



Flexibility through Information Sharing

Evidences from the Automotive Industry in Sweden

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ABSTRACT

Research has validated the contribution of information sharing to performance improvement. It has also suggested that flexibility is a highly important competitive priority for those companies where demand is volatile. Several studies argue that flexibility has been recognized as a key enabler for supply chain responsiveness. However, the impact of information sharing on supplier flexibility is still unexplored, especially for the companies that operate in agile business environments such as in the automotive industry where flexibility is a strategic requirement to manage demand uncertainty. In agile supply chains, such as in the automotive industry, information sharing can play an important role in responding to demand variability. In such settings, the demand volumes generally fluctuate, and hence create production-scheduling problems for the upstream suppliers such as first-tier suppliers. Interestingly, the impact of demand fluctuations on suppliers is higher than that of Original Equipment Manufacturers (OEMs).

The aim of this doctoral thesis is to investigate the role of information sharing between OEMs and first-tier suppliers, in enhancing supplier flexibility. Particularly, the research focuses on exploring the relationship between sharing demand schedules and inventory data, and volume and delivery flexibility. The questions on whether information sharing between OEMs and first-tier suppliers affect supplier flexibility remain unanswered. The following research questions have emerged:

- *RQ1: How does information sharing between OEMs and first-tier suppliers affect the latter's responsiveness to fluctuating demand?*
- *RQ2: What is the relationship between information sharing of OEMs' demand forecasts and inventory data, and suppliers' volume and delivery flexibility?*
- *RQ3: What factors should OEMs consider to improve the sharing of demand forecasts with suppliers?*

The empirical part of this thesis comprises three individual studies that constitute the empirical foundations of the research problem. Each study analyzes one research question using its own methodological approach. Hence, different research methods for collecting and analyzing data were used to address the research questions. Applying different research methods is deemed advantageous because it allows for methodological rigorousness in this doctoral thesis.

This thesis contributes to the body of knowledge in three dimensions—theory, method, and context. First, it contributes to the academic field of operations and supply chain

management by developing a model to explain how information sharing could affect suppliers' delivery performance. The model provides a measurement scale to measure the level of information sharing between OEMs and suppliers, and its impact on suppliers' delivery flexibility. Second, this thesis contributes to the methods by using state-of-the-art techniques, which is partial least squares structural equation modeling (PLS-SEM) including consistent PLS, and applying advanced concepts to empirically test the proposed model. Third, this thesis has a managerial contribution to examine the concept of information sharing and flexibility at the supplier level. Investigating the problem at the supplier level may enable managers to improve short-term decisions, such as production scheduling decisions, internal production, and inventory processes, and evaluate collaboration practices with OEMs.

This doctoral thesis is organized in a monograph format comprising five chapters: Introduction, Literature review, Methodology, Empirics, and Conclusion. As an outcome, several scientific articles have emerged from this thesis and have been submitted for consideration for publication in peer-reviewed journals and international conferences in the field of operations and supply chain management. These articles are listed and appended at the end of this dissertation.

Keywords: information sharing, demand forecast, inventory data, volume flexibility, delivery flexibility, responsiveness, delivery performance, first-tier supplier, automotive Industry, PLS-SEM.

SAMMANFATTNING

Forskningen har bekräftat att informationsdelning bidrar till förbättrade resultat. Den tyder även på att flexibilitet är en mycket viktig konkurrensmässig prioritering för företag som arbetar mot en volatil efterfrågan. Flera studier hävdar även att flexibilitet har erkänts som en viktig möjliggörande faktor för reaktionsförmåga i leveranskedjan. Informationsdelningens effekt på leverantörsflexibilitet är emellertid ännu outforskad, särskilt för företag som verkar i rörliga verksamhetsmiljöer, som inom bilindustrin, där flexibilitet är ett strategiskt krav för att hantera osäkerhet i efterfrågan. I rörliga leveranskedjor, som inom bilindustrin, kan informationsdelning spela en viktig roll när det gäller att svara på skiftande efterfrågan. I sådana miljöer observeras generellt skiftande efterfrågevolymer, vilket skapar problem med produktionsplaneringen för leverantörer i tidigare led, t.ex. primära leverantörer. Intressant nog har växlingarna i efterfrågan större påverkan på leverantörerna än vad OEM-företagen har.

Syftet med denna doktorsavhandling är att undersöka den roll som informationsdelning mellan OEM-företag och primära leverantörer spelar när det gäller att förbättra leverantörsflexibiliteten. Forskningen lägger särskilt fokus på att utforska förhållandet mellan delning av efterfrågescheman och lagerdata och volym- och leveransflexibilitet. Frågan om huruvida informationsdelning mellan OEM-företag och primära leverantörer påverkar leverantörsflexibiliteten är ännu obesvarad. Följande forskningsfrågor har formulerats:

- *FF1: Hur påverkar informationsdelning mellan OEM-företag och primära leverantörer de senares reaktionsförmåga vid skiftande efterfrågan?*
- *FF2: Vilket är förhållandet mellan informationsdelning av OEM-företagens prognoser på efterfrågan och lagerdata och leverantörernas volym- och leveransflexibilitet?*
- *FF3. Vilka faktorer bör OEM-företagen överväga för att förbättra delningen av prognoser på efterfrågan med leverantörerna?*

Den empiriska delen av denna avhandling omfattar tre individuella studier som lägger den empiriska grunden till forskningsproblemet. Varje studie analyserar en forskningsfråga genom att använda sin egen metod. Följaktligen användes olika forskningsmetoder för att samla in och analysera data vid arbetet med forskningsfrågorna. Användningen av olika forskningsmetoder ses som en fördel eftersom den möjliggör en rigorös metodik i denna doktorsavhandling.

Denna avhandling bidrar till den samlade kunskapen i tre dimensioner – teori, metod och kontext. För det första bidrar den till det akademiska området för verksamhetsförvaltning och förvaltning av leveranskedjan genom att ta fram en modell som förklarar hur informationsdelning skulle kunna påverka leverantörernas leveransprestanda. Modellen tillhandahåller en mätskala för att mäta graden av informationsdelning mellan OEM-företag och leverantörer och hur den påverkar

leverantörernas leveransflexibilitet. För det andra bidrar denna avhandling till metoderna genom att använda de senaste teknikerna, nämligen strukturell ekvationsmodellering med partiell minstakvadratmetod (PLS-SEM, Partial Least Squares Structural Equation Modeling), inklusive konsekvent PLS och tillämpning av avancerade koncept för att empiriskt testa den föreslagna modellen. För det tredje bidrar denna avhandling till ledningen genom att undersöka begreppet informationsdelning och flexibilitet på leverantörsnivå. En undersökning av problemet på leverantörsnivå kan ge chefer möjlighet att förbättra kortsiktiga beslut, som beslut om produktionsschema, intern produktion och lagerprocesser, och utvärdera praxis för samarbete med OEM-företag.

Denna doktorsavhandling är organiserad i monografiformat och består av fem kapitel: Inledning, Litteraturgenomgång, Metod, Empiri och Slutsats. Resultatet är ett flertal vetenskapliga artiklar som har kommit ur denna avhandling och skickats in för en eventuell publicering i kollegialt granskade tidskrifter och internationella konferenser inom området verksamhetsförvaltning och förvaltning av leveranskedjan. Dessa artiklar finns förtecknade och bifogas i slutet av denna avhandling.

Nyckelord: informationsdelning, prognos på efterfrågan, lagerdata, volymflexibilitet, leveransflexibilitet, reaktionsförmåga, leveransprestanda, primär leverantör, bilindustri, PLS-SEM.

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1. CHAPTER I: INTRODUCTION

1.1 Introduction to the Research Area

Information sharing is considered a critical issue for coordinating actions of supply chain systems (Fiala, 2005). Yigitbasioglu (2010) defines information sharing between firms as the information shared between a buyer and key suppliers, which is detailed, frequent, and timely enough to meet a firm's requirements. Research has validated the contribution of information sharing to performance improvement. For instance, Wu et al. (2014) find that information sharing has a partial mediation effect on supply chain performance. In addition, Prajogo and Olhager (2012) confirm that there is a positive relationship between information integration (i.e., information sharing and information systems between firms and suppliers) and logistics performance. Hill et al. (2012) and Datta and Christopher (2011) investigated the effectiveness of information sharing and coordination mechanisms in reducing uncertainty in supply chains. In their empirical study, Datta and Christopher (2011) find that information sharing across different members is essential in managing supply chains effectively under uncertainty. Despite their importance, these studies did not focus on the link between information sharing and flexibility capabilities to meet the firm's and customer's requirements.

Research has suggested that flexibility is a highly important competitive priority for those companies where demand is volatile. Several studies argue that flexibility has been recognized as a key enabler for supply chain response performance. For instance, Tachizawa and Thomsen (2007, p. 1115) highlight that “the ability to change or react to environmental uncertainty is key for competitiveness; in other words, flexibility is a critical aspect.” In addition, Koste and Malhotra (1999); Koste et al. (2004); and Narasimhan et al. (2004) emphasize that flexibility is essential in accommodating uncertainty, such as demand variability.

Ojha et al. 2013 (p. 2919) assert that “demand variability represents an opportunity for the flexible firm.” Flexibility is viewed as a firm's ability to match production with demand in the face of uncertainty and variability (Iravani et al., 2014). For suppliers,

flexibility is defined as their ability to manage variation from the buyer without significant trade-offs with other competitive priorities (Cousins et al., 2008). Competitive priorities refer to the strategic emphasis on developing certain manufacturing capabilities that either sustain or enhance a plant's position in the marketplace. Such emphasis may guide decisions regarding the production process, capacity, technology, planning, and control (Ward et al., 1998). Generally, competitive priorities are expressed in terms of at least four basic components—cost, quality, delivery, and flexibility (Ward et al., 1998; Boyer and Lewis, 2002; Díaz-Garrido et al., 2011; and Cai and Yang, 2014). Hence, flexibility is considered part of the operations strategy.

Operations strategy is concerned with “how the competitive environment is changing and what the operation has to do in order to meet current and future challenges. It is also concerned with the long-term development of its operations resources and processes so that they can provide the basis for sustainable advantage” (Slack and Lewis, 2011, p. 7). Porter (1996) argues that strategy is about achieving competitive advantage through being different—delivering a unique value to the customer. Therefore, flexibility can be considered a competitiveness tool that contributes to the overall operations strategy of a firm. In this context, flexibility is an important element to increase the competitiveness of the company (Christopher, 2000; Sánchez and Pérez, 2005; and Gosling et al., 2010), especially for those companies operating in an unpredictable business environment (i.e., volatile market). Furthermore, Reichhart and Holweg (2007, p. 1150) emphasize that the “flexibility of manufacturing systems in a supply chain should be regarded as a factor contributing to a supply chain's responsiveness and not vice versa.”

However, the impact of information sharing on supplier flexibility is still unexplored, especially for companies that operate in an agile business environment where flexibility is a strategic requirement to manage demand uncertainty. In his research paper, Christopher (2000, p. 37) confirms that flexibility is a key characteristic of an agile organization, and defines agility as “a business-wide capability that embraces organizational structures, information systems, logistics processes, and in particular, mindsets.” Furthermore, Christopher (2000, p. 39) highlights that sharing information between supply chain partners “can only be fully leveraged through collaborative

working between buyers and suppliers, joint product development, common systems, and shared information. In addition, Christopher and Towill (2000, p.209) highlight that “This form of cooperation in the supply chain is becoming more prevalent, as companies focus on managing their core competencies and outsource all other activities. In this new world, a greater reliance on suppliers and alliance partners becomes inevitable, and hence, a new style of relationship is essential.”

Most firms in the automotive industry use the Electronic Data Interchange system (EDI). EDI is a system used widely in the automotive industry to facilitate communication between Original Equipment Manufacturers (OEMs) and suppliers regarding order quantities, demand schedules, inventory level, last-minute changes, delivery time, and lead-time. EDI provides an efficient way for information sharing between OEMs and suppliers.

1.2 Research Problem: Flexibility through information sharing

In agile supply chains, such as in the automotive industry, information sharing can play an important role in responding to demand variability. Demand variability in this thesis refers to the fluctuating volumes in terms of quantity. In such settings, the demand volumes are generally fluctuating, and hence create production-scheduling problems for upstream suppliers such as first-tier suppliers. Interestingly, the impact of demand fluctuations on suppliers is higher than that of OEMs. This is due to the bullwhip effect (Lee et al., 2004). The bullwhip effect is usually reflected as oscillating volumes (e.g., overestimated or underestimated demand schedules) at the supplier side, resulting in several production planning problems. For example, it may affect production scheduling, workforce planning, inventory and material planning, and might even result in outsourcing decisions (Choi et al., 2013). In such situations, volume and delivery flexibility become important competitive priorities to absorb the bullwhip effect through information sharing.

