentangling resilience, agility and leanness in the context of supply chain

Cass Business School
CITY UNIVERSITY LONDON

Disentangling resilience, agility and leanness in the context of supply chain

Dear Sir/Madam,

This project aims to disentangle resilience, agility and leanness in the context of supply chain. It is undertaken by Cass Business School, City University London, United Kingdom.

Please note that this study is for academic research purpose, and all your answers will be treated as **strictly confidential**, i.e. we will not provide any other organization with your information. However, we will provide you with aggregated feedback and an executive summary after we have analyzed the data if you wish.

Regarding today's volatile and turbulent market accompanied by natural disasters and political upheavals, becoming resilient has become crucially important for many firms. While many researchers seek to identify factors that can help firms (and their supply chains) achieve resilience, questions regarding how resilience is disentangled from leanness and agility remained unanswered. The purpose of this research is then to disentangle resilience, agility and leanness in the context of supply chain.

We fully understand the demands on your time and we are very thankful for your help with this research project. The questionnaire will take about 30 minutes to complete.

If you have any questions or comments about this project, please do not hesitate to contact us. If you are interested in the results, please let us know, the results will be sent to you while the analysis is done.

Thank you very much for your help.

Sincerely yours,

Nina Kreuer <Nina.Kreuer.1@cass.city.ac.uk>
Masters Student, MSc in Supply Chain, Trade & Finance

Maryam Lotfi <maryam.lotfi.1@cass.city.ac.uk>
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Head, Operations & Supply Chain Management
Faculty of Management, Cass Business School, City University London
Cass Business School, City University London

Part 1: ***This part includes some general questions about your company. Please tick the appropriate choice.***

1- How many employees are in your company?
- Fewer than 100
- 100-249
- 250-499
- 500-999
- 1000 or more

2- How many years has it been since the present configuration of supply chain has been operational with the current set of plants and other assets?
___ years

3- Average annual sales level _____
- < €10 million
- € 10-50 million
- € 51-100 million
- € 101-250 million
- € 251-500 million
- > €500 million

4- Your area (select the closest):
- Manufacturing
- Supply Chain
- Sourcing/Strategic sourcing
- Marketing/Customer relations
- Other ______

5- How many years have you been in this position? ____ years

6- How many years with this company? ___ years

7- How many plants are there in your company? ___ plants

8- Industry sector (drop-down menu):

- Manufacturing
- Energy and water supply
- Construction
- Wholesale and retail trade; repair of motor vehicles and consumer goods
- Fishing
- Mining and quarrying
- Agriculture, hunting and forestry
- Hotel and restaurant industry
- Post and telecommunications
- Financial intermediation
- Real estate, renting and business activities
- Public administration and defense; compulsory social security
- Education
- Health and social work
- Other community, social and personal service activities
- Private households with employed persons
- Extra-territorial organizations and bodies
- Others

9- and sub-sector ________________

Part 2: Please indicate the extent to which you think implementing the following as practices would help your organization become lean, agile or resilience (-2highly negatively, 0- no effect, +2highly positively)

	Initiative	**Extent to which this initiative helps in becoming more … (-2: highly negative effect, +2: highly positive effect)**		
		Lean	**Agile**	**Resilient**
10	Total preventative maintenance (TPM)			
11	TQM			
12	JIT			
13	Statistical process control (SPC)			
14	Cellular manufacturing			
15	Producing outputs with minimum resources			
16	Integrating different functions in the company			
17	Computer based technologies to managing manufacturing processes			
18	Customizing the final product for individual end-customers			
19	Responding quickly to rapidly changing situation somewhere in the supply chain			
20	Reducing process downtime between product changeovers			
21	Flexible manufacturing equipment to produce different products with the same facilities			
22	Cross-functional workforce			
23	Alternative modes of transportation in the supply chain			
24	Decentralization of physical assets in multiple locations			
25	Security against deliberate intrusion			
26	Redundant suppliers for the same part with these suppliers being capable to substitute each other			
27	Business Continuity (BC) team			
28	Contingency plans made			
29	Establishing communication line in case of a disruption in the supply chain			
30	Visibility			

31	Detection systems in place to detect any supply chain disruption			
32	Excess capacity in the supply chain to absorb sudden increases in demand			
33	Implementing new technologies in your product			
34	Concurrent engineering for overlapping activities in product design to achieve simultaneous development			
35	Knowledge management, by creating an organization that encourages experimentation of innovative ideas to allow extensive dissemination of knowledge throughout the organization			
36	Time-to-market, i.e., introducing new products quickly			
37	Collaboration with suppliers: Ability to work effectively with suppliers for mutual benefit			

Appendix 2: Survey for the second quantitative study: How resilience along with leanness and agility affects performance outcomes?

Cass Business School
CITY UNIVERSITY LONDON

How resilience along with leanness and agility affects performance outcomes?

Dear Sir/Madam,

Many thanks for agreeing to participate in our research project.

This project investigates how resilience along with leanness and agility affects performance outcomes. It is undertaken by Cass Business School, City University London, United Kingdom.

Please note that this study is for academic research purpose, and all your answers will be treated as strictly confidential, i.e. we will not provide any other organisation with your information. However, we will provide you with aggregated feedback and an executive summary after we have analysed the data if you wish.

You are being requested to fill this survey because you are responsible for or at least well familiar with a supply chain for your company. The questions pertain to this supply chain that may have multiple plants within your company; depending on the context, the supply chain may refer to suppliers and customers for these plants. As you are familiar with competing supply chains in your sector or sub-sector, we request you to rate yourself from 1-to-7, 1 being low or well below average in this peer group, 4 being average, and 7 being best-in-class in this peer group of supply chains for most of these questions.

