Designing a Performance Measurement System for Supply Chain Agility

- A Company Case Study -

Master Thesis

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Acknowledgements

This master thesis was conducted as the final element of our Master of Science degree in Industrial Engineering and Management at the Faculty of Engineering at Lund University. The thesis was conducted at the Division of Engineering Logistics, which is part of the Department of Industrial Management and Logistics, and in collaboration with a multinational company within the retail sector.

There have been many people helping us in conducting this project. We especially want to thank our supervisor at the host company, for his support, time and engagement in the project. We also would like to thank all the people we have met and interviewed during the project for your kindness and helpfulness as well as for taking your time to talk to us.

Another person that have been with us all the way and that have helped us and supported us during the whole project is Andreas Norrman, our supervisor at Lund University. Thank you for all time put into this project and for all your insightful advice. We are very grateful for this.

Lund 2018
Sofie Järlid and Elin Söderberg

Abstract

Background

The world is changing fast today and the demand for product variety is increasing. At the same time, technological advances take place, new approaches to reach customers appear and the demand uncertainty increases. In order for the companies to stay competitive in this environment, supply chain agility has been pointed out to be a necessary capability. The concept of supply chain agility is quite new in research. The interest for the subject has increased lately, which has resulted in various definitions, constituents and measurements for supply chain agility. No consensus regarding these have yet been found.

Problem formulation

The case study company is experiencing difficulties in their current supply chain, which is inflexible and cannot respond fast enough to demand deviations or to the increased demand of fast deliveries that follows from the emerging e-commerce. They are also handling bulky products, which makes this an even bigger challenge. The company, therefore, want to investigate the opportunities lying within the concept of supply chain agility. In order to build a common understanding of the concept, the case study company desires to get a clear definition of supply chain agility, as well as examples of what in their operations that are influencing their supply chain agility and in what way. They also express a need for developing a common understanding of what constitutes supply chain agility and how the concept could be measured in a generic way throughout the whole category area.

Purpose

The purpose of this project is to identify the constituents of supply chain agility and to create a performance measurement system for measuring supply chain agility at a general level for the whole of the case study company.

Method

The project was conducted in the form of a case study. Theoretical contribution in the form of a literature review, consisting of 43 articles on the subject, provided a theoretical foundation for the study. Built on this, a multiple case study was conducted at a multinational company within the retail sector in order to collect empirical data for the project. A total of 25 interviews were conducted. From the empirical findings, a performance measurement system for measuring supply chain agility, adapted to the case study company, was created.

Conclusion

This report provides a summation of relevant literature on the topic of supply chain agility constitution and measurement. It also presents a condensation of how to measure supply chain agility and a performance measurement system adapted to the case study company for measuring the concept. Hence, through this report, a contribution to the research on how to measure supply chain agility is made.

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1 Introduction

In this section, an introduction to the project is provided. The section starts with providing a theoretical and company-specific background to the project. Following that, the problem formulation and purpose of the project are outlined and, further on, the research questions as well as the focus and delimitations of the project. The section ends with a description of the outline for the rest of the report.

1.1 Theoretical Background

The world is changing fast and the demand for product variety is increasing (Gaudenzi and Christopher, 2016). At the same time, technological advances take place, new approaches to reach customers appear and the demand uncertainty increases (Swafford et al., 2006). One example of market change is the turn towards e-businesses with omni-channel solutions, which increases the customers' expectations of fast, accurate and efficient order fulfilments (Krebs, 2015). In the latest research, supply chain agility has been described as an important business capability to remain competitive and tackle uncertainty and turbulence (Sharma et al., 2017). In order to stay competitive, there is a growing belief that companies need to adapt and transform their original supply chains in order to increase their supply chain agility (Christopher, 2000).

Supply chain agility has been a topic since the beginning of the 90's and various definitions and metrics have been presented of how to work with the concept (Arteta and Giachetti, 2004). Many authors include the ability to quickly sense and respond to changes into their definitions of supply chain agility (Sharma et al., 2017). The subject has, however, reached little consensus regarding its definition and boundaries, and the various definitions have resulted in different methods of measuring supply chain agility (Arteta and Giachetti, 2004; Swafford et al. 2006; APICS, 2017). It is, however, important for companies to measure their performance in order to be able to manage it. Tung et al. (2011) underline the essentiality of companies' abilities to clarify their goals and work in an effective and efficient manner. They further express that performance measurement systems can help companies in achieving this. Performance measurement is a broadly discussed subject in research and there are consequently many different dimensions and frameworks of how to measure performance (Neely et al., 1995; Tung et al., 2011; Bititci et al., 2015). A widely accepted model for supply chain measurement and management is the Supply Chain Operations Reference (SCOR) model (Ren et al., 2006), which is a process reference model providing a methodology for companies to improve their performance through five generic performance attributes with definitions as well as measurements for several levels of these (APICS, 2017). However, this model does not provide an exact way of measuring supply chain agility, rather a holistic approach (Magnusson, 2018). Hence, there is no established way to measure supply chain agility today.

1.2 Case Study Company

Due to confidentially reasons, the name of the company studied has been excluded from this report. The company is, however, a multinational company within the retail sector that handles bulky products. As the studied company is a smaller part of a larger organization, the studied company, further on called Company X, will be referred to as being a part of

Company Y. Company X is responsible for purchasing of production services activities and is divided into four product categories of varying sizes. Thus, Company X is mainly focused on sourcing and its position in the supply chain is between the suppliers and the transport function, which is another part of Company Y. The supply chain is displayed in figure 1.1.

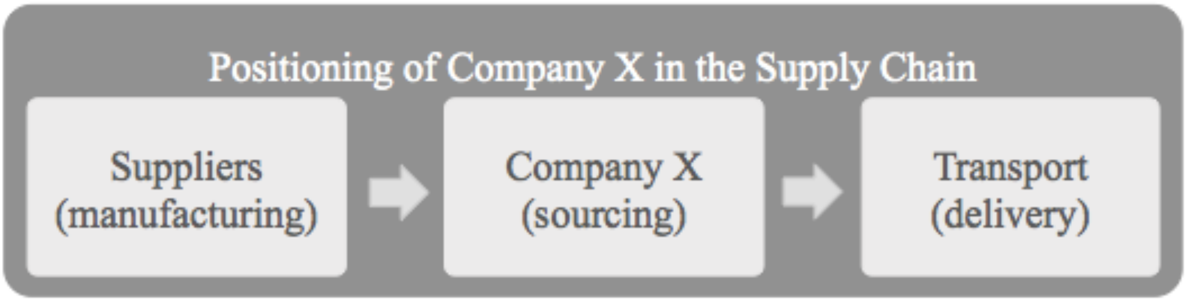

Figure 1.1. The position of Company X in the supply chain.

1.3 Problem Formulation

Company X is experiencing difficulties in their current supply chain, which is inflexible and cannot respond fast enough to demand deviations or to the increased demand of fast deliveries that follows from the emerging e-commerce. The e-commerce is also expected to change the market dynamics and result in an even more volatile demand. They are handling bulky products, which makes it an even bigger challenge to increase the flexibility in the supply chain due to the space issues in transport and inventory.

Even though Company X is aware of the situation and several attempts have been made in order to create a more flexible supply chain, they still believe that there is more to do. Therefore, they want to investigate the opportunities lying within supply chain agility. Today there is a lack of consensus regarding the definition of supply chain agility and the measurements that represents the concept, not only in research but also within Company X. To build a common understanding, Company X desires to get a clear definition of supply chain agility, as well as examples of what in their operations that are influencing their supply chain agility and in what way. They also express a need for developing a common understanding of what constitutes supply chain agility and how the concept could be measured in a generic way throughout the whole of Company X.

1.4 Purpose

The purpose of this project is to identify the constituents of supply chain agility and to create a performance measurement system for measuring supply chain agility at a general level for the whole of Company X.

1.5 Research Questions

This project aims to answer the following question:

Q1: How can supply chain agility be measured at Company X?

In order to answer the above question, the following sub-questions have been formulated:

Q2: What constitutes supply chain agility according to theory?
Q3: How can supply chain agility be measured according to theory?
Q4: What measures of supply chain agility are relevant for Company X?

In order to answer Q4 above, the following sub-question have been formulated:

Q5: What are the good examples and challenges in the area of supply chain agility for Company X?

Through identifying areas of good performance and areas in need for improvement, in terms of supply chain agility, areas relevant for measuring supply chain agility at Company X could be identified. The areas of good examples of supply chain agility are relevant to measure in order to make sure that the good work within these areas are kept. The challenging areas of supply chain agility are relevant to measure in order to be able to measure improvements within these areas. Answering research question five, therefore, contributes in answering research question four.

1.6 Focus and Delimitations

To conduct this project, directives needed to be followed and delimitations had to be made. These are further described below.

1.6.1 Directives

The main desires of Company X are to get a better understanding of supply chain agility and related concepts, to be able to measure supply chain agility and to distinguish examples of good performance and challenges of supply chain agility in the organisation. This is suggested to be done through a performance measurement system of supply chain agility, which is the focus of this study. A future objective is to use this performance measurement system at the whole of Company X and, later, at the whole of Company Y.

1.6.2 Delimitations

The time frame for the project is limited to 20 weeks. This has influenced the scope of the project in several ways. Firstly, the empirical studies are delimited to focus on only two out of the four product categories within Company X and only involve two cases. Secondly, the literature review is influenced to be limited in scope in terms of the number of articles read. Thirdly, the project does only involve creation of the performance measurement system, not implementing or testing of it.

The scope of the project is set to involve the processes reaching from the processes connected to enabling the manufacturing at the suppliers to the processes connected to enabling the arrival of the products to stores belonging to Company Y.

1.7 Outline of the Report

Following the introduction, the theoretical framework used in the project is presented and the methodology of the project is explained. This is followed by the empirical findings from studying Company X as well as both within-case and cross-case analyses. The project ends with designing and presenting the performance measurement system for measuring supply chain agility at Company X and with emphasizing the conclusions and research contributions of the project.

2 Theoretical Framework

In this section, the theoretical framework built up through the literature review is presented. The section starts with introducing the concept of performance measurement system and, then, continues with introducing definitions of supply chain agility as well as descriptions of concepts relating to supply chain agility. Following that, strategies to achieve supply chain agility are described and capabilities of the concept are identified. The section also includes a presentation of potential areas of measurement for supply chain agility. The section ends with a summary of the knowledge found in literature in the form of a theoretical construct.

2.1 Performance Measurement System

In this section, different aspects connected to performance measurement systems are presented. Firstly, different definitions and dimensions of a performance measurement system are identified. Following that, an overall view of the designing process of a performance measurement system is provided and, lastly, performance measurement systems connected to measuring performance in supply chains are presented.

2.1.1 Definitions and Dimensions of Performance Measurement System

There is no consensus among researchers when it comes to a consistent definition of a performance measurement system (Franco-Santos et al., 2007). Neely et al. (1995, p. 81) define a performance measurement system as *"the set of metrics used to quantify both the efficiency and effectiveness of action"*. They further describe it as including titles of the measures, formulas of how to calculate the measures, descriptions of how to collect the data for calculating the measures, and descriptions of who is responsible for data collection and calculation for the different metrics. Other authors define a performance measurement system less detailed as an important information system that supports the performance management process of the company (Brititci et al., 1997; Lebas, 1995).

Franco-Santos et al. (2007) have found two common features of a performance measurement system among the definitions in literature. These are *performance measures* and *supporting infrastructure*. Performance measures refers to the measures that are required for a performance measurement system to exist. Supporting infrastructure refers to the system or processes that enables the performance measurement system to be used. Franco-Santos et al. (2007) further suggest that there are three necessary processes that must be included in a performance measurement system for it to be defined as a performance measurement system. These are *measure design and selection*, *data capture* and *information provision*. Measure design and selection refers to the process of selecting what measures to use in order to assess the performance of the company. Data capture refers to the process of capturing the data needed to calculate the selected measures in the performance measurement system. Information provision refers to the process of presenting and distributing the results of the performance measurement.

For the remaining parts of this report, a performance measurement system will be referred to as consisting of the two features suggested by Franco-Santos et al. (2007): *performance measures* and *supporting infrastructure*, where supporting infrastructure is seen as consisting of information regarding who will use the metrics, how the data necessary for calculating the metrics will be gathered, and how the metrics will be presented. To summarize, drawn from the literature review, a performance measurement system will, in this report, consist of:

- A hierarchy of metrics
- Information regarding the organizational levels at which to use the metrics
- Information regarding the data gathering for calculating the metrics
- Information regarding the presentation of the metrics

2.1.2 Design of Performance Measurement System

What measuring attributes to choose is closely linked to the purpose of the performance measurement and by whom the measuring attributes should be used (Lebas, 1995). The importance of having the performance measurement system closely linked to the corporate strategy is a consideration that many authors share (Lebas, 1995; Bititci et al., 1997; Bourne et al., 2000; Neely et al., 2000; Lohman et al., 2004). The same goes for the importance of keeping the performance measurement system updated (Lebas, 1995; Bourne et al., 2000; Neely et al., 2000).

Neely et al. (1995) suggest a framework for performance measurement system design which divides the performance measurement system into three dimensions: Individual performance measures, Set of performance measures, and Relationship between performance measurement system and environment. The first dimension focuses on the individual performance measures, what they are used for and what they contribute with to the company. The second dimension views the performance measurement system as an own entity and focuses on the completeness of the system and relationships between the different performance measures included in the system. The third dimension focuses on the relationship between the performance measurement system, as an entity, and the environment in which the performance measurement system operates. The focus here is on the level of compatibility between the performance measurement system and the strategies, culture and structures within the company.

Lohman et al. (2004) suggest that the development of a performance measurement system is a coordination effort, rather than a design effort. By this, they emphasise the importance of understanding the current metrics in detail, identifying current shortcomings and taking ongoing initiatives into account.

2.1.3 Performance Measurement System of Supply Chain

A well-known performance measurement system created by APICS is the Supply Chain Operations Reference (SCOR) model (APICS, 2017). This model includes four dimensions: *Processes*, *Practices*, *People* and *Metrics*. The processes dimension provides a hierarchy of processes grouped under six main processes, which are Plan, Source, Make, Deliver, Return and Enable. The practices dimension includes emerging, standard as well as best practices for different sets of processes. The people dimension provides standards for managing talent in the supply chain. The last dimension, the metrics dimension, consists of measuring attributes grouped under five performance attributes: *Reliability*, *Responsiveness*, *Agility*, *Cost* and *Asset Management Efficiency*. According to Magnusson (2018), former member of APICS that has been involved on a high level in the organization, these performance attributes except *Agility* have an operational orientation. *Agility*, on the other hand, is of a more tactical and holistic level. This means that it provides a macro measurement rather than an operational one. By balancing the other four performance attributes against each other, different levels of agility could be achieved. The relationships between the different performance attributes and agility are, however, unknown. Magnusson (2018) emphasizes the difficulty in measuring agility, which is the reason for why the *Agility* part of the SCOR model is not fully developed nor tested.

In addition to the SCOR model, other authors have investigated the general features of performance measurement systems for supply chains. Caplice and Sheffi (1995) discuss the requirements of a performance measurement system to be customized to a company's unique logistical environment. The authors highlight six aspects to be considered when evaluating a logistical performance measurement system. These are summarized in table 2.1. The system should be comprehensive, causally oriented, vertically integrated, horizontally integrated, internally comparable, and useful. In order to be comprehensive, the system needs to capture the effects for each stakeholder of a policy and not only financial metrics. Causally means that it handles the root causes of a problem and not just the end results to raise the visibility of a long-term objective. Non-financial metrics are in general better to capture the root causes and indicate future performance compared to financial metrics that tend to give an internal focus and lead to myopic decision making. A system is vertically integrated if the overall strategy is translated into the related metrics for each decision-making level and it is horizontally integrated if the metrics cover and balance all different activities across different functions. For a system to be internally comparable, it has to be possible to make trade-offs between different metrics. Lastly, the system has to be useful, which means that it should be easy to understand and, thus, use. Caplice and Sheffi (1995) also argue that logistics performance measurement systems need to be transaction based, meaning that the system should not only be focused on the performance of an overall metric but, instead, also focus on sub-metrics. This is since the performance of the overall metric depends on several downstream players in the supply chain.

Table 2.1. Descriptions of the six evaluation criteria for measurement systems adopted from Caplice and Sheffi (1995, p. 288).

Criterion	Description
Comprehensive	The measurement system captures all relevant constituencies and stakeholder for the process.
Casually oriented	The measurement system tracks those activities and indicators that influence future as well as current performance.
Vertically integrated	The measurement system translated the overall firm strategy to all decision makers within the organization and is connected to the proper reward system.
Horizontally integrated	The measurement system includes all pertinent activities, functions, and departments along the process.
Internally comparable	The measurement system recognizes and allows for trade-offs between the different dimensions of performance.
Useful	The measurement system is readily understandable and provides a guide for actions to be taken.

Gunasekaran et al. (2001) also raise the issue with the lack of balance between financial and non-financial metrics in logistics performance measurement systems. Companies tend to focus on the financial performance metrics as they are important for strategic decision making and external reporting, but non-financial metrics are better describing the operations. The same authors also highlight the importance of dividing metrics into proper decision-making levels, such as operational, tactical and strategic levels, as well as making sure that appropriate metrics are assigned to the different operations in the supply chain: plan, source, production and delivery (Gunasekaran et al., 2001).

Caplice and Sheffi (1994) discuss the need of evaluating the individual metrics separately so that they reflect the operations fairly and do not contain any flaws that generate misleading data to the logistic management to base decisions on. One example of a flaw in a metric, that the authors describe, is the criteria for on time delivery that can be set too narrow in relation to the total ordering lead time. The authors performed a literature review to find suitable evaluation criteria for logistics measures. The review resulted in a number of eight different criteria: validity, robustness, usefulness, integration, economy, compatibility, level of detail and behavioural soundness (Caplice and Sheffi, 1994). The different criteria are further defined in table 2.2.

Table 2.2. Definitions of the eight evaluation criteria for metrics adopted from Caplice and Sheffi (1994, p. 14).

Criterion	Definition
Validity	The metric accurately captures the events and activities being measured and controls for any exogenous factors
Robustness	The metric is interpreted similarly by the users, is comparable across time, location & organizations, and is repeatable
Usefulness	The metric is readily understandable by the decision maker and provides a guide for action to be taken
Integration	The metric includes all relevant aspects of the process and promotes coordination across functions and divisions
Economy	The benefits of using the metric outweigh the costs of data collection, analysis, and reporting
Compatibility	The metric is compatible with the existing information, material and cash flows and systems in the organization
Level of Detail	The metric provides a sufficient degree of granularity of aggregation for the users
Behavioral Soundness	The metric minimizes incentives for counter-productive acts or game-playing and is presented in a useful form

2.2 Definition of Supply Chain Agility

There are plenty of different definitions of supply chain agility in literature, but no clear consensus of what the concept means (Sharma et al., 2017) and no accepted standard definition of the concept (Giachetti et al., 2003). According to Sharma et al. (2017), the main contradictions in the supply chain agility definitions in literature are having a strategic, capability-based or performance-based perspective when looking at the concept. They conducted a systematic literature review of 118 relevant articles within the area of supply chain agility published between the years 1999 and 2016. Based on these articles, they extracted a comprehensive definition of supply chain agility, which is *"...the strategic capability of a supply chain to quickly sense and respond to internal and external changes, either proactively or reactively, leveraging intra and inter-organizational capabilities in an effective manner that ensures profitability."* (Sharma et al., 2017, p. 543). This is the definition used in this project. Table 2.3 provides the definitions of supply chain agility found in literature. From these, it can be argued that a common characteristic for definitions of supply chain agility in research is the emphasis on the ability to adapt to change in some manner, which further justifies the selected definition above.

Table 2.3 Definitions of supply chain agility.

Author(s)	Definition supply chain agility
APICS (2017)	"*The ability to respond to external influences, the ability to respond to marketplace changes to gain or maintain competitive advantage*." (p. vii)
Arteta and Giachetti (2004)	"*The ability of an organization to adapt to change and also to seize opportunities that become available due to change*" (p. 495)
Braunscheidel and Suresh (2009)	"*A firm's supply chain agility (FSCA) is defined as the capability of the firm, both internally and in conjunction with its key suppliers and customers, to adapt or respond in a speedy manner to marketplace changes as well as to potential and actual disruptions, contributing to the agility of the extended supply chain*" (p. 119)
Christopher (2000)	"*The ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety.*" (p. 38)
Dove (2003)	"*The ability to manage and apply knowledge effectively, providing the potential for an organization to thrive in a continuously changing, unpredictable business environment*" (p. 329)
Gligor et al. (2013)	"*A firm's ability to quickly adjust tactics and operations within its supply chain to respond or adapt to changes, opportunities, or threats in its environment.*" (p. 95)
Ngai et al. (2011)	"*The capability of an organization to respond to market changes visible to customers using a set of supply chain competencies that enable such capability.*" (p. 233)
Sharifi and Zhang (1999)	"*The ability to cope with unexpected changes, to survive unprecedented threats of business environment, and to take advantage of changes as opportunities*." (p. 9)
Sharma et al. (2017)	"*The strategic capability of a supply chain to quickly sense and respond to internal and external changes, either proactively or reactively, leveraging intra and inter-organizational capabilities in an effective manner that ensures profitability.*" (p. 543)
Swafford et al. (2006)	"*The supply chain's capability to adapt or respond in a speedy manner to a changing marketplace environment.*" (p. 172)
Swafford et al. (2008)	"*The speed of the aggregate supply chain to adapt in a more customer-responsive manner.*" (p. 289)
Zhang and Sharifi (2007)	"*A manufacturing strategy that aims to provide manufacturing enterprises with competitive capabilities to prosper from dynamic and continuous changes in the business environment, reactively or proactively.*" (p. 352)

2.3 Concepts relating to Supply Chain Agility

In this section, concepts relating to supply chain agility are presented. Leanness is described followed by a description of the distinction or relationship between supply chain agility and leanness disputed in literature.

2.3.1 Leanness

There seems to be a broad consensus regarding the definition of leanness in research, where leanness is defined as doing more with less (Christopher, 2000; Agarwal et al., 2006) or as eliminating waste (Agarwal et al., 2006; Goldsby et al., 2006; Wee and Wu, 2009; Jasti and Kodali, 2015). This is done by improving value added activities and reducing non-value-added ones (Wee and Wu, 2009), which are not adding any value to the final product and are, hence, considered as waste (Jasti and Kodali, 2015). The lean concept is summarized in

Narasimhan et al.’s (2006, p. 443) definition of leanness: *“Production is lean if it is accomplished with minimal waste due to unneeded operations, inefficient operations, or excessive buffering in operations.”*, which is based on a literature study within the field.

2.3.2 Agility versus Leanness

Researchers have different views as to whether leanness and agility can be combined or not. Hallgren and Olhager (2009) recommend that lean and agile manufacturing should not be combined, since there is a negative relationship between having a cost leadership strategy and using agile manufacturing. They further emphasize that leanness and agility have different drivers and foster different operations capabilities and that leanness and agility, in turn, are aligned with different competitive strategies. Regarding performance outcomes, lean manufacturing has a greater impact on cost performance while agile manufacturing impacts flexibility (Hallgren and Olhager, 2009; Narasimham et al., 2006). Lean companies maximize profit through cost reduction and agile companies maximizes profit through providing exactly what the customers require (Agarwal et al., 2006). Hallgren and Olhager’s (2009) study further shows that agile manufacturing has no positive impact on cost performance, but that this is usually not a priority for agile companies, which instead often can charge a higher price due to their differentiation strategy. According to Goldsby and Garcia-Dastugue (2003) in Goldsby et al. (2006), companies using a lean approach and companies using an agile approach share a common goal of meeting the customer demand at the least cost possible, but that their demand characteristics and way of meeting the demand differ. At the same time, Narasimham et al. (2006) and Sharp et al. (1999) suggest that agility might presume leanness, while leanness might not presume agility. Sharp et al. (1999) further emphasis that a lean and an agile approach differ in several dimensions, both in terms of drivers, focus, suppliers, organisation, product, process and philosophy.

Other researchers suggest that leanness and agility can be combined into “leagility” (Naylor et al., 1999; Agarwal et al., 2006; Gaudenzi and Christopher, 2016), which is an emerging concept in research (Sharma et al., 2017). Leanness and agility is suggested to be able to complement each other if the company have an appropriate supply chain strategy (Naylor et al., 1999). There are different tactics for having a leagile approach (Sharma et al., 2017). Naylor et al. (1999) suggests a tactic that involves placing a decoupling point somewhere in the supply chain and use a lean approach upstream the decoupling point and an agile approach downstream the decoupling point. Upstream the decoupling point, efficiency should be measured, and downstream the decoupling point, effectiveness is a better metric (Gaudenzi and Christopher, 2016). Another tactic for having a leagile approach is to use the Pareto curve principle, which means using a lean approach for the 20% of the products that are most fast-moving and an agile approach for the 80% of the products being most slow-moving (Goldsby et al., 2006; Sharma et al., 2017). A third tactic for being leagile is to produce the company’s base level of demand in a lean way and to use additional capacity from outside as an agile element when peaks in demand (Goldsby et al., 2006).

2.4 Strategies for Achieving Supply Chain Agility

In this section, four strategies for achieving supply chain agility, mentioned in literature, are presented.

2.4.1 Supply Chain Integration

Integration is described as one important strategy to improve a firm's supply chain agility (Christopher, 2000; Hoek et al. 2001; Lin et al., 2006; Agarwal et al. 2007; Swafford et al. 2008). Lin et al. (2006) highlight two different types of supply chain integration: information integration and process integration. Information integration is defined as "*...the infrastructure of the supply chain, it includes the ability to use information technology to share data between buyers and supplies, thus effectively creating a virtual supply chain. Virtual supply chains are information-based rather than inventory-based*" (Lin et al., 2016, p. 288). The process integration is defined as "*...the foundation of the supply chain, process integration means that the supply chain is a confederation of partners linked into a network"* (Lin et al., 2016, p. 288). The two different types of supply chain integration are further described below.

Information Integration
By effectively coordinating information between different functions in the supply chain, the ability to monitor changes and react to them faster increases as the information processing lead times get shortened (Tarafdar and Qrunfleh, 2016). The use of IT systems enables companies to effectively manage information in terms of gathering, storing, sharing and accessing it. IT integration, in turn, represents the level of which an organization uses IT to integrate information. It enables real time information sharing and the possibility to coordinate the information, not only between an organization's functions, but also with the entire supply chain (Swafford et al., 2008). Swafford et al. (2008) conclude that IT integration has a direct positive impact on flexibility and, in turn, an indirect positive impact on the overall supply chain agility. The authors highlight the importance of also investing in IT integration while preparing for e-commerce to enable the coordination in the supply chain. For example, manufacturing need to have access to real time stock levels to plan the production efficiently (Swafford et al, 2008).

Process Integration
According to Hoek et al. (2001), process integration is a way to better handle changes and uncertainty by looking at the supply chain as a whole and collaborate across organizations. Agarwal et al. (2007) describe process integration as one essential part in order to build trust in the supply chain and that trust itself helps to generate accurate data in between the different tiers in the supply chain. Christopher (2000) argues that process integration is a prerequisite in order to fully benefit form information sharing in the supply chain. The process integration means that there is collaboration between the different parties in the supply chain, such as between supplier and buyer in terms of joint product development and information sharing. As firms have started to focus on managing their own core competencies and outsourcing other activities, process integration has become more important seeing that the dependence on suppliers has increased. A higher level of process integration may, in the end, lead to a supply chain with few boundaries as organizations use joint strategies and transparency of information (Christopher, 2000).

2.4.2 Positioning of the Decoupling Point

Depending on where a firm position the decoupling point (the point in the supply chain where the real demand drives the operations), the inventory setup should change. If the decoupling point is set at the manufacturer, the firm is more likely to carry inventory of raw materials and components. Meanwhile, if it is positioned further down in the supply chain, the firm is more likely to carry inventory of finished goods (Christopher, 2000). The postponement strategy is tightly connected to the decoupling point and to supply chain agility as it creates more flexibility and increases a firm's responsiveness (Christopher, 2000; Tarafdar and Qrunfleh, 2016; Um, 2016). The strategy means moving the decoupling point further downstream in the supply chain in order to delay the differentiation, which in turn creates the possibility to carry generic stocks. The generic stocks make it easier for a firm to forecast as there are fewer stock keeping variants that are spread over a larger number of final products. In addition, the delayed differentiation results in that the last stages of production are demand-driven instead of forecast-driven, which further reduces the demand uncertainty related to product variety (Christopher, 2000). Thus, by using generic stocks, a firm can quickly produce and deliver a wide range of products and increase the responsiveness to changes in customer demand (Tarafdar and Qrunfleh, 2016). Um (2016) also highlights the possibility for a firm to improve inventory turnaround and asset productivity by employing the strategy.

The postponement strategy relies on late differentiation that makes it possible for a firm to produce to orders instead of producing to stock. It also makes it possible for a firm to respond quickly to changes in customer preferences, which enables improvement in customer service. However, to achieve a large product variety by using generic stocks, the strategy relies on modularization where products are sharing the same modules or platform design. Hence, the strategy needs to incorporate a strong focus on product design. (Um, 2016)

2.4.3 Reduction of Complexity

Reducing complexity in the supply chain is another way to reach a higher level of supply chain agility (Christopher, 2000; Arteta and Giachetti, 2004; Um, 2016). Arteta and Giachetti (2004) have built a measure of a firm's agility based on assessing complexity with the motivation that less complex processes are easier to change and, hence, are more agile. Christopher (2000) describes an increased complexity as a natural result of a company's development. As companies grow they usually become more complex. Christopher (2000) further discusses that reducing complexity is a shared responsibility between the marketing and the logistics people, seeing that it is inherent in the product design, the structure of the organization and the design of the management processes. The ideas behind business process reengineering (BPR) movement can be seen as beneficial to decrease the complexity. BPR highlight the importance of reducing and eliminating non-value-adding activities which can be done by breaking down the organization into functional silos (Christopher, 2000). Another strategy is to focus on the human resources and build multi-skilled cross-functional working teams to increase organizational agility (Christopher, 2000). Um (2016) focuses on the product variety as the main driver of a company's complexity. By offering a wide product variety and a high level of product customization, the complexity in design, manufacturing and scheduling increase. Thus, a firm's offering needs to be balanced with the complexity it brings (Um, 2016).