Although the literature has explored many types of manufacturing flexibility, volume and delivery flexibility have not been explained sufficiently. Volume and delivery are

important aspects of manufacturing flexibility and are considered essential competitive priorities for suppliers who work in agile supply chains. For instance, Jack and Raturi (2002) emphasize the importance of volume and delivery flexibility as competitive strategies. In this regard, Stevenson and Spring (2007), and Jin et al. (2014) highlight that flexibility research has focused on how a firm's manufacturing capabilities could respond to uncertainty and enhance firm performance.

There are several reasons why this thesis focuses only on volume and delivery flexibility. First, theoretically these two types of flexibility are perhaps the most important manufacturing flexibility capabilities, particularly when the demand is fluctuating. Besides, they require significant amount of information sharing and collaboration between firms and their suppliers. In that sense, Thomé et al. (2014, p. 93) assert that “volume flexibility requires close coordination between a firm and its suppliers, especially in the case of increasing demand.” Therefore, it is interesting and relevant to investigate the impact of information sharing (as a collaboration and coordination mechanism) on these types of flexibility.

Second, the concepts of volume flexibility, delivery flexibility, as well as information sharing are of great importance in the automotive industry. Many CEOs, whom I interviewed in an earlier study prior to this research, assert that the automotive industry is characterized by a highly volatile demand, whose volumes fluctuate due to several factors such as the global financial crisis in 2008, and the increasing environment concerns. These factors have forced many OEMs worldwide to consider the importance of developing flexible suppliers and share information with them. On one hand, OEMs have eliminated their stock levels, and started to buy the components (e.g., input materials or parts) in small batches in order to reduce the inventory cost. On the other hand, many OEMs have been forced to reduce gas emissions to low levels according to the new European environmental legislations (i.e., Euro 6)¹. Therefore, there is a growing need today for flexible suppliers to respond to the customer orders (i.e., OEMs orders). This concern (e.g., industrial relevance) is elaborated in the next sections.

¹ Euro 6 is a European legislation that regulates the total number of emissions from both exhaust gases and Crankcase gases of vehicle engines.

Third, given the time constraint of this doctoral thesis, it is challenging to consider other types of manufacturing flexibility in one single research effort. Hence, investigating the impact of information sharing on other types of manufacturing flexibility is one of the main suggestions for future research studies. Nevertheless, a quick examination of published literature shows that the role of information sharing in enabling supplier flexibility has been overlooked, especially in those companies that operate in agile supply chains where demand uncertainty is high, such as in the automotive industry. Therefore, the questions on whether information sharing, between OEMs and first-tier suppliers affect supplier flexibility, remain unanswered. Thus, given the above discussion, the following research questions emerge:

- *RQ1: How does information sharing between OEMs and first-tier suppliers affect the latter's responsiveness to fluctuating demand?*
- *RQ2: What is the relationship between information sharing of OEMs' demand forecasts and inventory data, and suppliers' volume and delivery flexibility?*
- *RQ3: What factors should OEMs consider to improve the sharing of demand forecasts with suppliers?*

These research questions emerged based on an extended literature review for the underlying concepts of the research problem (as presented in Chapter 2). This includes examination of the following theories: information sharing in supply chains (Chu et al., 2012; Skipper and Hanna, 2009; Closs et al., 2005), and manufacturing flexibility (Reichhart and Holweg, 2007; Christopher and Holweg, 2011). The literature review is focused on two main streams: First, comprising the concepts of volume flexibility, delivery flexibility, responsiveness, agility, operations strategy, and competitiveness. Second, it focuses on buyer-supplier collaborations with respect to information sharing between OEMs and first-tier suppliers. The examination of the literature serves as the theoretical underpinning of the research questions RQ1, RQ2, and RQ3. This research aims to find answers to the stated research questions and provide a basis for future research in this important part of supply chain responsiveness and the relationship between OEMs and first-tier suppliers.

1.3 Research Scope

It is essential for any type of scientific research to consider narrowing down the scope of the investigation because of validity and reliability aspects (Booth et al., 2003). This could enhance credibility of the research in terms of generalizability of results. Hence, it is fundamental to define the boundaries and delimitations of particular research problems. Based on this rationality, the scope of this thesis does not consider investigating all types of information shared, studying the impact on all aspects of manufacturing flexibility, analyzing all echelons in the supply chain, or examining all industries. Instead, the focus of this research is to explore the role of information sharing as an enabler of suppliers' volume and delivery flexibility at the supplier level. Figure (1.1) shows a graphical scheme of the focus of this research.

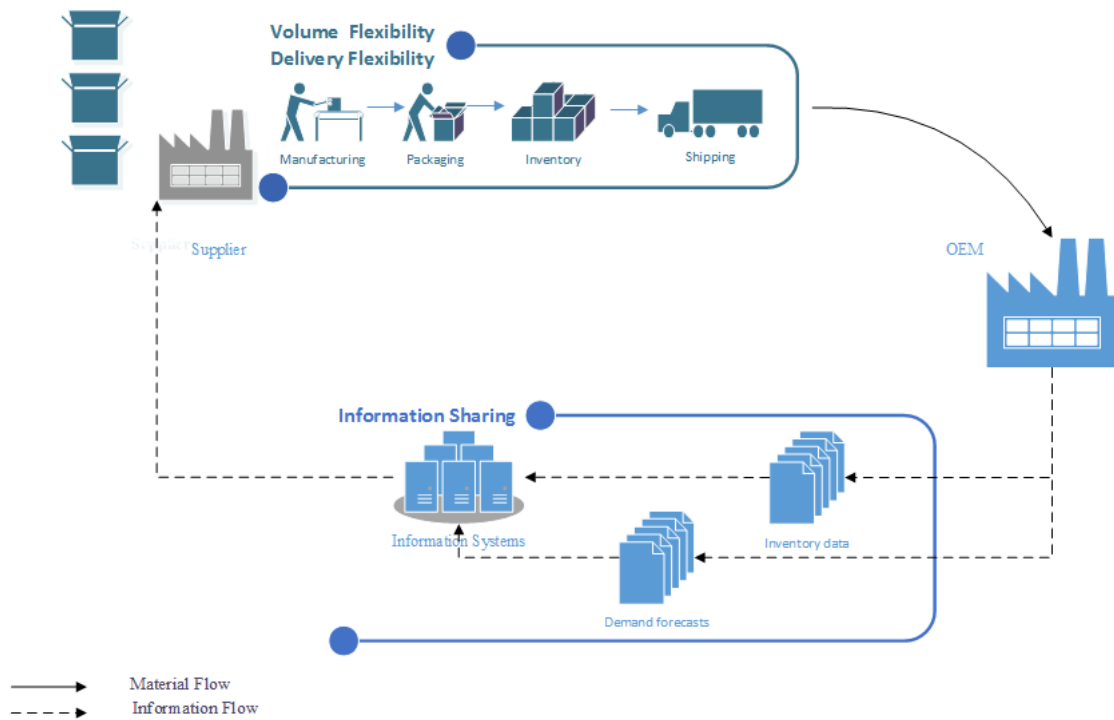


Figure 1.1: Focus of this thesis

This research focuses on downstream to upstream information sharing between OEMs and their direct first-tier suppliers. The scope of investigation is limited to the manufacturer-supplier part of the supply chain system. Figure (1.2) shows a schematic representation of the scope of the investigation as seen within the dashed-line border.

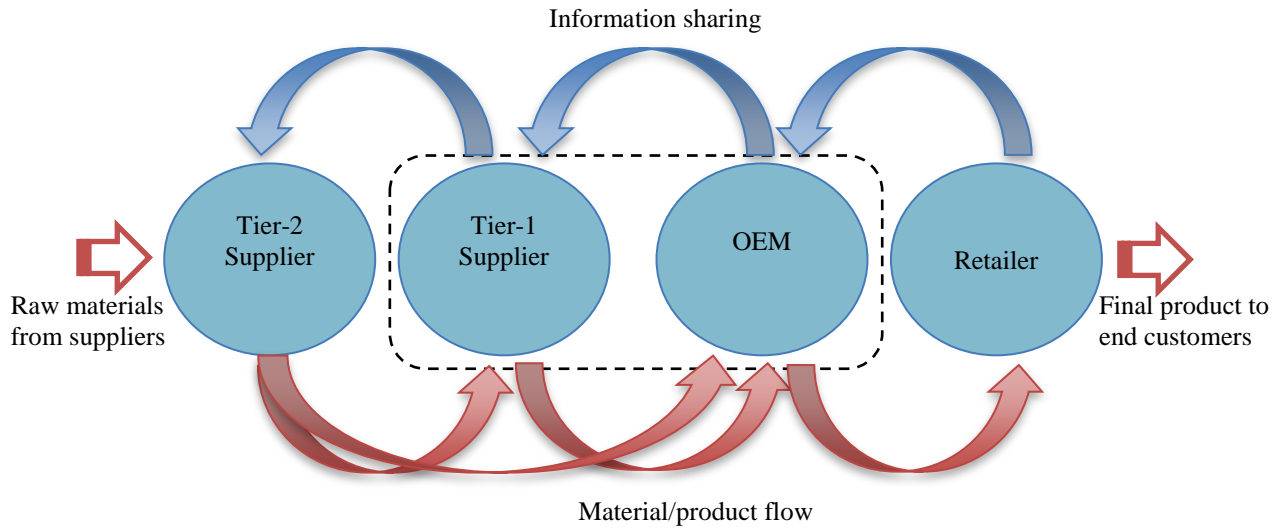


Figure 1.2: Scope of investigation

The following section provides an industrial context to the research problem. It also provides a pragmatic approach to the significance of this study and the rationale for investigating the automotive industry in this doctoral thesis.

1.4 Research Motivation

This thesis focuses on the automotive industry for the following reasons:

- The automotive industry has been characterized by high demand variability (Song and Yao, 2002). In this context, Holweg (2001, p. 80) indicates that “demand for automobiles of all types fluctuates substantially during a year.” Thus, the fluctuating demand volumes have become a major concern for both suppliers and manufacturers (Lim et al., 2014). These demand fluctuations have forced both OEMs and their suppliers to become more flexible to respond to the changes in the marketplace. Flexibility requires exchange of accurate information between OEMs and their suppliers. In today’s business environment, the business model of many automotive companies is based on lean philosophy, which includes several management approaches such as lean thinking, lean production, agility, and flexibility. These approaches require intensive exchange or sharing of business information between supply chain companies within the industry.

- Lean operations and business agility initiatives have forced OEMs to drastically reduce their safety stock level (Fliedner, 2003), urge their suppliers to reduce lot size, supply frequent deliveries (Cousins et al., 2008), and respond to numerous last-minute changes (Chang et al., 2008). All these factors will affect first-tier suppliers' production schedules. First-tier suppliers, however, often seek large orders, less frequent deliveries, and less product variability to achieve economies of scale and minimize cost. This business challenge has created a need for flexible suppliers capable of responding to demand fluctuations in a timely fashion. Demand fluctuations have created demand variability through many business partners in the supply chain, especially upstream partners. In the automotive industry, demand variability can be attributed (but not limited) to several factors as indicated below:

a) The Financial Crisis of 2008

The global financial crisis of 2008 has changed the demand pattern in which the numbers of produced vehicles have been increasing and decreasing annually. For example, Figure (1.3) shows some demand variability in the automotive industry in Sweden, especially the years after 2008.

The figure indicates that vehicle production volumes (of the major Swedish automakers Saab, Volvo cars, Volvo trucks, and Scania) were highly fluctuating after 2008 in comparison to the previous years. For instance, Volvo's car division produced 362,000 cars in 2008 but the number reduced to 311,400 in 2009, while increasing again to 387,800 in 2010. The number reached 462,300 in 2011 but decreased to 429,400 in 2012.