We fully understand the demands on your time and we are very thankful for your help with this research project. The questionnaire will take about 30 minutes to complete.

If you have any questions or comments about this project, please do not hesitate to contact us. If you are interested in the results, please let us know, the results will be sent to you while the analysis is done.

Thank you very much for your help.

Sincerely yours,

Maryam Lotfi <maryam.lotfi.1@cass.city.ac.uk>
PhD Candidate in Operations and Supply Chain Management
Faculty of Management, Cass Business School, City University London

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Head, Operations & Supply Chain Management
Cass Business School, City University London
&Executive Director, Munjal Global Manufacturing Institute
Indian School of Business, Mohali

Part 1: ***This part includes some general questions about your company. Please tick the appropriate choice.***

1- How many employees are at this location?
  - Fewer than 100
  - 100-249
  - 250-499
  - 500-999
  - 1000 or more

2- How many years has it been since plant start up? _____ years

3- Average annual sales level _____
  - < US $10 million
  - US$ 10-50 million
  - US $ 51-100 million
  - US $ 101-250 million
  - US $ 251-500 million
  - > $ 500 million $

4- Your areas (select the closest):
  - Manufacturing
  - Supply Chain
  - Quality (QA/QC)
  - Marketing/customer relations
  - Other_____

5- Title (select the closest):
  - VP
  - Director
  - Manager
  - Other________

6- How many years have you been in this position? ____ years

7- How many years with this company? ___ years

8- How many plants are there in your remit (company)? ___ plants

***Part 2: please indicate the extent to which your organization has been successful implementing the following practices across the supply chain (including the plant(s), customers, suppliers) in comparison with similar tier 1 suppliers* (1-very low/not at all, 4-average, 7-very high/best-in-class)**

	Initiative	**Not Applicable**	**1=Very low/Not at all 4=Average 7=Very high/Best-in-class**						
9	Total preventative maintenance (TPM)		1	2	3	4	5	6	7
10	JIT		1	2	3	4	5	6	7
11	Producing outputs with minimum resources		1	2	3	4	5	6	7
12	Integrating different functions in the company		1	2	3	4	5	6	7
13	Responding rapidly to changing situation somewhere in the supply chain		1	2	3	4	5	6	7
14	Reducing process downtime between product changeovers		1	2	3	4	5	6	7
15	Flexible manufacturing equipment to produce different products with the same facilities		1	2	3	4	5	6	7
16	Cross-functional workforce		1	2	3	4	5	6	7
17	Detection systems in place to detect any supply chain disruption		1	2	3	4	5	6	7
18	Business Continuity team		1	2	3	4	5	6	7
19	Contingency plans made		1	2	3	4	5	6	7
20	Establishing communication line in case of a disruption in the supply chain		1	2	3	4	5	6	7
21	Excess capacity in the supply chain to absorb sudden increases in demand		1	2	3	4	5	6	7
22	Knowledge management, by creating an organization that encourages experimentation of innovative ideas to allow extensive dissemination of knowledge throughout the organization.		1	2	3	4	5	6	7
23	Time-to-market, i.e., introducing new products quickly		1	2	3	4	5	6	7
24	Collaboration with suppliers: Ability to work effectively with suppliers for mutual benefit		1	2	3	4	5	6	7

***Part 3: Please rate your company's performance on the following performance measures across your supply chain (including the plant(s) customers, suppliers) in comparison with similar tier 1 suppliers* (1- very poor, 4-average, 7= best-in-class)**

	Performance measures	**1= very poor 4-average 7= best-in-class in the peer group)**						
25	Distribution cost per unit: transportation and handling costs to customer location	1	2	3	4	5	6	7
26	Manufacturing cost per unit: labor, maintenance and Re-work costs	1	2	3	4	5	6	7
28	Inventory cost per unit: work-in-process + finished goods inventories+ raw material	1	2	3	4	5	6	7
29	Mix Flexibility: Number of products from this supply chain without incurring high costs	1	2	3	4	5	6	7
30	Time to detect undesirable risk event in the plant or supply side in a timely manner	1	2	3	4	5	6	7
31	Time to design a solution when an undesirable event occurs in the supply chain	1	2	3	4	5	6	7
32	Time to deploy a solution when an undesirable event occurred in the plant or supply side in a timely manner	1	2	3	4	5	6	7
33	Time to recover from risk incidents or disruptions and to return to normal operational state rapidly.	1	2	3	4	5	6	7
34	Fill Rate: the proportion of orders that can be filled on the required date	1	2	3	4	5	6	7
35	Customer acceptance rate	1	2	3	4	5	6	7
36	End-customer repair and warranty costs for the products produced by this supply chain	1	2	3	4	5	6	7
37	Percentage change possible in demand volume of specific products without incurring high incremental	1	2	3	4	5	6	7
38	Percentage change possible in customer lead time in response to changes in delivery schedule without incurring high incremental costs	1	2	3	4	5	6	7
39	Number of new products introduced in response to customer demand without incurring high incremental costs	1	2	3	4	5	6	7
40	Order cycle time of customer (shorter preferred)	1	2	3	4	5	6	7
41	Orders with the right quantity as a percentage of total orders (even if the order is sometimes late)	1	2	3	4	5	6	7
42	Orders delivered at the right time as a percentage of total orders (even if the quantity is sometimes short)	1	2	3	4	5	6	7

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