2.4.4 Relationships

Leveraging good relationships in the supply chain is one way to increase supply chain agility (Christopher, 2000; Lin et al., 2006). Lin et al. (2006) argue that both the suppliers and customers are important in this regard, whilst Christopher (2000) focuses on the supplier relations. Having high quality supplier relations make it easier to improve responsiveness to sudden market changes as the suppliers otherwise tend to limit the responsiveness. For example, the lead time for introduction of new products could be substantially shortened by involving the supplier in the development process (Christopher, 2000). To achieve good supplier relations, one prerequisite is to limit the supplier base to only focusing on a few suppliers and create mutual dependencies where both parties see themselves as vital links in the supply chain. By doing so, the possibility to find suppliers that are willing to synchronize operations in accordance with the company need increases. However, the danger of single sourcing must still be recognized. Another precondition, previously described in relation to supply chain integration, is the need for a high level of information sharing and trust in order to create a clear visibility downstream the supply chain. Lastly, a third precondition is to have a high connectivity with strategic suppliers, meaning that apart from a high level of information sharing, there should also be a close collaboration across the organization at all levels (Christopher, 2000).

2.5 Supply Chain Agility Capabilities

Different authors have different views on what capabilities that constitute supply chain agility. Most authors describe supply chain agility by using a couple of capabilities. Dove (2003) argues that agility can be achieved by two key enablers, knowledge management and response ability. The knowledge management relates to the fact that companies need to control new valuable information and the response ability refers to how quick companies can apply the new knowledge (Dove, 2003).
Braunscheidel and Suresh (2009) use flexibility and integration as key capabilities for describing supply chain agility meanwhile Ngai et al. (2011) emphasise the importance of three different supply chain competences: IT competence, operational competence and management competence. Swafford et al. (2006) instead focus on three dimensions of flexibility constituting supply chain agility: procurement/sourcing flexibility, manufacturing flexibility and distribution/logistics flexibility. Other authors extend their view of supply chain agility to include more capabilities. Gligor et al. (2013) suggest that supply chain agility consist of five capabilities: alertness, accessibility, decisiveness, swiftness and flexibility. Alertness is defined as the ability to quickly detect changes, accessibility is defined as the ability to access relevant data, and decisiveness is defined as the ability to make decisions resolutely. These capabilities together constitute the cognitive part of agility. The other part, the physical one, consists of swiftness and flexibility, where swiftness being defined as the ability to implement decisions quickly and flexibility being defined as the ability to modify the range of tactics and operations to the extent needed. Zhang and Sharifi (2007) use a total number of seven supply chain capabilities to describe agility: responsiveness, flexibility, quickness, competency, proactiveness, partnership and focusing on customer.

Even though there is no clear consensus in the literature of which capabilities that constitute supply chain agility, there are still several similarities. Many authors describe responsiveness, flexibility, quickness and competency as the four main capabilities of supply chain agility (Sharifi and Zhang, 1999; Zhang and Sharifi, 2000; Lin et al., 2006; Khalili-Damghani and

Tavana, 2013). These four capabilities are also the ones most frequently mentioned in literature. A list of selected authors and their view of the capabilities constituting supply chain agility is presented in table 2.4.

The four main capabilities of supply chain agility are further described in the remaining parts of this section.

Table 2.4. Capabilities constituting supply chain agility. Two stars (**) represents that the capabilities of supply chain agility have a central role in the literature. One star (*) represents that the capabilities are mentioned in the literature, but that it does not have a central role.

Author	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**	**Intra-Organizational Integration**	**Inter-Organizational Integration**	**Alertness**	**Accessibility of Information**	**Decisiveness**	**Proactiveness**	**Customer Focus**
Braunscheidel and Suresh (2009)		**			**	**					
Christopher (2000)	**	**	**	**		*	*	*			
Dove (2003)	**							**			
Gligor et al. (2013)	**	**					**	**	**		
Khalili-Damghani and Tavana (2013)	*	*	*	*							
Lin et al. (2006)	*	*	*	*							
Ngai et al. (2011)	*	*		**		*		*			
Sangari et al. (2015)				*	*	*		*			
Sharifi and Zhang (1999)	**	**	**	**							
Sharma et al. (2017)	*	*		*	*	*		*			
Swafford et al. (2006)	*	**									
Swafford et al. (2008)	**	**	*		*	*					
Zhang and Sharifi (2000)	**	**	**	**							
Zhang and Sharifi. (2007)	**	**	**	**		**				**	**

2.5.1 Responsiveness

Responsiveness is mentioned much in the supply chain agility literature (Sharifi and Zhang, 1999; Christopher, 2000; Zhang and Sharifi, 2000; Dove, 2003; Lin et al., 2006; Zhang and Sharifi, 2007; Khalili-Damghani and Tavana, 2013; Sharma et al., 2017) and is often directly included in or directly connected to the definitions of supply chain agility presented in literature. To mention a few, Christopher (2000, p. 38) defines agility as "*the ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety*", Dove (2003, p. 309) describes it as being characterized as "*deriving from a balance of physical ability to act (response ability) and the intellectual ability to understand what to act upon (knowledge management)*" and Swafford et al. (2006, p. 172) define agility as "*the supply chain's capability to adapt or respond in a speedy manner to a changing marketplace environment*". It could be argued that these definitions are directly linked to responsiveness. Zhang and Sharifi (2000) even point out that responsiveness is the most essential capability out of the suggested four and that the other three capabilities; flexibility, quickness and competency; act as necessary elements to achieve responsiveness.

The definitions of responsiveness in the literature are similar to each other. Khalili-Damghani and Tavana (2013, p. 296) define responsiveness as "*sensing, perceiving and anticipating changes, immediate reaction to changes by incorporating them into the system, and recovery from change*", Lin et al. (2006, p. 287-288) define it in their work as "*the ability to identify changes and respond to them quickly, reactively or proactively, and also to recover from them*" and Zhang and Sharifi (2007, p. 354) define it as "*the capability to identify, respond to and recover from changes*". It can be argued that three common sub-capabilities of responsiveness could be extracted from these definitions:

- Identify change
- React to change
- Recover from change

The first sub-capability, identify change, would include the sensing, perceiving and anticipating of change; the second sub-capability, react to change, would include the immediate reaction or response to change; and the third sub-capability, recover from change, would include the long-term recovery from change. Also, other capabilities of supply chain agility, that other authors have suggested, that do not explicitly name responsiveness as one of the main dimensions of supply chain agility can be argued to have similarities to the three sub-capabilities above. Of Gligor et al.'s (2013) suggested capabilities presented above, it could for example be argued that both alertness and accessibility are included in identify change, while decisiveness and swiftness could be argued to be a part of react to change.

2.5.2 Flexibility

Many authors describe flexibility as a key capability of supply chain agility (Sharifi and Zhang, 1999; Zhang and Sharifi, 2000; Lin et al., 2006; Zhang and Sharifi, 2007; Swafford et al., 2008; Braunscheidel and Suresh, 2009; Gligor et al., 2013; Khalili-Damghani and Tavana, 2013; Sharma et al., 2017). Christopher (2000) even suggests that the origins of agility lies in a flexible production. Also, Swafford et al. (2006) emphasise the importance of flexibility in the agility context. They suggest that an organization's agility is derived from three different kinds of flexibility inherent in the three main processes: procurement/sourcing, manufacturing and distribution/logistics, which would mean that they suggest flexibility to be the main capability of agility. However, Zhang and Sharifi (2007) suggest that flexibility differ in importance for different companies depending on the company philosophy. Flexibility is suggested to be essential for responsive players meanwhile it is less important for proactive and quick players. Also, Beamon (1999) suggests that different types of flexibility are suitable for different kind of supply chains. Swafford et al. (2008) also conclude that flexibility related to the manufacturing and distribution, hence closer to the customer, has a higher impact on a firm's agility performance and that shorter lead times enable flexibility. This would mean that the quickness capability of supply chain agility influences the flexibility capability.

There are different opinions in literature regarding the definition and dimensions of flexibility. This is since the assessment of flexibility of a system is complex (Beamon, 1999). Zhang and Sharifi (2007, p. 354) define flexibility as "*the capability to perform different tasks and achieve different objectives with the same set of resources/facilities.*" while Swafford et al. (2008, p. 290) describe it as representing "*those abilities of reducing supply chain lead time, ensuring production capacity, and providing product variety while fulfilling customer expectations*" and Gligor et al. (2013, p. 97) define it as "*the ability to modify the range of tactics and operations to the extent needed*". Both Lin et al. (2006) and Khalili-Damghani and Tavana (2013) use definitions similar to the one suggested by Zhang and Sharifi (2007) in their works which, according to this literature review, seems to be the most common definition of flexibility in agility contexts.

Regarding the capabilities of flexibility, there are several mentioned in literature. Gerwin (2005) suggests seven sub-capabilities of flexibility: volume flexibility, mix flexibility, changeover flexibility, modification flexibility, rerouting flexibility, material flexibility and sequencing flexibility. Braunscheidel and Suresh (2009) instead make the conclusion that there are two main flexibility dimensions:

- Mix flexibility
- Volume flexibility

The mix flexibility relates to the product variety a firm uses to meet changing customer demand and that can be produced effectively and efficiently. The volume flexibility, on the other hand, relates to the ability of a firm to change the output level without compromising performance either from a cost or quality perspective. These dimensions are also described as sub-capabilities of flexibility by several other authors (Beamon, 1999; Sharifi and Zhang, 1999; Gerwin, 2005; Khalili-Damghani and Tavana, 2013). It can also be argued that the definitions of flexibility mentioned above support these two sub-capabilities being part of flexibility.

2.5.3 Quickness

Quickness is described as another important capability of supply chain agility (Sharifi and Zhang, 1999; Christopher, 2000; Zhang and Sharifi, 2000; Lin et al., 2006; Zhang and Sharifi, 2007; Khalili-Damghani and Tavana, 2013). The definitions of this capability in literature are quite similar to each other. Lin et al. (2006, p. 288) define quickness as "*the ability to complete an activity as quickly as possible*". Zhang and Sharifi (2007) use a similar definition. So does Sharifi and Zhang (1999), but with the additional explanation of the constitutions of the capability, being: quick new products time to market, products and services delivery quickness and timeliness and fast operations time. Khalili-Damghani and Tavana (2013, p. 296) use a similar definition expressed as "*develop new products quickly for the market, products and services delivery quickness and timeliness, and fast operation time*".

From the presented definitions of quickness in agility contexts, it can be argued that three sub-capabilities of quickness could be extracted:

- Operations lead time
- Delivery lead time and timeliness
- New product time to market

2.5.4 Competency

Another capability of supply chain agility presented in literature is competency (Sharifi and Zhang, 1999; Christopher, 2000; Zhang and Sharifi, 2000; Lin et al., 2006; Zhang and Sharifi, 2007; Khalili-Damghani and Tavana, 2013; Sangari et al., 2015; Sharma et a., 2017). Christopher (2000) argues that in order to compete on today's market, companies need to leverage the competencies of the network. By doing so, the responsiveness to the market needs also increases.

The definitions of the capability are quite similar in research but the opinions of the constituents of competency differ. Zhang and Sharifi (2007, p. 354) define competency as "*the capability to operate efficiently, produce high-quality and high-performance products, deliver on time, innovate, and manage core competency*". A less detailed definition is given by Lin et al. (2006, p. 288) who describe it as "*the ability to efficiently and effectively realize enterprise objectives*". A similar definition is given by Sharifi and Zhang (1999) who also identifies ten abilities that constitutes competency: strategic vision; appropriate technology or sufficient technological ability; products/services quality; cost effectiveness; high rate of new products introduction; change management; knowledge, competent and empowered people; operations efficiency and effectiveness; cooperation; integration. Khalili-Damghani and Tavana (2013, p. 296) describe similar sub-capabilities being part of competency and define the capability as the ability of "*developing business practices difficult to copy*". Sangari et al. (2015) say that competency especially contribute in achieving supply chain agility is human or cultural competence, which consist of three types of competence: management competence, employee competence and the competence of creating a culture of learning and change. The management competence includes the ability of making appropriate responses to market changes and to make use of inter-organizational collaboration to work proactively in identifying opportunities and to lever marketing strategy. The competence of employees refers to the ability of the employees to support the top-management decisions and to implement a firm's response to internal and external changes. The creation of a culture of learning and change includes an aim to focus on continuous improvement and learning as well as on minimizing of resistance to change, which is important to support the management and employee competence. Ngai et al. (2011) have a similar view of management competence being part of the competence that supports supply chain agility and describes it as the firm's ability to use human resources. However, they also highlight two additional dimensions of a firm's supply chain competence, namely information technology (IT) competence and operational competence. The IT competence is described as the ability of a firm to effectively utilize IT to manage information and provide a foundation for supply chain agility. The operational competence is referred to as the ability of a firm to manage its resources to facilitate supply chain agility.

Since there are a large variety of views on the dimensions of competency, there are no common sub-capabilities to be identified in literature.

2.5.5 Summary of Capabilities

To summarize, based on the literature review performed in this project, four capabilities of supply chain agility has been identified. Within each of these capabilities, various numbers of sub-capabilities has been extracted from literature. A summarizing picture of the constituents of supply chain agility based on this literature review is shown in figure 2.1.

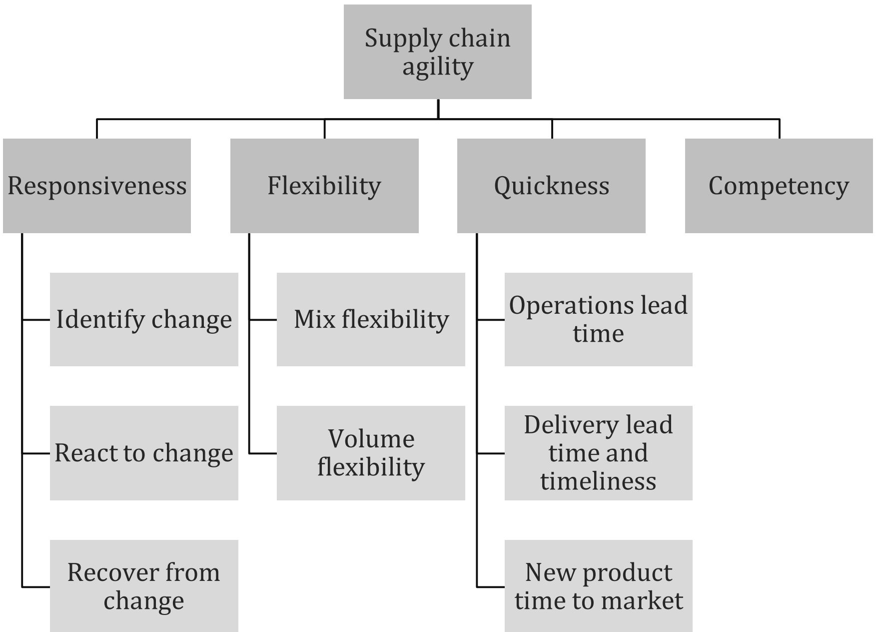

Figure 2.1. Capabilities and sub-capabilities of supply chain agility.

2.6 Areas of Measurement for Supply Chain Agility

Supply chain agility is a relatively new concept in literature (Sharma et al, 2017) and, hence, a consensus of agility measurements has not emerged yet (Giachetti et al., 2003). However, supply chain agility has been an area of academic interest the recent years and up to date the relationship between supply chain agility and some different groups of performance measures has been seen (Sharma et al., 2017). However, the inter-relationships of these performance measures are not validated in research.

In the remaining of this section relevant areas for measuring supply chain agility, extracted from literature, will be presented grouped under the four capabilities: responsiveness, flexibility, quickness and competency. The relevant areas are areas mentioned in literature as important to supply chain agility and could be in various forms, for example suggested measures of supply chain agility, suggested dimensions of measurement of supply chain agility, features connected to strategies for achieving a higher level of supply chain agility, etc.

2.6.1 Responsiveness

The relevant areas for measuring responsiveness found in literature are grouped under the three sub-capabilities identified in section 2.5.1, namely identify change, react to change and recover from change.

Identify Change
Lin et al. (2006) suggest several enabling attributes of supply chain agility including capturing demand information quickly, making information accessible in the whole of the supply chain and actively share knowledge with partners. These are connected to having access to updated information throughout the whole supply chain to reach a high level of supply chain agility. Tsourveloudis and Valavanis (2002) are of similar opinion and suggest two important aspects of the information infrastructure that is needed to enable a high level of supply chain agility, namely interoperability and networking. Interoperability refers to

information standardization as well as to proper exchange and storage of information. Networking refers to the ability to exchange information, which influences the ability to utilize information. Zhang and Sharifi (2007) also emphasize information sharing as an important agility provider. In the context of external relationships to the organization, they see it as important that suppliers continually receive adequate information and are informed of decisions. Also, within the organization, they emphasize a free flow of information important for enabling agility.

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of identifying change is shown in table 2.5. It could be argued that these suggested agility attributes are connected to the sub-capability identify change and that they could be grouped under the two themes: information update and information access. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.5.

Table 2.5. Suggested metrics for the sub-capability identify change.

Authors	Agility attributes	Suggested metrics
INFORMATION UPDATE		
Lin et al. (2006)	Capture demand information immediately	Time delay in sharing customer demand information in supply chain
INFORMATION ACCESS		
Lin et al. (2006)	Information accessible supply chain-wide	Level of external information sharing in supply chain Level of internal information sharing in organization Level of standardization in information sharing
Lin et al. (2006)	Actively share intellectual property with partners	
Tsourveloudis and Valavanis (2002)	Interoperability	
Tsourveloudis and Valavanis (2002)	Networking	
Zhang and Sharifi (2007)	Suppliers are audited, ranked and informed of decisions	
Zhang and Sharifi (2007)	Suppliers are fed continually with adequate information	
Zhang and Sharifi (2007)	Free flow of information and communication	
Zhang and Sharifi (2007)	Information is distributed company-wide to empower people	

React to Change

Swafford et al. (2008) suggest a couple of time-related measurements of supply chain agility that emphasize the importance of making changes happen in a speedy manner for the company to be agile. Speed in reducing manufacturing lead time, speed in increasing frequency of new product introductions, speed in adjusting delivery capability and speed in improving responsiveness to changing market needs are included among these. Other time-related measurements are found in the agility dimension of SCOR (APICS, 2017). One of these is the time required to find or obtain additional sources. A less general one, also mentioned in SCOR (APICS, 2017), is focusing on the time it takes to negotiate new contracts with suppliers. Other authors that suggest time-related measurements of agility are

Tsourveloudis and Valavanis (2002), who suggest sustainability and expansion ability as two agility providers. Sustainability is seen as connected to the ability to reroute and reschedule jobs effectively and expansion ability is seen as connected to the time and cost needed to increase or decrease capacity. They also suggest a production infrastructure dimension as part of agility measurement and thereby part variety, which is the number of products the manufacturing system can handle in a time period, as a suggested measure for this. Arteta and Giachetti (2004) more generally suggest ease of change as a constituent of agility, which is seen as being connected to the time and cost of change projects. They also suggest complexity as the overall measure of agility, which they suggest consists of the individual activities of the process, the actors, and the flows between them. Another measure connected to agility found in SCOR (APICS, 2017) is the current finished goods inventory on hand required to sustain current order fulfilment. This adds an inventory dimension to agility together with the suggested measurement of the number of worldwide storage or distribution facilities that is suggested by Sethi and Sethi (1990) in Swafford et al. (2006).

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of reacting to change is shown in table 2.6. It could be argued that these suggested agility attributes are connected to the sub-capability react to change and that they could be grouped under the four themes: time to change, effort of change, ability to change and inventory. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.6.

Table 2.6. Suggested metrics for the sub-capability react to change.

Authors	**Agility attributes**	**Suggested metrics**
	TIME TO CHANGE	
APICS (2017)	Time required in negotiating new source/volume contracts/terms	
APICS (2017)	Time required to find/obtain additional sources	Time to increase/decrease source/production/delivery capacity
Arteta and Giachetti (2004)	Ease of change	
Swafford et al. (2008)	Speed in reducing manufacturing lead time	
Swafford et al. (2008)	Speed in increasing frequencies of new product introductions	Time to reduce production lead time
Swafford et al. (2008)	Speed in adjusting delivery capability	
Swafford et al. (2008)	Speed in improving responsiveness to changing market needs	Time to reroute or reschedule operations in production
Tsourveloudis and Valavanis (2002)	Sustainability	
Tsourveloudis and Valavanis (2002)	Expansion ability	
	EFFORT OF CHANGE	
Arteta and Giachetti (2004)	Complexity	Number of actors involved in decision making process

ABILITY TO CHANGE		
Tsourveloudis and Valavanis (2002)	Part variety	Number of new products the manufacturing system can handle in a given time period
INVENTORY		
APICS (2017)	Current finished goods inventory on hand required to sustain current order fulfilment	Number of inventory locations in supply chain
Sethi and Sethi (1990) in Swafford et al. (2006)	Number of worldwide storage/distribution facilities	

Recover from Change

The measurements connected to this sub-capability in literature are all found in SCOR (APICS, 2017). Some of them are connected to the reestablishment of cycle times after an increase or decrease in product volumes. Others are connected to the amount of inventory that can be phased in or out without cost penalty given 30 days.

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of recovering from change is shown in table 2.7. It could be argued that these suggested agility attributes are connected to the sub-capability recover from change and that they could be grouped under the two themes: recovery time and recovery inventory. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.7.

Table 2.7. Suggested metrics for the sub-capability recover from change.

Authors	**Agility attributes**	**Suggested metrics**
RECOVERY TIME		
APICS (2017)	Procurement order cycle time re-established and sustained for increased quantities sources given 30 days	Time to re-establish and sustain source/production/delivery lead time after increased/decreased product volumes
APICS (2017)	Procurement order cycle time re-established and sustained for decreased quantities sources given 30 days	
APICS (2017)	Manufacturing cycle time re-established and sustained for increased quantities produced given 30 days	
APICS (2017)	Manufacturing cycle time re-established and sustained for decreased quantities produced given 30 days	
APICS (2017)	Logistics cycle time re-established and sustained for increased quantities delivered given 30 days	
APICS (2017)	Logistics cycle time re-established and sustained for decreased quantities delivered given 30 days	

RECOVERY INVENTORY		
APICS (2017)	Amount of inventory that can be obtained, delivered and phased in and sustained for order fulfilment given 30 days	Amount of inventory that can be phased in/out and be sustained in a given time period
APICS (2017)	Amount of inventory that can be returned, sold or diverted without cost penalty to ramp down to decreased quantities delivered given 30 days	

2.6.2 Flexibility

The relevant areas for measuring flexibility found in literature are grouped under the two sub-capabilities identified in section 2.5.2, namely mix flexibility and volume flexibility.

Mix Flexibility
Beamon (1999) defines mix flexibility as the ability to change the variety of products produced. The measurements found in literature that can be connected to mix flexibility seems to support this definition. Swafford et al. (2008) suggest a flexibility measure of the ability to accommodate changes in the production mix. A similar measure is suggested by Sethi and Sethi (1990) in Swafford et al. (2006). Slack (1991) in Beamon (1999) suggest that the number of different products that can be produced within a given time period is a measure of mix flexibility.

Tsourveloudis and Valavanis (2002) identify the following measures to be part of measuring agility: part commonality, versatility, operation commonality, reconfigurability and the range of adjustments that is possible. Part commonality refer to the number of common parts in final products, versatility refers to the variety in operations a system can perform, operation commonality refers to the similarity between different operations, reconfigurability refers to the set of part types that can be produced within a setup and the range of adjustments refers to the adjustability of the system. Sethi and Sethi (1990) in Swafford et al. (2006) find that the number of different manufacturing routings for each product is influencing agility and Gerwin (2005) suggest that measuring the number of components handled by the equipment as a measure of mix flexibility. The number of suppliers selected per component is another measurement that could contribute in measuring agility (Kekre et al., 1995 in Swafford et al., 2006). Other production related measurements are suggested by Sethi and Sethi (1990) in Giachetti et al. (2003), Tsubone and Horikawa (1999) in Giachetti et al. (2003) and Chang et al. (1989) in Giachetti et al. (2003). Connected to the manufacturing process, Chandra and Tombak (1992) in Swafford et al. (2006) suggest that the number of different tasks that a typical worker can perform could be measured as part of the flexibility measurement.

Another dimension of mix flexibility found in literature is focused on the effort of changing between production of different products. The effort is either connected to the time to change (Taymaz, 1989 in Giachetti et al., 2005; Slack, 1991 in Beamon, 1999; Sharifi and Zhang, 1999 in Swafford et al., 2006), the cost to change (Taymaz, 1989 in Giachetti et al., 2005) or both (Tsourveloudis and Valavanis, 2002).

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of mix flexibility is shown in table 2.8. It could be argued that these suggested agility attributes are connected to the sub-capability mix flexibility and that they could be grouped under the four themes: product, manufacturing setup, effort to change and people. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.8.

Table 2.8. Suggested metrics for the sub-capability mix flexibility.

Authors	**Agility attributes**	**Suggested metrics**
PRODUCT		
Kekre et al. (1995) in Swafford et al. (2006)	Number of suppliers selected per component on a global basis	Percentage of common parts in final products
Tsourveloudis and Valavanis (2002)	Part commonality	Number of suppliers per product or component
MANUFACTURING SETUP		
Chang et al. (1989) in Giachetti et al. (2003)	Average number of machines capable of processing an operation	Number of different products that a manufacturing setup can handle Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup
Gerwin (2005)	Number of components handled by the equipment	
Sethi and Sethi (1990) in Giachetti et al. (2003)	Ratio of the number of operations that can be processed without changing the setup when switching to another operation to the total number of operations processed	
Sethi and Sethi (1990) in Giachetti et al. (2003)	Ratio of operations a machine can perform/switching cost	
Sethi and Sethi (1990) in Swafford et al. (2006)	Accommodate changes in production mix as required	
Sethi and Sethi (1990) in Swafford et al. (2006)	Number of different manufacturing routings for each product	
Slack (1991) in Beamon (1999)	Number of different products that can be produced within a given time period	
Swafford et al. (2008)	Ability to accommodate changes in the production mix	
Tsubone and Horikawa (1999) in Giachetti et al. (2003)	Ratio of the number of operations performable on an alternative machine to the total number of operations assigned a certain machine	
Tsourveloudis and Valavanis (2002)	Versatility	
Tsourveloudis and Valavanis (2002)	Range of adjustments or adjustability	
Tsourveloudis and Valavanis (2002)	Operation commonality	
Tsourveloudis and Valavanis (2002)	Reconfigurability	

EFFORT TO CHANGE		
Sharifi and Zhang (1999) in Swafford et al. (2006)	Reduce setup/changeover time	Cost of changing operations from one product to another product
Slack (1991) in Beamon (1999)	Time required to produce a new product mix	
Taymaz (1989) in Giachetti et al. (2003)	Cost to set up from one operation to another operation	
Tsourveloudis and Valavanis (2002)	Changeover effort	Time to change operations from one product to another product
Taymaz (1989) in Giachetti et al. (2003)	Time to reset from one operation to another operation	
PEOPLE		
Chandra and Tombak (1992) in Swafford et al. (2006)	Number of different tasks the typical worker can perform	Number of different tasks the typical worker can perform

Volume Flexibility

Beamon (1999) defines volume flexibility as the ability to change the output level of products produced. Another consideration regarding this kind of flexibility influencing agility is that it defines the range of volume over which the firm can run profitably (Tsourveloudis and Valavanis, 2002). The measurements found in literature that can be connected to volume flexibility seems to support these definitions. Some of them refers to the cost of changing volumes (Beamon, 1999), others to the ability of changing volumes (Swafford et al., 2008) in terms of both cost and time (Tsourveloudis and Valavanis, 2002).

Other measurements relate to the supplier base and how the capacity can be changed within and between them (Sethi and Sethi, 1990 in Swafford et al., 2006; Kekre et al., 1995 in Swafford et al., 2006). SCOR (APICS, 2017) provides additional measures regarding the flexibility of the company’s resources within its agility dimension.

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of volume flexibility is shown in table 2.9. It could be argued that these suggested agility attributes are connected to the sub-capability volume flexibility and that they could be grouped under the two themes: effort to change and resources. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.9.

Table 2.9. Suggested metrics for the sub-capability volume flexibility.

<table>
<tr><th>Authors</th><th>Agility attributes</th><th>Suggested metrics</th></tr>
<tr><td colspan="3">EFFORT TO CHANGE</td></tr>
<tr><td>Beamon (1999)</td><td>Cost associated with volume changes</td><td rowspan="7">Cost of increasing/decreasing source/production/delivery capacity in a given time period

Number of suppliers per product or component</td></tr>
<tr><td>Kekre et al. (1995) in Swafford et al. (2006)</td><td>Number of suppliers selected per component on a global basis</td></tr>
<tr><td>Swafford et al. (2008)</td><td>Ability to change production volume capacity</td></tr>
<tr><td>Sethi and Sethi (1990) in Swafford et al. (2006)</td><td>Extent to which supplier short-term capacity can be influenced</td></tr>
<tr><td>Sethi and Sethi (1990) in Swafford et al. (2006)</td><td>Influence supplier's short-term capacity</td></tr>
<tr><td>Sethi and Sethi (1990) in Swafford et al. (2006)</td><td>Change volume allocation among existing suppliers on a global basis</td></tr>
<tr><td>Tsourveloudis and Valavanis (2002)</td><td>Expansion ability - time and cost needed to increase/decrease capacity</td></tr>
</table>

<table>
<tr><th colspan="3">RESOURCES</th></tr>
<tr><td>APICS (2017)</td><td>Amount of staff that can be recruited/hired and trained to increase and sustain quantities sourced given 30 days</td><td rowspan="10">Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period

Amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period

Amount of capacity that can be obtained/terminated to increase/decreased and sustain quantities sourced/produced/delivered in a given time period</td></tr>
<tr><td>APICS (2017)</td><td>Amount of staff that can be laid-off or diverted to other activities without cost penalty to decrease quantities delivered given 30 days (connected to Source)</td></tr>
<tr><td>APICS (2017)</td><td>Amount of staff that can be recruited/hired and trained to increase and sustain quantities produced given 30 days</td></tr>
<tr><td>APICS (2017)</td><td>Amount of staff that can be laid-off or diverted to other activities without cost penalty to decrease quantities delivered given 30 days (connected to Make)</td></tr>
<tr><td>APICS (2017)</td><td>Amount of assets/capacity that can be obtained to increase and sustain quantities produced given 30 days</td></tr>
<tr><td>APICS (2017)</td><td>Amount of capital equipment assets that can be recycled or sold without cost penalty to decrease quantities delivered given 30 days (connected to Make)</td></tr>
<tr><td>APICS (2017)</td><td>Amount of staff that can be recruited/hired and trained to increase and sustain quantities delivered given 30 days</td></tr>
<tr><td>APICS (2017)</td><td>Amount of staff that can be laid-off or diverted to other activities without cost penalty to decrease quantities delivered given 30 days</td></tr>
<tr><td>APICS (2017)</td><td>Amount of assets/capacity that can be obtained to increase and sustain quantities delivered given 30 days</td></tr>
<tr><td>APICS (2017)</td><td>Amount of capital equipment assets that can be recycled or sold without cost penalty to decrease quantities delivered given 30 days</td></tr>
</table>

2.6.3 Quickness

The relevant areas for measuring quickness found in literature are grouped under the three sub-capabilities identified in section 2.5.3, namely operations lead time, delivery time and timeliness, and new product time to market.