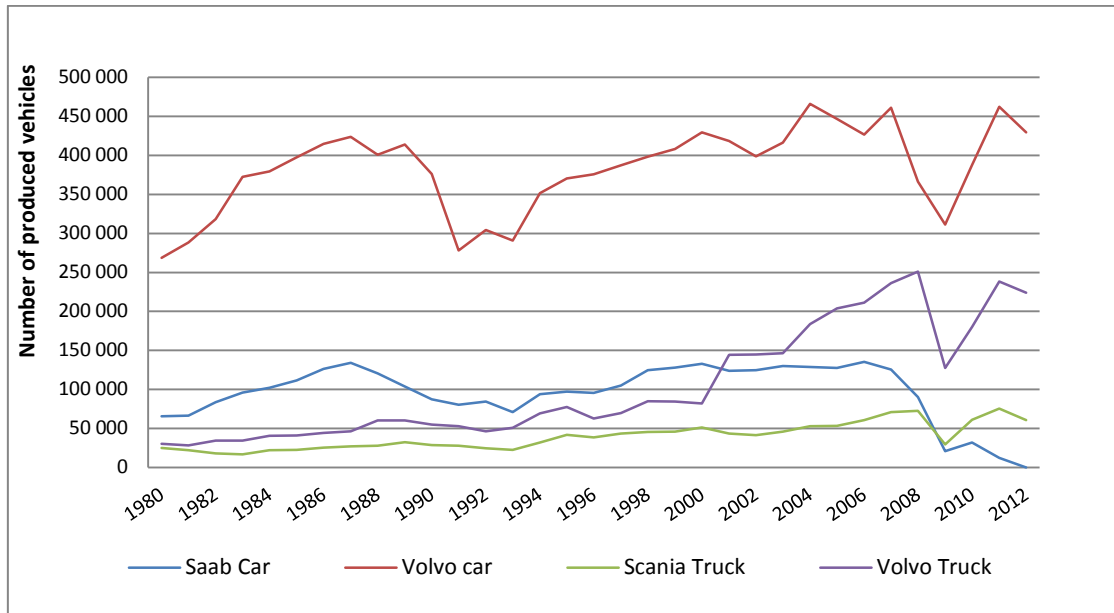


Figure 1.3: Swedish vehicle manufacturers' total production (Source: Adapted from "Swedish Association of Automobile Manufacturers and Importers - BLI Sweden," 2014)

b) Environmental Legislations

The environmental legislations, which have been introduced by the European Union (EU) during the last five years, have created a fluctuating demand to supply chain member companies in the automotive industry. As shown in Table (1.1), the Euro 6 legislation, for instance, requires automotive manufactures to reduce the gas emissions for both gasoline and diesel-based engines to certain levels.

Table 1.1: European Environmental Legislations (Source: Campestrini and Mock (2011, p. 37)

EU emission limits for gasoline passenger cars (in g/km)							
Legislation	Effective date*	CO	HC	HMHC	NO _x	HC+NO _x	PM
Euro3	Jan 2000	2.30	0.20	--	0.15	--	--
Euro4	Jan 2005	1.00	0.10	--	0.08	--	--
Euro5	Sep 2009	1.00	0.10	0.068	0.06	--	0.0050
Euro6	Sep 2014	1.00	0.10	0.068	0.06	--	0.0045

EU emission limits for diesel passenger cars (in g/km)							
Legislation	Effective date*	CO	HC	HMHC	NO _x	HC+NO _x	PM
Euro3	Jan 2000	0.64	--	--	0.50	0.56	0.0500
Euro4	Jan 2005	0.50	--	--	0.25	0.30	0.0250
Euro5	Sep 2009	0.50	--	--	0.18	0.23	0.0050
Euro6	Sep 2014	0.50	--	--	0.08	0.17	0.0045

*For new vehicle types

These regulations, such as Euro 6 emission requirements have affected the design of some components of the current or existing versions of the engines, gearbox transmission, or other parts. As a result, many supply problems had emerged such as suspension of orders, changes in delivery schedules or production quantities. Therefore, such requirements have contributed to increase demand fluctuation for some main parts and components.

c) Oil Price Variability

Many manufacturing industries such as the automotive (Scholtens and Yurtsever, 2012), steel, metal, and heavy equipment industries are sensitive to oil/gas prices (Jiménez-Rodríguez, 2008). Oil price fluctuations can affect the demand and production volumes (Lee and Ni, 2002). Thus, oil and gas prices could have a severe consequence on the overall supply chain including upstream suppliers, prompting some disturbances such as demand forecasting inaccuracies, delivery delays, low energy-consumption rates, production delays and rescheduling, prolonged cash cycle, postponing payments, etc.

d) Supply Chain Disruptions

Supply chains are “constantly subject to unpredictable events or disruption that can adversely influence their ability to achieve performance objectives” (Datta and Christopher, 2011, p. 765). In this regard, disruptions can include but are not limited to terrorist attacks, wars, natural disasters, labor disputes, supplier bankruptcy, system or production breakdown, fire, and dependency on a single supplier (Chopra and Sodhi, 2004). In fact, the literature includes several cases and examples of supply chain disruptions where many suppliers and manufacturers shutdown production. Although supply risk management has been the commonly accepted proactive approach to mitigate risk associated with supply disruption (Craighead et al., 2007), such disruptions can still affect the demand and cause turbulence to the entire supply chain and other suppliers.

e) Increasing Customer Requirements

The unprecedented sophistications in customer requirements have increased the demand uncertainty, resulting in extensive customization processes in which the mass

production model has become obsolete. For instance, today's model is based on customized products that satisfy different customer segments with different needs and tastes. Thus, many supply chains have become demand-driven (Christopher and Ryals, 2014). In the automotive industry, for instance, car manufacturers and suppliers use modular production to cope with customization. According to Islamoglu et al. (2014, p. 6954), "modular assembly is being applied to an increasing number of vehicles and parts manufacturers to manage the ever-changing demands of the automotive industry." Hence, changes in customer requirements have shifted not only the production paradigm but also the completion model.

f) Recalls Due to Quality Issues

This has affected not only car manufacturers but also suppliers causing demand volume fluctuations and production delays, production rescheduling, repairs and delays, delivery problems, procurement issues, and increased operation costs associated with recall, repair, rework, return, resell, and shipping. For example, Toyota had two major recalls during 2009 and 2010. On November 25, 2009, Toyota announced a recall of more than eight million cars to fix their floor mats and sticky accelerators, and on February 8, 2010, announced a recall of more than 100,000 vehicles to update the anti-lock braking system (ABS) software in response to problems reported in hybrid cars (Monden, 2012). In 2015, Japanese carmakers Honda and Daihatsu recalled approximately five million cars globally to replace defective airbag inflators made by Takata (BBC Business News, 2015).

On one hand, these drivers have changed the competition model in which supply chain flexibility becomes more critical (Simchi-Levi et al., 2012), so many companies focus on the flexibility aspects such as adopting volume flexibility and delivery flexibility to respond to demand changes. On the other hand, these drivers motivate effective sharing of information on demand forecast and inventory data between supply chain partners. Datta and Christopher (2011) investigated the effectiveness of information sharing and coordination mechanisms in reducing uncertainty. In their study, they find that wide information sharing across different members is considered essential in managing supply chains effectively during uncertainty (Datta and Christopher, 2011, p. 765).

Therefore, the question of how flexibility is achieved through information sharing has been the main motivation of this thesis.

The following sections attempt to answer questions that might emerge concerning the structure of the automotive supply chain, background information, the relevance of focusing on first-tier suppliers, and the automotive industry.

1.4.1 Why has this thesis focused on first-tier suppliers?

This research mainly focuses on first-tier suppliers for the following three reasons: First, the supplier perspective has been recently recognized as a new way to research operations management in supply chains (Rota et al., 2002). As will be shown in Chapter 2, little is known about the supplier perspective in the automotive industry. According to Pujawan (2004), most research has viewed flexibility from a manufacturer's perspective but not from that of a supplier. Thus, it would be worthy to understand suppliers' opinion about volume flexibility as operations strategy to compete in an agile supply chain, and to investigate what they do in order to respond to customers' orders with high volume changes. Therefore, it is interesting to understand "why" and "investigate" the problem from the supplier's perspective.

Second, suppliers are responsible for 70% to 80% of the total value creation in the automotive industry (Bennett and Klug, 2012; Harrison and van Hoek, 2008). These ratios justify the importance of the first-tier suppliers' role and their significant contribution to value creation in the automotive industry, which means that suppliers have gained substantial portions of the value creation. In this regard, many vehicle manufacturers have outsourced some of their production to external suppliers. Therefore, recent research indicates that the automotive suppliers play an important role in the automotive business. In this context, first-tier suppliers are responsible for production of semi-finished products, parts, or components that are necessary to build the automotive vehicle (e.g., passenger cars, buses, trucks, or other types of automotive vehicles). According to a recent report from the Scandinavian Association of Automotive Suppliers (FKG), 60% of new technology is devised by suppliers, which indicates that they invest as much as the OEMs in research and development (R&D).

Table (1.2) shows some major products or components that first-tier suppliers usually deliver to OEMs. A single car comprises about 30,000 parts counting every part down to the smallest screw (“Toyota,” 2015). Most of these parts are produced by suppliers who use different materials and manufacturing processes. Generally, first-tier suppliers are responsible for producing (or assembling) major parts or components. For example, Figure (1.4) shows how some components of the Volvo car model XC70 are being supplied from different first-tier suppliers.

Table 1.2: Examples of major products produced or assembled by first-tier suppliers

Examples of some major parts and components produced by first-tier suppliers	
Engine castings	Engine forgings
Cast aluminum sub-frames	Heat shields
Steering systems	External plastics (bumpers, trim)
Brake calipers	Oil pans
Trim (door cards, headlining, plastics, etc.)	Entertainment
Drive shafts	Small pressings
Harnesses	Bearings
Engine accessories (starter, air conditioning)	Transmission components
Seating	Instrument clusters
Fuel tanks	Large/medium pressings
Tires	Glass
HVAC assembly	Steel wheels
Alloy wheels	Hinges
Chassis Suspension Module 40	Carpets
Lighting	Hot stampings
Misc. assemblies (pedals, mirrors, roof rails)	Suspension springs
Electronics	Welded assemblies
Navigation	Switchgear
Shock absorbers	12V lead/acid battery

Third, first-tier suppliers possess unique characteristics (compared to other tier suppliers), rendering it difficult for them to respond to demand fluctuations. For instance, first-tier suppliers usually:

- Lack information on demand forecasts due to the large number of last-minute changes received from OEMs or due to poor communication with OEMs regarding information on orders, shipment delivery schedules, or quantities.
- Use minimum levels of buffers to avoid the high cost associated with holding stock in inventories. To address this issue, first-tier suppliers can pursue make-to-order

(MTO) operations strategy. MTO strategy requires high levels of flexibility to address the issue of demand variability (Song and Yao, 2002). Suppliers can also implement the assemble-to-order (ATO) strategy to address the demand variability issue. However, ATO requires holding sufficient buffer and inventory of raw materials and components, which means the inventory cost can increase in this case.

- Produce customized products while other tier suppliers produce standardized ones.

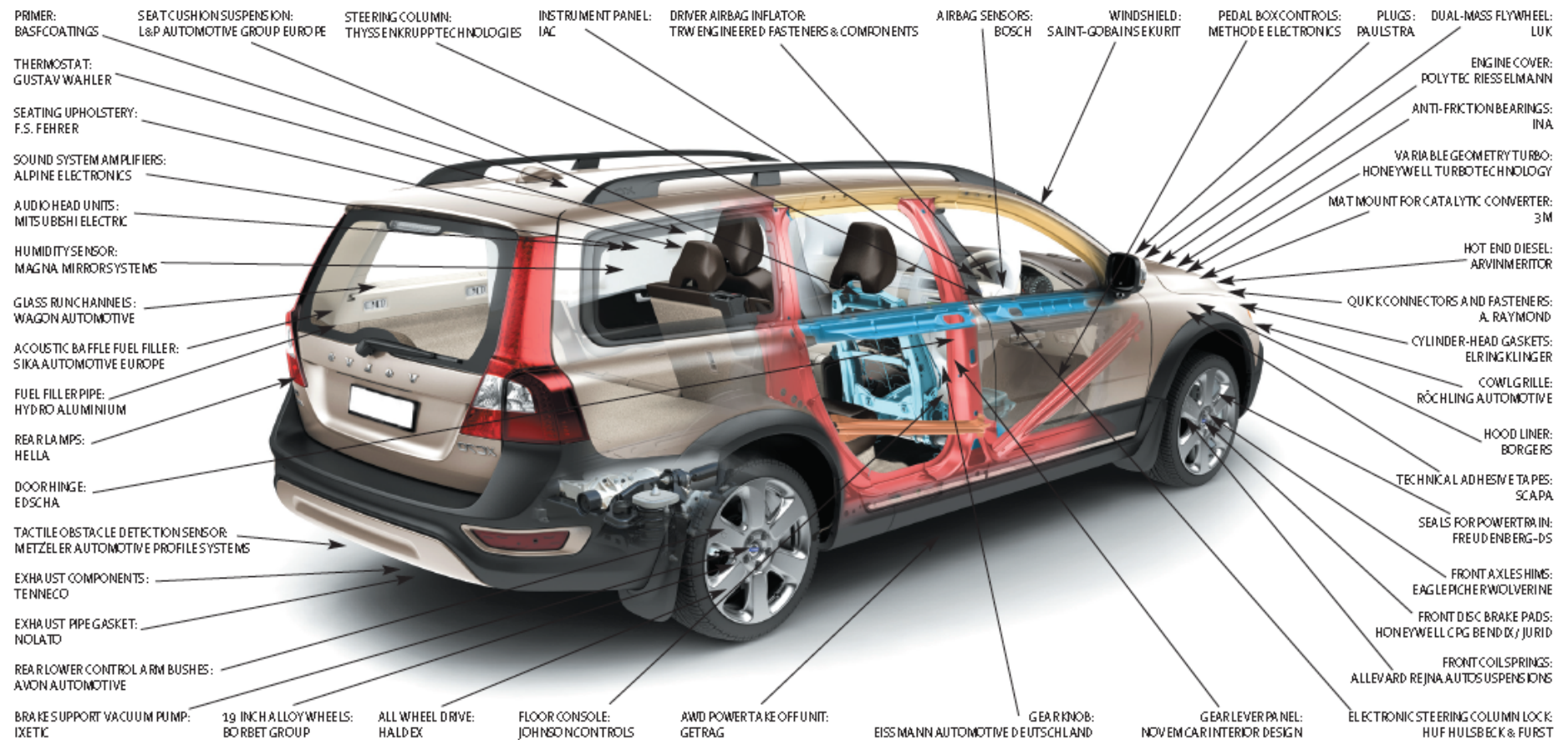


Figure 1.4: Contribution of different first-tier suppliers to the car Volvo-XC70 (Source: Wingett, 2007)

Since suppliers rely only on OEMs to obtain the actual data on demand quantities, first-tier suppliers usually lack information on the demand quantities of the final products. Lack of information can result from poor communication between OEMs and suppliers regarding orders and shipment information, causing delivery problems. According to a recent study conducted by SAP SE (2014), 40% of the delivery problems are attributed to poor communication between OEMs and suppliers. This percentage signifies the impact of sharing demand information (between these two segments), especially on the delivery precision of suppliers.

According to Lee et al. (2004), lack of information on demand forecasts usually results in the bullwhip effect. Theoretically, the bullwhip effect is usually reflected as oscillating volumes (e.g., overestimated or underestimated demand schedules) at the supplier side, resulting in several production and capacity planning problems. For instance, OEMs may provide the first-tier suppliers with overestimated schedules to urge them to build up more capacity. As a result, first-tier suppliers may build up unneeded extra capacity just because they lack accurate information on the demand. Thus, first-tier suppliers might not be able to predict if the demand is increasing or decreasing, which may result in an inadequate response to the demand fluctuations.

Inadequate response can be costly for suppliers who operate in an agile supply chain. For instance, delayed deliveries could be detrimental to the suppliers. In the event of a late delivery, for instance, some OEMs have a tendency to:

- Terminate the purchase (completely or partly) of the particular part and other parts that the OEM does not consider having any use due to the late delivery;
- Make substitute purchases from other suppliers; or
- Request the supplier to compensate the OEM's direct and indirect losses and damages arising out of or relating to the late delivery.

In some cases, the OEM charges the supplier extra costs if shipments are not executed per the delivery instructions or agreement. For instance, when the supplier causes extra or unforeseen transport costs, the OEM may choose to charge the supplier. Examples of

these unforeseen transport costs are:

- Prolonged waiting time prior to loading;
- Wasted trip—transport booked, no goods ready or loaded;
- Booking deviations—shipment incomplete compared to transport booking.

Consequently, lacking information could negatively affect the ability of a first-tier supplier to respond to changes in ordered quantities. Hence, OEMs share information (such as inventory levels, demand forecasts, productions schedules) with their first-tier suppliers in order to ensure continuous flow of products and avoid shipment delivery delays. Hence, investigating this issue from a first-tier supplier level in this research has a managerial contribution by suggesting a framework to improve the ability of the supplier to improve response performance.

1.4.2 Why has this thesis focused on the automotive industry in Sweden?

Since this research study has been conducted in a Swedish university, it is of high priority to consider the investigating industries in Sweden. However, due to time and financial limitations, not all industries could be investigated for this study. Therefore, we limit our investigation to only one industry, the automotive industry in Sweden, for the reasons mentioned below.

First, the automotive industry in Sweden is considered an important part of the country's economic system. According to reports published on the official website of the FKG, the Swedish automotive industry generates half a million jobs, of which about 110000 are directly employed, and 71000 can be found in the supplier chain, which represents almost 30% of the Swedish engineering industry (FKG, 2014). According to FKG, suppliers of automotive components and parts represent a significant portion of that industry. Studies have identified 1000 suppliers, of which 50% are classified as small companies (i.e., having a turnover of less than 3 million €). However, the 500 biggest companies have a turnover of more than 14 billion € and employ about 90000 people in Sweden. Some of these companies are subsidiaries of the world's biggest suppliers such as Autoliv, Plastal, SKF, Kongsberg, Haldex, SAPA, and SSAB (FKG,

2014). Scandinavian-owned companies of significant size are globally active while small and middle-sized companies are mostly family-owned and some are based on innovations, service providers, or IT companies.

Second, the automotive industry has been recently characterized by high demand variability in which volumes are fluctuating and thus become a major concern for both suppliers and manufacturers (Tachizawa and Thomsen, 2007; Laurent Lim et al., 2014). Demand fluctuations have affected OEMs to place more pressure on their suppliers to respond rapidly to fluctuating volumes. In this regard, OEMs often use the Just-in-Time (JIT) strategy to reduce their safety stock level (Fliedner, 2003), urge their suppliers to reduce the minimum lot size but supply more frequent deliveries (Cousins et al., 2008), and issue procurement orders with many last-minute changes (Chang et al., 2008). For example, in Sweden, Volvo and Scania use JIT with their first-tier suppliers among other suppliers. This strategy forces suppliers to connect their computers with the buyers such as Volvo and Scania and share information via EDI systems. However, first-tier suppliers' production schedules are affected because of fluctuating volumes. Hence, first-tier suppliers often seek large orders, less frequent deliveries, and less product variability to achieve economy of scale. This challenge has created a need for flexible suppliers capable of responding to demand fluctuations in terms of product volume and delivery.

1.5 Supply Chain Structure in the Automotive Industry

Automotive supply chains include several manufacturing processes of complex products such as trucks, buses, passenger cars, commercial cars, and other types of automotive vehicles. The industry embraces many integrated and unintegrated processes such as, R&D, manufacturing, assembly, logistics, distribution, marketing, and sales. The industry also involves other services such as financial services, long-term leasing, repair and maintenance services, and scrapping. Therefore, the supply chain of the automotive industry involves several companies having several players and actors. These actors play different roles in the value creation process.

The main players involved in the Swedish automotive sector are vehicle makers (VM) or OEMs and suppliers (which can be first-tier, second-tier, or third-tier):

- OEMs are responsible for manufacturing and final assembly of vehicles. They are mainly involved in certain business processes such as design, R&D, and final manufacturing operations (e.g., welding, assembly, engine assembly, etc.). Some examples of popular OEMs are Scania, Volvo, Volkswagen, Toyota, and Ford. OEMs often collect information on demand directly from their distributors, dealers, end customers, or even competitors. Since the demand is uncertain, OEMs usually implement several manufacturing strategies such as JIT and lean production. Therefore, OEMs use few buffers in order to avoid building-up unnecessary inventory.
- First-tier suppliers are responsible for delivering components, parts, or systems directly to OEMs. They are mainly involved in the manufacturing and/or sub-assembly process. However, they lack information on demand and only depend on their manufacturers to provide them with such schedules. Since demand could be uncertain at the endpoint, first-tier suppliers would have fluctuating demand volumes. Therefore, such types of companies usually implement MTO strategy to overcome demand variability (Song and Yao, 2002). Examples of first-tier suppliers include those of tires, seats, glass, batteries, navigation systems, transmission systems, airbag system, dashboards/exhaust and filtration systems, among others.
- Second-tier suppliers deliver their finished products directly to first-tier suppliers. They can be subsystem assemblers or suppliers of finished components or parts. Second-tier suppliers also have fluctuating demand, but they obtain information on demand from multiple resources (i.e., from their first-tier suppliers and OEMs). Therefore, they usually implement make-to-stock (MTS) strategies, but maintain high amounts of buffers to ensure continuous production. Examples of second-tier suppliers include those of fiber for seats; electronics/sensors; bearings; metal parts; or heating, ventilation, and air conditioning (HVAC) system assemblers.
- Third-tier suppliers are responsible for delivering semi-finished products or raw material to first-tier or second-tier suppliers. They are involved in procurement and

sales to ensure the availability of raw material at any point of time. Therefore, their key business role is trading the raw material rather than manufacturing. However, third-tier suppliers also have fluctuating demand, but obtain information on demand from multiple resources (i.e., from their first-tier and second-tier suppliers, and OEMs). Examples of third-tier suppliers include those of plastic, metal, or aluminum parts.

There are several other differences in terms of products, main business processes, manufacturing strategy, use of buffers, demand characteristics, and sources of demand information between the OEM and upstream suppliers. These differences are summarized in Table (1.3), which was created based on the understanding of literature.

Table 1.3: Comparison of the different aspects among major automotive supply chain members

Aspects	Major supply chain members in the automotive industry			
	OEMs	First-tier suppliers	Second-tier suppliers	Third-tier suppliers
Delivered products	Vehicles	Components, systems to OEMs	Sub-components, subsystems to first-tier suppliers	Raw materials to second-tier suppliers
Main business processes	Assembly, manufacturing, R&D	Manufacturing, sub-assembly	Sub-assembly products to first-tier suppliers	Purchasing of raw materials
Manufacturing strategy	JIT, Lean production	MTO, ATO	MTS	MTS
Buffers	Low	Medium	High	High
Demand characteristics	Uncertain	Fluctuating volumes	Fluctuating volumes	Fluctuating volumes
Source of demand information	Distributors, Dealers, competitors, and final customers	OEMs	First-tier suppliers and OEMs	Second-tier suppliers, first-tier suppliers

There are also other segments in the automotive supply chain. These include:

- **Distributors:** These companies are responsible for logistics and transportation from OEM to dealers or directly to customers).
- **Dealers:** They are the agent companies that sell vehicles directly to the end customers, wherein they can select a wide variety of vehicles in the showrooms

or order vehicles according to their own preferences. The dealers also offer repairing services and cover warranty aspects for new cars.

- **Repair and maintenance companies:** These after-sale service companies are garages that usually provide authorized repair work and maintenance services to one or several brands of vehicles.
- **Scrapping and recycling companies:** These companies are responsible for the scrapping process and/or recycling of out-of-service or damaged vehicles.

1.6 Research Design and Methodology

This thesis comprises three studies that constitute the empirical foundations of the research problem. Each study attempts to answer one research question. As shown in Table (1.4), each study has its own methodological approach depending on the nature of the research question. These studies are elaborated in Chapter 3, but briefly described as follows:

Study No. 1 concerns the first research question RQ1. The study focuses on identifying the types of information that could affect suppliers' ability to respond to demand fluctuations. Since the purpose of the study is to explore how information is shared, what kind of information OEMs share with their direct suppliers, and how information sharing affects suppliers' operations, the nature of the study is explorative. Hence, the study follows a qualitative approach based on a multi-case study approach. Data were collected through 16 semi-structured interviews with company managers of eight different automotive suppliers based in Sweden. A set of 20 open-ended questions was developed to guide the interview process. The interview questions were developed based on a theoretical review of the underlying concepts of the RQ1 (i.e., volume flexibility, delivery flexibility, and information sharing in supply chains). The study was conducted from October 2013 to June 2014. The findings were used to support the arguments presented in Study No. 2.

Study No. 2 concerns the second research question RQ2. This study examines whether sharing demand forecasts and inventory data affect suppliers' delivery flexibility under

the mediation effect of volume flexibility. A model comprising four constructs, 24 indicators, and six hypotheses were developed. The study, therefore, follows a quantitative approach based on a web-based survey questionnaire. The questionnaire comprises 30 questions, which were developed based on the literature review of the aforementioned variables. The web-based questionnaire was distributed to 203 manufacturing plants (of supplier firms) in Sweden. Subsequently, 52 valid responses were collected, generating a response rate of 26%. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM), and regression analysis to test the validity and reliability of the factors, model fit, and proposed hypothesis. The data analysis was accomplished using IBM SPSS 20.0 and Smart PLS 3.0 Pro software packages. The study was conducted from January 2014 to April 2014.