Operations Lead Time

The measurements within this sub-capability are all related to the time it takes to source and produce products. Sharifi and Zhang (1999) in Swafford et al. (2006) suggest that the ability to reduce the manufacturing lead times is a way of measuring supply chain agility. Similar to this, Swafford et al. (2008) suggest that the ability to reduce manufacturing throughput times to satisfy customer delivery is contributing in achieving supply chain agility. The manufacturing cycle time is also measured as part of the agility dimension in SCOR (APICS, 2017), which is also the case for procurement cycle time.

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of operations lead time is shown in table 2.10. It could be argued that these suggested agility attributes are connected to the sub-capability operations lead time and that they could be grouped under the two themes: production lead time and source lead time. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.10.

Table 2.10. Suggested metrics for the sub-capability operations lead time.

Authors	Agility attributes	Suggested metrics
PRODUCTION LEAD TIME		
APICS (2017)	Manufacturing cycle time	Production lead time
Sharifi and Zhang (1999) in Swafford et al. (2006)	Reduce manufacturing lead times	
Swafford et al. (2008)	Ability to reduce manufacturing throughput times to satisfy customer delivery	
SOURCE LEAD TIME		
APICS (2017)	Procurement cycle time	Source lead time

Delivery Lead Time and Timeliness

The measurements found in literature that is connected to this sub-capability are focusing on the time it takes to deliver the products. Goldman et al. (1994) in Swafford et al. (2006) suggest that the ability to reduce the delivery lead times is a way of measuring supply chain agility. In the agility measurement section of SCOR (APICS, 2017), both the logistics order cycle time and the percentage of orders with on time and accurate documentation are mentioned.

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of delivery lead time and timeliness is shown in table 2.11. It could be argued that these suggested agility attributes are connected to the sub-capability delivery lead time and timeliness and that they could be grouped under the two themes: delivery lead time and timeliness. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.11.

Table 2.11. Suggested metrics for the sub-capability delivery lead time and timeliness.

Authors	Agility attributes	Suggested metrics
DELIVERY LEAD TIME		
APICS (2017)	Logistics order cycle time	Delivery lead time
Goldman et al. (1994) in Swafford et al. (2006)	Reduce delivery lead time	
TIMELINESS		
APICS (2017)	Percentage of orders with on time and accurate documentation	Percentage of orders on time and with accurate documentation

New Product Time to Market
The measurements found in literature that are connected to this sub-capability are focused on the time it takes to develop and introduce new products. Lin et al. (2006) argue that fast introduction of new products is part of one main enabling attribute in achieving supply chain agility. Similarly, Goldman et al. (1994) in Swafford et al. (2006) suggest that the ability to decrease ramp-up time for new products and the ability to reduce product development cycle time are ways of measuring supply chain agility.

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of new product time to market is shown in table 2.12. It could be argued that these suggested agility attributes are connected to the sub-capability new product time to market and that they could be grouped under the two themes: product development time and introduction time new products. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.12.

Table 2.12. Suggested metrics for the sub-capability new product time to market.

Authors	**Agility attributes**	**Suggested metrics**
PRODUCT DEVELOPMENT TIME		
Goldman et al. (1994) in Swafford et al. (2006)	Reduce product development cycle time	Product development lead time
INTRODUCTION TIME NEW PRODUCTS		
Goldman et al. (1994) in Swafford et al. (2006)	Decrease ramp-up time for new products	Time to introduce new products
Lin et al. (2006)	Fast introduction of new products	

2.6.4 Competency

The relevant areas for measuring competency found in literature are not grouped under any sub-capabilities since these could not be clearly extracted from the literature described in section 2.5.4.

Zhang and Sharifi (2007) and Lin et al. (2006) both suggest that good relationships with other supply chain actors are an important enabler of agility. Lin et al. (2006) put emphasis on the trust dimension of relationships while Zhang and Sharifi (2007) suggest that the number of suppliers as well as their involvement in product development and planning activities influence agility. Toni et al. (1994) in Gunasekaran et al. (2001) highlight that the level of partnership could be measured by the stage at which the supplier gets involved in the operations of the customer organization. Other authors suggest that partnership could be measured by the level of mutual improvement initiatives and problem-solving efforts between the supplier and customer (Graham et al., 1994 in Gunasekaran et al., 2001; Thomas and Griffin, 1996 in Gunasekaran et al, 2001; Maloni and Benton, 1997 in Gunasekaran et al., 2001).

Another enabling attribute within the competency capability of agility is suggested to be vertical integration (Lin et al., 2006; Zhang and Sharifi, 2007). This is connected to the operations efficiency and effectiveness dimension of competency.

Many authors also emphasis the technology dimension of competency being important in achieving agility (Lin et al., 2006; Zhang and Sharifi, 2007; Swafford et al., 2008). Swafford et al. (2008) also suggest several areas of use of IT to coordinate and integrate activities in the supply chain.

Zhang and Sharifi (2007) highlight people to be another agility provider. They suggest that employees at all levels should contribute in decision making to reach agility and that the people should be trained and trusted. Tsourveloudis and Valavanis (2002) also emphasis the level of training in terms of education and cross-training programs as a part of a measure of agility. They also suggest job rotation as another part. Lin et al. (2006) as well as Zhang and Sharifi (2007) further suggest team based structures and goals being part of agility measurement.

Another suggested ability of competency mentioned in section 2.5.4 is a high rate of new product introductions. This is also suggested as one of the measures of supply chain agility by Goldman et al. (1994) in Swafford et al. (2006).

A summary of the relevant areas for measuring supply chain agility, referred to as agility attributes, that are described in literature within the area of competency is shown in table 2.13. It could be argued that these suggested agility attributes are connected to the competency capability and that they could be grouped under the five themes: cooperation and integration, effective and efficient operations, technology, people and decision making, and new product introduction. It could also be argued that each group of suggested agility attributes together could be grouped around and translated into the suggested metrics also seen in table 2.13.

Table 2.13. Suggested metrics for the capability competency.

Authors	**Agility attributes**	**Suggested metrics**
COOPERATION AND INTEGRATION		
Graham et al. (1994) in Gunasekaran et al. (2001)	Extent of mutual cooperation leading to improved quality	Total number of suppliers
Lin et al. (2006)	Trust-based relationships with customers/suppliers	
Maloni and Benton (1997) in Gunasekaran et al. (2001)	Extent of mutual assistance in problem solving efforts	Level of supplier involvement in product development
Thomas and Griffin (1996) in Gunasekaran et al. (2001)	Buyer-vendor cost saving initiatives	Level of supplier involvement in short and long-term planning
Toni et al. (1994) in Gunasekaran et al. (2001)	The entity and stage at which supplier is involved	
Zhang and Sharifi (2007)	Reducing number of suppliers	Number of cooperation initiatives between supplier and customer in improving performance
Zhang and Sharifi (2007)	Involving suppliers in product development	
Zhang and Sharifi (2007)	Involving suppliers in short and long-term planning	

EFFECTIVE AND EFFICIENT OPERATIONS		
Lin et al. (2006)	Vertical integration	Level of vertical integration
Zhang and Sharifi (2007)	Vertical integration	
TECHNOLOGY		
Lin et al. (2006)	Virtual connection	Use of integrated IT system in supply chain
Swafford et al. (2008)	Use of IT to coordinate/integrate activities in design and development	
Swafford et al. (2008)	Use of IT to coordinate/integrate activities in procurement	
Swafford et al. (2008)	Use of IT to coordinate/integrate activities in manufacturing	
Swafford et al. (2008)	Use of IT to coordinate/integrate activities in logistics and distribution	
Swafford et al. (2008)	Use of enterprise resource planning or supply chain planning software for managing/coordinating global supply chain activities	
Zhang and Sharifi (2007)	Virtual organization model	
Zhang and Sharifi (2007)	Information system provides capability for info update for customers and suppliers	
PEOPLE AND DECISION MAKING		
Lin et al. (2006)	Team-based goals and measures	Amount of employee training and education programs in a given time period Amount of different jobs per employee in a given time period Level of decentralization in decision making Level of cross-functional teamwork
Tsourveloudis and Valavanis (2002)	Training level	
Tsourveloudis and Valavanis (2002)	Job rotation	
Zhang and Sharifi (2007)	Flat, flexible and team-based organization	
Zhang and Sharifi (2007)	Employees at all levels contribute to decision making	
Zhang and Sharifi (2007)	People trusted and empowered	
Zhang and Sharifi (2007)	People receive continuous training and education	
NEW PRODUCT INTRODUCTION		
Goldman et al. (1994) in Swafford et al. (2006)	Increase frequency of new product introduction	Number of new product introductions in a time period

2.6.5 Summary

As mentioned above, there are no consensus in literature in how to measure supply chain agility. This is further supported by the fact that even if only four capabilities of supply chain agility were chosen in this investigation, together with a number of sub-capabilities, 41 metrics were extracted after synchronizing these. This emphasis the difficulty in finding one or a few conventional metrics of supply chain agility.

2.7 Theoretical Construct

Table 2.14 provides a summary of the supply chain agility concept; including the capabilities, the sub-capabilities and the suggested metrics; presented in the literature review.

Table 2.14. Theoretical construct of the supply chain agility concept.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Time delay in sharing customer demand information in supply chain* • *Level of external information sharing in supply chain* • *Level of internal information sharing in organization* • *Level of standardization in information sharing*	• *Time to increase/decrease source/production/delivery capacity* • *Time to reduce production lead time* • *Time to reroute or reschedule operations in production* • *Number of actors involved in decision making process* • *Number of new products the manufacturing system can handle in a given time period* • *Level of inventory in supply chain*	• *Time to reestablish and sustain source/production/delivery lead time after increased/decreased product volumes* • *Amount of inventory that can be phased in/out and be sustained in a given time period*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing setup can handle* • *Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup* • *Number of suppliers per product or component* • *Cost of changing operations from one product to another product* • *Time to change operations from one product to another product* • *Number of different tasks the typical worker can perform*	• *Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/-delivered in a given time period* • *Cost of increasing/-decreasing source/production/delivery capacity in a given time period* • *Number of suppliers per product or component* • *Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period* • *Amount of labour that can be laid-off or diverted to other activities to decrease and sustain production volumes in a given time period*	• *Production lead time* • *Source lead time*	• *Delivery lead time* • *Percentage of orders on time and with accurate documentation*	• *Product development lead time* • *Time to introduce new products*	• *Total number of suppliers* • *Level of supplier involvement in product development* • *Level of supplier involvement in short and long term planning* • *Number of cooperation initiatives between supplier and customer in improving product performance in a given time period* • *Level of vertical integration* • *Use of integrated IT system in supply chain* • *Amount of employee training and education programs in a given time period* • *Amount of different jobs per employee in a given time period* • *Level of decentralization in decision making* • *Level of cross-functional team work* • *Number of new product introductions in a given time period*

3 Method

In this section, the methods used in the project are described. The methods are ranging from the overall approach of the project down to the research approach and research method used. Following that, the methods for designing the construct and demonstrating solution feasibility are described.

3.1 Overall Approach

Gammelgaard (2004) describes the importance of choosing the right methodological framework for an analysis in order to ensure a clear structure and to reach practical relevance of a logistics report. The author suggests three different approaches, the analytical-, the actor's- and the system approach. The analytical and the actor's approach describe two extremes in terms of objectivity of knowledge and the importance of being close to the studied subject. The system approach is somewhere in between the two approaches. The overall research approach in this report has been set to follow the system approach, which describes a holistic view of the research project where it is understood as a system containing mutually dependent components. The system approach aims not to find an absolute truth to a problem but to seek for a solution that works in practice (Gammelgaard, 2004). The system approach is found suitable for this project since the concept of supply chain agility is dependent on the system of all tiers in the supply chain, from manufacturing to the end customer. To reach supply chain agility, the different processes need to be integrated and information need to be shared (Christopher, 2000; Collin and Lorenzin, 2006; Baramichai et al., 2007). The supply chain agility concept can, thus, be seen as a holistic view of a system.

An overall system overview of the project is shown in figure 3.1. The main purpose of the project has been to design a performance measurement system for measuring supply chain agility at Company X. In order to do this, an investigation of the current performance measurement system and the current processes' impact on supply chain agility at Company X were explored. This was done through the investigation of four areas: manufacturing, sourcing, delivery and strategic direction. The first three areas are connected to Company X in the meaning that they are the main and adjacent parts of the responsibilities of the company in the supply chain. These three areas will, further on in the report, be referred to as Company X's supply chain. The three areas of investigation in Company X's supply chain are described below:

Manufacturing refers to the subcontracted manufacturing activities that Company X is controlling.

Sourcing refers to the activities that are connected to the purchasing of products performed by Company X.

Delivery refers to the activities connected to the transportation of finished products to the retail stores, which is managed by the transport function at Company Y.

In addition to the three areas of the supply chain, the strategic direction of Company X was also investigated to include the future processes and make sure that the performance measurement system reflects the future work. The system starts at the enabling activities for the manufacturing and ends at the enabling activities for the delivery of the goods to the retail stores, in accordance to the delimitations of the project.

Figure 3.1. System overview of the project.

3.2 Research Approach

The project followed a constructive research approach. This approach was chosen since it provides the project with a hands-on method of how to structure the research, primarily based on empirics, to come up with innovative solutions to a real-world problem (Kasanen et al., 1993). It is an approach that aims to create a theoretical contribution by finding and testing a solution of a real problem in a target organization (Jönsson and Lukka, 2005). The approach consists of six steps shown in figure 3.2 (Kasanen et al., 1993).

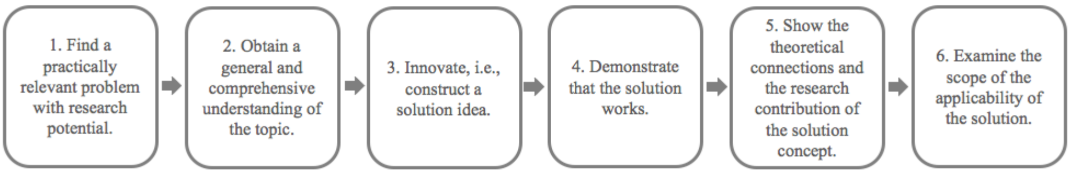

Figure 3.2. The six steps in the constructive research approach process (Kasanen et al., 1993).

Due to the limited time frame, the project only followed the four first steps in the approach, where step one equals the problem formulation and purpose described in section 1.3 and 1.4 of the report. To follow the above described approach, the study started by building up a theoretical understanding of the research area by analysing previous research in a literature review. The literature review was the first step in a multiple case study (step two in the constructive research approach). The cases were analysed separately, in within-case analyses, as well as together, in a cross-case analysis. The findings from the literature review as well as from the case study analyses were used to build the construct (step three in the constructive research approach). Lastly, a construct validation was performed via theory triangulation and tactics related to the case study as well as a validation workshop (step four in the constructive research approach). Step two, three and four in this research approach are further described below.

3.3 Research Method

To get an understanding of the topic (step two in the constructive research approach), a case study was conducted. The case study approach was chosen due to its advantage of breaking down complex problems into smaller instances without losing the holistic view of the research (Verschuren, 2003) as well as its aim to answer the questions “how?” and “why?” (Yin, 2014 p.11).

A case study can either be of single or multiple case design (Voss et al. 2002; Yin, 2014, p. 50). This study was performed as a multiple case study described by Yin (2014, p. 60) consisting of two cases, each including a specific product family and a specific market region:

- Product X on the European market (ProductX EU)
- Product Y on the North American market (ProductY NA)

Each case stretches across the three main areas of Company X's supply chain as well as the strategic direction dimension, described in section 3.1, and was conducted to investigate the performance measurement system of supply chain agility at Company X as well as the processes' impact on the supply chain agility. The selection of cases is further explained in section 3.3.2. In addition to the two separate cases, ProductX EU and ProductY NA, the performance measurement system and processes common to the whole of Company X, and thereby to the two cases, are investigated separately. The main reason for choosing a multiple case study design was the advantages of multiple case studies in building a stronger external validity with stronger robustness (Voss et al., 2002; Yin, 2014, p. 57). In figure 3.3, a system overview of the case study is shown. The investigation of the common features for the whole of Company X is represented graphically by the area named *Company X* in the figure. This investigation also covered additional areas of investigation, not pictured in figure 3.3, that were deemed necessary to include in order to get a thorough investigation of the common features of the cases.

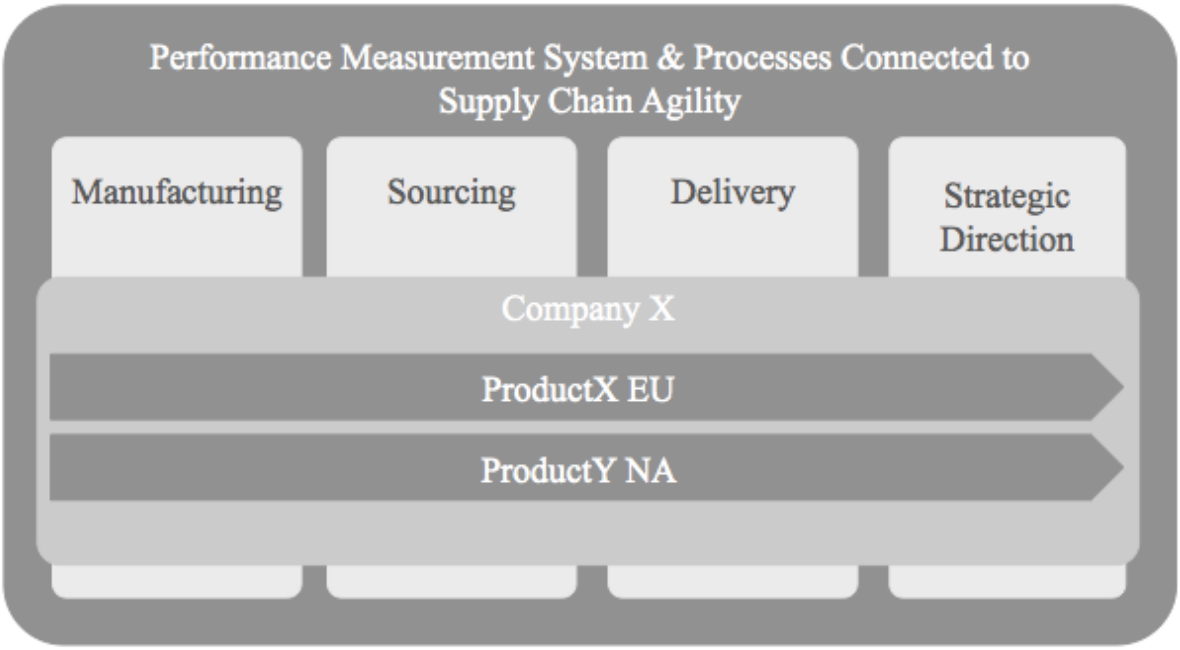

Figure 3.3. System overview of the case study.

The unit of analysis in a case study is important as it defines the case that is going to be studied (Yin, 2014, p. 31). As the purpose of this study was to explore the possibilities for Company X to measure supply chain agility, the unit of analysis was set to be the *Performance Measurement System & Processes Connected to Supply Chain Agility*.

Another vital step of a case study is to decide what research questions the study should be based on. Well-defined questions increase the focus of the study and set clear guidelines for the data collection (Voss et al., 2002). The purpose of this case study was to answer the second, third, fourth and fifth research question:

Q2: What constitutes supply chain agility according to theory?
Q3: How can supply chain agility be measured according to theory?
Q4: What measures of supply chain agility are relevant for Company X?
Q5: What are the good examples and challenges in the area of supply chain agility for Company X?

By answering the above research questions, research question one could also be answered:

Q1: How can supply chain agility be measured at Company X?

In figure 3.4, the adopted processes framework of the multiple case study has been depicted.

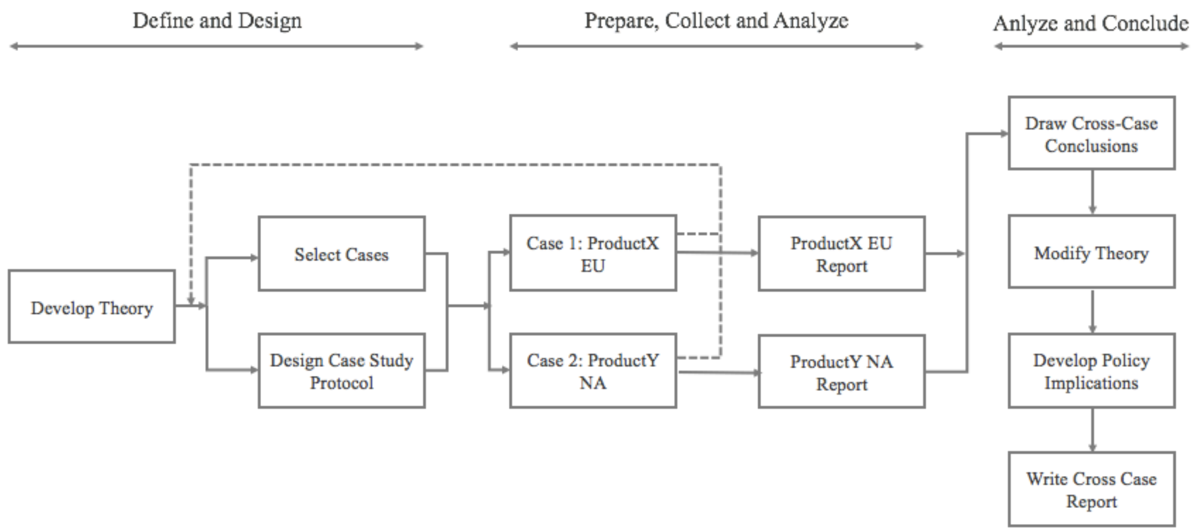

Figure 3.4: The multiple case study process as adapted from Yin (2014, p. 60).

3.3.1 Development of Theory

Examining the literature is essential for building theory, both conflicting and similar findings are important input to the study (Eisenhardt, 1989). Performing a literature review is one way of structuring and identifying the most relevant theory of a subject (Rowley and Slack, 2004). Hence, in this case study, a literature study was conducted to get a thorough theoretical base to build the rest of the project from. From the literature review, research question two and three aim to be answered:

Q2: What constitutes supply chain agility according to theory?
Q3: How can supply chain agility be measured according to theory?

The literature review was conducted using the framework presented by Rowley and Slack (2004), which includes the following five steps:

- Scanning
- Making notes
- Structuring the literature review
- Writing the literature review
- Building a bibliography

The different steps are described further below. They were not conducted in separate phases, but in parallel and as part of an iterative process as a result of new sources of information emerging.

Scanning
This step consisted of scanning relevant databases for information regarding the subject to get an initial and broad understanding of supply chain agility constituents and measurements and the key themes within these areas. The literature review was conducted in the database ISI Web of Science. The search strategy used when gathering information was the citation pearl growing strategy (Rowley and Slack, 2004), which means starting from a carefully chosen set of key documents and, based on these, enlarge the search through references and themes presented in the documents. The key documents were chosen based on either of two criteria:

- The document is among the top results of the most cited articles when searching for *"supply chain agility"* or *"performance measurement system"*.
- The document is experienced to have a content very relevant to the project.

The chosen key documents are presented in table 3.1.

Table 3.1. Key documents.

Title	Year	Author	Subject
Supply chain agility: review, classification and synthesis	2017	Sharma, N., Sahay, B., Shankar, R. and Sarma, P.	Supply chain agility
Agility index in the supply chain	2006	Lin, C., Chiu, H. and Chu, P.	Supply chain agility measurement
The antecedents of supply chain agility of a firm: Scale development and model testing	2006	Swafford P., Ghosh S., and Murthy N.	Supply chain agility measurement
The agile supply chain: Competing in volatile markets	2000	Christopher M.	Supply chain agility
Performance measurement system design: A literature review and research agenda	1995	Neely, A., Gregory, M. and Platts, K.	Performance measurement system

The documents, in which the searches resulted in, were assessed based on their title and abstract and were read if they, based on these, were evaluated to contribute to the literature review. About 80 documents were read and, of these, 43 were later included in the literature review.

Making Notes
The key take-aways in each read article were summarized while reading it together with important citations and insights within new areas of supply chain agility measurement as well as within areas already explored. This was done to enhance the categorization of the documents.

Structuring the Literature Review
In this step, key themes from the literature were discovered and the documents were organized around these. The case study database, attached in Appendix I, shows the key themes as well as the documents' connections to these. The detected key themes were the following:

- Performance measurement system
- Supply chain agility
    - Definition
    - Relating concepts
    - Strategies
    - Capabilities
    - Areas of measurement

Writing the Literature Review
The literature was written in accordance with Rowley and Slack's (2004) recommended approach, in which all relevant content connected to each key theme is grouped together under separate sections.

Building a Bibliography
Building the bibliography was an ongoing process throughout the whole project. To enhance the process, each document used in the literature review was downloaded and saved.

3.3.2 Selection of Cases

When selecting cases at Company X to investigate in the case study, there were three requirements for the cases that needed to be fulfilled in order to fulfill the purpose of the project to develop a generic performance measurement system of supply chain agility that could be applied to the whole of Company X. The requirements were:

- The selected cases should be on an appropriate level of aggregation.
- The selected cases should be representative for the whole of Company X.
- The selected cases should show problematics related to supply chain agility that are representative for the whole of Company X.

The selection of cases was made together with representatives from Company X and it was decided that the cases were to be selected within different product categories and regions of Company X. Designing of performance measurement systems require a close connection to the company's employees and company goals (Bourne et al., 2000), which was why the selection of cases, to build the performance measurement system on, were made in close cooperation with representatives from Company X.

Case selection could either use literal replication or theoretical replication. In studies based on literal replication, the researcher selects cases that are expected to attain the same results, while in studies based on theoretical replication, the choice of cases has been made so that differing results are expected (Yin, 2014, p.57). The selection of cases in this study was made to form theoretical replication. The chosen cases were contrasting in nature for the construct to be challenged in terms of generalizability. This is since the aim is for the construct to be generalizable enough to be used at the whole of Company X and not just parts of it. This approach is similar to what Meredith (1998) describes as *testing*.
Product X on the European market (ProductX EU) was chosen as case one and *Product Y on the North American market* (ProductY NA) was chosen as case two. The cases were chosen

to contrast each other in several different ways, which are further described below. The two cases also support all set requirements for the selection of cases. Firstly, they are of an appropriate aggregation level for the case study: products families, which is the level for which the units are usually measured at Company X. Secondly, they are both representative for Company X in terms of size since they belong to the two largest product categories in terms of sales. Thirdly, they both emphasize problems representative to Company X in the area of supply chain agility. For these requirements, there were no other cases that fitted as well and therefore it was decided, together with representatives from Company X, that focus should be on ProductX EU and ProductY NA. Below follows a short description of the two selected cases.

ProductX EU: Product X is an iconic product family that has been a part of Company X's assortment since the 50's and is continuously increasing in sales. Hence, it is an important product family for Company X but the raising demand is putting pressure on the capacity planning. Product X is detailed and therefore requires labour intensive work. Since the production of Product X is mostly situated in Europe, the lead times are relatively short.

ProductY NA: Product Y is a high-volume sale product family. The production of the product is automated. The product family has a limited shelf life of six months after packaging, which complicates the planning. The North American market is highly competitive compared to the other markets, which often leads to market-specific special offers and sales solutions.

The selected cases are different in many ways, such as in terms of market conditions, product types and manufacturing processes. However, there are also some similarities. Both cases are important to Company X as they belong to the two largest product categories. Together, they therefore give a broad image of Company X. Further on, the problematics with the two selected product families are expected to be representative for the whole of Company X, which is advantageous when investigating the processes further. The differences and similarities of the selected cases are summarized in table 3.2 and 3.3.

Table 3.2. Differences between the two selected cases.

Characteristics	ProductX EU	ProductY NA
Product category	X	Y
Market	Europe	North America
Market characteristics	Less competitive	Competitive
Manufacturing	Labour-intensive	Automated
Number of suppliers	Many	Few
Product mix	Wide	Narrow

Table 3.3. Similarities between the two selected cases.

Characteristics	ProductX EU	ProductY NA
Sales level	High	High
Importance of region	High	High
Representation of problematics for Company X	High	High

3.3.3 Design of Case Study Protocol

It is important to be prepared when starting the data collection since it can be a very complex task that should not be jeopardized (Yin, 2014, p.71). Thus, designing a case study protocol can be very useful, especially for creating reliability as well as validity (Voss, 2002; Yin, 2014, p. 84). There are different ways of how to construct the protocols. This study was following the outlines of the protocol described by Yin (2014, p. 84-85), which starts with a case study overview, followed by a data collection plan, data collection questions and, lastly, the schedule for the case study report. The case study protocol used in this project is found in Appendix II.

3.3.4 Collection of Data

The purpose of the data collection at Company X was to answer research question five:

> *Q5: What are the good examples and challenges in the area of supply chain agility for Company X?*

Through identifying areas of good performance and areas in need for improvement, in terms of supply chain agility, areas relevant for measuring supply chain agility at Company X could be identified. The areas of good examples of supply chain agility are relevant to measure in order to make sure that the good work within these areas are kept. The challenging areas of supply chain agility are relevant to measure in order to be able to measure improvements within these areas. Answering research question five, therefore, also contributed in answering research question four:

> *Q4: What measures of supply chain agility are relevant for Company X?*

There are several different ways of collecting case evidence. By using multiple sources, data triangulation is possible, which further improves data validity (Yin, 2014, p. 121). In this study, the collection was based on five sources:

- Interviews
- Meetings
- Company data warehouse (Qlikview)
- Company X intranet
- Literature review

Interviews

Interviews are one of the most important data collection methods for case studies (Voss, 2002; Yin, 2014, p. 110). The method was chosen since it provides the study with targeted information of the topic and creates possibilities for powerful insights. However, the risk of biased answers forces the interviewer to be perceptive and objective (Yin, 20014, p. 106). The case study included both prolonged and shorter interviews according to the guidelines set by Yin (2014, pp. 111-112). In total, 25 interviews were held in this study. The interviewees were chosen so that the four main areas described in section 3.1: manufacturing, sourcing, delivery and strategic direction, were covered. Apart from the main investigation areas, the interviewees were also chosen to cover the information collection for the two cases and Company X in general (see case study interviews in Appendix II). The prolonged interviews were either performed separately, covering multiple sittings where the researchers met the interviewee in different stages of the study, or in one long meeting. To avoid dependency on only a few key informants, shorter interviews were also held where the focus was to confirm findings that were already believed to have been established. Both types of interviews were performed in a semi-structured manner that allowed questions supplementary to the interview guide (see Appendix III) (Bhandarkar et al., 2010).