Study No. 3 constitutes the empirical foundations for RQ3. The aim of this study is to investigate the collaboration practices undertaken by OEMs to improve delivery performance of first-tier suppliers. The study combines both the descriptive and explorative aspects of the research question; hence, it is based on in-depth case analysis in one of the biggest Swedish automotive companies, and 10 of its suppliers. For the scope of the study, the analysis focuses on one product line, the Chassis Production Unit. The study is based on multiple sources of secondary data (interviews with functional managers, company documents such as logistics manual, delivery plans, delivery schedules, delivery agreements, supply contracts, meeting minutes, and customer EDI data). These data sources allow for triangulation of data to search for empirical evidences, which in turn provide empirical creditability for the study. This study was conducted between November 2014 and June 2015 in which several meetings, field visits, and interviews were conducted. Table (1.4) outlines the research design landscape of the entire doctoral thesis.

This approach of using different research methods allows for methodological rigorousness that aims for a thorough analysis of the subject under study. The underlying methodological aspects of these three studies are elaborated and presented in Chapter 3. The chapter considers the rationale behind selecting the particular methodologies for each study, and explains methods used for collecting and analyzing

empirical data. The chapter also reflects on the unit and level of analysis in each study. Although the unit of analysis in the three studies is the supplier's main product factory or production facility, the level of analysis may not necessarily be the operation level. This issue is discussed thoroughly in Chapter 3.

Table 1.4: Research design landscape of the doctoral thesis

Research problem	Theoretical frame of reference	Research design	Research questions	Objective/Purpose	Methodology of data collection	Method of data Analysis
Impact of information sharing between OEMs and first-tier suppliers on the latter's volume and delivery flexibility	<ul style="list-style-type: none"> Manufacturing flexibility theory—focus on volume and delivery flexibility aspects (Reichhart and Holweg, 2007); Responsiveness and flexibility (Christopher and Holweg, 2011) Information sharing in supply chains (Closs et al., 2005; Skipper and Hanna, 2009) Chu et al., 2012). 	Study 1: Exploratory qualitative multiple case studies	RQ1: How does information sharing between OEMs and first-tier suppliers affect the latter's responsiveness to fluctuating demand?	<p>The aim of this study is to explore how information sharing between OEMs and first-tier suppliers may affect suppliers' ability to respond to demand fluctuations in terms of volume and delivery flexibility.</p> <p>This involves exploring how information is being shared with first-tier suppliers, what kind of information OEMs share with their direct suppliers, and how information sharing affects suppliers' operations.</p>	Explorative study of 16 semi-structured interviews with eight international supplier companies based in Sweden.	Content analysis, thematic analysis, cross-comparison between case companies.
		Study 2: Explanatory (Quantitative) study	RQ2: What is the relationship between information sharing of OEMs' demand forecasts & inventory data, and suppliers' volume & delivery flexibility?	The aim of this study is to develop a conceptual model to quantify the impact of information sharing on delivery flexibility under mediation effect of volume flexibility.	An online structured survey questionnaire was sent to 203 suppliers, and 52 responses were collected, response rate of 26%	PLS-SEM, Linear regression, hypothesis testing, Reliability analysis
		Study 3: Descriptive in-depth case study	RQ3: What factors should OEMs consider to improve the sharing of demand forecasts with suppliers?	The aim of this study is to describe and explore the activities or practices that OEMs should undertake to improve the sharing of demand forecast and ultimately the delivery performance of first-tier suppliers.	In-depth case study: Two levels of analysis; OEM and supplier perspectives. Case company is a truck manufacturer	Content analyses

1.7 Thesis structure

Owing to the nature of the research questions, this doctoral thesis is organized in a monograph format, which means it follows the traditional thesis chapters. As illustrated in Figure (1.5), the manuscript has five chapters.

Chapter 1 presents a holistic view of the research problem, theoretical underpinnings, methodology, and contribution to the body of knowledge. It describes the problem situation; introduce the problem background, definition, significance, research objectives, questions, design and focus, and thesis disposition. This chapter is the most important part of the thesis because it encapsulates the rationale for the “why,” “how,” and “what” that has been analyzed during the four-year doctoral research.

Chapter 2 provides critical analyses to previous studies, theories, concepts, models, frameworks, and methodologies. The aim of this chapter is to provide a theoretical frame of reference to the research problem. It also provides a critical examination of the research gap. The literature review provides a broad understanding of the theoretical underpinnings of the research questions, arguments, and methodologies.

Chapter 3 highlights the design aspects of the research problem, such as the research philosophy, research approach, and methods for collecting data, data coding, and data analysis techniques. It also discusses the validity and reliability aspects of the conducted research.

Chapter 4 presents the empirical data collected through interviews, case study, and company’s information. The chapter will have three field studies. Study No. 1 concerns the research question RQ1, Study No. 2 about RQ2, and Study No. 3 about RQ3.

Chapter 5 presents the findings obtained in the three field studies by analyzing the empirical data. In addition, the chapter reviews the key findings based on the themes identified in the conceptual framework. Since it is important to relate the findings of the scientific research to the existing literature, this chapter discusses the findings in the

light of the flexibility theories that guided the empirical part. This chapter also concludes the thesis by outlining the contribution of this research to the body of knowledge as well as the limitations. It ends with the theoretical and practical implications and suggests directions for future research.

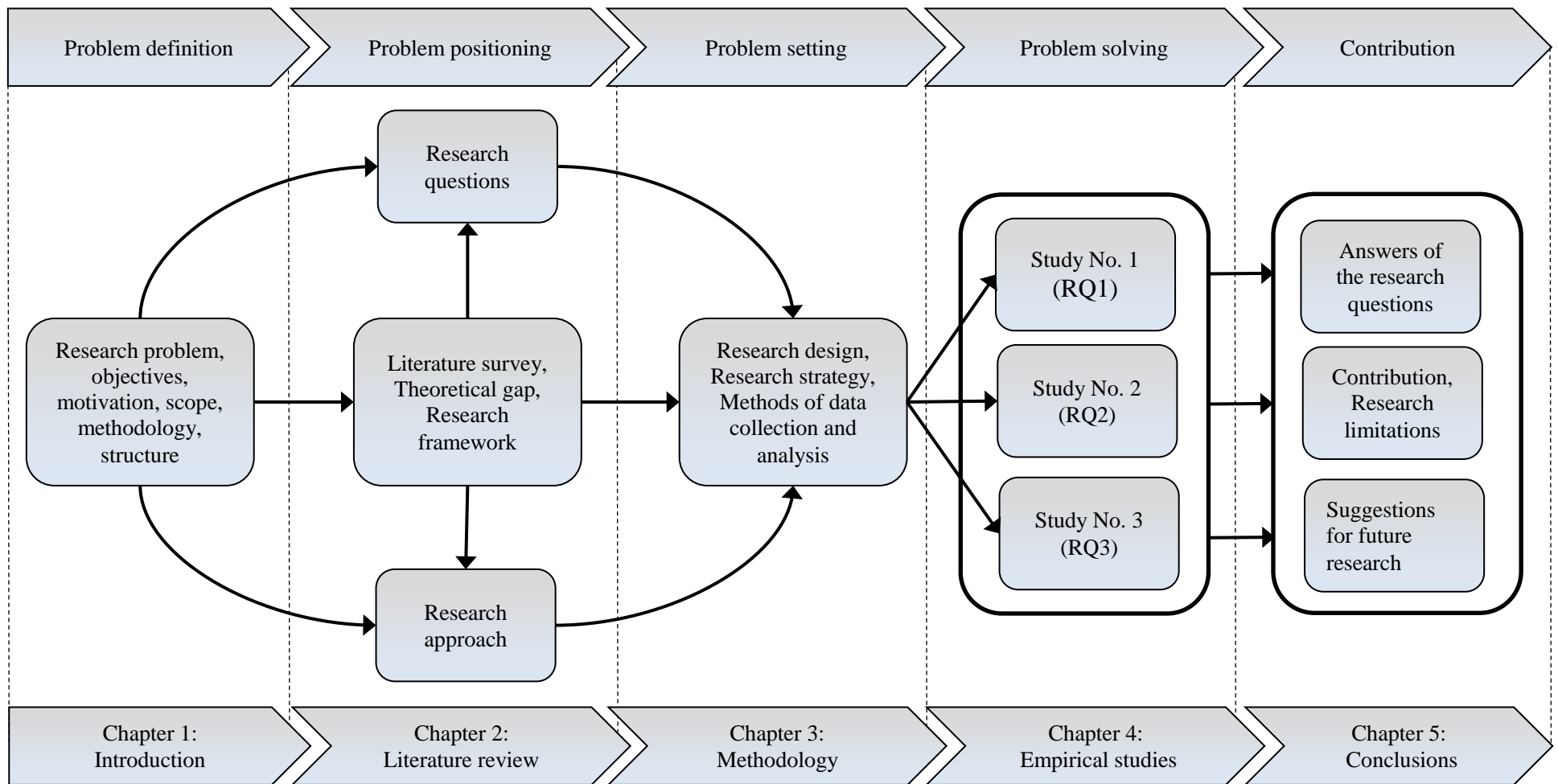


Figure 1.5: Schematic depiction of the thesis structure

2. CHAPTER II: LITERATURE REVIEW

2.1 Introduction

The research problem, investigating the role of information sharing in supplier flexibility, combines studying two different topics—information sharing and flexibility within the supply chain context. This particular combination of addressing two different topics in a single research problem is inspired by the model proposed by White et al. (2005), which is based on Christopher (2000), and is presented in Figure (2.1). The model shows that the business competition paradigm has changed from yesterday's agile manufacturing business model to today's agile supply chain. This argument is widely supported by literature. However, the model does not cover the transformation phase from “agile manufacturing” to “agile supply chain.” Hence, it is important to investigate how the move from yesterday to today can be achieved. Therefore, it is interesting to focus on the relationship between information sharing and flexibility. The point of departure of this thesis is to review related literature regarding concepts and assumption theories behind our investigation, which underpin the research questions.

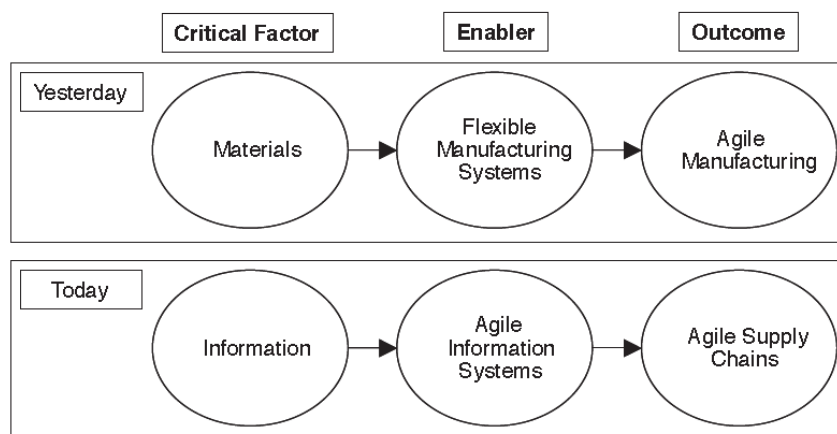


Figure 2.1: Evolution of the agility paradigm (Source: White et al., 2005, p. 339)

This chapter covers the theories and assumptions that underpin the research questions outlined in Chapter 1. It provides an overview of the previous research and studies on the role of information sharing on suppliers' flexibility, particularly the volume and

delivery flexibility aspects. The literature review also explores collaboration practices on sharing demand forecast and inventory data between OEMs and suppliers, and the impact on suppliers' delivery performance. This review has two main purposes. The first purpose is to provide a context to the research problem by reviewing relevant theories, models, concepts, and frameworks. The second is to outline the research questions and position this research study to fit into the existing body of knowledge. Furthermore, the literature review allows researchers to evaluate different methodologies or research approaches and understand how such methods have been implemented (Booth et al., 2003). Therefore, this chapter examines previous research in order to define the research questions and refocus the research methodology.