Meetings
Meetings were attended in order to collect information about the strategic direction of the company and to attain information about how the employees make use of metrics in their daily work.

Company Data Warehouse
From the data warehouse, Qlikview, quantitative data were collected. The collected data were mainly different kinds of performance measurements. Since the data warehouse is extensive with multiple applications, the search for data was guided by representatives from Company X.

Company X Intranet
The internal network was used for two main purposes. The first one was to collect information during preparations for interviews in order to form appropriate questions. The second purpose was to find supplementary information about subjects raised during the interviews.

Literature Review
The performed literature review, described in section 3.3.1, was used in order to give a theoretical input to the case study. The theory found in the literature review was used to structure the company-specific data collection that was built upon the sources described above.

3.3.5 Analysis of Cases

The study followed the two-folded approach described by Eisenhardt (1989). The approach begins with a within-case analysis, where the idea is to become familiar with each case as a stand-alone unit. In the second step, a cross-case analysis is performed in order to search for patterns. To lower the risk of premature assumptions, the data is investigated in several different ways. These are described below.

There are several different techniques that could be used for the case analysis. The most commonly used is the pattern matching technique. The technique is good for strengthening the internal validity by finding similarities between literature and empirical evidence (Yin, 2014, pp. 142-143). This study used pattern matching during the literature review to come up with a proposition of a metrics hierarchy to be used for measuring supply chain agility. The technique was also used in the within case analyses in order to identify good examples and challenges of supply chain agility. This was done by comparing the empirics gathered from the whole of Company X and the two individual cases with the findings from the literature of the capabilities and strategies connected to supply chain agility.

The theoretical proposition was later on evaluated in within-case analyses for the two cases and the common case for the whole of Company X, where the explanation building technique was used. Explanation building is a special type of pattern matching that further improves the internal validity and reliability of the analysis. The technique is more difficult to use as it requires several analytical steps (Yin, 2014, pp. 147-150). The different steps of the analytical method are presented in table 3.4 together with a clarification of what steps that have been used in this study.

Table 3.4. The performed phases of explanation building, adopted from Yin (2014, p.149).

Steps in explanation building	**Performed steps**
1. Make an initial theoretical proposition	X
2. Compare the findings of an initial case against theoretical proposition	X
3. Revise the proposition	X
4. Compare to other details from the case against the revision	
5. Compare the revise to the finding from other cases	X
6. Repeat the process as many times as needed	

The first step performed of the explanation building equals the proposed metrics hierarchy built from the literature review. The second and third steps were performed by comparing the proposition to the identified good examples and challenges of supply chain agility from the two cases and from the common features for the whole of Company X, and revise it until a suitable metrics hierarchy was found for each of them. The fifth phase of explanation building was performed in the cross-case analysis, where the suggested metrics hierarchies from the two different cases and the common case of the whole of Company X were compared to each other to identify differences and similarities between the suggested metrics hierarchies. The findings from the cross-case analysis were then used in the design of the construct described below.

In figure 3.5, a schematic picture of the case analysis approach is presented. The distinction in illustration for Company X has been done to mark out that it is not one of the two specific cases. The analysis part of Company X is, however, included since it contains important common processes of the two cases that cannot be extracted in full from only one case.

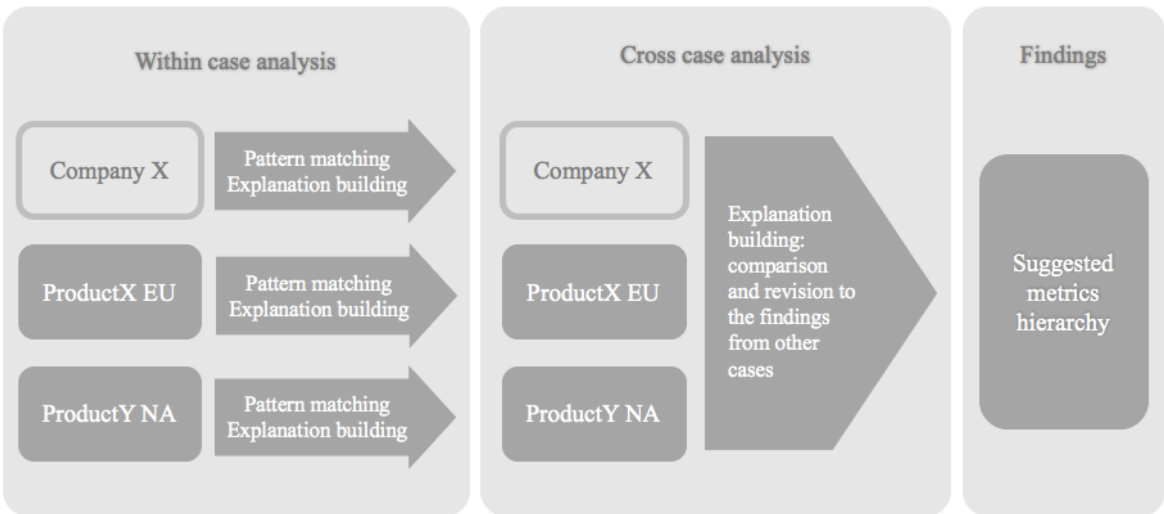

Figure 3.5. The case analysis approach.

3.4 Design of Construct

The third step in the constructive research approach is the innovative part of the study, where the construct is designed. The construct in this study was set to be the performance measurement system for measuring supply chain agility at Company X. The design of construct was structured following the criteria of a performance measurement system found in literature, listed below:

- A hierarchy of metrics
- Information regarding the organizational levels at which to use the metrics
- Information regarding the data gathering for calculating the metrics
- Information regarding the presentation of the metrics

In addition to the criteria, a verification step was included in the construct in order to investigate the fit between the performance measurement system and Company X.

Since the outcome of the cross-case analysis was *a hierarchy of metrics,* which is one of the criteria of a performance measurement system, the design of construct was focused on further adaptation of the metrics hierarchy to Company X as well as to fulfil the rest of the four criteria. To help this process, five out of the six evaluation criteria explained by Caplice and Sheffi (1995), shown in table 3.5, were used. The criterion *internally comparable* was not used since the evaluation of this was deemed to require an implementation, which is out scope for this study.

Table 3.5. The used evaluation criteria for measurement system adopted from Caplice and Sheffi (1995, p.63).

Criterion	Description	Used
Comprehensive	The measurement system captures all relevant constituencies and stakeholder for the process.	X
Casually oriented	The measurement system tracks those activities and indicators that influence future as well as current performance.	X
Vertically integrated	The measurement system translated the overall firm strategy to all decision makers within the organization and is connected to the proper reward system.	X
Horizontally integrated	The measurement system includes all pertinent activities, functions, and departments along the process.	X
Internally comparable	The measurement system recognizes and allows for trade-offs between the different dimensions of performance.	
Useful	The measurement system is readily understandable and provides a guide for actions to be taken.	X

Metrics Hierarchy

The metrics hierarchy was further adapted to Company X in two steps, involving reformulation and horizontal adaptation. The reformulation was done in order to make the metrics hierarchy more *useful* for Company X, and to make it more *casually oriented*. The reasons for reformulating the metrics was, in turn, extracted from five out of the eight metrics criteria suggested by Caplice and Sheffi (1994) (see table 3.6). The criteria *behavioural soundness* and *economy* were not used since both would require an implementation or an additional investigation which has been excluded from this study. The criterion *integration* was not used either in this stage but was instead included in the subsequent step: horizontal adaptation.

Table 3.6 The used evaluation criteria for reformulating metrics adopted from Caplice and Sheffi (1994, p.14).

Criterion	Definition	Used
Validity	The metric accurately captures the events and activities being measured and controls for any exogenous factors	X
Robustness	The metric is interpreted similarly by the users, is comparable across time, location & organizations, and is repeatable	X
Usefulness	The metric is readily understandable by the decision maker and provides a guide for action to be taken	X
Integration	The metric includes all relevant aspects of the process and promotes coordination across functions and divisions	
Economy	The benefits of using the metric outweigh the costs of data collection, analysis, and reporting	
Compatibility	The metric is compatible with the existing information, material and cash flows and systems in the organization	X
Level of Detail	The metric provides a sufficient degree of granularity of aggregation for the users	X
Behavioral Soundness	The metric minimizes incentives for counter-productive acts or game-playing and is presented in a useful form	

The second step in adapting the metrics hierarchy further to Company X was to evaluate the metrics hierarchy based on *horizontal integration*, fulfilling another measurement system criterion from Caplice and Sheffi (1995). The horizontal integration was done by dividing the metrics into the three decision making levels: operation, tactical and strategic suggested by Gunasekaran et al. (2001). This step was also performed in order to evaluate the *comprehensiveness* of the metrics hierarchy by investigating if the metrics cover all the relevant functions.

Decision Making Levels of Users

To define the different decision-making levels of the users, the metrics hierarchy was *vertically integrated* in accordance to the measurement system evaluation criterion from Caplice and Sheffi (1995). This step was performed by dividing the metrics into three out of the four suggested categories by Gunasekaran et al. (2001): plan, source, production and delivery. The category plan was excluded from the division since it was out of scope for this study. Also, an additional category, supply chain/organization, was included to also get the holistic view of the supply chain and the included individual companies' other processes.

Data Gathering

To fulfil the criterion of a performance measurement system to contain *information regarding the data gathering for calculating the metrics,* the metrics in the metrics hierarchy were divided into their related functions for data gathering: suppliers, Company X, transport, and other functions within Company Y. The purpose of the division was to show which actors that are responsible for the data collection. A more thorough description of the data gathering was excluded due to the limitation of not having full access to the complete performance measurement system (Qlikview) used at Company X.

Verification

To fulfil the last criterion of a performance measurement system, to include *information regarding the presentation of the metrics,* the presentation of the metrics hierarchy was evaluated and adopted to feedback given during a workshop with employees from Company X. The workshop was also used to increase the usefulness of the performance measurement system by verifying and adopting the findings within the three other criteria of a performance measurement system, according to the given feedback.

3.5 Demonstration of Solution Feasibility

The fourth step in the constructive research approach involves demonstrating that the solution works. In this project, this was achieved through demonstrating that the research method was conducted in a manner that makes the result reliable, valid and generalizable. This was done using different tactics in both the constructive research approach and in the case study. The tactics are further described in this section.

3.5.1 Constructive Research Approach

According to Oyegoke (2011), the most appropriate validation method of constructs is to perform pilot case studies. The pilot cases are, on the other hand, often not realistic due to the extensive work needed, which involves both costs and risks. In this study, the pilot cases were excluded since the time frame of the study was limited. Instead, a workshop was performed with representatives from Company X to validate the final construct. The representatives had earlier been interviewed during the project and are potential users of the developed performance measurement system. The representatives had a chance to evaluate and elaborate on the suggested performance measurement system as well as giving their thoughts on it and suggesting eventual improvements. Based on the feedback and insights from this workshop, the final version of the performance measurement system was created.

Another alternative to the pilot cases that can strengthen validity of the construct is triangulation. Oyegoke (2011) suggests four different types of triangulation:

1. Data source triangulation - the same data are found in different contexts.
2. Investigator triangulation - the same phenomenon is examined by several investigators.
3. Theory triangulation - investigators with different stand points interpret the same results.
4. Methodological triangulation - several approaches are utilized to increase confidence of the findings.

Since four different data collection methods were used in this study, data source triangulation (1) was employed. Investigator triangulation (2) was also used since two researchers were involved in the study.

3.5.2 Case Study

Yin (2014, p. 45) highlights four different tests that can be used to increase the validity of the research. The different tests are: construct validity, internal validity, external validity and reliability. Within each test, there are several suggested tactics explained by Yin (2014, pp. 45-49). The tests are further explained below.

The *construct validity* investigates to what extent the researcher defines objective measures that reflect what is being studied. There are three different tactics that may be used to increase the construct validity: use of multiple sources of evidence, establishment of a chain of evidence and, having key informants review the draft case study. This study employed all of these tactics.

The *internal validity* test is mainly based on two concerns. The first one concerns to what extent the researcher verifies that the logic behind the data analysis is correct. The second concern considers whether the researcher makes correct inferences. There are four tactics that can help handle these concerns: pattern matching, explanation building, addressing rival explanations and using logic models. This study used both pattern matching and explanation building.

The *external validity* test deals with issues of making the study findings generalizable beyond the study itself. The generalizability is describing the extent to which it is possible to use the findings from a research in other contexts (Meredith, 1998). One way of creating better conditions for that is to make sure that the research questions that are going to be answered include *"how"* or *"why"* in their formulations. A tactic that can be employed to improve external validity in multiple case studies is the replication logic, which was used in this study. However, the fact that the case study was conducted only within two out of the four product categories within Company X decreases the generalizability.

The *reliability* measures the extent to which the same study is possible to repeat and to what extent the retrieved results would be similar, if not the same. In order to create this possibility, documentation is needed. The use of a case study protocol and a case study database are tactics that increase the case study reliability. This study used a case study protocol and database.

3.5.3 Summary of Reliability, Validity and Generalizability Tactics

The tactics used to increase reliability, validity and generalizability in the project is summarized below. In table 3.7, the validation tactics for the constructive research approach are presented and in table 3.8, the tactics used specifically in the case study are presented according to the framework suggested by Yin (2014, p. 45).

Table 3.7. Summary of the validity tactics used in constructive research approach

Triangulation type	**Used**
Data source triangulation	X
Investigator triangulation	X
Theory triangulation	
Methodological triangulation	

Table 3.8. Summary of the validity tactics used for the case study

Tests	Case Study Tactic	Used
Construct validity	Use multiple sources	X
	Establish chain of evidence	X
	Have key informants review draft case study report	X
Internal validity	Do pattern matching	X
	Do explanation building	X
	Address rival explanations	
	Use logic models	
External validity	Use replication logic in multiple-case studies	X
Reliability	Use case study protocol	X
	Develop case study database	X

4 Empirics

In this section, the findings from the empirical studies at Company X are presented. The section is divided into three parts. The first part presents the common processes for the whole of Company X, and thereby also for both cases studied, ProductX EU and ProductY NA. The following two parts present the individual processes of each case studied.

4.1 Company X

This section aims to describe the common processes for the whole of Company X, and thereby also for the two cases investigated: ProductX EU and ProductY NA, both belonging to the same category area. The section is divided into five parts. In the first part, the management structure of Company X is described. In the second part, the performance measurement system used at Company X today is described. In the following two sections, an overview of the common features within sourcing and delivery for the category area is provided. The last section provides a description of the strategic direction for the whole of Company X.

4.1.1 Management Structure

This part of the empirics describes the management structure at Company X at a holistic level. The section is divided into three parts. In the first part, the time horizons for decision making at Company X are described. Following that, the intra- and inter-category decision-making is explained.

Time Horizons for Decision-Making
Company X is using three main decision-making levels with differing time horizons, as shown in table 4.1. In addition to the strategic level, they also have a long-term capacity plan that stretches until 2030 and which is focusing on material availability.

Table 4.1. Time horizons for different decision-making level.

Decision making level	Time horizon
Strategic	1.5-5 years
Tactical	0.5-1.5 years
Operational	1 week-0.5 year

Intra-Category Decision-Making
The different categories within Company X are independent in their decision-making and creativity as well as new initiatives are encouraged. The category area manager is continuously working with improving the internal communication and to secure that the employees have the right mandate to make decisions in order for the organization to be quicker.

Inter-Category Decision-Making
Even though Company X is fast in making decisions within specific product categories, the decision-making process becomes complex when other functions within Company Y needs to be involved. The experience that the decision-making process becomes more complex outside Company X seems to be shared by other employees. One interviewee points out the different ownerships as a main cause to the complexity in decision making. The responsibilities are not

only divided into different product categories but also into different markets throughout the whole Company Y structure, from sourcing to retail, which sometimes makes it hard to figure out the responsibilities and make fast decisions. Because of the many stakeholders within Company Y, it can take months to repair a disruption in the flow. The delays in decision making also cause frustration among suppliers as they cannot get quick directives.

One example of a slow process that is related to the challenge of having many stakeholders is the product development. Company X is not responsible for developing new products themselves but they are in charge of creating the right supplier base for producing the new products and are, hence, part of the product development process. Today, the product development process for the existing range at Company X is very slow. It takes about two years to introduce new products, which requires a long planning horizon. However, there are some projects going on in order to come up with more standardized solutions so that everything does not have to be drawn from scratch every time a new product is to be developed.

4.1.2 Performance Measurement System

This part of the empirics describes the performance measurement system at Company X at a holistic level. The section is divided into four parts, each connected to one of the criteria for a performance measurement system described in the theoretical framework. Firstly, the metrics used today at the whole of Company X are presented. Following that, the data gathering and presentation of the metrics are described. Lastly, the general use of the metrics is presented.

Metrics
The four most important Key Performance Indicators (KPIs) for Company X overall are *quality, service, cost* and *sustainability*. These can be applied by all functions within Company X and are divided into different sub-metrics depending on the operations of the specific function. The KPIs are evaluated in a long-term perspective of five years but, as the market conditions are changing fast, it is hard to make up plans according to the metrics for more than one to two years. The different overall KPIs are described below.

Quality is ranked as the most important KPI for Company X and it is mainly measured in terms of *cost of poor quality (COPQ)* and *customer returned product quality (CRPQ)*. *COPQ* measures the cost caused by customer returns to the store as well as the related costs for transport- and handling damages. The *CRPQ* is the way to measure the customer's experiences of the offer. It is based on the information received when a customer returns a product. The measure is, in turn, used to evaluate and decide what products that should be included in the range and what supplier development projects that should be focused on.

The quality work is not included in the everyday work to the same extent as the second most important KPI, namely *service*. *Service* is mainly measured in terms of *availability* in store. According to the guidelines of the KPI, *availability* should be prioritized over product price and cost in short term decision making. Even though *quality* is ranked higher than *service*, the *availability* measure in seen as the most important KPI for Company X by several employees as it is a part of the daily work and operations. The logic behind the KPI is that goods need to be dispatched and received on time to reach high availability. For Company X, this is measured in terms of *service level* and *On Time Delivery (OTD) sender*. *Service level* expresses the share of what is in stock at store in relation to what should be in stock at store at a certain time and *OTD sender* is a sub-metric of the broader measure *OTD supply chain*.

OTD supply chain consists of the sub-metrics *OTD sender* and *OTD logistics*. The aim of this division is to create a fair performance evaluation for the different functions. *OTD sender* is a measure of the punctuality of when a supplier has an order ready for dispatch given a specific order creation time. The measure is used to evaluate the performance of the suppliers. *OTD logistics* is a measure of punctuality of when the order is received in the store given a specific dispatch time. This measure is mainly used by the transport function to evaluate the performance of the carriers. As mentioned, *OTD supply chain* combines the sub-metrics *OTD sender* and *OTD logistics*, and expresses the overall performance of the supply chain.

Company X is also making use of measures related to *cost*. Connected to this, they measure *total cost*, *purchase price* from the suppliers, *equipment utilization (EQU)* and *direct delivery (DD) share*. The *total cost* is defined as the total cost of the goods from the purchasing of the goods from the suppliers until the arrival of the goods in store. *EQU* is measuring the volume per shipment in relation to the maximum volume of the carrier or specific equipment. *DD share* reflects how much volumes that are shipped with a direct flow from the supplier to the store in relation to the total volumes shipped. Both *DD*-share and *EQU* have a high impact on the logistics costs and, therefore, on the *total cost.*

The fourth KPI that is described to be among the four most important ones for Company X is *sustainability*. This measure includes, among other things, measures of production standards and standards for raw material sourcing.

In table 4.2, a summary of the most important KPIs for Company X, and the most relevant metrics connected to these, according to the interviewees are presented. There are, however, many other existing metrics used at Company X.

Table 4.2. The most frequently used metrics and their connections to the most important KPIs at Company X.

Metrics at Company X
Quality ● COPQ ● CRPQ Service ● Availability ○ Service level ○ OTD supply chain ■ OTD sender ■ OTD logistics Cost ● Total cost ○ Purchase price ○ EQU ○ DD share Sustainability

Presentation of Metrics

The main supporting infrastructure for presenting the performance measurement system at Company X is the IT system Qlikview. Almost all reporting is done through Qlikview, which constitutes many different applications. The employees need to request for access for all the applications they need. Each application is usually connected to either a KPI or a PI (Performance Indicator). Of these, the applications connected to a KPI are of most importance for the organization. Within each application, it is possible to see different aggregation levels by adjusting the settings. In this way, it is possible to see the overall performance as well as detailed information about a specific product or supplier. The data is often presented in graphs where the user can adjust the x- and y-axis according to their own preferences. All applications should have an architect blueprint with information regarding the application, how it works, and how it should be used. Today, some applications are created too fast and all routines are not always followed. For example, it happens that definitions are missing in the applications. However, there are often more thorough documentation connected to the KPIs than for the PIs.

Data Gathering for Calculating the Metrics
Most of the information for calculating metrics in Qlikview is automatically gathered from several different data warehouses belonging to different functions, such as retail and product development, since Company X makes use of many different IT systems. However, when there are changes in product range manual adjustments, such as in prices, have to be made. Most of the information regarding the performance of the suppliers is provided from the ordering system GPS, where order information connected to the suppliers, and how they plan production and order transports, are found. However, in order to get hold of the information regarding stock levels at hand, equipment utilization, consumption rates and produced volumes, the supply planners ask for weekly summary reports from the suppliers, which are manually shared via email. Some suppliers find it time consuming with the weekly updates since they have to extract the data from their own IT systems and then fill in the reports from Company X manually.

Use of Metrics
All employees are using Qlikview and usually also the same applications but, depending on their decision-making level, the users go more or less into detail in each application. To help the communication and analyses, it is common that employees extract information from Qlikview to create their own reports to simplify the information interpretation and sharing. All the goals for the different KPIs are presented in the Category Council reports, which are specific for each category within Company X. The goals are currently set to year 2021.

Sometimes functions are assigned KPIs that they cannot influence. For instance, all categories within Company X are assigned *service level* as a part of the *availability* KPI, but Company X cannot control much more than the metric *OTD sender*. There do also exist some overlaps in applications in Qlikview, making it possible to interpret some of the performance measurements differently. For example, there is a possibility to change the settings so that the metrics can be shown in relation to different time frames, which may have an impact on the interpretation of the results and, thereby, on the decision making.

4.1.3 Sourcing

In this section, a general overview of the sourcing processes at Company X is provided, followed by descriptions of the supplier relations, the information flow between Company X and the suppliers and, lastly, the supplier assessment and collaboration.

Sourcing Processes
Company X does not own any factories themselves. Instead, they are purchasing all manufacturing activities from contracted suppliers. One of the most important processes connected to sourcing at Company X is to divide production volumes of the product families

between the suppliers in accordance with the suppliers' available capacities. The capacity planning for production is built on forecasts. All markets have seasonality and the peak seasons are during the end of summer, when the catalogue is released, and right before Christmas each year. Deviations from the forecasts are usually larger during the peak seasons, but deviations are also a general issue throughout the year that makes the capacity planning process more difficult. The deviations from the forecasts can be handled in several different ways, which varies for the different product categories.

Supplier Relations
At Company X, it is found important to have good relationships with the suppliers. Thus, for each supplier there is a team consisting of Production Engineers, which are mainly responsible for the quality on an engineering level, one Supply Planner, who handles all the operational tasks in the collaboration with the supplier, and one Business Developer, who is responsible for the supplier development and leads the team. At higher levels, a Need Planner is responsible for knowledge development and sharing between suppliers and Supply Planners.

Information Sharing
The information flows between the suppliers and Company X are, at large, handled manually, which results in that the parties are not provided with all-time updated data. This sometimes complicates the daily operational work as information regarding changes does not reach the parties in time. Another example of such problematics is the ordering system that delays creation of orders from stores, which results in the suppliers having less time to prepare the orders. It especially becomes a problem when there is an increased demand on several markets.

Company X is sharing Supply Plan Information (SPI) reports, provided by the Demand Planner, weekly with all suppliers. This report consists of a forecast and an information sheet that provides guidelines of how to interpret the SPI. The SPI contains, among other information, safety stock levels, sales forecast and need forecast for the following 52 weeks. However, the real need of Company X, and thereby the real order flow to the suppliers, usually deviates a lot from the forecast provided in the SPI reports. As mentioned, the forecast deviations vary throughout the year but are largest during peak seasons.

The SPI report is not a commitment from Company X's side to purchase any quantities of any product. Even so, suppliers set their prices and build their capacity in accordance with the forecast. If the demand is lower than forecasted, the suppliers do not get compensated. However, Company X may indirectly cover some of these costs since they may have to accept higher price offers from the suppliers for upcoming orders. The idea behind the SPI reports is not that suppliers should produce exactly in accordance to it, rather an appropriately calculated average of it, and then use safety stocks as buffers. The suppliers' abilities to interpret the SPI forecasts differ. In general, suppliers that are also working with other customers than Company X are very good at interpreting the SPI forecasts and experience that the forecasts are a good and useful tool, whilst suppliers only producing for Company X generally find it harder to use the forecasts and think that they need to be more accurate.

Regarding the information sharing from the suppliers to Company X, the suppliers register their capacity in excel files. However, there is no good tool to check whether the capacities promised by the suppliers are fulfilled or not and there is sometimes a difference between what the suppliers say that they can produce and what they actually can produce. Some suppliers are too optimistic as they sometimes have less capacity than they express themselves to have. This is a problem since Company X wants to be certain in regards to the availability of capacity.

Supplier Assessment and Collaboration
Company X has requirements of how flexible a supplier have to be in terms of how much extra capacity they should have. This is discussed and agreed upon during meetings between Company X and the suppliers but it is not stated in any agreement. The capacities are evaluated monthly during BCP (Business Contingency Plan) meetings, where the planned capacities are compared to the available capacities for each product. Each year, Company X also conducts a supplier classification of all suppliers connected to the category area. The classification aims to evaluate the strategic fit between Company X and the suppliers as well as the suppliers' performances, which is based on the four main KPIs, *quality, service, cost* and *sustainability,* and the suppliers' abilities to innovate. From the results of the supplier classification, the suppliers are placed in one out of six groups ranging from prioritized- to critical suppliers. Company X is collaborating with the different supplier groups to different extents. For example, only the prioritized suppliers are invited to the Supplier Days once a year where representatives from the different suppliers and from Company X meet and share ideas. Independently from the classification, Company X conducts yearly supplier surveys with all suppliers to measure the suppliers' satisfaction with the collaboration.

There is no stipulated punishment in the agreements for the suppliers if they cancel orders or postpone them. It does, however, lower the performance for the suppliers in terms of *OTD sender*, which might eventually lead to that the order volumes are switched over to a better performing supplier. If a supplier does not perform well in comparison to other alternative suppliers, the supplier could be excluded from business for a time, indefinitely or forever. The time horizon for these decisions is 32 weeks. Getting larger ordering volumes is the only incentive given from Company X to the suppliers for them to perform better, but it has been working well according to the interviewees.

The collaboration between the suppliers and Company X, in terms of common investments, is a discussed subject. So far, all the investments in additional production capacity have been a responsibility of the suppliers. However, to better secure capacity, the possibility of changing this business setup, and thereby let Company X invest more, has now started to be investigated.

4.1.4 Delivery

In this section, a general overview of the delivery processes at Company X is provided, followed by a description of the transport solutions used and the relationships with the carriers.

Delivery Processes
Company X buys all the physical transport services from external service providers but they are performing all the coordination and planning themselves. The overall focus for the transport function is to find transport solutions that correspond to the lowest costs and the fastest transport times. Due to differences between markets, such as equipment availability, infrastructure, legislation and operation modes, the transport setups are adjusted to fit different markets. The transportation function exchanges information with other parts of

Company Y to different extents. The information flow between the transport function and Company X is mostly automated.

Transport Solutions
Truck is the main transportation mode for shorter distances worldwide. For longer distances, trains and boats are used. Air freight can exceptionally also be used for emergency orders. There are mainly three different transport solutions used for transporting the goods from the suppliers to the stores: direct delivery, delivery via distribution centres (DCs) or delivery via consolidation points (CPs). Direct delivery means that the goods are shipped directly to the stores from the suppliers. This transport solution is the most challenging one since the storage space and the unloading time slots at the stores are very limited, which creates more restrictions. Direct deliveries are mostly used for high volume products of which a store can sell a full truckload within a couple of weeks. Delivery via DCs is used for goods that the stores cannot handle a full truckload of due to the storage space limitations. The truckloads from the suppliers are split and bundled together with other products that have been stored in the DC before they are delivered to the stores. This is mostly for less bulky products that do not sell as well as the ones using the direct delivery solution. This type of transport solution is also used for seasonal goods and for goods from suppliers that are not able to deliver as frequent as needed. Deliveries are normally sent once a month to the DCs and then further shipped from the DCs to the stores once a week. Delivery via CPs is mainly used to increase the fill rate by consolidating volumes from suppliers that are only delivering a few pallets each.

One of the main challenges that Company X is facing is the needed change in transport setups due to the emerging e-commerce. Today, the solution in almost all the markets is to use the existing stocks in the stores for online orders. This is deemed insufficient and, instead, Company X wants to prepare the suppliers and the other actors connected to the transport solution so that shipments either could go directly to the customers from the suppliers or via dedicated DCs.

Carrier Relationships
It is relatively easy for carriers to change customers, especially during peak seasons, which makes it important for the transport function within Company Y to have good relationships with the carriers. The contacts between the transport function and the carriers are mainly managed by the Business Developers. The carriers give a maximum capacity that they can handle, expressed in volume, and the transport function within Company Y never requires more than that. This puts requirements on the transport planning. In addition, a limited visibility of the supply chain does, due to lack of a common planning tool, complicate the transport planning for the transport function within Company Y. Because of this, a lot of time consuming manual work is needed to gather information from many different sources and there are no real-time updates, which complicate the sharing of forecasts with the carriers.

4.1.5 Strategic Direction

In this section, the overall strategic direction of Company X is described in terms of future goals, future challenges and ongoing improvement projects.

Future Goals
There is a common philosophy that costs are among the most important aspects to consider as Company X's business idea is based upon costs. However, several persons think that an

increased focus on agility also will be needed in the future. Company X is making use of a strategic business plan that reaches to year 2022, in which the goal for Company X's wished position is to be agile in order to deliver in accordance to the customer need. However, at the moment there is no common view of what supply chain agility is among the employees, which complicates the fulfilment of the goal.

Another goal that Company X is working towards is to reach a higher direct delivery share to the stores until year 2020 so that no distribution centres will be needed by that time. The project is mainly aiming for reducing cost.

Future Challenges
Company X needs to prepare for future e-commerce and multi-channel solutions, which agility is believed to be closely related to. The general growth focus for Company Y has turned from focusing on increasing the number of stores towards focusing on pop-up stores and e-commerce in order to meet the new customer preferences.

Ongoing Improvement Projects
For improving the information sharing, and thereby enable a closer collaboration and relationship with the suppliers, Company X is a part of several different IT system projects that are focusing on improving information sharing. One example of such IT system project is to introduce a Supplier Portal, in which they hope to be able to share more information with the suppliers and introduce real time updates. Another IT system project aims to improve the visibility and involve the suppliers in Company X's capacity planning. This will be done by creating an IT tool that translates the suppliers' capacities into a common measurement that makes it possible to compare real versus planned capacity. The tool will also allow the suppliers to get real time updates of Company X planned need. A third IT system project aims to improve internal and external collaboration by increasing transparency in the supply chain using a common demand plan and a common safety stock calculation. Today, the different parties have different forecasts that are not always up to date. With this new system both suppliers and the different parts of Company Y can get access to the same information. This would enhance the decision making in the supply chain and increase the possibility of making quick aligned decisions from reliable information.

4.2 Case 1: ProductX EU

This section aims to describe the features of the individual case ProductX EU. The section starts with giving an overview of the different processes in the supply chain connected to ProductX EU, and continues with describing the separate processes: manufacturing, sourcing and delivery, individually. The section ends with providing an overview of the strategic direction connected to the case.

4.2.1 Mapping of Supply Chain

There are nine different suppliers of varying sizes that produce Product X on the European market. The suppliers are mainly assembling manufactures. Most of the components for Product X are sourced locally by the suppliers, which reduce both costs and lead times. One component is, however, sourced from China with a lead time of two to four months, of which eight weeks are spent in production and seven to eight weeks are spent in transport. It is Company X that sets up sourcing agreements with the Chinese supplier but the manufacturing suppliers order themselves.

There is a very limited amount of inventory in the supply chain distributed on only a few inventory locations. That is mainly because of the bulkiness of the product that consumes a lot of space and, thus, makes it hard and expensive to store. This has led to that most of the products are sent with direct delivery. Thus, the stock at hand is positioned in the stores and at the suppliers'.

In figure 4.2, a schematic view of a representative supplier for ProducX EU is presented. The arrows represent the material flow. There are nine suppliers in total, those supply chains are similar to the one presented in figure 4.2. Since direct delivery setups are used, no additional inventory locations are depicted.

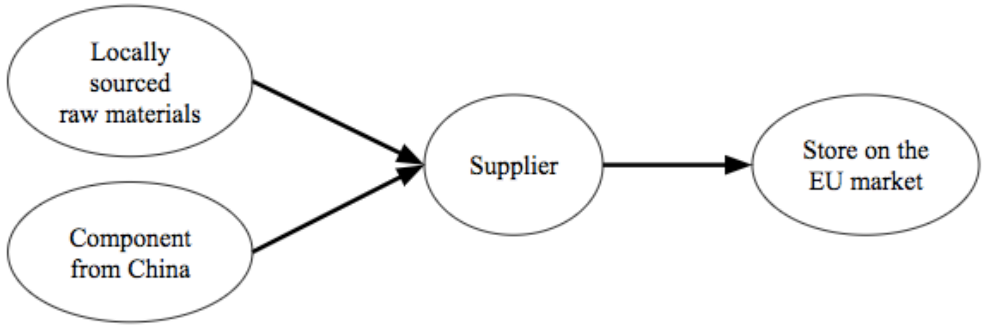

Figure 4.2. Schematic view of the supply chain for ProductX EU.

4.2.2 Manufacturing

In comparison to other product categories within Company X, the production within the product category that Product X belongs to is more complex due to the large amount of specific details in the products. This makes the need for labour much higher as there is barley no automation. Even though the high amount of labour creates some sort of flexibility as staff can be moved from one line to another without major switching costs, the production is slower and it becomes a problem at places where labour is a limited resource. Product X, in turn, is one of the most complex product families within its category as the component from China is critical for the production. The component from China is a critical bottleneck for Product X since it is single sourced and has a long lead time. The component is hard to source locally as smaller changes may impact the result of the finished product, which may limit what markets a supplier can serve. In addition, the component is the most expensive used and carrying stocks of it, hence, has a huge impact on both costs and risk. Historically, capacity has also been a critical bottleneck but it varies with time. At the moment there is more capacity available than needed. Since there is a very limited storage space for Product X, a higher capacity than needed causes problems. The decision of whether to let the production lines stand still and pay extra for the unused labour, or to find and pay for extra inventory must be made.

There is one dominant supplier for ProductX EU that produce more than three times the volume of the second largest supplier. The supplier is located in central EU and has 22 different assembly lines that they can shift in between. They are also, in general, good at interpreting the SPI reports and produce the right volumes needed. Another smaller supplier of ProductX EU has five assembly lines that can only produce a limited range of product families due to specialized equipment. This supplier even has a dedicated line for Product X in order to handle the complexity of the product. A 20% increase or decrease in production volume can usually be solved within a few days, but a decrease in volume gives financial consequences for this supplier. Bigger suppliers are, in general, more flexible than smaller suppliers as they often work actively with flexibility. The amounts of flexibility for different suppliers are, however, varying as they have different strategies. Some suppliers are using flexible lines, that can produce a wide product mix and that have spare capacity, meanwhile others are using more inventory.

4.2.3 Sourcing

The demand for Product X is harder to forecast than for other product families within the same product category. The only thing Company X knows for sure is that the demand increases during peak seasons but it is hard to predict how much. The demand for Product X has historically been doubled from one year to another and it has continuously been exceeded the expectations of sales. In addition, Product X is an iconic product that the retail function often puts in the catalogue and runs promotions on. According to internal rules, the retail function does not have to announce a campaign in advance unless it is expected to increase the sales volumes with more than 30%. However, unannounced promotions happen, which further complicates the planning.

The product category that Product X belongs to usually try to make the suppliers have a flexibility in production capacity of 20% above and below forecast. However, as Product X deviates a lot from forecasts they have now tried to increase the upside capacity flexibility to 30% above forecast. The same does, however, not imply for downside capacity flexibility.

The time it takes to increase the capacity for Product X above 20% over forecast depends mainly on the raw material and labour availability as well as of how many other products that need an increase in capacity. Normally it takes a few weeks. To find a more long-term solution to a capacity increase, it takes about six to nine months to create a new production line and about one year to start up the production at a new supplier. Even though there are several different suppliers that can produce, the time it takes to switch production of the product family at the suppliers' is also dependant on how much raw material the suppliers have for their current production as they need to use that up first.

It is up to the suppliers themselves to decide how much inventory they should keep of both raw materials and finished goods, since the suppliers are carrying the main risk for the inventories. Company X's decision of not getting involved in deciding inventory levels is based on the risk this would add to Company X since there is a risk of not getting the goods sold. A supplier agreement could be ended with five months' notice so the suppliers are recommended not to keep more stock than that. Suppliers often build stocks when they see that they cannot match the volumes needed according to the SPI reports, which normally occurs during peak seasons when they keep approximately three times the demand in stock. The suppliers are normally paying for the stocks but sometimes Company X comes up with special solutions during campaigns, summer holidays or similar events. The suppliers are willing to keep stocks even if they must pay for it themselves since good stock levels generate good results in terms of the metric *OTD sender* that, in turn, generates more orders.

4.2.4 Delivery

On the European market, the main transportation mode is truck. In order to react upon sudden changes on the European market, the transport function within Company Y can make use of spot solutions, which are temporary solutions that have not been stated in any agreements. This is possible due to the good availability of carriers on the European market. If a carrier does not perform according to requirements, the carrier is usually exchanged for another carrier within one to two weeks via a spot solution with another already agreed supplier. The spot solutions are more expensive than contracted transport services but they can be in place within less than two weeks compared to an agreed solution that takes about a month to get ready. A spot solution is typically used when there is a sudden need for a new route or a sudden volume change.

In some cases, there are problems connected to the information flow between Company Y's transport function and Company X as well as the suppliers. This may result in that that information about volume changes is delayed so that spot solutions need to be used instead of agreed solutions. Employees believe that the transport flexibility could be improved by better internal and external communication and information sharing as there are several possibilities to solve a transportation problem if they get the information in time.

4.2.5 Strategic Direction

Several persons believe that automation is the next step for Product X's product category as the production will then be less dependent on labour availability. However, an increased automation may lead to a smaller number of suppliers that are assigned bigger volumes, which would increase the dependency of only a few suppliers. Today they have big suppliers that are producing hundreds of different products. To prepare for increased automation, there are thoughts from Company X's side to investigate the possibilities of increased standardization and modularization as some of the products, even today, only have minor differences.

Product X is continuously developing. For example, a few years ago the packaging solution got changed. This decreased the volume of the packaging a lot. However, the product development is slow. A couple of years ago, a product feature was introduced to Product X. Even though the introduction of the feature at the suppliers', handled by Company X, only took a week or a few weeks, it took almost a year for the product development function within Company Y to prepare.

The category manager believes that it is important from an agility perspective to partnership for long time horizons with the suppliers as well as giving them more ownership. If they know that their businesses are secured, they dare to invest and adapt to Company Y's philosophy.

4.3 Case 2: ProductY NA

This section aims to describe the features of the individual case ProductY NA. The section starts with giving an overview of the different processes in the supply chain connected to ProductY NA, and continues with describing the separate processes: manufacturing, sourcing and delivery, individually. The section ends with providing an overview of the strategic direction connected to the case.

4.3.1 Mapping of Supply Chain

There are two different suppliers that produce Product Y in the North American market. One of them is placed in south east of the US and serves the northeast side of North America. The other supplier has two factories that are both located in Mexico. One of the factories serves, together with the supplier in the US, the southeast side of North America and the other factory serves the west side of North America.

The supplier situated in the US normally purchases all components for Product Y from a European supplier, with a lead time of three to six weeks, and assemblies them. The sourcing lead times for all components are equal to the transport lead times since there are rarely any problems with availability at the European supplier's. In contrast to the US supplier, the Mexican supplier produces their own components and sources most raw materials for this locally. One exception is a raw material from Europe with a lead time of four to six weeks.

From the suppliers, Product Y is transported with direct delivery setups to the Company Y stores. The high share of direct deliveries has made it possible to eliminate most of the inventory buffers further downstream in the supply chain and, thereby, to reduce costs. Thus, the suppliers and stores stand for most available stock of finished products in the supply chain. One exception is the established Customer Distribution Centres (CDCs), which are a smaller part of the regular DCs, where product Y is stored to serve the additional distribution channel: phone delivery. Phone delivery has been common for several years on the North American market, which is why Company X has adapted the supply chain for this from the very beginning.

In figure 4.3, a schematic view of the supply chain for Product Y on the North American market is presented. The arrows represent the material flow. Since direct delivery setups are used, no additional inventory locations are depicted, apart from the CDCs. The material flow to the CDCs are significantly smaller than the other depicted flows, which is indicated schematically by the thinner arrows.

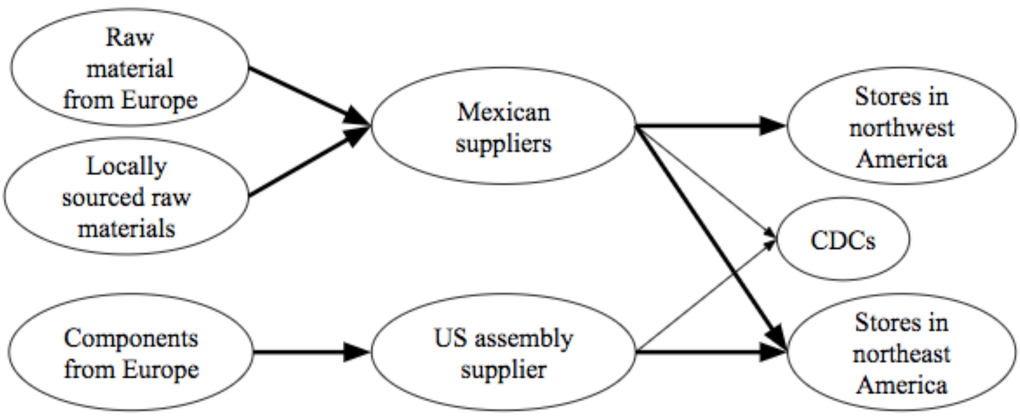

Figure 4.3. Schematic view of the supply chain for ProductY NA.

4.3.2 Manufacturing

As mentioned above, Company X is collaborating with two suppliers producing Product Y for the North American market, the US supplier and the Mexican supplier. This section has, therefore, been divided into three parts. The first one describes the common features for the two suppliers and the following two parts describe the features that are only connected to one out of the two suppliers.

Common Features
The assembly production of Product Y is automated. The packaging of the product is included, as a last step, in the line production. The packaging gives Product Y the limited shelf life of six months, which occasionally leads to scrap of products. Thus, the limited shelf life within this product category increases the importance of good communication regarding the inventory at the suppliers'. Company X is therefore involved by asking for reports containing information about the production dates of the finished goods in stock. They also encourage the suppliers to use a good practice of warehouse management, such as the FIFO (First in First Out) rule.

US Supplier
The US supplier purchases the components instead of producing them themselves. All components, apart from one, can exceptionally be sourced locally on the North American market if needed. Thus, this specific component, which can only be sourced from Europe, is the main bottleneck for increasing production volumes due to the long transport lead time. Since the US supplier does not produce their own components, the supplier is more flexible in terms of product mix and they are therefore able to produce a wide range of products even though they only have one production line. At the same time, this makes Product Y more expensive since purchasing components is more expensive than producing them themselves. The assembly production at the supplier's is highly automated, which has resulted in that the supplier can handle a production volume increase of 50% in a week by just using overtime. If the increase is bigger than that, the raw material buffers need to be refilled, which takes about six weeks.

Mexican Supplier
The Mexican supplier can cope with demand increases of 30-40% for a short period. Their ability to increase volumes further depends on the availability of raw materials since they are producing the components themselves today. This has, however, not always been the case. A few years back, the supplier sourced some components from Europe with a lead time of ten weeks. As investments were made in vertical integration, meaning that the supplier started to produce the components in-house instead of sourcing them, the supplier managed to decrease the lead times for the components to two days.

The main bottleneck for the Mexican supplier is similar to the one of the US supplier since it is related to the same component. However, in the case of the Mexican supplier, the raw material for producing the component is rather the bottleneck. The production of the specific component is the most limiting factor for the supplier in reaching a high performance because the production is complicated to plan. The reason for this is the need for trained people in the production. The education takes time and the staff is usually very specialized in one type of component. In addition, the capacity calculation is extra complicated as the demand is fluctuating a lot, which makes it hard to plan the labour and the education as the need for staff differs during the year.

4.3.3 Sourcing

Compared to other product families within the same product category as Product Y, product Y is a high-volume product in terms of sales. The supply chain setup makes it respond to an increase or decrease of about 20% in sales volume for a shorter period without any problems, but if the demand deviates more than that it causes problems with availability in stores. Because of the slim inventory setup in the supply chain, suppliers and stores need to cooperate to build up stocks to assure availability during sales increasing events or peak seasons.

Since Company X usually source products from several suppliers, they can change the volumes between the suppliers to secure a proper supply of products. This also creates a competitive environment for the suppliers, which makes them want to keep performing at a high level. In the case of ProductY NA, the supplier base is limited to only two suppliers, which limits the ability for Company X to put this kind of pressure on the suppliers for them to perform better. This is a problem since Company X wants the suppliers to stay competitive.

Another factor that complicates the forecast planning is that the supply planners are not always informed about future events to increase sales by the retail function, which makes it difficult for them to prepare and plan for the supply accordingly. In the past, it has happened that the retail function has missed to communicate when free home-deliveries have been offered to the customers on the North American market, which increased the sales volumes significantly and had a huge impact on both sourcing and production.

4.3.4 Delivery

On the North American market, truck is the main transportation mode. The availability of carriers is, however, limited on the North American market, especially for transportation services from Mexico into the US. This is because also many other American companies have their production positioned in Mexico. The low availability leaves smaller room for negotiation of prices and performance.

Since one supplier is situated in Mexico, the goods must pass international borders in order to reach the rest of North America. The crossing of the Canadian border is less challenging compared to the Mexican border. To cross the Mexican border, heavy paperwork has to be in place and the crossing itself is time-consuming as there are limited resources in customs. This often leads to delay in transportation. It also happens that the carriers are not ready for loading on time, which is a problem that decreases the overall performance of the supply chain. Even if the score on the metric *OTD sender* is high, the delay in transportation is reflected in *OTD logistics* and, hence, in *OTD supply chain*. The suppliers and their related carriers collaborate to solve this problem by having common meetings where they decide on focus areas for the different parties in order to improve the performance of the supply chain and be able to deliver the products on time.

4.3.5 Strategic Direction

To overcome the challenge of having a limited supplier base in North America, the product category that product Y belong to is exploring the possibility to increase the supplier base in order to increase the competitiveness on the market. They have ongoing projects that aim to find more suppliers in North America and are also evaluating the possibility of sourcing products from Asia.

In order to decrease the risk of scrapping products due to exceeded shelf life, there is an ongoing project that aims to increase the shelf life of the products. This would mean a larger time buffer in the supply chain and it would enable Product Y to be stored longer time, which would also help the future plans of increasing the number of inventory locations in the supply chain. To cope with the increased online ordering that comes from the emerging e-commerce, there are, namely, plans to increase the number of CDCs in the supply chain.

Another ongoing project within the product category of Product Y is a pilot project on another market for introducing Vendor Managed Replenishment (VMR), meaning that the suppliers are accessing the actual stock levels at the stores and that they are replenishing the stocks when needed instead of producing according to orders generated by the stores or the current ordering system.

5 Within-Case Analysis

In this section, the two cases ProductX EU and ProductY NA will be analysed individually. Following that, the common features of the whole of Company X, and thereby for the two cases, will be analysed as a separate case.

5.1 Case 1: ProductX EU

In this analysis of the ProductX EU case, good examples and challenges connected to supply chain agility drawn from the empirics are identified, with help from the literature. Following that, the individual examples of both good performance and challenges within the area of supply chain agility are matched with appropriate metrics of supply chain agility identified in literature.

5.1.1 Good Examples and Challenges Connected to Supply Chain Agility

The identified examples of good performance and challenges within the agility area resulting from the analysis are presented in table 5.1 grouped under the four capabilities of supply chain agility identified in literature. In the remaining of this section, the identified examples are presented and their connections to supply chain agility are motivated.

Table 5.1. Good examples and challenges connected to supply chain agility in the ProductX EU case.

	Examples from case	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**
Good examples	Many alternative suppliers	*	*		
	Labour-intensive production		*		*
	Assembly production	*	*		
	Local sourcing of components	*		*	
	Future strategy of modularization		*		
	Design improvement work	*	*		
	Future strategy of further partnership with suppliers	*			*
Challenges	Many alternative suppliers				*
	Labour-intensive production			*	*
	Limited labour availability	*	*		
	Low forecast accuracy	*			
	Slim inventory setup in supply chain	*			
	Long lead times for sourcing of components	*		*	
	Limited internal communication	*			*
	Limited solutions for over capacity	*	*		
	Single sourcing of components	*	*		
	Complex production	*	*		

Good Examples Connected to Supply Chain Agility
Having *many alternative suppliers* for Product X on the European market increases the possibility of changing volumes between different suppliers, which makes the sourcing process more flexible in terms of volume. Even though there is one dominant supplier, the eight other suppliers can be used as backups, which makes it easier to handle a possible increase in volume as it can be spread over several actors. An increased volume flexibility also contributes to an increased responsiveness as it influences the ability to react to changes in volume. In conclusion, having many alternative suppliers contributes, in the ProductX EU case, to supply chain agility by increasing the flexibility and responsiveness of the supply chain.

The use of *labour intensive production* for Product X both has its benefits and drawbacks in terms of supply chain agility. As a good example, the flexibility dimension is pointed out. Having a large share of labour in the production generally makes it easier to change from producing one product into producing another one in comparison to when more automated equipment is used. It is also generally easier to handle a larger number of different products within the manufacturing system than in the case of a more automated production solution. Hence, having a labour-intensive production contributes to mix flexibility, but the extent to which it contributes to this sub-capability depends on the knowledge of the employees and on the variety of tasks that the employees can perform, which is connected to the competence capability. A labour-intensive production also, in some respects, contributes to the volume flexibility sub-capability since there is often a more definite capacity limit when a larger number of machines are involved. In conclusion, having a labour-intensive production contributes in some respects to supply chain agility by increasing flexibility and is also connected to the competency capability.

Assembly production is used by the suppliers of Product X on the European market. When components are only combined, not produced, it increases the number of different products that the manufacturing system can handle. This provides a better mix flexibility and, hence, enables a higher level of flexibility in the supply chain. Assembly production also makes it easier to introduce new products to the manufacturing system as the components can be exchanged to other components. This contributes to an increased responsiveness of the system. Having assembly production therefore contributes to supply chain agility, in the ProductX EU case, by increasing the flexibility and responsiveness of the system.

In the case of ProductX EU, *local sourcing of components* is seen as a good example of supply chain agility since it decreases the transport distances and, thus, the order lead times of getting the components needed for production. This is the case for most components for Product X on the European market. Having a short source order lead time increases the quickness in the supply chain and decreases the time it takes to react to sudden changes, which contributes to the responsiveness of the system. In conclusion, local sourcing of components contributes to supply chain agility by increasing the quickness and responsiveness of the supply chain.

A *future strategy of modularization* would increase the mix flexibility without compromising product complexity. In addition, it would further enhance assembly production since less changeovers in the manufacturing setup would be needed if different products share the same modules. This can be seen as a vital step in order to sustain mix flexibility when introducing a more automated production. In conclusion, this future strategy of modularization would, in the ProductX EU case, contribute to supply chain agility by increasing the flexibility in production.

The *design improvement work* that has been done in order to decrease the bulkiness of Product X has made the handling of the product easier. This is especially true for transport and inventory as less resources need to be changed in order to change the volume capacity. Hence, the design improvement work is a good example of supply chain agility contribution since it increased the flexibility and, in turn, the responsiveness of the supply chain.

By applying the *future strategy of further partnership with suppliers* mentioned in the ProductX EU case, the business understanding would increase for both parties as it would be easier to synchronize the operations and information sharing. The closer collaboration in the supply chain would be good from an agility perspective, since it would ease the adaptation to changes throughout the whole supply chain. In conclusion, a future strategy of further partnership with the suppliers would contribute to supply chain agility since it would increase the responsiveness and competency capabilities in the supply chain.

Challenges Connected to Supply Chain Agility

Even though having *many alternative suppliers* in the case of ProductX EU enables a higher level of volume flexibility, it also makes it harder to build close relationships with the suppliers if they are many. Thus, it is seen as a challenge in the case, where there are nine different suppliers only on the European market, to build strong relationships and trust with all of them. Since cooperation and integration are parts of the competency capability of supply chain agility, having many alternative suppliers could also be seen as influencing supply chain agility negatively.

The use of *labour intensive production* for Product X on the European market both has its benefits and drawbacks in terms of supply chain agility. As a challenge, the quickness dimension is pointed out since a labour-intensive production is more likely to be slower than a more automated one. This is also dependent on the competency capability in the form of how much education and training the employees get. Having a labour-intensive production, hence, also influences supply chain agility negatively in some respects in the case, since it decreases quickness. It is also dependent on the competency capability.

In the case of ProductX EU, the *limited labour availability* is a challenge connected to having labour intensive production since the production is highly dependent on labour. Not having available labour, hence, influences the time to react to changes negatively since it decreases the ability to increase capacity. From this perspective, the current strive towards a more automated production can be seen as beneficial since less labour would be needed. However, this must be balanced against the definite capacity limit that an automated production has and the negative impact it could have on mix flexibility. A limited labour availability also limits the volume flexibility in production. In conclusion, limited labour availability influences the supply chain agility negatively in the case of ProductX EU since it decreases the responsiveness and flexibility of the system.

Having a *low forecast accuracy* is a challenge that originates from having inaccurate data to base the planning on. If there are many forecast deviations, as in the case for ProductX EU, it is even harder to identify the upcoming need and plan production capacity accordingly. Thus, for Product X there is not only a problem with the external information accuracy, but also the internal, since the forecasts are created by Company Y. This low forecast accuracy influences supply chain agility negatively since it decreases the responsiveness of the supply chain.

There is a *slim inventory setup in the supply chain* for Product X on the European market, which follows from the high share of direct deliveries that has almost eliminated the use of DCs, and from the bulkiness of the product. The low number of inventory locations in the supply chain makes it less able to adapt quickly to change. From this perspective, the slim inventory setup decreases the responsiveness in the system. However, the number of inventory locations must be balanced against the risk of an increased inventory throughput time that influences the ability to identify change. In conclusion, the slim inventory setup in the supply chain influences supply chain agility negatively since it decreases the responsiveness of the system.

In order to be quick and achieve short operations lead times, all related lead times need to be short. In the case of ProductX EU, the *long lead times for sourcing of components* that results from long transportation distances, is a challenge. Having long lead times also influences the responsiveness negatively since it takes longer time to adapt to changes. Hence, these long lead times for sourcing of components influences supply chain agility negatively since it decreases the quickness and responsiveness of the supply chain.

The *limited internal communication*, as in the case when information regarding sales increasing events does not reach Company X in advance, can be seen as a natural result of a complex organization with several stakeholders. However, it lowers the ability to find a suitable solution in time and, in turn, decreases the responsiveness. This can also be connected to the competency capability since the internal communication is influenced by internal collaboration and teamwork. Thus, in conclusion, limited internal communication is a challenge from an agility perspective since it decreases responsiveness. It is also related to the competency capability.

The *limited solutions for over capacity* that exist for Product X on the European market today impact the volume flexibility of the supply chain since the volumes are not easily reduced. In the case of overcapacity, there are two main problems, namely that lines dedicated to Product X risk being unused and that there is no space for storing the bulky additional production of Product X. Since Product X is hard to plan, due to the many forecast deviations, it is argued that it is challenging from an agility perspective not to have a plan ready for how to handle the situation of extra capacity to make it possible to react fast on change. In conclusion, having limited solutions for how to handle over capacity influences supply chain agility negatively since it decreases the flexibility and responsiveness of the supply chain.

Even though it can be argued that close relationships with suppliers influence supply chain agility positively, the situation of *single sourcing of components* becomes a problem when the lead time is long. This is the case for one component that is sourced from China in the case of ProductX EU. This is a challenge since the long lead time decreases the volume flexibility due to the lack of components in place which, in turn, also limits the responsiveness to change. In conclusion, single sourcing of components influences supply chain agility negatively in this case since it decreases the flexibility and responsiveness in the supply chain.

The design of Product X, including detailed features, causes a *complex production* process. A complex production process limits the volume flexibility as it is harder to find additional production capacity (or to find alternative use for extra production capacity) as some suppliers need to dedicate machines to be able to produce the product. The limited volume flexibility also limits the ability to act to change and hence, in conclusion, the complex production process of Product X influences supply chain agility negatively since it reduces the flexibility and responsiveness in the supply chain.

5.1.2 Metric Matching

In this section, the good examples and challenges connected to supply chain agility in the ProductX EU case presented in section 5.1.1 are matched with appropriate metrics of supply chain agility suggested in the theoretical framework. The section is divided into four subsections, one for each capability of supply chain agility.

Responsiveness
The connections between the empirical findings and the theoretical findings for the responsiveness capability are presented in table 5.2. Metrics from all three sub-capabilities of responsiveness are represented and there are many examples from the cases connected to each metric, which implies that responsiveness is an important capability in this case. Most examples from the cases were found to be connected to the sub-capability react to change, and in particular the metric *time to increase/decrease source/production/delivery capacity*, which from this case can be argued to be of most importance for Company X in the responsiveness dimension of supply chain agility for Product X on the European market.

Table 5.2. Connections between the good examples and challenges connected to supply chain agility in the ProductX EU case and the metrics connected to responsiveness from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
RESPONSIVENESS - IDENTIFY CHANGE	
Level of external information sharing in supply chain	Future strategy of partnership with suppliers
Level of internal information sharing in organization	Limited internal communication, Low forecast accuracy
Level of standardization in information sharing	Limited internal communication
RESPONSIVENESS - REACT TO CHANGE	
Time to increase/decrease source/production/delivery capacity	Local sourcing of components, Long lead times for sourcing of components, Many alternative suppliers, Single sourcing of components, Complex production, Limited solutions for over capacity, Limited labour availability
Number of new products the manufacturing system can handle in a given time period	Assembly production
Number of inventory locations in supply chain	Slim inventory setup in SC, Local sourcing of components, Long lead time for sourcing of components, Design improvement work

RESPONSIVENESS - RECOVER FROM CHANGE	
Time to re-establish and sustain source/production/delivery lead time after increased/decreased product volumes	Single sourcing of components
Amount of inventory that can be phased in/out and be sustained in a given time period	Local sourcing of components, Long lead times for sourcing of components, Design improvement work

Flexibility

The connections between the empirical findings and the theoretical findings for the flexibility capability are presented in table 5.3. Metrics from both sub-capabilities of flexibility are represented and there are several examples from the cases connected to each metric, which would argue that flexibility is an important capability in this case. There is a wide spread of metrics connected to the examples from the ProductX EU case for both sub-capabilities, a few more within the volume flexibility dimension than in the mix flexibility dimension, which would imply that the volume flexibility dimension is slightly more important for Company X in the case of ProductX EU. Especially the two metrics *cost of increasing/decreasing source/production/delivery capacity in a given time period* and *amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/delivered in a given time period* seems to be of extra importance.

Table 5.3. Connections between the good examples and challenges connected to supply chain agility in the ProductX EU case and the metrics connected to flexibility from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
FLEXIBILITY - MIX FLEXIBILITY	
Percentage of common parts in final products	Future strategy of modularization
Number of different products that a manufacturing setup can handle	Assembly production, Future strategy of modularization, Labour intensive production
Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup	Labour-intensive production
Cost of changing operations from one product to another product	Future strategy of modularization, Labour intensive production
Time to change operations from one product to another product	Future strategy of modularization, Labour intensive production
Number of different tasks the typical worker can perform	Labour-intensive production

FLEXIBILITY - VOLUME FLEXIBILITY	
Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/delivered in a given time period	Labour-intensive production, Many alternative suppliers, Single sourcing of components, Limited solutions for over capacity, Complex production, Limited labour availability
Cost of increasing/decreasing source/production/delivery capacity in a given time period	Labour-intensive production, Design improvement work, Limited solutions for over capacity, Single sourcing of components, Complex production
Number of suppliers per product or component	Many alternative suppliers
Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period	Labour-intensive production, Limited labour availability
Amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period	Labour intensive production

Quickness
The connections between the empirics and the theory for the quickness capability are presented in table 5.4. Metrics from one out of three sub-capabilities of quickness are represented. The sub-capabilities new product time to market and delivery lead time and timeliness are not represented, which is natural since both the product development function and the transport function in general is a common feature for the two cases, ProductX EU and ProductY NA, and is therefore analysed further on at a generic level in section 5.3. Within the represented sub-capabilities, all metrics suggested from theory are connected to at least one example from the ProductX EU case. However, there are only between one and two examples per metric, which would argue that quickness is not as important as the responsiveness and flexibility capabilities of supply chain agility for Company X for Product X on the European market. Most examples are connected to the metric *source lead time*, which would argue that this is of most importance in this case.