The literature survey was performed on recent contributions (i.e., mainly focusing on the last 15 years since 2000) using different scientific search engines and databases (such as Google Scholar, Scopus, Science Direct, Web of Knowledge, ProQuest, Business Source Premier, and other scientific databases). The search also included e-journals available at the library of the Royal Institute of Technology (KTH). This search included access to the journals published by several publishers, for example: Elsevier, Emerald, Taylor & Francis, EBSCO, IEEE, Springer, Sage Publications, Wiley Online Library, etc. Several keywords, such as but not limited to volume flexibility, delivery flexibility, supplier flexibility, information sharing in the automotive industry, delivery performance, supply strategy, demand variability, demand uncertainty, demand responsiveness, fluctuating volumes, agile supply chains, sharing demand schedules, sharing inventory data, sharing information in agile supply chains, and information sharing in supply chains, were used to search for relevant articles, books, e-books, conference papers, notes, and other sources of secondary data.

This chapter is organized in the following manner. It starts by reviewing and explaining the underlying theories, concepts, and terms of the research problem so that the reader becomes familiar with the complex topic and terminologies such as agility, responsiveness, and flexibility. The chapter reviews the concept of flexibility aspects in the light of the operation strategy and supply chain management theories, focusing on the volume and delivery aspects of flexibility. The discussion progresses to review the

concept of information sharing between OEMs and suppliers as a way to achieve flexibility, focusing on the impact of information sharing on performance, types of information, and characteristics of effective information sharing. The chapter ends with the proposed research framework and research questions.

2.2 Agility, Responsiveness, and Flexibility

Until recently, agility, responsiveness, and flexibility have been used to express the same meaning. For instance, flexibility has been interchangeably used with other terms such as agility or responsiveness. Although these terms seem to have the same meaning, they are not the same (Bernardes and Hanna, 2009). Several studies have attempted to provide conceptual definitions for them; for instance, Bernardes and Hanna (2009) have used the ladder of abstraction to clarify the differences between these terms. According to their conceptualization, which is shown in Table (2.1), agility is predominantly used to describe an approach to organizing that provides for rapid system reconfiguration in the face of unforeseeable changes, while responsiveness commonly refers to a system behavior involving a timely purposeful change in the presence of modulating stimuli. Flexibility, however, is most commonly associated with the inherent property of systems, which allows them to change within pre-established parameters.

Table 2.1: Summary of conceptualization of flexibility, agility, and responsiveness (Source: Adapted from Bernardes and Hanna (2009, p. 41))

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

2.2.1 Agility

Agility is “a business-wide capability that embraces organizational structures, information systems, logistics processes, and in particular, mindsets” (Christopher, 2000, p. 37). In fact, several authors have defined the concept of agility. For instance, Sharifi and Zhang (2001) characterize agility in three main dimensions: ability to cope with unexpected challenges, ability to survive unprecedented threats, and ability to convert changes into opportunities. On the other hand, Wadhwa and Rao (2003) support this claim; they define agility as the ability of the firm to cope with unpredictable changes in market and customer demand. In their study, Wadhwa and Rao (2003) argue that the main difference between flexibility and agility is the nature of the situation that requires change; that is flexibility is the response to known situations where the procedures are already in place to manage the change, while agility incorporates the ability to respond to unpredictable changes in market or customer demands. Table (2.2) provides a review of several definitions of the agility concept.

In the light of the above discussion, it can be concluded that agility is concerned with innovative responses rather than relying on predefined procedures (Bernardes and Hanna, 2009), so an agile supply chain requires innovative processes. In fact, this conclusion is supported by Fisher (1997), who asserts that functional products require efficient supply processes and thereby an efficient supply chain, while innovative products require responsive processes and thereby a responsive supply chain. Accordingly, it is important to emphasize that agility does not mean lean; however, lean is a strategy whose main characteristic is doing more with less (Christopher, 2000).

Table 2.2: Definitions of Agility (Source: Adapted Bernardes and Hanna (2009, p. 38))

Definition of agility	Reference
The ability to accelerate the activities on a critical path that commences with the identification of a market need and terminates with the delivery of a customized product	(Kumar and Motwani, 1995)
A comprehensive response to the business challenges of profiting from rapidly changing, continually fragmenting, global markets for high-quality, high-performance, customer-configured goods and services	(Goldman et al., 1995)
The ability to produce and market successfully a broad range of low cost, high-quality products with short lead times in varying lot sizes, which provide enhanced value to individual customers through customization	(Vokurka and Fliedner, 1998)
The ability of an enterprise to respond quickly and successfully to change	(McGaughey , 1999)
The capability of surviving by reacting quickly and effectively to changing markets, driven by customer-designed products and services	(Gunasekaran, 1999)
The ability of an organization to thrive in a constantly changing, unpredictable business environment	(Rigby et al., 2000)
The ability of enterprises to cope with unexpected changes, to survive unprecedented threats from the business environment, and to take advantage of changes as opportunities	(Sharifi and Zhang, 1999)
The organization's capacity to gain competitive advantage by intelligently, rapidly, and proactively seizing opportunities and reacting to threats	(Meredith and Francis, 2000)
The ability to both create and respond to change in order to profit in a turbulent business environment	(Highsmith, 2004)
A set of interlinked changes in marketing, production, design, and organization.	(Storey et al., 2005)
Ability to efficiently change operating states in response to uncertain and changing demands placed on it	(Narasimhan et al., 2006)

2.2.1 Responsiveness

Responding to changes in market requirements is considered an important aspect in supply chain design and management, especially for firms whose operations strategy focuses on MTO. According to Holweg, (2005, p. 605), responsiveness is defined as “the ability to react purposefully and within an appropriate time-scale to customer demand or changes in the marketplace, to bring about or maintain competitive advantage.” In fact, several authors have defined the concept of responsiveness. Table (2.3) provides a review of several definitions of this concept.

Table 2.3: Definitions of responsiveness (Source: Adapted from Bernardes and Hanna (2009, p. 39))

Definition of responsiveness	Reference
A firm's ability to respond in a timely manner to customer's needs and wants	(Tunc and Gupta, 1993)
The ability to fill customers' orders quickly	(Upton, 1995a)
The ability to react purposefully and within an appropriate timescale, to significant events, opportunities, or threats to bring about or maintain competitive advantage	(Barclay et al., 1996)
The ability of a manufacturing system to make a rapid and balanced response to the predictable and unpredictable changes characterizing today's manufacturing environment	(Gindy et al., 1999) and (Saad and Gindy, 1998)
The ability of a production system to achieve its operational goals in the presence of disturbances	(Matson and McFarlane, 1999)
The ability to respond and adapt time effectively based on the ability to read and understand actual market signals	(Catalan and Kotzab, 2003)
The ability to plan and control the flow of materials through a sequence of supply chain processes in order to meet end customer buying behavior	(Harrison and Godsell, 2003)
The firm's ability to respond in a timely manner to the needs and wants of its customers	(Chen et al., 2004)
The ability of the manufacturing system or organization to respond to customer requests in the marketplace	(Holweg, 2005)
Product-specific action taken as a function of the knowledge generated and disseminated in logistics operations	(Hult et al., 2006)
The speed with which the system can adjust its output within the available range of the four external flexibility types in response to an external stimulus	(Reichhart and Holweg, 2007)

2.2.2 Flexibility

Flexibility is a broad concept for which numerous definitions are presented in the operations management literature. Most studies in the literature define flexibility as the ability of the manufacturing system to respond to changes. Table (2.4) mentions some related definitions. For instance, Holweg (2005) defines flexibility as a generic ability to adapt to internal and/or external influences. Zhang et al. (2003) define flexibility as the organization's ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses. Das (2001) defines flexibility as the ability of a manufacturing system to change states across an increasing range of volume and variety, while adhering to stringent time and cost metrics.

Despite the tremendous amount of contributions on flexibility literature, this concept has not been well understood because the terms “ability” and “changes,” which appear in most definitions are quite broad. The former term can include a wide range of capabilities such as technological (e.g., automated production systems), organizational (e.g., knowledge and human resources), or other types of capabilities (e.g., financial). Further, the term “changes” can include a wide range of incidences. Based on Gupta and Buzacott (1989), these changes could be fluctuations in demand volumes, changes in product design, packaging material, legislations, market competition, business models, resource availability, work procedures, business process, purchasing orders, introducing new technology, introducing new products, or other types of changes.

Furthermore, when reviewing these definitions, most scholars have defined flexibility from the OEM perspective but not that of the supplier. However, a recent definition of flexibility provided by Cousins et al. (2008) has drawn the attention to supplier flexibility, by defining flexibility as the ability of the supplier to manage variation from the buyer firm without significant trade-offs with other competitive priorities (Cousins et al., 2008). Therefore, this research uses the definition by Cousins et al. (2008) in order to narrow down the focus of the thesis.

Table 2.4: Definitions of flexibility (Source: Adapted from Bernardes and Hanna (2009, p. 34))

Definition of flexibility	Reference
Ability to respond effectively to changing circumstances	(Grewin, 1987)
The quickness and ease with which plants can respond to changes in market conditions	(Cox, 1989)
The adaptability of a system to a wide range of possible environments that it may encounter	(Sethi and Sethi, 1990)
The ability of a manufacturing system to generate high net revenues consistently across all conceivable states of the nature in which it may be called to function	(Ramasesh and Jayakumar, 1991)
The ability to cope with changing circumstances or instability caused by the environment	(Gupta and Somers, 1992)
The ability of the system to quickly adjust to any change in relevant factors like product, process, loads, and machine failure	(Nagarur, 1992)
A response to external uncertainty	(Newman et al., 1993)
A generic ability to adapt to internal and/or external influence	(Holweg, 2005)
The ability of a manufacturing system to change states across an increasing range of volume and/or variety, while adhering to stringent time and cost metrics	(Upton, 1994) (Upton, 1995b)
The ability to respond quickly to changing customer needs at reasonable price	(Small and Chen, 1997)
The capability of an organization to move from one task to another quickly and as a routine procedure	(Vokurka and Fliedner, 1998)
The ability of the firm to respond to a variety of customer requirements, which exist within defined constraints	(Backhouse and Burns, 1999)
The ability of a manufacturing system to change states across an increasing range of volume and/or variety, while adhering to stringent time and cost metrics	(Das, 2001)
Flexibility is a prerequisite to become agile	(Wadhwa and Rao, 2003)
The organization's ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses	(Zhang et al., 2003)
A generic ability to adapt to internal and/or external influences	(Holweg, 2005)
The ability of the supplier to manage variation from the buyer firm without significant trade-offs with other competitive priorities	(Cousins et al., 2008)

2.3 Difference between Manufacturing and Supply Chain Flexibility

Although there has been considerable progress on flexibility, research studies often mix up two different perspectives of the concept—“manufacturing flexibility” and “supply chain flexibility.” A recent study by Thomé et al. (2014) elucidated the difference between the two concepts. In their research paper, entitled “A multi-tier study on supply chain flexibility in the automotive industry,” the authors address the concept in an attempt to distinguish between manufacturing flexibility and supply chain flexibility. As a result, “manufacturing flexibility” refers to the flexibility of individual firms or the manufacturing system while “supply chain flexibility” is a broad concept of flexibility that extends beyond the boundary of the firm, which incorporates the inter-firm flexibility across multiple tiers within the supply chain level. Thomé et al. (2014) summarize the literature in five key aspects of manufacturing flexibility: (1) types, (2) dimensions, (3) timeframe, (4) hierarchy, and (5) uses. These five aspects are discussed below.

2.3.1 Types of Manufacturing Flexibility

The study of flexibility aspects refers to the seminal work of Slack (1987) and Upton (1994). Both scholars assert that flexibility of a manufacturing system can be expressed in terms of: product flexibility, mix flexibility, volume flexibility, and delivery flexibility. Product flexibility is defined as the ability to introduce changes to existing products (or introduce new products, in which case it is called launch flexibility). Mix flexibility is the ability to change the product mix that the system delivers. Volume flexibility is the ability to increase or decrease the aggregated output of the system. Delivery flexibility is the ability to change the planned or agreed delivery time and destination. In addition to this classification, Upton, (1994) suggests another classification of manufacturing flexibility—“internal” and “external.” Thomé et al. (2014, p. 92) highlight that internal flexibility refers to the competencies that are internal to the system (such as machine, labor, material handling, and routing flexibilities) and used to deliver external flexibility. The number of internal flexibility types varies depending on the specific operational setting of each manufacturing system. For example, Reichhart and Holweg (2007) propose that internal flexibility

includes seven types of flexibility—machinery, material handling, operations, routing, expansion, program, and others. External flexibility, however, refers to the flexibility types that are the commonly recognized four types, originally suggested by Suarez et al. (1996); Pagell and Krause, (2004); Sawhney, (2006) in Thomé et al. (2014, p. 92).