Table 5.4. Connections between the good examples and challenges connected to supply chain agility in the ProductX EU case and the metrics connected to quickness from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
QUICKNESS - OPERATIONS LEAD TIME	
Production lead time	Labour intensive production
Source lead time	Local sourcing of components, Long lead times for sourcing of components

Competency
The connections between the empirical findings and the theoretical findings for the competency capability are presented in table 5.5. There are only between one and two examples per metric, which would imply that competency is not as important as the responsiveness and flexibility capabilities of supply chain agility for Company X for Product X on the European market. Most examples are connected to cooperation with the suppliers in the form of supplier involvement in product development and planning as well as common initiatives with the suppliers, which would argue that supplier cooperation is of most importance in this case.

Table 5.5. Connections between the good examples and challenges connected to supply chain agility in the ProductX EU case and the metrics connected to competency from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
COMPETENCY	
Total number of suppliers	Many alternative suppliers
Level of supplier involvement in product development	Many alternative suppliers, Future strategy to further partnership with suppliers
Level of supplier involvement in short and long term planning	Many alternative suppliers, Future strategy to further partnership with suppliers
Number of cooperation initiatives between supplier and customer in improving performance in a given time period	Many alternative suppliers, Future strategy to further partnership with suppliers
Amount of employee training and education programs in a given time period	Labour intensive production
Amount of different jobs per employee in a given time period	Labour intensive production
Level of cross-functional teamwork	Limited internal communication

5.2 Case 2: ProductY NA

In this analysis of the ProductY NA case, good examples and challenges connected to supply chain agility drawn from the empirics are identified, with help from the literature. Following that, the individual examples of both good performance and challenges within the area of supply chain agility are matched with appropriate metrics of supply chain agility identified in literature.

5.2.1 Good Examples and Challenges Connected to Supply Chain Agility

The identified examples of good performance and challenges within the agility area resulting from the analysis are presented in table 5.6 grouped under the four capabilities of supply chain agility identified in literature. In the remaining of this section, the identified examples are presented and their connections to supply chain agility are motivated.

Table 5.6. Good examples and challenges connected to supply chain agility in the ProductY NA case. The star in parenthesis (*) represents that vertical integration, even though it is a good example of supply chain agility in this case, also generally reduce flexibility but that this is not seen as a challenge in this case.

	Examples from case	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**
Good examples	Few alternative suppliers				*
	Automated production			*	
	Assembly production	*	*		
	Local sourcing of components	*		*	
	Established CDCs	*		*	
	Project to implement VMR	*		*	*
	Packaging improvement work	*	*		
	External collaboration			*	*
	Vertical integration		(*)	*	*
Challenges	Few alternative suppliers	*	*		
	Automated production		*		
	Slim inventory setup in supply chain	*			
	Long lead times for sourcing of raw materials	*		*	
	Limited internal communication	*			*
	Component bottleneck	*	*	*	
	Delay in transportation			*	

Good Examples Connected to Supply Chain Agility

As there are only two suppliers on the North American market that produce Product Y, there are *few alternative suppliers* to use as backups. This can be seen as both a good example and a challenge connected to supply chain agility. From a collaborative perspective, it is easier to manage good relationships with few suppliers than with many. Having few suppliers may therefore contribute to the competency capability through increased possibilities for collaboration and integration, which in turn would contribute to supply chain agility. As there are plans of increasing the competition by introducing more suppliers, this situation might however change in the future.

The use of *automated production* methods for Product Y on the North American market both has its benefits and drawbacks in terms of supply chain agility. As a good example, the production lead time could be argued to be shorter for an automated production solution than for a labour intensive one. This makes the production quicker and, hence, the automated production in the ProductY NA case is contributing to supply chain agility through increased quickness in the supply chain.

In the ProductY NA case both the suppliers make use of *assembly production.* As already described in the ProductX EU case in section 5.1.1, this is contributing to the supply chain agility by increasing the flexibility and responsiveness of the system.

Local sourcing of components is used on a regular basis by the Mexican supplier and it decreases the lead time compared to importing the components from Europe. As already described in the ProductX EU case in section 5.1.1, this is contributing to the supply chain agility by increasing the quickness and responsiveness of the supply chain.

In order to reduce the lead time to the customers that are ordering online, the use of dedicated DCs could be seen as beneficial. Thus, the fact that there are already *established CDCs* on the North American market as part of the DCs increases the quickness in terms of delivery time and thereby also the responsiveness to change, which in turn both contribute to supply chain agility.

The *project to implement VMR* is seen as a good example of increasing transparency in the supply chain and easing the planning for the suppliers since they would not have to produce to orders. Since the order handling time would be eliminated for Company X, it could also be argued that this would make the supply chain quicker. By implementing this project, the level of integration in the supply chain would also increase, which is part of the competency capability of supply chain agility. To conclude, the implementation of VMR is seen as a good example of action that contributes to supply chain agility through the increase of the quickness, the competency and the responsiveness in the supply chain.

The *packaging improvement work*, that has been done to decrease the volume of the products, is seen as a good example of improving agility. A lower packaging volume increases volume flexibility in relation to transport and inventory, since less resources are required in order to adapt to changes. It also influences the amount of inventory that can be phased in within a time period since the inventory takes less space and, hence, more inventory is enabled to be phased in if needed. Another packaging improvement project is the ongoing project to increase the shelf life of the packed products. Having longer shelf life would further influence the amount of inventory that could be phased in during a time period, which would further contribute to the responsiveness of the system. The packaging improvement work in the ProductY NA case, hence, contributed to supply chain agility through the increase of flexibility and responsiveness in the supply chain.

The initiative of the suppliers to increase the *external collaboration* with carriers, by introducing a meeting to discuss improvement work, is seen as a good example of increasing supply chain agility. Apart from that it may lead to an improved delivery timeliness, it may also contribute to better relationships in the supply chain and better cooperation, which is part of the competency capability of supply chain agility. Hence, this would increase the competency capability as well as the quickness in the supply chain and thereby contribute to supply chain agility.

Unlike the US supplier, the Mexican supplier is producing most components themselves. A few years back, the Mexican supplier managed to decrease the lead time of components by investing further in *vertical integration*. This contributed to supply chain agility through an increase in quickness. It also contributed to the competency capability of supply chain agility through increased integration in the supply chain. However, vertical integration may need to be balanced against the reduction in mix flexibility that follows from investments in machines. In this case, the advantages within the quickness capability did overweigh the drawbacks within the flexibility capability, which is the reason why vertical integration is only seen as a good example of supply chain agility in the case of ProductY NA.

Challenges Connected to Supply Chain Agility
As already mentioned, having *few alternative suppliers* can be seen as both a good example and a challenge connected to supply chain agility. From a volume flexibility perspective, it is seen as a challenge in the ProductY NA case as there are no backup suppliers to switch production volumes to. This decreases the volume flexibility and thereby the responsiveness in the supply chain, hence, influencing the supply chain agility negatively.

The use of *automated production* methods for Product Y on the North American market both has its benefits and drawbacks in terms of supply chain agility. As a challenge, the flexibility dimension is pointed out. Automated productions have more definite capacity limits in comparison to labour intensive productions, which limits the range of volume flexibility. It could also be argued that automated solutions generally have lower levels of mix flexibility than labour intensive solutions since it is easier to change tasks for employees then for machines. To conclude, having an automated production solution influences some aspects of supply chain agility negatively by limiting the flexibility.

Since there is a s*lim inventory setup in the supply chain* in the case of ProductY NA, due to the high share of direct deliveries, there are less buffers close to the customers to cover for sudden demand changes. As already described in the ProductX EU case in section 5.1.1, this is influencing the supply chain agility negatively through decreased responsiveness of the system.

The *long lead times for sourcing of raw materials*, as is the case for the Mexican supplier, increase operations lead time and limits the ability to react to change. The same is seen for the components for the US supplier. As already described in the ProductX EU case in section 5.1.1, this is influencing the supply chain agility negatively through decreased quickness and responsiveness of the supply chain.

Limited internal communication is seen as a challenge since Company X is not always informed by retail of future sales increasing events, such as free home deliveries in the North American market. As already described in the ProductX EU case in section 5.1.1, this is influencing the supply chain agility negatively through decreased responsiveness. It is also related to the competency capability.

Both suppliers in the ProductY NA case have the same component as their main bottleneck, but for different reasons. For the US supplier, it is because of the long souring lead time from Europe meanwhile, for the Mexican supplier, it is because of the long sourcing lead time of raw materials for making the component as well as the availability of educated labour in production. The *component bottleneck* influences supply chain agility negatively due to the decreased volume flexibility and the low level of quickness in the sourcing process. This also limits the responsiveness in the supply chain.

The risk of *delay in transportation*, due to customs and a low availability of carriers on the North American market, increases the delivery lead time and reduces the delivery timeliness. This, in turn, influence the supply chain agility negatively through limited quickness.

5.2.2 Metric Matching

In this section, the good examples and challenges connected to supply chain agility in the ProductY NA case presented in section 5.2.1 are matched with appropriate metrics of supply chain agility suggested in the theoretical framework. This is in order to sort out what metrics in the theoretical framework that is of most importance in the ProductY NA case, that is those aspects that are done well from an agility perspective today, and that therefore are good to keep up and improve further, and those aspects that are not done well from an agility perspective today, and that therefore are good to keep track on to improve. The section is divided into four subsections, one for each capability of supply chain agility.

Responsiveness

The connections between the empirical findings and the theoretical findings for the responsiveness capability are presented in table 5.7. Metrics from all three sub-capabilities of responsiveness are represented and there are many examples from the cases connected to each metric, which implies that responsiveness is an important capability in this case. Most examples from the cases were found to be connected to the sub-capability react to change, and in particular the metrics *time to increase/decrease source/production/delivery capacity* and *number of inventory locations in supply chain*, which from this case can be argued to be of most importance for Company X in the responsiveness dimension of supply chain agility for Product Y on the North American market.

Table 5.7. Connections between the good examples and challenges connected to supply chain agility in the ProductY NA case and the metrics connected to responsiveness from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
RESPONSIVENESS - IDENTIFY CHANGE	
Time delay in sharing customer demand information in supply chain	Project to implement VMR
Level of external information sharing in supply chain	Project to implement VMR
Level of internal information sharing in organization	Limited internal communication
Level of standardization in information sharing	Limited of internal communication
RESPONSIVENESS - REACT TO CHANGE	
Time to increase/decrease source/production/delivery capacity	Local sourcing of components, Long lead times for sourcing of raw materials, Few alternative suppliers, Component bottleneck
Number of new products the manufacturing system can handle in a given time period	Assembly production
Number of inventory locations in supply chain	Slim inventory setup in SC, Local sourcing of components, Long lead times for sourcing of raw materials, Established CDCs
RESPONSIVENESS - RECOVER FROM CHANGE	
Time to re-establish and sustain source/production/delivery lead time after increased/decreased product volumes	Component bottleneck
Amount of inventory that can be phased in/out and be sustained in a given time period	Local sourcing of components, Long lead times for sourcing of raw materials, Packaging improvement work

Flexibility
The connections between the empirical findings and the theoretical findings for the flexibility capability are presented in table 5.8. Metrics from both sub-capabilities of flexibility are represented but there are only a few examples from the cases connected to each metric, which would argue that flexibility is not an as important capability as responsiveness in this case.

Table 5.8. Connections between the good examples and challenges connected to supply chain agility in the ProductY NA case and the metrics connected to flexibility from the theoretical framework.

Metrics from the literature	Connected good examples and challenges of supply chain agility
FLEXIBILITY - MIX FLEXIBILITY	
Number of different products that a manufacturing setup can handle	Assembly production, Automated production, Vertical integration
Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup	Automated production
Cost of changing operations from one product to another product	Automated production
Time to change operations from one product to another product	Automated production
FLEXIBILITY - VOLUME FLEXIBILITY	
Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/delivered in a given time period	Automated production, Few alternative suppliers, Component bottleneck
Cost of increasing/decreasing source/production/delivery capacity in a given time period	Automated production, Packaging improvement work
Number of suppliers per product or component	Few alternative suppliers

Quickness
The connections between the empirical findings and the theoretical findings for the quickness capability are presented in table 5.9. Metrics from two out of three sub-capabilities of quickness are represented. The sub-capability new product time to market is not represented, which is natural since the product development is a common feature of the two cases, ProductX EU and ProductY NA, and is therefore analysed in section 5.3. Within the represented sub-capabilities, all metrics suggested from theory are connected to at least one example from the ProductY NA case. Most examples are connected to the metric *source lead time*, which implies that this is an important in this case. Due to the spread of metrics it could also be argued that quickness is an important capability of supply chain agility for Company X for Product Y on the North American market.

Table 5.9. Connections between the good examples and challenges connected to supply chain agility in the ProductY NA case and the metrics connected to quickness from the theoretical framework.

Metrics from the literature	Connected good examples and challenges of supply chain agility
QUICKNESS - OPERATIONS LEAD TIME	
Production lead time	Automated production, Vertical integration
Source lead time	Local sourcing of components, Long lead times for sourcing of raw materials, Project to implement VMR, Vertical integration, Component bottleneck
QUICKNESS - DELIVERY LEAD TIME AND TIMELINESS	
Delivery lead time	Established CDCs, Delay in transportation
Percentage of orders on time and with accurate documentation	Delay in transportation, External collaboration

Competency

The connections between the empirical findings and the theoretical findings for the competency capability are presented in table 5.10. There are only between one and two examples per metric, which would argue that competency is not as important as the responsiveness and quickness capabilities of supply chain agility for Company X in the ProductY NA case. Most examples are connected to cooperation with the suppliers in the form of supplier involvement in planning as well as common initiatives with the suppliers, which implies that supplier cooperation is important in this case.

Table 5.10. Connections between the good examples and challenges connected to supply chain agility in the ProductY NA case and the metrics connected to competency from the theoretical framework.

Metrics from the literature	Connected good examples and challenges of supply chain agility
COMPETENCY	
Total number of suppliers	Few alternative suppliers
Level of supplier involvement in product development	Few alternative suppliers
Level of supplier involvement in short and long-term planning	Few alternative suppliers, Project to implement VMR
Number of cooperation initiatives between supplier and customer in improving performance in a given time period	Few alternative suppliers, External collaboration
Level of vertical integration	Vertical integration
Use of integrated IT system in supply chain	Project to implement VMR
Level of cross-functional teamwork	Limited internal communication

5.3 Company X

In this analysis of the aspects common for the whole of Company X, and thereby for the two cases ProductX EU and ProductY NA, good examples and challenges connected to supply chain agility drawn from the empirics are identified, with help from the literature. Following that, the individual examples of both good performance and challenges within the area of supply chain agility are matched with appropriate metrics of supply chain agility identified in literature.

5.3.1 Good Examples and Challenges Connected to Supply Chain Agility

The identified examples of good performance and challenges within the agility area resulting from the analysis are presented in table 5.11 grouped under the four capabilities of supply chain agility identified in literature. In the remaining of this section, the identified examples are presented and their connections to supply chain agility are motivated.

Table 5.11. Good examples and challenges connected to supply chain agility for the whole of Company X.

	Common examples from cases	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**
Good examples	Fast within category decision making	*			*
	Capacity planning improvement work	*			*
	Future strategy to increase transparency	*			*
	Supplier relations	*			*
	Supporting management				*
Challenges	Unreliable capacity data	*			
	Limited transport availability	*	*	*	
	Future strategy to eliminate DCs	*		*	
	Long lead times for new products	*		*	
	Many stakeholders	*			
	Complicated information flow	*			
	Lack of integrated IT system	*			*
	Limited risk sharing				*
	Delay in order creation	*			

Good Examples Connected to Supply Chain Agility

At Company X, creativity and new initiatives are encouraged. The categories are independent from each other in their decision making, which enables *fast within category decision making*. The Category Area Manager is working with securing accurate internal information sharing and that all employees have accurate mandate to make decisions, which is connected to the competency capability of supply chain agility as well as to the ability to react quickly to changes. Hence, the fast within category decision making contributes to supply chain agility through the increase of competency and responsiveness.

Company X is struggling with unreliable capacity data that reduces the planning accuracy. The *capacity planning improvement work* project is, thus, seen as a good example of improving the ability to identify change throughout the supply chain. It also contributes in enhancing the integration in the supply chain and in increasing the involvement of suppliers in the planning process, which both is part of the competency capability of agility. In conclusion, the capacity planning improvement work contributes to supply chain agility through increased competency and responsiveness in the supply chain.

The *future strategy to increase transparency*, by sharing more information on the Supplier Portal and by introducing the new IT-tool that will make all actors have updated information, has the possibility of improving information sharing in the supply chain and, hence, lead to a better integration of Company X and their suppliers. This is part of the competency capability of supply chain agility and would also enhance the ability to identify changes quicker for all actors in the supply chain. In conclusion, the future strategy to increase transparency would contribute to supply chain agility through increased competency and responsiveness in the supply chain.

Company X has established routines of how to work with *supplier relations* in the form of dedicated supplier teams, use of supplier surveys, and use of supplier classification resulting in closer relationship to good performing suppliers. Having good relationships with the suppliers improves the collaboration and mutual problem solving in the supply chain, which is part of the competency capability of agility. The external communication could also contribute to the supply chain being more responsive. Hence, good supplier relations contribute to supply chain agility through increased competency and responsiveness in the supply chain.

To become more agile, it is important that there is a *supporting management* that leads the organization in the right direction. The fact that the wished position of Company X expresses a focus on improving agility, and that this is communicated internally, is a step in the right direction. Hence, this is seen as contributing to supply chain agility through the shared strategic vision, which is part of the competency capability of agility.

Challenges Connected to Supply Chain Agility
Unreliable capacity data given from the suppliers lowers the responsiveness as it is harder to identify and react to changes when decisions must be made based on inaccurate data. The estimated flexibility in capacity given by the suppliers cannot be fully trusted. Unreliable capacity data therefore influences supply chain agility negatively since it decreases the responsiveness of the supply chain.

The *limited transport availability* during peak seasons, that also makes is easy for carriers to change customers, limits the ability to react to changes since it makes it harder to adapt the delivery capacity, which is connected to the flexibility capability of supply chain agility. This also influences the transport timeliness, which is part of the quickness capability of supply chain agility. Hence, the limited transport availability is influencing supply chain agility negatively through decreased responsiveness, flexibility and quickness in the supply chain.

There is a *future strategy to eliminate DCs* and instead focus on direct deliveries. This can be seen as a move in the wrong direction in terms of supply chain agility, since the number of different inventory locations would decrease. DCs that are situated close to the customers act as buffers in order to quickly respond to deviations from forecasts, which increase the quickness and responsiveness of the supply chain. Hence, the future strategy to eliminate DCs would influence supply chain agility negatively through decreased quickness and responsiveness of the supply chain.

The currently *long lead times for new products* to be developed and introduced are about two years long. Even the lead times for developing and introducing new product features are long. For example, for Product X it took about a year to introduce a new feature, which is found to be a long time according to the interviewees. Since the responsibility of developing and introducing new products and product features lies on the product development function, and not on Company X, this is seen as a common process for the two cases, ProductX EU and ProductY NA. This influences supply chain agility negatively through limited quickness, which in turn also affects the responsiveness negatively by limiting the ability to react to changed customer preferences.

There are *many stakeholders* in Company Y's organizational structure. Company X is only a small part of the total company and there are dependencies on other functions, which limits the possibilities of making fast decisions. This influences supply chain agility negatively since it limits the responsiveness in terms of the ability to quickly react to change.

Another aspect that makes the decision making within Company X harder is the *complicated information flow*. The transport function experiences that they do not get updated forecasts and some suppliers are having problems with how they should interpret the SPI reports due to the many deviations. The complicated information flow influences supply chain agility negatively through decreased responsiveness in the supply chain since it makes it harder to identify changes.

Even though there are several ongoing initiatives of improving the IT integration at Company X, such as the project of the Supplier Portal, there is a *lack of an integrated IT system* today. For example, a lot of information sharing with suppliers are done manually today by emailing of excel files. Another example is that the transport function misses a common planning tool for transport. The lack of an integrated IT systems today is influencing supply chain agility negatively through limited integration, which is connected to the competency capability of agility, and through limited responsiveness in the supply chain by limiting the ability to identify changes.

It can be argued that the *limited risk sharing* in the supply chain in Company X's case could contribute negatively to the supplier relations and, hence, to the supply chain agility. This is since the suppliers generally have the full responsibility for both inventory and investments in flexible production and increased capacity. Not sharing the responsibility of improving performance in the supply chain, therefore, influences supply chain agility negatively through limiting the competency capability of supply chain agility.

Current *delays in order creation* in the ordering system makes it harder for the suppliers to fulfil orders in time. In order for all actors in the supply chain to be able to identify and adapt to changes, it is important that information is accurate and shared in a timely manner throughout the supply chain. In conclusion, having delays in order creation influences supply chain agility negatively since it decreases the responsiveness of the supply chain.

5.3.2 Metric Matching

In this section the good examples and challenges, presented in section 5.3.1, connected to supply chain agility that are common for the whole of Company X, and thereby for the two cases ProductX EU and ProductY NA, are matched with appropriate metrics of supply chain agility suggested in the theoretical framework. All good examples and challenges of supply chain agility are matched with appropriate metrics except the good example *supporting management*, which is seen as a holistic example including the strategic direction of Company X. Since this common view of supply chain agility and the strategic direction of the company is a superior prerequisite in achieving a higher level of supply chain agility, no specific metric at the same aggregation level as the other metrics is found. Therefore, this good example does not have any metric connected to it. Still, it is seen as an important good example of supply chain agility, which is why it is mentioned in the previous section. This section is divided into four subsections, one for each capability of supply chain agility.

Responsiveness
The connections between the empirical findings and the theoretical findings for the responsiveness capability are presented in table 5.12. Metrics from two out of the three sub-capabilities of responsiveness are represented. The sub-capability recover from change is not represented. There are, in general, many examples from the cases connected to each metric, which would argue that responsiveness is an important capability for the common parts of Company X. Most examples from the cases are found to be connected to the sub-capability identify change, and in particular the metric *level of external information sharing in supply chain*, which therefore could be argued to be of most importance for Company X in the responsiveness dimension of supply chain agility for processes common for all categories.

Table 5.12. Connections between the good examples and challenges connected to supply chain agility at Company X and the metrics connected to responsiveness from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
RESPONSIVENESS - IDENTIFY CHANGE	
Time delay in sharing customer demand information in supply chain	Capacity planning improvement work, Complicated information flow, Future strategy to increase transparency, Delay in order creation
Level of external information sharing in supply chain	Unreliable capacity data, Capacity planning improvement work, Supplier relations, Complicated information flow, Lack of integrated IT system, Future strategy to increase transparency
Level of internal information sharing in organization	Complicated information flow, Unreliable capacity data, Fast within category decision making, Future strategy to increase transparency, Lack of integrated IT system
Level of standardization in information sharing	Capacity planning improvement work, Future strategy to increase transparency, Lack of integrated IT system
RESPONSIVENESS - REACT TO CHANGE	
Time to increase/decrease source/production/delivery capacity	Limited transport availability
Number of actors involved in decision making process	Fast within category decision making, Many stakeholders, Supporting management
Number of inventory locations in supply chain	Future strategy to eliminate DCs

Flexibility
The connections between the empirical findings and the theoretical findings for the flexibility capability are presented in table 5.13. Only one metric from the sub-capability volume flexibility is represented, which implies that the flexibility capability of supply chain agility is not as important as the responsiveness capability for processes common to all categories at Company X.

Table 5.13. Connections between the good examples and challenges connected to supply chain agility at Company X and the metrics connected to flexibility from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
FLEXIBILITY - VOLUME FLEXIBILITY	
Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/delivered in a given time period	Limited transport availability

Quickness

The connections between the empirics and the theory for the quickness capability are presented in table 5.14. Metrics from two out of the three sub-capabilities of quickness are represented. The sub-capability operations lead time is not represented, which could possibly be explained by the fact that operations are different from each other within the different categories at Company X. Within the two other sub-capabilities, all metrics suggested in the theoretical construct are represented by one example each from the whole of Company X. It could therefore be argued that the quickness capability of supply chain agility is not as important as the responsiveness capability for processes common to all categories at Company X.

Table 5.14. Connections between the good examples and challenges connected to supply chain agility at Company X and the metrics connected to quickness from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
QUICKNESS - DELIVERY LEAD TIME AND TIMELINESS	
Delivery lead time	Future strategy to eliminate DCs
Percentage of orders on time and with accurate documentation	Limited transport availability
QUICKNESS - NEW PRODUCT TIME TO MARKET	
Product development lead time	Long lead times for new products
Time to introduce new products	Long lead times for new products

Competency

The connections between the empirical findings and the theoretical findings for the competency capability are presented in table 5.15. There are in general few examples from the cases connected to each metric, which would argue that the competency capability of supply chain agility is not as important as the responsiveness capability for processes common to all categories at Company X. However, the metric *use of integrated IT system in supply chain* is connected to many examples from the whole of Company X and could therefore be argued to be of importance to Company X.

Table 5.15. Connections between the good examples and challenges connected to supply chain agility at Company X and the metrics connected to competency from the theoretical framework.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
COMPETENCY	
Level of supplier involvement in short and long-term planning	Capacity planning improvement work
Number of cooperation initiatives between supplier and customer in improving performance in a given time period	Supplier relations, Limited risk sharing
Use of integrated IT system in supply chain	Capacity planning improvement work, Lack of integrated IT system, Future strategy to increase transparency
Amount of employee training and education programs in a given time period	Fast within category decision making
Level of decentralization in decision making	Fast within category decision making

6 Cross-Case Analysis

In this section the two cases, ProductX EU and ProductY NA, will be analysed together. From the within-case analyses in section 5, the metrics found in each case, ProductX EU and ProductY NA, as well as the metrics found for the common processes for the whole of Company X are compared and put together to a common metrics hierarchy that are of potential importance for measuring supply chain agility at Company X. The metrics hierarchy is presented at the end of this section.

6.1 Metric Gap Analysis

The first step in developing the common metrics hierarchy involves a presentation of the common metrics for the two cases and the metrics connected to the whole of Company X to form a draft of a metrics hierarchy for measuring supply chain agility. The second step involves a further investigation of the metrics that only were identified in one out of the two cases, ProductX EU or ProductY NA, as well as the metrics appearing in literature but that are not connected to any of the two cases nor to the common processes at Company X. These steps are further described in the remaining of this section.

6.1.1 Common Metrics

In table 6.1 the common metrics identified in both two cases, ProductX EU and ProductY NA, are presented together with the metrics identified from the common processes at the whole of Company X. These metrics form a draft of metrics hierarchy to be used in the performance measurement system of supply chain agility at Company X.

Table 6.1. Common metrics of supply chain agility in the two cases and for the common processes at Company X.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Time delay in sharing customer demand information in supply chain* • *Level of external information sharing in supply chain* • *Level of internal information sharing in organization* • *Level of standardization in information sharing*	• *Time to increase/decrease source/-production/-delivery capacity* • *Number of actors involved in decision making process* • *Number of new products the manufacturing system can handle in a given time period* • *Number of inventory locations in supply chain*	• *Time to reestablish and sustain source/-production/-delivery lead time after increased/-decreased product volumes* • *Amount of inventory that can be phased in/out and be sustained in a given time period*	• *Number of different products that a manufacturing setup can handle* • *Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup* • *Cost of changing operations from one product to another product* • *Time to change operations from one product to another product*	• *Amount of capacity that can be obtained/-terminated to increase/decrease and sustain quantities sourced/produced/delivered in a given time period* • *Cost of increasing/-decreasing source/production/delivery capacity in a given time period* • *Number of suppliers per product or component*	• *Production lead time* • *Source lead time*	• *Delivery lead time* • *Percentage of orders on time and with accurate documentation*	• *Product development lead time* • *Time to introduce new products*	• *Total number of suppliers* • *Level of supplier involvement in product development* • *Level of supplier involvement in short and long term planning* • *Number of cooperation initiatives between supplier and customer in improving performance in a given time period* • *Use of integrated IT system in supply chain* • *Amount of employee training and education programs in a given time period* • *Level of decentralization in decision making* • *Level of cross-functional teamwork*

6.1.2 Additional Metrics from Cases

To evaluate whether an additional metric from a case, which is a metric that is only present in one out of the two cases, ProductX EU or ProductY NA, should be included in the set of suggested metrics of importance, the following two criteria are used:

1. The metric is relevant for Company X. Thus, it is not connected to only one specific good example or challenge of supply chain agility within only one category that is not true for other categories within Company X.
2. The metric is directly and strongly connected to a strategy of reaching a higher level of supply chain agility mentioned in section 2.4. Thus, the metric represents an agility strategy that could help in increasing the overall supply chain agility at Company X.

If the metric fulfils one or both described criteria, the metric is selected to be included in the metrics hierarchy for measuring supply chain agility at Company X. The remaining of this section is divided into two parts, one for each investigated case, ProductX EU and ProductY NA.

ProductX EU

Table 6.2 shows the additional metrics that are only identified in the ProductX EU case, and not in the case of ProductY NA nor the common processes for the whole of Company X. The metrics are assessed in groups depending on the good examples and challenges of supply chain agility that they are connected to.

Table 6.2. Additional metrics from the ProductX EU case.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
FLEXIBILITY - MIX FLEXIBILITY	
Percentage of common parts in final products	Future strategy of modularization
Number of different tasks the typical worker can perform	Labour-intensive production
FLEXIBILITY - VOLUME FLEXIBILITY	
Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period	Labour-intensive production
Amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period	Labour-intensive production
COMPETENCY	
Amount of different jobs per employee in a given time period	Labour intensive production

The metric related to the *future strategy of modularization* is directly and strongly connected to the agility strategy of positioning the decoupling point. This is because modularization makes it easier to delay the differentiation in the supply chain. This metric, hence, fulfils the second criterion above. The metric *percentage of common parts in final products* is therefore added to the metrics hierarchy.

The metrics connected to the *labour-intensive production* are all relevant for the whole of Company X. This is since the labour in the production is not just connected to one specific example within one category. Instead, labour is part of the production even in other product categories, even though it is to varying extents. Hence, these metrics fulfils the first criterion above. The metrics *percentage of common parts in final products*, *number of different tasks that the typical worker can perform*, *amount of labour that can be hired and trained to increase and sustain production volumes in a given time period*, *amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period* and *amount of different jobs per employee in a given time period* are, therefore, added to the metrics hierarchy.

ProductY NA

Table 6.3 shows the additional metric that is only identified in the ProductY NA case, and not in the case of ProductX EU nor the common processes of the whole of Company X.

Table 6.3. Additional metric from the ProductY NA case.

Metrics from the literature	**Connected good examples and challenges of supply chain agility**
COMPETENCY	
Level of vertical integration	Vertical integration

The additional metric from the ProductY NA case relates to the initiative to start with *vertical integration*. Even though vertical integration had a very positive effect on reduction of lead time in the case of ProductY NA, it generally lowers the mix flexibility due to investments in machines. Thus, the positive effect of vertical integration is dependent on a specific situation, hence, the metric does not fulfil either criteria one or two. The metric *level of vertical integration* is therefore not added to the metrics hierarchy.

6.1.3 Additional Metrics from Theory

To evaluate whether an additional metric from the theoretical construct, which is a metric that is suggested in literature but not represented by a good example or challenge of supply chain agility in any case of the empirical study, should be included in the metrics hierarchy for supply chain agility at Company X, the following two criteria are used:

1. The metric gives additional relevant input to the metrics hierarchy. Thus, no clear overlaps with already represented metrics exists.
2. The metric is directly and strongly connected to a strategy of reaching a higher level of supply chain agility mentioned in section 2.4. Thus, the metric represents an agility strategy that could help in increasing the overall supply chain agility at Company X.

If the metric fulfils both described criteria, the metric is selected to be included in the metrics hierarchy. The additional metrics from the theoretical construct is shown in table 6.4.

Table 6.4. Additional metrics from the theoretical construct.

Sub-capabilities	Metrics from the literature
RESPONSIVENESS - REACT TO CHANGE	Time to reduce production lead time
RESPONSIVENESS - REACT TO CHANGE	Time to reroute or reschedule operations in production
FLEXIBILITY - MIX FLEXIBILITY	Number of suppliers per product or component
COMPETENCY	Number of new product introductions in a given time period

The first metric, *time to reduce production lead time*, does not fulfil criterion two above since it is not directly and strongly connected to a strategy of increasing supply chain agility described in section 2.4. Even though it could be argued that the metric is bringing additional relevant input to the metrics hierarchy, there is still a connection to the more concrete and measurable metrics *production lead time* and *time to increase/decrease source/production/delivery capacity*. Since criterion two is not fulfilled, this metric is not included.

The second metric, *time to reroute or reschedule operations in production*, does not fulfil criterion one above since it does not provide any large additional input to the metrics hierarchy. This is since similar metrics, such as *time to change operations from one product to another product* and *time to increase/decrease source/production/delivery capacity* is already included, which provides enough information for Company X to know about the production at the suppliers'. Since criterion one is not fulfilled, this metric is not included.

The third metric, *number of suppliers per product or component*, is already represented in the metrics hierarchy, but under the sub-capability volume flexibility. In the theoretical construct, this metric was represented under both the mix and volume flexibility sub-capabilities, why the metric is now seen as an additional metric from the theoretical construct. However, since the metric, from the within case analysis, seems to be of more importance within the volume flexibility sub-capability, this is where it belongs in Company X's case. Thus, the metric does not fulfil criterion one above and is not included.

The fourth metric, *number of new product introductions in a given time period*, does not fulfil criterion one above. It is the responsibility of the product development function at Company Y to initiate the development of new products, and not of Company X, whose contribution to this metric is more connected to the metric *number of new products the manufacturing system can handle in a given time period* already included in the metrics hierarchy. Hence, the metric is not included.

6.2 Suggested Metrics

Table 6.5 shows the final suggested metrics hierarchy for measuring supply chain agility at Company X after including the additional metrics from the two cases as well as from the theoretical construct. The hierarchy consists of 36 metrics and will be the base for building the performance measurement system for measuring supply chain agility at Company X.

Table 6.5. Suggested metric hierarchy for measuring supply chain agility at Company X.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Time delay in sharing customer demand information in supply chain* • *Level of external information sharing in supply chain* • *Level of internal information sharing in organization* • *Level of standardization in information sharing*	• *Time to increase/decrease source/production /delivery capacity* • *Number of actors involved in decision making process* • *Number of new products the manufacturing system can handle in a given time period* • *Number of inventory locations in supply chain*	• *Time to reestablish and sustain source/production/ delivery lead time after increased/decrease d product volumes* • *Amount of inventory that can be phased in/out and be sustained in a given time period*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing setup can handle* • *Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup* • *Cost of changing operations from one product to another product* • *Time to change operations from one product to another product* • *Number of different tasks the typical worker can perform*	• *Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/-delivered in a given time period* • *Cost of increasing/decreasing source/production/delivery capacity in a given time period* • *Number of suppliers per product or component* • *Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period* • *Amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period*	• *Production lead time* • *Source lead time*	• *Delivery lead time* • *Percentage of orders on time and with accurate documentation*	• *Product development lead time* • *Time to introduce new products*	• *Total number of suppliers* • *Level of supplier involvement in product development* *Level of supplier involvement in short and long term planning* • *Number of cooperation initiatives between supplier and customer in improving performance in a given time period* • *Use of integrated IT system in supply chain* • *Amount of employee training and education programs in a given time period* • *Amount of different jobs per employee in a given time period* • *Level of decentralization in decision making* • *Level of cross-functional teamwork*

7 Designing of Construct

In this section, the suggested performance measurement system for measuring supply chain agility at Company X is constructed and adapted to Company X. The first part of the section is divided into three parts, each with focus on a specific constituent of a performance measurement system. Following this, a verification is made for all the four constituents of a performance measurement system. The section ends with presenting the final suggested performance measurement system for Company X after adapting it further.

7.1 Metrics Hierarchy

In this part of the construction of the performance measurement system, the suggested metrics hierarchy is further adapted to Company X. This is done in two steps. Firstly, the formulations of the metrics are adapted and the compatibility of the metrics is evaluated. Secondly, the horizontal integration of the metrics hierarchy is evaluated further.

7.1.1 Formulation and Compatibility of Metrics

In this section, the metrics hierarchy in the performance measurement system for measuring supply chain agility at Company X is evaluated as an entity. Based on the suggested metrics hierarchy for measuring supply chain agility at Company X presented in section 6.2, the metrics are aggregated to a sufficient level and are reformulated to make the system more useful and understandable for Company X. The changes made in the metrics hierarchy are presented and motivated in table 7.1. The reasons for changing the metrics have been selected from the criteria of metrics assessment in the work of Caplice and Sheffi (1994) and are the following:

- Increased uniformity in level of detail
- Increased usefulness of metric
- Increased robustness in metric formulation
- Increased validity in fitting Company X's processes
- Increased compatibility with Company X's existing metrics

Increased uniformity in level of detail is used as a reason for changing the metrics to increase the uniformity in aggregation level for the metrics in the metrics hierarchy. *Increased usefulness of metric* represents the aim of making the metrics more useful to Company X though increasing the ease of understanding the metrics and reducing the number of them in the metrics hierarchy. *Increased robustness in metric formulation* is used to increase the uniformity in metric formulation and thereby making the interpretation of them easier. *Increased validity in fitting Company X's processes* represents the aim of further adapting the metrics to Company X's processes. *Increased compatibility with Company X's existing metrics* is used to adapt the set of metrics further to existing metrics at Company X.

Table 7.1. Changes made to the suggested metrics hierarchy for measuring supply chain agility at Company X.

Original metrics	New metrics	Reasons for change
Time delay in sharing customer demand information in supply chain	Level of IT system integration in supply chain	• Increased usefulness of metric • Increased uniformity in level of detail
Level of standardization in information sharing in supply chain		
Use of integrated IT system in supply chain		
Time to increase/decrease source/production/delivery capacity	Time to change source/production/delivery capacity	• Increased usefulness of metric
Number of actors involved in decision making process	Number of actors involved in decision making process	• Increased usefulness of metric
Level of decentralization in decision making		
Number of new products the manufacturing system can handle in a given time period	Number of different products that a manufacturing system can handle	• Increased usefulness of metric • Increased uniformity in level of detail
Number of different products that a manufacturing setup can handle		
Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup		
Time to re-establish and sustain source/production/delivery lead time after increased/decreased product volumes	Time to re-establish and sustain source/production/delivery lead time after changed product volumes	• Increased usefulness of metric
Amount of inventory that can be phased in/out and be sustained in a given time period	Level of inventory that can be phased in/out and be sustained in a given time period	• Increased robustness in metric formulation
Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/delivered in a given time period	Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period	• Increased usefulness of metric • Increased uniformity in level of detail
Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period		
Amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period		
Cost of increasing/decreasing source/production/delivery capacity in a given time period	Cost of changing source/production/delivery capacity in a given time period	• Increased usefulness of metric
Number of suppliers per product or component	Number of suppliers per product family, component or raw material	• Increased usefulness of metric

Total number of suppliers		• Increased validity in fitting Company X´s processes
Production lead time	Supplier production lead time	• Increased validity in fitting Company X´s processes
Source lead time	Supplier source lead time	• Increased validity in fitting Company X´s processes
Delivery lead time	Company Y delivery lead time	• Increased validity in fitting Company X´s processes
Percentage of orders on time and with accurate documentation	OTD supply chain	• Increased compatibility with Company X’s existing metrics
Product development lead time	Product development and introduction lead time	• Increased usefulness of metric • Increased uniformity in level of detail
Time to introduce new products		
Level of supplier involvement in product development	Level of supplier involvement in internal processes	• Increased usefulness of metric • Increased uniformity in level of detail
Level of supplier involvement in short and long-term planning		
Number of cooperation initiatives between supplier and customer in improving performance in a given time period	Number of cooperation initiatives with suppliers in improving performance in a given time period	• Increased validity in fitting Company X´s processes
Amount of employee training and education programs in a given time period	Number of employee training and education programs in a given time period	• Increased robustness in metric formulation
Amount of different jobs per employee in a given time period	Number of different tasks the typical worker can perform	• Increased usefulness of metric
Number of different tasks the typical worker can perform		

The adapted metrics hierarchy is shown in table 7.2 and consists of 25 metrics, which are formulated to match the processes, language and existing metrics at Company X. This is an attempt to make the performance measurement system more useful to Company X. It can, however, be argued that some metrics are less easily measured than others and that these need further adaptation to specific situations in order to be fully usable.

Table 7.2. Adapted metrics hierarchy for measuring supply chain agility at Company X.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Level of external information sharing in supply chain* • *Level of internal information sharing in organization*	• *Time to change source/production/-delivery capacity* • *Number of actors involved in decision making process* • *Number of inventory locations in supply chain*	• *Time to reestablish and sustain source/production/delivery lead time after changed product volumes* • *Level of inventory that can be phased in/out and be sustained in a given time period*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing system can handle* • *Cost of changing operations from one product to another product* • *Time to change operations from one product to another product* • *Number of different tasks the typical worker can perform*	• *Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period* • *Cost of changing source/production/-delivery capacity in a given time period* • *Number of suppliers per product family, component or raw material*	• *Supplier production lead time* • *Supplier source lead time*	• *Company Y delivery lead time* • *OTD supply chain*	• *Product development and introduction lead time*	• *Level of supplier involvement in internal processes* • *Number of cooperation initiatives with suppliers in improving performance in a given time period* • *Level of IT system integration in supply chain* • *Number of employee training and education programs in a given time period* • *Level of cross-functional teamwork*

7.1.2 Horizontal Categorization

In this section, it is investigated to what extent the adapted metrics hierarchy for measuring supply chain agility at Company X covers all relevant processes in the supply chain for Company X. This is in order to validate the balance of the metrics used in the performance measurement system. The individual metrics' connections to the different processes: source, make, deliver and supply chain/organization is shown in table 7.3. The dimension supply chain/organization is used for metrics that are not connected to any specific process among source, make or deliver, but to the whole of the supply chain or to other processes connected to an individual organization. In the table, it is seen that there is a spread among the different dimensions for the set of metrics and within all the four capabilities of supply chain agility: responsiveness, flexibility, quickness and competency, there are metrics connected to at least three out of the four dimensions: source, make, deliver and supply chain/organization. The responsiveness capability and the quickness capability are even connected to all of them. This indicate that the adapted metrics hierarchy for measuring supply chain agility at Company X represents all relevant processes in Company X's supply chain and, hence, has a high level of coverage and balance of metrics.

Table 7.3. Horizontal spread for the adapted metrics hierarchy for measuring supply chain agility at Company X.

Metrics	**Source**	**Make**	**Deliver**	**Supply chain/ Organization**
RESPONSIVENESS - IDENTIFY CHANGE				
Level of external information sharing in supply chain				*
Level of internal information sharing in organization				*
RESPONSIVENESS - REACT TO CHANGE				
Time to change source/production/delivery capacity	*	*	*	
Number of actors involved in decision making process				*
Number of inventory locations in supply chain				*
RESPONSIVENESS - RECOVER FROM CHANGE				
Time to re-establish and sustain source/production/delivery lead time after changed product volumes	*	*	*	
Level of inventory that can be phased in/out and be sustained in a given time period	*	*	*	
FLEXIBILITY - MIX FLEXIBILITY				
Percentage of common parts in final products	*	*		*
Number of different products that a manufacturing system can handle		*		
Cost of changing operations from one product to another product		*		
Time to change operations from one product to another product		*		
Number of different tasks the typical worker can perform		*		

FLEXIBILITY - VOLUME FLEXIBILITY				
Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period	*	*	*	
Cost of changing source/production/delivery capacity in a given time period	*	*	*	
Number of suppliers per product family, component or raw material	*			
QUICKNESS - OPERATIONS LEAD TIME				
Supplier production lead time		*		
Supplier source lead time	*			
QUICKNESS - DELIVERY LEAD TIME AND TIMELINESS				
Company Y delivery lead time			*	
OTD supply chain		*	*	*
QUICKNESS - NEW PRODUCT TIME TO MARKET				
Product development and introduction lead time				*
COMPETENCY				
Level of supplier involvement in internal processes	*	*	*	*
Number of cooperation initiatives with suppliers in improving performance in a given time period	*	*		
Level of IT system integration in supply chain				*
Number of employee training and education programs in a given time period				*
Level of cross-functional teamwork				*

7.2 Decision Making Levels of Users

In this part of the construction of the performance measurement system, the decision-making levels of the intended users of the metrics are evaluated in order to find out the spread in decision-making levels of the metrics. This is done through an investigation of the vertical integration of the metrics hierarchy.

7.2.1 Vertical Categorization

In this section, it is investigated to what extent the adapted metrics hierarchy for measuring supply chain agility at Company X covers the relevant decision-making levels at Company X. This is to validate the balance of the metrics between different decision-making levels and to evaluate the level of aggregation for the metrics used in the performance measurement system. The individual metrics' connections to the different decision-making levels: operational, tactical and strategic, are shown in table 7.4. The time horizons used for the different decision-making levels are adapted from the time horizons used at Company X, which are 1 week to 0,5 years for the operational level, 0,5 to 1,5 years for the tactical level and 1,5 to 5 years for the strategic level. In the table, it is seen that there is a spread among the different decision-making levels and within all the four capabilities of supply chain agility: responsiveness, flexibility, quickness, competency, there are metrics connected to at least two out of the three decision making levels. Within all capabilities, except for the competency capability, the metrics are even connected to all of them. This can be explained by the fact that the competency capability is connected to management and is, hence, less connected to operational tasks. In addition, the metrics within the capability need to be evaluated based on a long-term horizon, on the tactical or strategic level, as they cannot be measured properly in a shorter time period. In contrary, the decision-making level of metrics within the quickness capability is biased towards the operational level, which is the result of the metrics mainly reflecting operations performed on a weekly basis. However, the total spread among the different decision-making levels for all capabilities indicates that the adapted metrics hierarchy represents all decision-making levels at Company X and, hence, has a high level of coverage and balance of metrics in terms of aggregation level.

Table 7.4. Vertical spread for the adapted metrics hierarchy for measuring supply chain agility at Company X.

Metrics	**Operational**	**Tactical**	**Strategic**
RESPONSIVENESS - IDENTIFY CHANGE			
Level of external information sharing in supply chain	*	*	*
Level of internal information sharing in organization	*	*	*
RESPONSIVENESS - REACT TO CHANGE			
Time to change source/production/delivery capacity		*	
Number of actors involved in decision making process			*
Number of inventory locations in supply chain	*	*	*
RESPONSIVENESS - RECOVER FROM CHANGE			
Time to re-establish and sustain source/production/delivery lead time after changed product volumes		*	
Level of inventory that can be phased in/out and be sustained in a given time period		*	
FLEXIBILITY - MIX FLEXIBILITY			
Percentage of common parts in final products			*
Number of different products that a manufacturing system can handle			*
Cost of changing operations from one product to another product	*		
Time to change operations from one product to another product	*		
Number of different tasks the typical worker can perform	*		
FLEXIBILITY - VOLUME FLEXIBILITY			
Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period		*	
Cost of changing source/production/delivery capacity in a given time period		*	
Number of suppliers per product family, component or raw material		*	*

QUICKNESS - OPERATIONS LEAD TIME			
Supplier production lead time	*		
Supplier source lead time	*		
QUICKNESS - DELIVERY LEAD TIME AND TIMELINESS			
Company Y delivery lead time	*		
OTD supply chain	*	*	
QUICKNESS - NEW PRODUCT TIME TO MARKET			
Product development and introduction lead time		*	*
COMPETENCY			
Level of supplier involvement in internal processes		*	*
Number of cooperation initiatives with suppliers in improving performance in a given time period		*	*
Level of IT system integration in supply chain		*	*
Number of employee training and education programs in a given time period		*	*
Level of cross-functional teamwork		*	*

7.3 Data Gathering

In this part of the construction of the performance measurement system, the data gathering for the metrics included in the performance measurement system is evaluated. This is done through investigating where in the supply chain the need for data gathering efforts are most prominent in the case of Company X. This is to determine the data gathering need for the performance measurement system. The need for data gathering for each individual metric is shown in table 7.5, where each metric is connected to the information sources needed for data collection: suppliers, Company X, Transport, and other functions within Company Y. In the table it is seen that there is a spread among the different information sources and within the four capabilities of supply chain agility. This implies that information needs to be gathered from many different sources. It can also be seen that the information gathering need, especially for the metrics within the sub-capability mix flexibility, are to some extent biased towards the suppliers. This means that the suppliers have an important role for gathering the data needed for this performance measurement system and that the communication with them is critical.

Table 7.5. Data gathering need for the adapted metrics hierarchy for measuring supply chain agility at Company X.

Metrics	Suppliers (Manufact-uring)	Company X (Sourcing)	Transport (Delivery)	Other functions within Comapny Y
RESPONSIVENESS - IDENTIFY CHANGE				
Level of external information sharing in supply chain	*	*	*	
Level of internal information sharing in organization		*		
RESPONSIVENESS - REACT TO CHANGE				
Time to change source/production/delivery capacity	*	*	*	
Number of actors involved in decision making process		*		
Number of inventory locations in supply chain	*	*	*	*
RESPONSIVENESS - RECOVER FROM CHANGE				
Time to re-establish and sustain source/production/delivery lead time after changed product volumes	*	*	*	
Level of inventory that can be phased in/out and be sustained in a given time period	*	*	*	
FLEXIBILITY - MIX FLEXIBILITY				
Percentage of common parts in final products	*	*		
Number of different products that a manufacturing system can handle	*			
Cost of changing operations from one product to another product	*			
Time to change operations from one product to another product	*			
Number of different tasks the typical worker can perform	*			
FLEXIBILITY - VOLUME FLEXIBILITY				
Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period	*	*	*	
Cost of changing source/production/delivery capacity in a given time period	*	*	*	
Number of suppliers per product family, component or raw material	*	*		
QUICKNESS - OPERATIONS LEAD TIME				
Supplier production lead time	*			
Supplier source lead time	*			

QUICKNESS - DELIVERY LEAD TIME AND TIMELINESS				
Company Y delivery lead time			*	
OTD supply chain	*		*	
QUICKNESS - NEW PRODUCT TIME TO MARKET				
Product development and introduction lead time	*	*		*
COMPETENCY				
Level of supplier involvement in internal processes	*	*	*	*
Number of cooperation initiatives with suppliers in improving performance in a given time period	*	*		*
Level of IT system integration in supply chain	*	*	*	*
Number of employee training and education programs in a given time period		*		
Level of cross-functional teamwork		*		

Because of limited access to the Qlikview applications, it could not with certain be said which of the mentioned metrics included in the adapted metrics hierarchy that Company X already measures today. It can, hence, not be defined to what extent the data collection for the adapted set of metrics can make use of existing data collection at Company X.

7.4 Verification

The adapted metrics hierarchy for measuring supply chain agility at Company X was presented and discussed, together with other parts of the performance measurement system, at a workshop where 17 persons from varying decision making levels at Company X were present, whereof eight persons were physically present. All interviewees were invited to this workshop. The aim of the workshop was to verify the performance measurement system and gather ideas of how to further adapt it to Company X. To complement the workshop, a survey was sent out to the participants, which nine persons answered. The result from the survey is shown in Appendix IV. In this section, the outcomes from the workshop and survey as well as their implications on the final performance measurement system are presented. The section is divided into four parts, one for each part of the performance measurement system: metrics hierarchy, decision making levels of users, data gathering, and presentation.

7.4.1 Metrics Hierarchy

The participants of the workshop agreed on that the metrics within the responsiveness and flexibility capabilities were the ones of most importance to Company X. Table 7.6 shows the ranking in importance of the metrics according to the respondents of the survey. The respondents marked all metrics that they found important to Company X. The percentages represent the share of respondents that found each metric important. In the table, it is seen that the metrics connected to the information flow, cost, time and cooperation are viewed as most important to Company X since they have a higher percentage connected to them. However, the table does not show a clear pattern of what kind of metrics that are seen as the least important to Company X apart from metrics connected to inventory.

Table 7.6. Metrics ranking, according to the respondents of the survey, grouped by the capabilities of supply chain agility.

Metric	Ranking
RESPONSIVENESS	
Level of external information sharing in supply chain	44%
Level of internal information sharing in organization	44%
Time to change source/production/delivery capacity	67%
Number of actors involved in decision making process	89%
Number of inventory locations in supply chain	11%
Time to re-establish and sustain source/production/delivery lead time after changed product volumes	44%
Level of inventory that can be phased in/out and be sustained in a given time period	22%
FLEXIBILITY	
Percentage of common parts in final products	89%
Number of different products that a manufacturing system can handle	44%
Cost of changing operations from one product to another product	67%
Time to change operations from one product to another product	33%
Number of different tasks the typical worker can perform	11%
Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period	33%
Cost of changing source/production/delivery capacity in a given time period	67%
Number of suppliers per product family, component or raw material	44%
QUICKNESS	
Supplier production lead time	56%
Supplier source lead time	56%
Company Y delivery lead time	33%
OTD supply chain	33%
Product development and introduction lead time	67%
COMPETENCY	
Level of supplier involvement in internal processes	67%
Number of cooperation initiatives with suppliers in improving performance in a given time period	22%
Level of IT system integration in supply chain	44%
Number of employee training and education programs in a given time period	22%
Level of cross-functional team work	78%

In order to adapt the performance measurement system further to Company X, the metrics viewed as least important, meaning that only one third (33%) or less of the respondents found the metric important, were removed from the metrics hierarchy.

Regarding the completeness of the metrics hierarchy, additional dimensions of metrics were suggested on the workshop. One of these was a management dimension and, within this, metrics connected to communication, leadership, clear responsibilities and time limits for decision making were suggested. It can be argued that the communication part is covered for example within the metrics *level of external information sharing in supply chain* and *level of internal communication in organization.* The leadership dimension is not easily connected to a suitable and useful metric. However, it could be argued that leadership, in the case of supply chain agility, is connected to change management, which is part of the competency capability of supply chain agility according to some authors mentioned in the literature review. In lack of a more detailed description, *level of change management* was added as a metric in the final performance measurement system. Regarding clear relationships, this could be argued to be included to some extent in the *number of actors involved in decision making process*, which is already included as a metric in the performance measurement system. Regarding time limits for decision making, it is a goal or rule rather than something that could be measured. However, it could be connected to the metric *time to make decisions*, which could be argued to be part of the sub-capability react to change. This was therefore also added as a metric in the final performance measurement system shown in table 7.7 in section 7.5.

Another dimension that was said to be missing was the customer perspective. It can, however, be argued that all capabilities influence the experience of the customer and that the customer perspective, therefore are implicitly embedded in the system. Because of this, no additional metrics were added to the final performance measurement system within this dimension.

Even though the metric *OTD supply chain* was not seen as a metric of large importance for supply chain agility by Company X, a connected metric was discussed during the workshop, namely *OTD sender.* This metric would, in a better way, represent the responsibilities of Company X and, hence, be a more appropriate metric to include in the final performance measurement system. Therefore, this metric was included under the same sub-capability that *OTD supply chain* was previously grouped under, namely delivery lead time and timeliness.

Another perspective discussed was the cost perspective. Within this area, there was no consistent view among the participants of the workshop. Since cost aspects connected to supply chain agility is already included in the performance measurement system, it could be argued that this perspective is already covered. Additional cost aspects may be of importance to Company X, but since this performance measurement system is focused on the aspects connected to supply chain agility, and since it is argued in literature that there should be a balance between financial and non-financial metrics, other cost aspects were not added to the performance measurement system. In addition, it could be pointed out that an agile strategy might have a negative relationship to a cost leadership strategy since agility is more connected to differentiation as discussed by Hallgren and Olhager (2009).

Since the task was to make a performance measurement system for the whole of Company X, the metrics are general in character. Because of this, they were concluded at the workshop to be a good base for further discussion on supply chain agility in the category area. To further adapt them to specific product categories, product families or supply chains they, therefore, must be further specified to each specific situation. At this level, also more operational metrics that they are using today could be included to further adapt the system.

7.4.2 Decision Making Levels of Users

The participants on the workshop agreed on that the metrics hierarchy is a good base for discussion of what to focus on and how to approach supply chain agility on both a higher and a lower level of the organization. Because of the general characteristic of the metrics, they fit the whole of Company X but they have to, especially the operational ones, be further specified to adapt to specific situations for the different product categories, product families and supply chains for Company X.

7.4.3 Data Gathering

Some of the metrics in the metrics hierarchy Company X already measures, for example the former metric *OTD supply chain* and the newly added metric *OTD sender*. As mentioned, the metrics are general in order to fit the whole of Company X and, therefore, they will have to be further adapted to specific situations. When specifying the metrics further, the representatives from Company X believed that more overlaps with what they already measure is to be found, which would ease the data gathering for the metrics.

7.4.4 Presentation

Company X is today in a discussion phase regarding how to approach the concept of supply chain agility. The participants on the workshop agreed on that the presentation of the metrics hierarchy fitted the phase that they are in now. The presentation was suggested to be improved further by providing an example of a situation when each metric could be measured, in an advantageous way, in order to enhance the improvement work within the supply chain agility area. This would ease the understanding further. However, the whole of the analysis, in which good examples and challenges of supply chain agility for Company X are connected to the metrics in this report, was not presented during the workshop. Since specific examples for the different metrics are already presented in this report, which could be read as a complement to the performance measurement system in order to increase the understanding of the metrics, they will not be included in the final performance measurement system.

7.4.5 Summary

In general, the participants on the workshop were satisfied with the performance measurement system presented to them. The workshop, however, brought in many new ideas and inputs to the performance measurement system, which made it possible to further adapt it to Company X. The most significant influences on the performance measurement system was the removal of nine metrics of less importance and the addition of three metrics that the representatives from Company X found missing.

7.5 Final Performance Measurement System

After making the described changes in order to adapt the performance measurement system further to Company X, the final metrics hierarchy for measuring supply chain agility at Company X is presented in table 7.7. The metrics hierarchy consists of 19 metrics, which is arguably a large number of metrics. Even tough it would be more ideal to attain a more aggregated performance measurement system of supply chain agility, the authors of this report are of the opinion that that this number of metrics is needed in order to represent a fair evaluation of supply chain agility in this early stage of investigation due to the complexity of the research area. In order to be fully useful to Company X, the metrics hierarchy need to be further adapted to the different product categories. Adapting the metrics further could improve the measurability and formulation of the metrics and, thereby, the ease of usage.

The performance measurement system is a base for discussion of the supply chain agility concept for operational, tactical and strategic levels in the organization. The metrics can be used at varying organizational levels but, as already mentioned, they need to be further adapted to the company, especially the ones on the operational level.

The gathering of data for the performance measurement system includes several information sources, including: suppliers, Company X, transport, and other functions within Company Y. However, some information Company X already gathers today within different Qlikview applications.

Table 7.7. Metrics hierarchy for measuring supply chain agility at Company X. The metrics added based on the workshop are in bold text.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Level of external information sharing in supply chain* • *Level of internal information sharing in organization*	• *Time to change source/-production/-delivery capacity* • *Number of actors involved in decision making process* • ***Time to make decisions***	• *Time to reestablish and sustain source/-production/-delivery lead time after changed product volumes*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing system can handle* • *Cost of changing operations from one product to another product*	• *Cost of changing source/-production/-delivery capacity in a given time period* • *Number of suppliers per product family, component or raw material*	• *Supplier production lead time* • *Supplier source lead time*	• ***OTD sender***	• *Product develop-ment and introduction lead time*	• *Level of supplier involvement in internal processes* • *Level of IT system integration in supply chain* • *Level of cross-functional teamwork* • ***Level of change management***

8 Conclusions and Research Contribution

In this section, the conclusions and research contributions of the project are presented. Firstly, the fulfilment of the purpose and the research questions are discussed. Following that, the project's contribution to research is highlighted as well as the limitations of the project. The section ends with presenting opportunities for future research for both Company X and for research.

8.1 Fulfilment of Purpose and Research Questions

Below, the fulfilment of the purpose as well as the fulfilment of each research question is motivated.

8.1.1 Purpose

The purpose of the project was to identify the constituents of supply chain agility and to create a performance measurement system for measuring supply chain agility at a general level for the whole of Company X. Supply chain agility could be argued to consist of four capabilities: responsiveness, flexibility, quickness and competency. These capabilities are described further in section 8.1.3. Within each capability, metrics of relevance to Company X has been put together in a metrics hierarchy, which is further described in section 8.1.2 together with its supporting infrastructure. Through answering the following research questions, it could be argued that the purpose of the project is fulfilled.