As seen in the previous discussion, flexibility is not the same as agility; in fact, it is a key characteristic of an agile organization (Christopher, 2000). In this regard, Wadhwa and Rao (2003) empathize that flexibility is a prerequisite to become agile. Duclos et al. (2003) provide an integrated conceptual model to analyze the components of supply chain flexibility. In their study, they examine flexibility classification, schemes, and commonalities of flexibility typologies. Although their study does not involve empirical data (i.e., only conceptual framework), it is a significant attempt to investigate inter-firm flexibility measures. They claim that the flexibility strategy must extend beyond a firm as supply chain management extends beyond the firm's boundaries.

Within a supply chain context, Reichhart (2007) examines flexibility across multiple tiers. In particular, he investigates how flexibility propagates through the supply chain network. The author finds that flexibility dimensions (i.e., types) can convert into each other, for example mix flexibility was found to transform into volume flexibility at various stages in the supply chain. Furthermore, the author finds that mix flexibility can directly transform into volume flexibility while delivery flexibility frequently converts into a combination of mix and volume flexibility. Thus, it means that volume and delivery flexibility are of great importance, especially at the supplier level. Cousins et al. (2008) define volume flexibility as the ability of the supplier to increase or decrease the aggregated output of the system, and delivery flexibility as the ability of the supplier to change the planned or agreed delivery time and destination.

2.3.2 Dimensions of Manufacturing Flexibility

Reichhart and Holweg (2007) also propose a framework to integrate internal and external types of flexibility together with flexibility dimensions. Flexibility dimensions were originally proposed by Slack (1987) in which he identifies two dimensions for each type of flexibility—range and response. In addition to the “range” and “response,”

Upton (1994) incorporates “uniformity” as a third dimension to flexibility. According to Reichhart and Holweg (2007, p. 1147), the “range” dimension refers to the “maximum number of different outcomes a resource with the respective flexibility type can achieve, such as the total number of different products a given machine can produce.’. The “response” dimension refers to “the time and cost with which different values within a range can be achieved,” while the “uniformity” dimension refers to “the ability of a resource to provide consistent performance throughout its range.” Figure (2.2) depicts the types and dimensions of manufacturing flexibility.

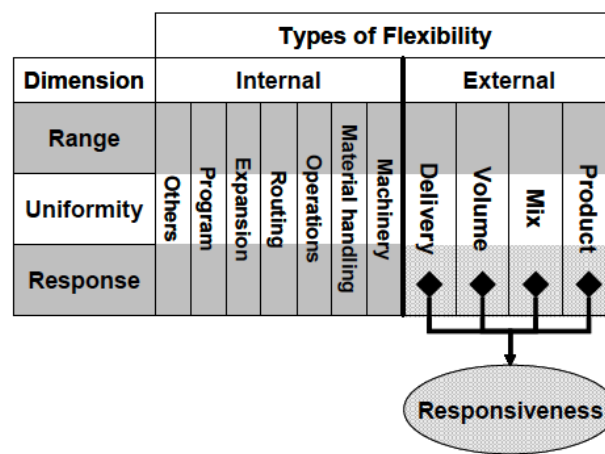


Figure 2.2: Relationship between flexibility and responsiveness (Source: Reichhart and Holweg, 2007, p. 1150)

2.3.3 Timeframe of Manufacturing Flexibility

Several studies, (Zelenović, 1982; Carlsson, 1989; Upton, 1994), have viewed the concept of manufacturing flexibility from a timeframe perspective. In this regard, the authors argue that flexibility should be perceived either as a short-term or long-term approach. For instance, “a system may be very flexible in the long term but shows almost no flexibility within an operational time horizon of a few days” (Thomé et al., 2014, p. 92).

2.3.4 Hierarchy of Manufacturing Flexibility

Literature has also provided another key perspective to view flexibility, which is the hierarchy within a firm. Supporters of this perspective, such as Koste and Malhotra (1999), emphasize that flexibility is realized as a bottom-up approach, which exists at

five different organizational levels or tiers—individual, shop floor, plant, functional, and strategic business unit level. As illustrated in Figure (2.3), the individual resource is the first tier of flexibility levels that includes three types: machine, labor, and material and handling flexibility. The shop floor level is the second tier, including operations and routing flexibility. The plant level is the third tier in the hierarchy, which involves volume, expansion, mix, new product, and modification flexibility. The functional level is the fourth tier, including operations and routing flexibility. The strategic business unit is the last tier in the flexibility hierarchy model in which the strategic flexibility is realized.

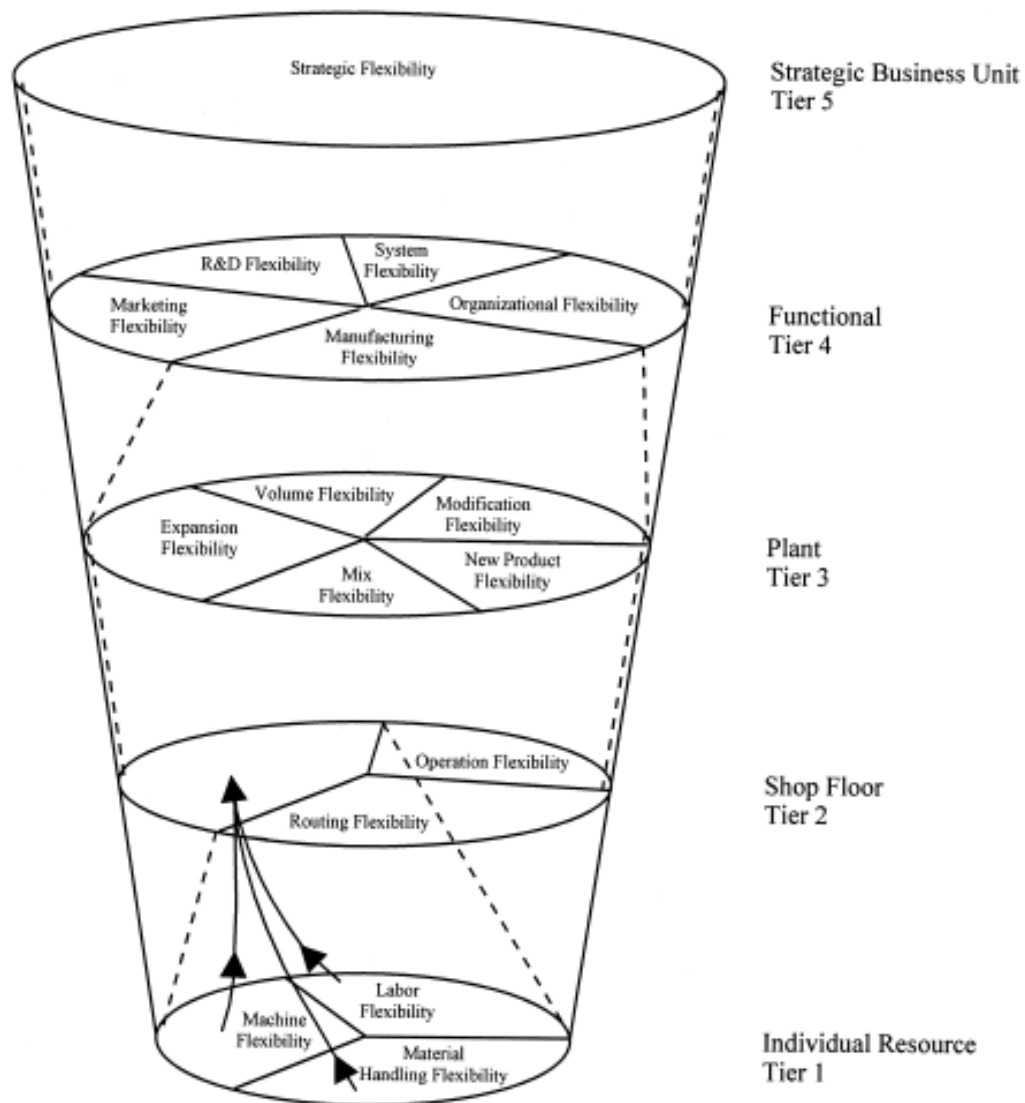


Figure 2.3: Hierarchy of flexibility (Sources: Koste and Malhotra, 1999, p. 87)

The functional level is the fourth tier in this hierarchy, which involves R&D, marketing, manufacturing, organizational, and system flexibility. The strategic business unit is the last tier in the flexibility hierarchy model in which the strategic flexibility is realized.

In conclusion, the cone-shaped model of flexibility provides a comprehensive understanding of the hierarchical perspective of flexibility, emphasizing it to be viewed as a bottom-up approach, which begins at the individual level and propagates to the corporate level in a firm.

Sánchez and Pérez (2005), however, emphasize that flexibility is assumed in three hierarchical levels—Basic, System, and Aggregate. The “Basic” level represents the types of flexibility that are embedded at the shop floor of a plant; and includes product, volume, and routing flexibility. The “System” level represents the flexibility types rooted at the company level, including delivery, transshipment, and postponement flexibility. The “Aggregate” level characterizes the flexibility types that are manifested at the chain level; and includes launch, response, sourcing, and access flexibility. As shown in Figure (2.4), this model provides a holistic understanding of the flexibility concept.

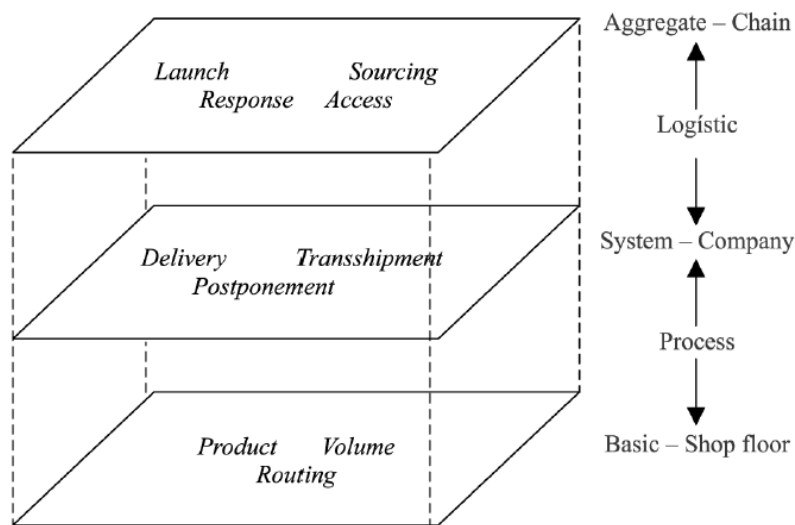


Figure 2.4: Levels of supply chain flexibility (Sources: Sánchez and Pérez, 2005, p. 685)

However, when comparing the two models, one can recognize that the term “flexibility dimensions” was misinterpreted with the term “flexibility types” in their respective studies. These studies used the term “dimension” to express the meaning of “types,” which is incorrect. Besides, both studies misinterpreted manufacturing flexibility with

supply chain flexibility, for instance by using some manufacturing flexibility types to express supply chain types. Surprisingly, this misinterpretation was missing in the review study conducted by Thomé et al. (2014). Indeed, this may confuse the audience (i.e., researchers and practitioners), rendering it difficult to measure the actual level of flexibility of a firm or even a supply chain. Furthermore, this misinterpretation could also indicate that this research topic has still not provided a clear and concise distinction between the two terms. A major problem could be confined to the broad conceptualization of the flexibility concept or lack of studies that associate or link the concept to other important supply chain issues or concerns, such as with information sharing.

2.3.5 Uses of Manufacturing Flexibility

According to Lucas and Kirillova (2011), several studies, including Gerwin (1993), Sanchez (1995), Chang et al. (2003), and Sawhney (2006), argue that a firm should view manufacturing flexibility as a proactive tool to create and sustain competitive advantage. Other studies, such as those shown in Table (2.4), have viewed flexibility as a reactive tool to respond to uncertainty or changes in the market conditions. Whether flexibility is considered a reactive or proactive tool, the literature emphasizes it as a source of competitive advantage.