8.1.2 Q1: How Can Supply Chain Agility be Measured at Company X?

This first research question is the overall research question for the project and all following research questions contribute to the fulfilment of this one. The final performance measurement system for measuring supply chain agility at Company X is presented in section 7.5 and in table 8.1 below. It represents the answer to the first research question of how supply chain agility can be measured at Company X. The metrics hierarchy in the final performance measurement system consists of 19 metrics, grouped under the four supply chain agility capabilities extracted from literature: responsiveness, flexibility, quickness and competency. Each capability is divided into sub-capabilities, in accordance with findings from literature. An exception is the competency capability, where no common sub-capabilities were found in research. Responsiveness is divided into the three sub-capabilities identify change, react to change, and recover from change. Flexibility is divided into the two sub-capabilities mix flexibility and volume flexibility. Quickness is divided into the three sub-capabilities operations lead time, delivery lead time and timeliness, and new product time to market. For each sub-capability, relevant areas for measurement are shown in table 8.1 in the form of metrics. The metrics included in the metrics hierarchy are extracted from literature and, then, adapted to Company X through empirical findings. The metrics hierarchy is also validated and further adapted through a workshop with representatives from Company X as well as a survey sent out to the same people.

Table 8.1. Metrics hierarchy for measuring supply chain agility at Company X. The metrics added based on the workshop are in bold text.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Level of external information sharing in supply chain* • *Level of internal information sharing in organization*	• *Time to change source/-production/-delivery capacity* • *Number of actors involved in decision making process* • ***Time to make decisions***	• *Time to reestablish and sustain source/-production/-delivery lead time after changed product volumes*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing system can handle* • *Cost of changing operations from one product to another product*	• *Cost of changing source/-production/-delivery capacity in a given time period* • *Number of suppliers per product family, component or raw material*	• *Supplier production lead time* • *Supplier source lead time*	• ***OTD sender***	• *Product develop-ment and introduction lead time*	• *Level of supplier involvement in internal processes* • *Level of IT system integration in supply chain* • *Level of cross-functional teamwork* • ***Level of change management***

The metrics hierarchy is complemented by a supporting infrastructure of information regarding decision making level of users, data gathering and presentation. Users at all decision-making levels, being strategic, tactical and operational, could make use of the metrics hierarchy for measuring supply chain agility. However, since the metrics are general in character, they must be further adapted to specific product categories, product families and supply chains at Company X in order to be useful, especially at the operational level. In some cases, further adaption could also improve the measurability of the metrics. To calculate the metrics in the metrics hierarchy, data from a spread of information sources has to be collected. The identified information sources needed are suppliers, Company X, transport, and other functions within Company Y. The information gathering need is to some extent biased towards the suppliers, especially or the metrics within the sub-capability mix flexibility. Due to limited data access, it is not defined to what extent Company X already measures the metrics included in the metrics hierarchy. The metrics included in the metrics hierarchy are presented in a generic way in order for the performance measurement system to be general enough to fit the whole of Company X and for it to be used as a base for discussions regarding supply chain agility.

The metrics hierarchy forms, together with its supporting infrastructure, a performance measurement system for measuring supply chain agility at Company X. This is, hence, a way of measuring supply chain agility at Company X.

8.1.3 Q2: What Constitutes Supply Chain Agility According to Theory?

The second research question contributes to the fulfilment of the first research question. The answer to the question of what constitutes supply chain agility according to theory is not obvious. There are several different capabilities mentioned in literature. Table 8.2 shows the ones found in the literature review of this project. The most mentioned capabilities of supply chain agility, and the ones that have been used in this project, are however the four capabilities presented in section 2.5 and in figure 8.1. From the descriptions of these capabilities in literature, connected sub-capabilities have also been extracted, as mentioned above. These are also shown in figure 8.1. Hence, the answer to the second research question is that supply chain agility mainly constitutes the four capabilities: responsiveness, flexibility, quickness, and competency.

Table 8.2. Capabilities constituting supply chain agility. Two stars (**) represents that the capabilities of supply chain agility have a central role in the literature. One star (*) represents that the capabilities are mentioned in the literature, but that it does not have a central role.

Author	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**	**Intra-Organizational Integration**	**Inter-Organizational Integration**	**Alertness**	**Accessibility of Information**	**Decisiveness**	**Proactiveness**	**Customer Focus**
Braunscheidel and Suresh (2009)		**			**	**					
Christopher (2000)	**	**	**	**		*	*	*			
Dove (2003)	**							**			
Gligor et al. (2013)	**	**					**	**	**		
Khalili-Damghani and Tavana (2013)	*	*	*	*							
Lin et al. (2006)	*	*	*	*							
Ngai et al. (2011)	*	*		**		*		*			
Sangari et al. (2015)				*	*	*		*			
Sharifi and Zhang (1999)	**	**	**	**							
Sharma et al. (2017)	*	*		*	*	*		*			
Swafford et al. (2006)	*	**									
Swafford et al. (2008)	**	**	*		*	*					
Zhang and Sharifi (2000)	**	**	**	**							
Zhang and Sharifi. (2007)	**	**	**	**		**				**	**

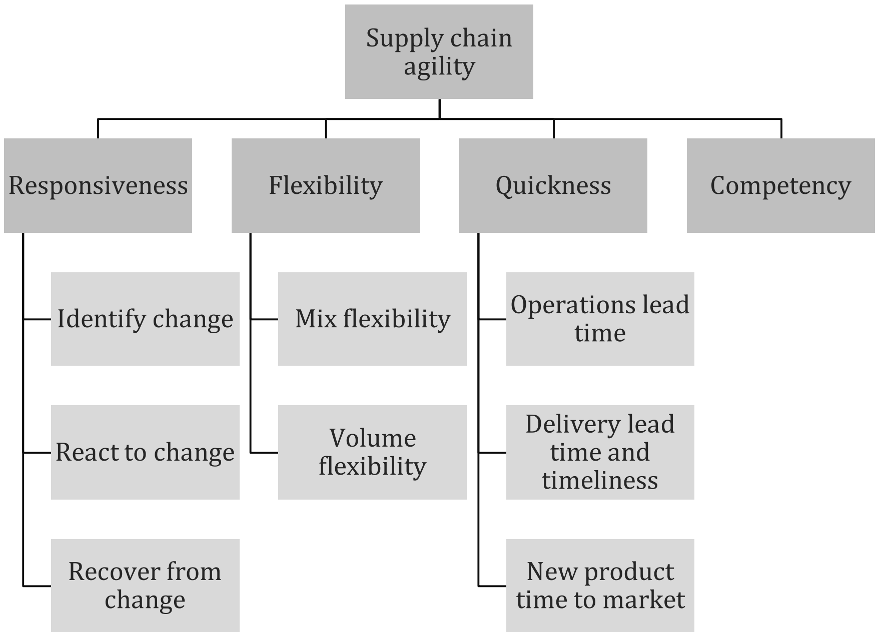

Figure 8.1. Capabilities and sub-capabilities of supply chain agility.

8.1.4 Q3: How Can Supply Chain Agility be Measured According to Theory?

The third research question contributes to the fulfilment of the first research question. The answer to the question of how supply chain agility can be measured according to theory is not obvious. There is no common way of measuring supply chain agility to be found in literature. However, extracting important areas of supply chain agility from literature and consolidating them into metrics has resulted in 41 potential metrics. These are presented individually in section 2.6. By combining these metrics, one way of measuring supply chain agility, aligned with theory, is presented in table 8.3.

8.1.5 Q4: What Measures of Supply Chain Agility are Relevant for Company X?

The fourth research question contributes to the fulfilment of the first research question. The answer to the question of what measures of supply chain agility that are of relevance to Company X lies within the suggested metrics hierarchy presented in section 6.2 and in figure 8.4. Here, only the relevant metrics from the theoretical construct connected to each investigated case at Company X are summarized. This resulted in a set of 36 metrics, which according to the empirical findings could be seen as metrics of relevance for Company X in measuring supply chain agility. This metrics hierarchy was then further evaluated in the verification stage and, at the end of the project, transformed into the final metrics hierarchy consisting of 19 metrics.

Table 8.3. Theoretical construct of the supply chain agility concept.

Responsiveness			Flexibility		Quickness			Competency
Identify change	**React to change**	**Recover from change**	**Mix flexibility**	**Volume flexibility**	**Operations lead time**	**Delivery lead time and timeliness**	**New product time to market**	
• *Time delay in sharing customer demand information in supply chain* • *Level of external information sharing in supply chain* • *Level of internal information sharing in organization* • *Level of standardization in information sharing*	• *Time to increase/decrease source/production/delivery capacity* • *Time to reduce production lead time* • *Time to reroute or reschedule operations in production* • *Number of actors involved in decision making process* • *Number of new products the manufacturing system can handle in a given time period* • *Level of inventory in supply chain*	• *Time to reestablish and sustain source/production/delivery lead time after increased/decreased product volumes* • *Amount of inventory that can be phased in/out and be sustained in a given time period*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing setup can handle* • *Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup* • *Number of suppliers per product or component* • *Cost of changing operations from one product to another product* • *Time to change operations from one product to another product* • *Number of different tasks the typical worker can perform*	• *Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/-delivered in a given time period* • *Cost of increasing/-decreasing source/production/delivery capacity in a given time period* • *Number of suppliers per product or component* • *Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period* • *Amount of labour that can be laid-off or diverted to other activities to decrease and sustain production volumes in a given time period*	• *Production lead time* • *Source lead time*	• *Delivery lead time* • *Percentage of orders on time and with accurate documentation*	• *Product development lead time* • *Time to introduce new products*	• *Total number of suppliers* • *Level of supplier involvement in product development* • *Level of supplier involvement in short and long term planning* • *Number of cooperation initiatives between supplier and customer in improving product performance in a given time period* • *Level of vertical integration* • *Use of integrated IT system in supply chain* • *Amount of employee training and education programs in a given time period* • *Amount of different jobs per employee in a given time period* • *Level of decentralization in decision making* • *Level of cross-functional team work* • *Number of new product introductions in a given time period*

Table 8.4. Suggested metric hierarchy for measuring supply chain agility at Company X.

Responsiveness			Flexibility		Quickness			Competency
Identify change	React to change	Recover from change	Mix flexibility	Volume flexibility	Operations lead time	Delivery lead time and timeliness	New product time to market	
• *Time delay in sharing customer demand information in supply chain* • *Level of external information sharing in supply chain* • *Level of internal information sharing in organization* • *Level of standardization in information sharing*	• *Time to increase/decrease source/production /delivery capacity* • *Number of actors involved in decision making process* • *Number of new products the manufacturing system can handle in a given time period* • *Number of inventory locations in supply chain*	• *Time to reestablish and sustain source/production/ delivery lead time after increased/decrease d product volumes* • *Amount of inventory that can be phased in/out and be sustained in a given time period*	• *Percentage of common parts in final products* • *Number of different products that a manufacturing setup can handle* • *Number of operations performable on an alternative manufacturing setup divided by the total number of operations assigned a certain manufacturing setup* • *Cost of changing operations from one product to another product* • *Time to change operations from one product to another product* • *Number of different tasks the typical worker can perform*	• *Amount of capacity that can be obtained/terminated to increase/decrease and sustain quantities sourced/produced/- delivered in a given time period* • *Cost of increasing/decreasing source/production/delivery capacity in a given time period* • *Number of suppliers per product or component* • *Amount of labour that can be hired and trained to increase and sustain production volumes in a given time period* • *Amount of labour that can be laid-off or diverted to other activities without cost penalty to decrease and sustain production volumes in a given time period*	• *Production lead time* • *Source lead time*	• *Delivery lead time* • *Percentage of orders on time and with accurate documentation*	• *Product development lead time* • *Time to introduce new products*	• *Total number of suppliers* • *Level of supplier involvement in product development* *Level of supplier involvement in short and long term planning* • *Number of cooperation initiatives between supplier and customer in improving performance in a given time period* • *Use of integrated IT system in supply chain* • *Amount of employee training and education programs in a given time period* • *Amount of different jobs per employee in a given time period* • *Level of decentralization in decision making* • *Level of cross-functional teamwork*

8.1.6 Q5: What Are the Good Examples and Challenges in the Area of Supply Chain Agility for Company X?

The fifth research question contributes to the fulfilment of the fourth research question. The answer to the question of what are the good examples and challenges within the supply chain agility area for Company X lies within the good examples and challenges presented in the report. The examples connected to ProductX EU are presented in section 5.1.1 and in table 8.5, the examples connected to ProductY NA are presented in section 5.2.1 and in table 8.6, and the examples connected to the whole of Company X are presented in section 5.3.1 and in table 8.7. In the mentioned sections, good examples and challenges of supply chain agility identified from the empirical studies are further described and motivated in accordance with theory.

Table 8.5. Good examples and challenges connected to supply chain agility in the ProductX EU case.

	Examples from case	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**
Good examples	Many alternative suppliers	*	*		
	Labour-intensive production		*		*
	Assembly production	*	*		
	Local sourcing of components	*		*	
	Future strategy of modularization		*		
	Design improvement work	*	*		
	Future strategy of further partnership with suppliers	*			*
Challenges	Many alternative suppliers				*
	Labour-intensive production			*	*
	Limited labour availability	*	*		
	Low forecast accuracy	*			
	Slim inventory setup in supply chain	*			
	Long lead times for sourcing of components	*		*	
	Limited internal communication	*			*
	Limited solutions for over capacity	*	*		
	Single sourcing of components	*	*		
	Complex production	*	*		

Table 8.6. Good examples and challenges connected to supply chain agility in the ProductY NA case. The star in parenthesis (*) represents that vertical integration, even though it is a good example of supply chain agility in this case, also generally reduce flexibility but that this is not seen as a challenge in this case.

	Examples from case	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**
Good examples	Few alternative suppliers				*
	Automated production			*	
	Assembly production	*	*		
	Local sourcing of components	*		*	
	Established CDCs	*		*	
	Project to implement VMR	*		*	*
	Packaging improvement work	*	*		
	External collaboration			*	*
	Vertical integration		(*)	*	*
Challenges	Few alternative suppliers	*	*		
	Automated production		*		
	Slim inventory setup in supply chain	*			
	Long lead times for sourcing of raw materials	*		*	
	Limited internal communication	*			*
	Component bottleneck	*	*	*	
	Delay in transportation			*	

Table 8.7. Good examples and challenges connected to supply chain agility for the whole of Company X.

	Common examples from cases	**Responsiveness**	**Flexibility**	**Quickness**	**Competency**
Good examples	Fast within category decision making	*			*
	Capacity planning improvement work	*			*
	Future strategy to increase transparency	*			*
	Supplier relations	*			*
	Supporting management				*
Challenges	Unreliable capacity data	*			
	Limited transport availability	*	*	*	
	Future strategy to eliminate DCs	*		*	
	Long lead times for new products	*		*	
	Many stakeholders	*			
	Complicated information flow	*			
	Lack of integrated IT system	*			*
	Limited risk sharing				*
	Delay in order creation	*			

8.2 Research Contribution

Since supply chain agility is a relatively new concept in literature (Sharma et al, 2017), no consensus regarding how to measure the concept has emerged (Giachetti et al., 2003). In order to contribute to the research of supply chain agility measurement, this report aims to provide a system for measuring supply chain agility that takes the current findings in literature into account. In order to do this, the report also aims to define what constitutes supply chain agility. The report provides a summation of relevant literature on the topic of supply chain agility constitution and measurement. It also presents a condensation of how to measure supply chain agility and a performance measurement system adapted to Company X for measuring the concept. The approach of having a metrics hierarchy based on constituents of supply chain agility and company relevance in the performance measurement system has not been found in previous research. This way of structuring metrics within the supply chain agility area could, therefore, spark an interesting academic discussion. Hence, through this report, a contribution to the research on supply chain agility constitution and measurement is made.

8.3 Limitations

There are four limitations identified throughout the project related to limited data gathering. The first limitation is connected to interruptions in the data collection through cancelled interviews and difficulty in scheduling interviews. The second limitation is connected to limited data access in terms of limited contact with different suppliers. The third limitation is connected to limited data access in terms of limited access to Qlikview applications. The fourth limitation is connected to the limited number of participants in the verification phase of the project in the form of a limited number of participants on the validation workshop and a limited number of respondents of the validation survey.

Another limitation to the project is that it only takes two cases at Company X into account. The generalizability of the results would have been higher if more cases were investigated.

Additionally, the scope of the project only consisted of constructing a performance measurement system. The result has neither been tested nor implemented and, as such, decisions regarding these following steps are not discussed. This limits the extent to which the performance measurement system could be argued to work.

8.4 Future Research

To further increase the understanding of supply chain agility and its measurement, future research must be made. Below, future research opportunities for both Company X and for research are presented.

8.4.1 For Company X

The performance measurement system presented in this report is a base for discussion of the supply chain agility concept at Company X. In order for Company X to develop the performance measurement system further and make use of the system, the following actions have to be made. Firstly, a common understanding of the concept of supply chain agility must be adopted and used throughout the whole organization. Secondly, further adaptation of the performance measurement system has to be made to specific category areas, product families and supply chains at Company X in order for the metrics to fit the special circumstances within each of these. The third step consists of defining who should make use of each metric and at what decision-making level each metric should be used, as well as deciding how these people should have the metrics presented to them. As a fourth step, the data collection must be defined and compared to what is already measured at Company X. Functions and people also have to be assigned responsibilities for certain parts of the data collection process. Following that, a fifth step would contain testing and possibly revising the performance measurement system to further adapt it. A last step would be to implement the performance measurement system for supply chain agility measurement at Company X.

8.4.2 For Research

In order to make the findings from this report more substantiated, further studies in the form of empirical testing of the performance measurement system are needed. It would also be suitable to aggregate the metrics further in order to reduce the number of metrics in the performance measurement system and, instead, having fewer, more comprehensive ones. This could therefore be a subject for future research.

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Appendix I: Case Study Database

In the table below, the articles used in the literature review are presented and classified into their different subjects. One star (*) means that the article briefly discusses the subject meanwhile two stars (**) means that the article describes the subject in detail. A total of 43 articles are included in the case study database.

Authors	**Performance Measurement System**	**Definition of Supply Chain Agility**	**Concepts Relating to Supply Chain Agility**	**Strategies for Achieving Supply Chain Agility**	**Supply Chain Agility Capabilities**	**Areas of Measurement for Supply Chain Agility**
Agarwal et al. (2007)				**		
Agarwal et al. (2006)			**			
APICS (2017)	**	*			*	**
Arteta and Giachetti (2004)		*		*		**
Beamon (1999)					*	*
Bititci et al. (1997)	**					
Bourne et al. (2000)	**					
Braunscheidel and Suresh (2009)		*			**	
Caplice and Sheffi (1995)	**					
Caplice and Sheffi (1994)	**					
Christopher (2000)		*	**	**	**	
Dove (2003)		*			**	
Franco-Santos et al. (2007)	**					
Gaudenzi and Christopher (2016)			**			
Gerwin (2005)					*	*
Giachetti et al. (2003)		*				*
Gligor et al. (2013)		*		*	**	
Goldsby et al. (2006)			**			
Gunasekaran et al. (2001)	**					
Hallgren and Olhager (2009)		*	**			
Hoek et al. (2001)				**		
Jasti and Kodali (2015)			**			
Khalili-Damghani and Tavana (2013)					**	*
Lebas (1995)	**					
Lin et al. (2006)				*	**	**
Lohman et al. (2004)	**					

Ngai et al. (2011)		*			**	
Narasimhan et al. (2006)			**			
Naylor et al. (1999)			**			
Neely et al. (1995)	**					
Neely et al. (2000)	**					
Sangari et al. (2015)				*	*	
Sharifi and Zhang (1999)		*			**	
Sharma et al. (2017)		**	*		*	*
Sharp et al. (1999)			**			
Swafford et al. (2008)		*			**	*
Swafford et al. (2006)		*			*	**
Tarafdar and Qrunfleh (2016)				**		
Tsourveloudis and Valavanis (2002)						**
Um (2016)				**		
Wee and Wu (2009)			**			
Zhang and Sharifi (2007)		*			**	**
Zhang and Sharifi (2000)					**	*

Appendix II: Case Study Protocol

Below the case study protocol for the case study conducted in the project is presented. It contains the following parts: case study overview, data collection plan, data collection questions and schedule.

Case Study Overview

Purpose

The purpose of this project is to identify the constituents of supply chain agility and to create a performance measurement system for measuring supply chain agility at a general level for the whole of Company X.

Case Study Questions

The purpose of the case study was to answer the second, third, fourth and fifth research question:

Q2: What constitutes supply chain agility according to theory?
Q3: How can supply chain agility be measured according to theory?
Q4: What measures of supply chain agility are relevant for Company X?
Q5: What are the good examples and challenges in the area of supply chain agility for Company X?

By answering the above research questions, research question one could also be answered:

Q1: How can supply chain agility be measured at Company X?

Selected Cases

Case 1: ProductX EU
Product X is a product family. EU represents that Product X will be investigated only on the European market.

Case 2: ProductY NA
Product Y is product family. NA represents that Product Y will be investigated only on the North American market.

Key Documents

Title	Year	Author	Subject
Supply chain agility: review, classification and synthesis	2017	Sharma, N., Sahay, B.S., Shankar, R. and Sarma, P.R.S.	Supply chain agility
Agility index in the supply chain	2006	Lin, C., Chiu, H. and Chu, P.	Supply chain agility measurement
The antecedents of supply chain agility of a firm: Scale development and model testing	2006	Swafford P.M., Ghosh S., and Murthy N.	Supply chain agility measurement
The agile supply chain: Competing in volatile markets	2000	Christopher M.	Supply chain agility
Performance measurement system design: A literature review and research agenda	1995	Neely, A., Gregory, M. and Platts, K.	Performance measurement system

Preparations for Unexpected Events

Poor Data Quality

To avoid incidents where poor data quality limits the case analysis, several different methods and sources will be used to collect data in order to achieve data triangulation. In case this is not possible, the data will still be used but the problematics will be expressed as limitations to the project so that the report remains transparent.

Interruptions in Interview Plan

In case an interviewee does not show up or cancels an interview, the first action will be to reschedule the interview. If that is not possible, the next action will be to find other possible interviewees that are believed to be able to provide the study with the same information. If there are no other adequate interviewees, the final solution will be to search for the needed data from other sources such as the intranet, data warehouse or literature. If the data could not be found, the problematics will be expressed as limitations to the project so that the report remains transparent.

In case of an interviewer or researcher cannot participate during the scheduled interview, the second interviewer will perform the interview on its own. If that is not possible, the second action will be to reschedule the interview so that at least one researcher can perform the interview.

Data Collection Plan

Since the two cases belong to different product categories within Company X, there will be specific key contact persons and interviewees for each case. The data sources will. however, be the same for both cases.

Data Sources

- *Interviews* will be performed in order to gain qualitative data that can contribute to a deeper understanding of the systems, processes and KPIs of the two cases.
- *Meetings* will be attended in order to collect information about the strategic direction of the category area and to attain information about how the employees make use of metrics in their daily work.
- The company data warehouse, *Qlikview*, will be used to collect quantitative data for the different cases.
- The *Company X intranet* will be used to search for information in order to prepare for interviews and to search for supplementary information about the subjects that has been raised during the interviews.
- By performing a *literature review*, relevant theory for the case study analysis will be retrieved.

Key Contact Persons

General Key Contact Person

Category Area Logistics Manager

ProductX EU

Category Sourcing Specialist

Category Manager

ProductY NA
Category Sourcing Specialist
Category Manager

Case Study Interviews

Date and Place	Position	General	ProductX EU	ProductY NA
19 April - Skype	Business Developer			X
20 March - Skype	Category Sourcing Specialist	X	X	
28 March - Skype	Supply Planner		X	
14 March - Älmhult	Category Manager	X	X	
27 April - Skype	Transport Planner			X
29 March - Lund	Category Area Logistics Manager	X	X	X
8 March - Skype	Lead Supply Planner	X		
29 March - Älmhult	Supply Planner			X
14 March - Skype	Deputy Manager	X	X	
17 March - Skype	Capacity Planning Developer	X		
24 March - Skype	Supply Planner			X
17 March - Skype	Business Developer	X		
9 March - Skype	Need Planner			X
6 April - Skype	Transport Capacity Planner		X	
28 March - Skype	Category Manager Global Transport and Services	X		
9 March - Skype	Category Sourcing Specialist	X		X
2 April - Skype	Supply Planner		X	
12 March - Älmhult	Category Area Manager	X		
26 March - Älmhult	Need Planner		X	
23 March - Skype	Operations Developer Global Transport and Services	X		
5 April - Skype	Representatives from Manufacturer			X
19 March - Älmhult	Category Manager	X		X
4 April - Älmhult	Logistics Manager	X		
5 April - Skype	Supply Planner			X

Data Collection Questions

Yin (2014, p. 90) describes 5 different levels of questions that should be considered when structuring a case study to assure that the right questions are posed to fulfil the overall purpose of the study. Below is a description of how the questions in this study are connected to the five different levels suggested by Yin (2014, pp.90-91).

Level 1: Questions for specific interviewees
See Appendix III
Level 2: Questions for an individual case
Q4 and Q5
Level 3: Questions for multiple cases
Q4
Level 4: Questions for the entire study
Q1, Q2 and Q3
Level 5: Normative questions beyond the narrow scope of the study
Excluded from this study

Schedule

Activity	Description	Time period
Project start-up	Initial study of Company X and methodologies to define the scope of the study.	15/1 - 19/1 2018
Literature study supply chain agiliy/performance measurement system	Study of supply chain agility and performance measurement system to gain insights of relevant literature for the literature review.	22/1 - 25/1 2018
Company study	Finding of relevant contact persons for each case.	26/1 - 31/1 2018
Development of methodology	Report writing.	1/2 - 12/2 2018
Literature review	Study of performance measurement system for supply chain agility.	8/2 - 23/2 2018
Preparation for data collection	Construction of interview guides as well as search for the right applications in Qlikview.	26/2 - 2/3 2018
Data collection	Performing of interviews. Searching on the intranet and Qlikview.	5/3 - 23/3 2018
Data collection summary	Report writing.	26/3 - 30/3 2018
Data analysis	Performing of within-case and cross-case analyses.	2/4 - 16/4 2018
Designing construct	Development of performance measurement system for supply chain agility at Company X.	12/4 - 20/4 2018
Verifying construct	Preparation for and performing of workshop.	26/4 - 2/5 2018
Refine construct based on the workshop	Report writing.	3/5 - 11/5 2018
Iterative process with the Supervisors	Feedback seminars and report writing.	14/5 - 18/5 2018
Presentation	Presentation of project.	between 4-8/6 2018

Appendix III: Interview Guide

Introduction

- Presentation of the purpose of the master thesis
- Introduction to the theoretical findings
- Explanation of the how the data collection will be used

Background Information

1. What are your responsibilities?
2. What time horizon are you making decisions on?
3. What is the main goal in your work right now?
4. What is the largest challenge in you in your work right now?
5. To what extent is supply chain agility included in your work? How and why?

Current Measurements and Their Purpose

1. How do you make use of KPIs in your work?
2. What KPIs are you using?
3. How are the KPIs presented?
4. What is the purpose of each KPI?
5. How is the data for calculating these KPIs gathered?
6. How often are these KPIs updated?

Mapping of Processes

The questions were adopted to the responsibilities (operational, tactical, strategic) and position (manufacturing, sourcing, delivery) of the interviewees.

1. What processes are included in *X*?
2. Could you please describe the processes?
3. What actors are involved in *X*?
4. What kind of collaboration is there between the actors in *X*?

Capabilities of Supply Chain Agility

The questions were adopted to the responsibilities (operational, tactical, strategic) and position (manufacturing, sourcing, delivery) of the interviewees.

Responsiveness

1. How is responsiveness in *X* measured?
2. How long time does it take for *X* to...:
    a. ...identify change?
    b. ...react to change?
    c. ...recover from change?
3. How does *X*...:
    a. ...identify changes?
    b. ...react to change?
    c. ...recover from change?
4. What does the internal/external information sharing look like?
5. How important is responsiveness in *X*?

Flexibility

1. How is flexibility in *X* measured?
2. What methods can be used in order to increase/decrease capacity in *X*?
3. How much and how quick can capacity be increased/decreased in *X*?
4. How many different products can be handled in *X*?
5. How much time does it take to change product mix in *X*?
6. How important is flexibility in *X*?

Quickness

1. How is quickness in *X* measured?
2. What is the lead time for *X*?
3. How much time does it take to develop and introduce a new product?
4. How do you work with and measure timeliness in *X*?
5. How important is quickness in *X*?

Competency

1. How are you working with securing *X* competency?
2. What does the internal/external collaboration look like?
3. How integrated are the IT system within *X* and between *X* and *Y*?
4. How integrated are the processes within *X* and between *X* and *Y*?
5. Could you please describe the relationship within *X* and between *X* and *Y*?
6. What does the decision-making process look like in *X*?
7. Do you measure anything related to the above questions connected to competency?

Appendix IV: Workshop Survey

Below follows a summary of the answers from the survey, distributed in connection to the verification workshop held with employees at Company X. Among the 17 people that attended the workshop, 9 of them filled in the survey of what metrics that are the most important from the metrics hierarchy presented in section 7.2 in this report. The respondents could mark an unlimited amount of metrics in each question for question one to four. For question five to seven, text answers were collected.

1. Could you please mark the metrics that you think are the most important for Company X within the responsiveness capability?

Metric	Number of respondents
Level of external information sharing in supply chain	4
Level of internal information sharing in organization	4
Time to change source/production/delivery capacity	6
Number of actors involved in decision making process	8
Number of inventory locations in supply chain	1
Time to re-establish and sustain source/production/delivery lead time after changed product volumes	4
Level of inventory that can be phased in/out and be sustained in a given time period	2

2. Could you please mark the metrics that you think are the most important for Company X within the flexibility capability?

Metric	Number of respondents
Percentage of common parts in final products	8
Number of different products that a manufacturing system can handle	4
Cost of changing operations from one product to another product	6
Time to change operations from one product to another product	3
Number of different tasks the typical worker can perform	1
Amount of capacity that can be adapted to change product volumes sourced/produced/delivered in a given time period	3
Cost of changing source/production/delivery capacity in a given time period	6
Number of suppliers per product family, component or raw material	4

3. Could you please mark the metrics that you think are the most important for Company X within the quickness capability?

Metric	Number of respondents
Supplier production lead time	5
Supplier source lead time	5
Company Y delivery lead time	3
OTD supply chain	3
Product development and introduction lead time	6

4. Could you please mark the metrics that you think are the most important for Company X within the competency capability?

Metric	Number of respondents
Level of supplier involvement in internal processes	6
Number of cooperation initiatives with suppliers in improving performance in a given time period	2
Level of IT system integration in supply chain	4
Number of employee training and education programs in a given time period	2
Level of cross-functional team work	7

5. Do you think that there are any overlaps to existing metrics used at Company X today? (if yes, please exemplify)
6. Do you have any suggestions of how we can improve the presented material?
7. Would you like to add anything else?