As inferred in the aforementioned discussion, the concept of flexibility (in the operations management literature) was studied during the 80s and early 90s. During that period, the concept was used to refer to “manufacturing flexibility of an individual manufacturing system or firm level.” Nevertheless, the literature has shifted the concept of flexibility to the “supply chain level” since the late 90s. This change has extended the “manufacturing flexibility” to what is known today as “supply chain flexibility.” Yet, the latter concept is often confused with the former. In this regard, Stevenson and Spring (2007), and then More and Babu (2009) conducted state-of-the-art literature reviews of the concept of flexibility at the supply chain level, providing a comprehensive review of the definitions, types, and other aspects of the concept. By analyzing and comparing their reviews with that of Thomé et al. (2014), it can be

emphasized that most previous studies on this topic have used the concept of manufacturing flexibility interchangeably with supply chain flexibility, thereby neglecting other important aspects that may influence flexibility levels (for instance, information sharing in supply chain). Therefore, it is important to view this issue from other broad theoretical perspectives. The following section attempts to summarize these theories.

2.4 Theoretical Perspectives on Flexibility

Due to its broad sense, flexibility is viewed from various theoretical perspectives, which can be summarized according to two (at least) common theoretical perspectives: Economic and resource-based view (RBV). The following subsections provide a general explanation of each theoretical perspective.

2.4.1 Economic Perspective

The flexibility concept was initially observed in the micro-economic theory and later appeared in the decision-making theory. In both cases, it is argued that flexibility is good in an uncertain environment (Marschak and Nelson, 1962). These perspectives were used to evaluate the flexibility decisions. For example, Gupta and Buzacott (1989) provide conceptual foundations for models covering the economic evaluation of investments in flexible automated manufacturing systems. The flexibility concept also appears in connection with the economies of scale or economies of scope concepts. The terms “economies of scale” and “economies of scope” are sometimes used interchangeably (Besanko et al., 2013), but they should not be. The former is achieved when the average unit cost can be reduced by increasing the output rate, and this is usually done by focusing on one product and producing more. The latter is achieved when it is cheaper for a firm to produce several products than to specialize in one single product.

Accordingly, it can be argued that specialization in a single product may allow firms to achieve economies of scale while flexibility capabilities may allow for developing economies of scope. Therefore, advocates of the economic theory view flexibility as a strategic tool to sustain profitability. For instance, Hyun and Ahn (1992) also define

volume-flexibility as the ability to accelerate production quickly and operate profitably at different production volumes. Similarly, Chryssolouris and Lee (1992) define volume-flexibility as the ability to operate profitably at different production volumes. New (1996) and D'Souza and Williams (2000) have also focused on the cost and profit aspects of volume-flexibility.

2.4.2 The Resource-Based View (RBV) Perspective

This perspective of the firm has also been used to conceive the flexibility concept. In this theory, flexibility is viewed based on the capabilities and resources perspective of a firm. In other words, a firm can achieve flexibility when it sustains and develops the necessary capabilities and resources to compete in the marketplace. Examples of such capabilities include automated manufacturing systems, integrated supply and logistic processes, IT systems, collaboration with suppliers, holding inventories, JIT production, and other kinds of technological capabilities. These capabilities and resources are developed within the firm to absorb (or react to) any potential impact that may follow unexpected changes in demand, market, prices, supplies, and other types of uncertainties. Therefore, the operational dimension of flexibility is important to develop quick responses to such uncertainties.

The literature also covers other theoretical perspectives on flexibility—for instance, organizational theory (Shimizu and Hitt, 2004) and system control theory (De Leeuw and Volberda, 1996). This thesis, however, utilizes the operational perspective to theoretically analyze the research problem.

2.5 Flexibility as a Competitive Weapon of Operation Strategy

As shown in the previous section, flexibility is defined as the ability of the supplier to manage variation from the buyer without significant trade-offs with other competitive priorities (Cousins et al., 2008). Competitive priorities refer to the strategic emphasis on developing certain manufacturing capabilities that either sustain or enhance a plant's position in the marketplace. Such emphasis may guide decisions regarding the production process, capacity, technology, planning, and control (Ward et al., 1998).

Generally, competitive priorities are expressed in terms of at least four basic components: cost, quality, delivery, and flexibility (Cai and Yang, 2014; Díaz-Garrido et al., 2011; Boyer and Lewis, 2002; Ward et al., 1998).

Flexibility is considered an essential part of operations strategy. Operations strategy is defined as “the total pattern of decisions that shape the long-term capabilities of any type of operation and their contribution to the overall strategy, through the reconciliation of market requirements with operations resources” (Slack and Lewis, 2011, p. 22). In their book, entitled *Operations Strategy*, Slack and Lewis (2011) provide a holistic view of the operations strategy concept, emphasizing on flexibility and other competitive priorities. For instance, Slack and Lewis (2011) assert that operations strategy is concerned with “how the competitive environment is changing and what the operation has to do in order to meet current and future challenges. It is also concerned with the long-term development of its operations resources and processes so that they can provide the basis for a sustainable advantage” (Slack and Lewis, 2011, p. 7). In this regard, Porter (1996) argues that strategy concerns achieving competitive advantage through being different—delivering a unique value to the customer. Figure (2.5) illustrates the concept of operations strategy in which flexibility is seen as a performance objective.

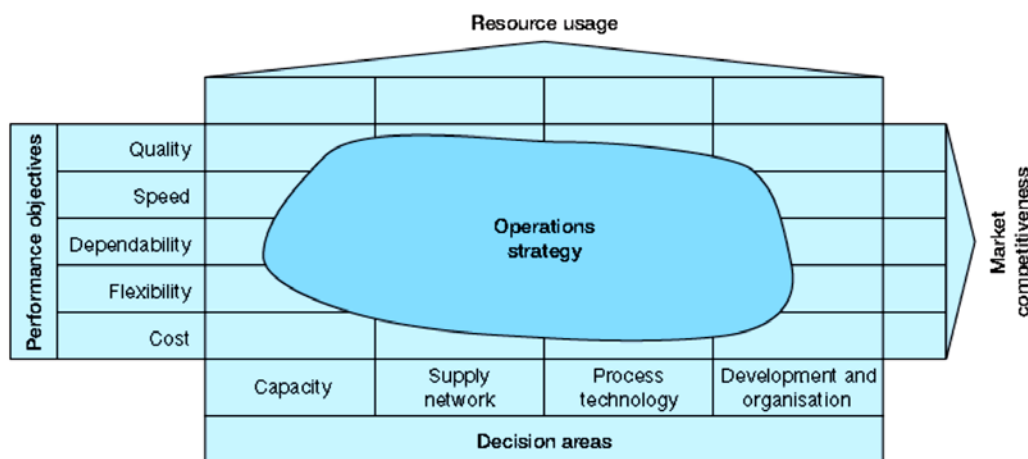


Figure 2.5: Operations strategy framework (Source: Slack and Lewis, 2011, p. 30)

Therefore, flexibility can be considered a competitive weapon that contributes to the overall operations strategy of the firm. In this perspective, Simchi-Levi (2010, p. 13)

argues that “flexibility can be a powerful tool for gaining competitive advantage, reducing costs, and improving responsiveness.” In fact, several studies, such as Upton (1994, 1995), Sanchez (1995), Christopher (2000), Sánchez and Pérez (2005), Gosling et al. (2010), and (Simchi-Levi, 2010) argue that flexibility is a crucial element to increase the competitiveness of the company, especially for those operating in an unpredictable business environment (i.e., volatile market). Therefore, flexibility can be used as a dimension of operations strategy to cope with demand fluctuations.

2.6 Information Sharing and Supply Chain Collaboration

Min et al. (2005) highlight that information sharing is an important part of supply chain collaboration. Supply chain collaboration can be classified into two types: external and internal. External collaboration concerns cooperation and coordination with other organizations or stakeholders outside the firm boundaries. Usually, there are two types of external collaborations: with suppliers and with customers. However, internal collaboration concerns cooperation and coordination between the internal units, functions, and departments within the firm boundaries. Figure (2.6) shows a schematic representation of these types of collaborations.

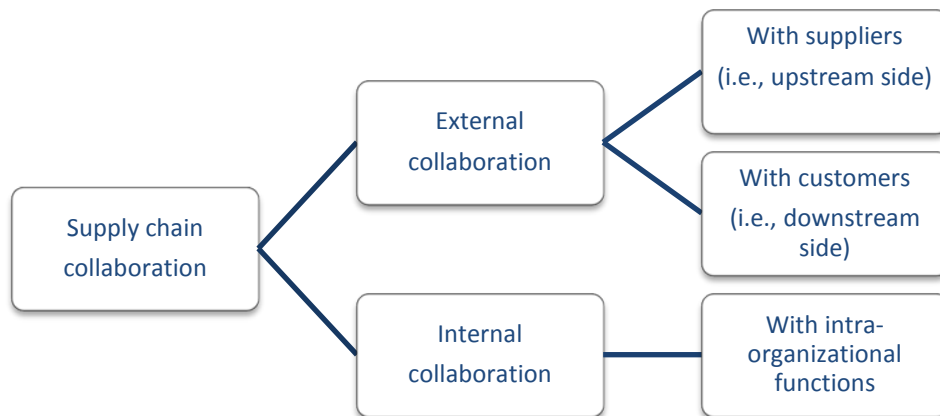


Figure 2.6: General types of collaboration in the supply chain

Barratt (2004) asserts that collaboration, in the supply chain context, is a very broad and encompassing concept and can take place either in the upstream or downstream activity side. As shown in Figure (2.7), Barratt (2004) classifies collaboration into two main categories: vertical and horizontal.

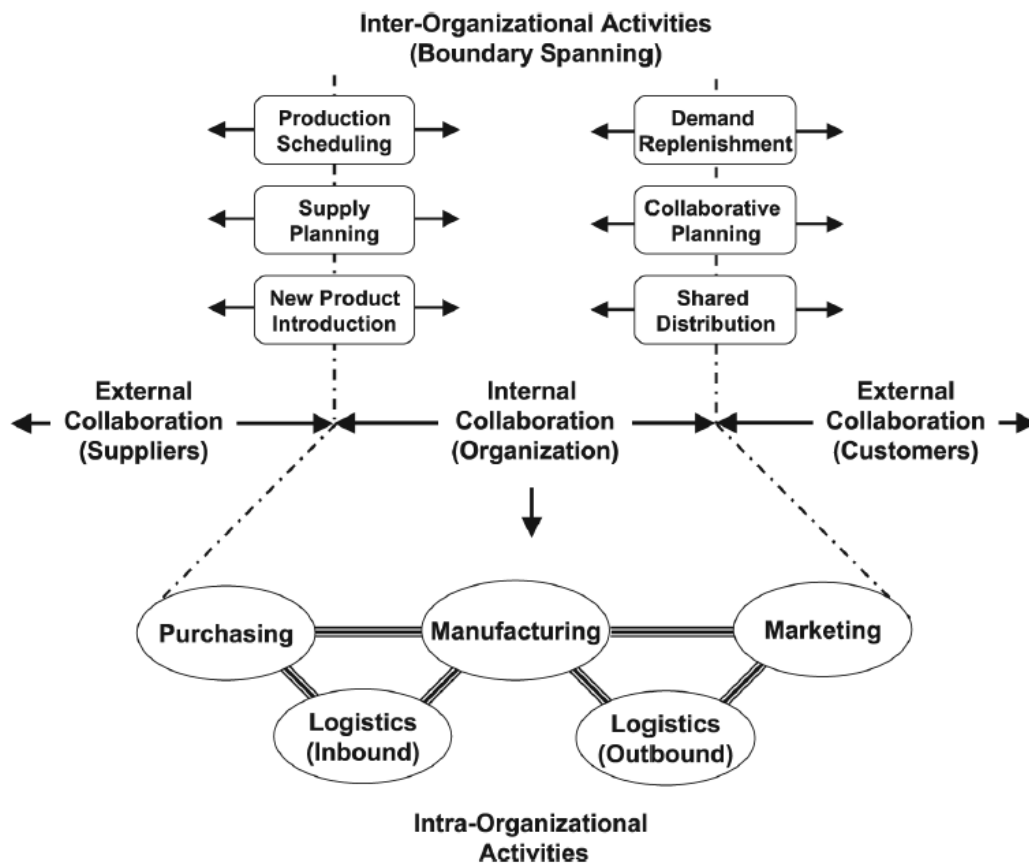


Figure 2.7: Scope of vertical collaborations (Source: Barratt, 2004, p. 34).

Vertical collaboration concerns customers and suppliers while horizontal collaboration concerns competitors and other organizations. Accordingly, Barratt (2004) classified vertical collaboration into two types: internal and external collaboration. Internal collaboration refers to the intra-firm coordination between the internal departments and functions of a firm, such as marketing and logistics, purchasing, and manufacturing. External collaboration refers to the vertical supply chain collaboration that includes inter-organizational activities in the upstream side (e.g., Supplier Relationship Management (SRM), Collaborative Product Design and Vendor Managed Inventory (VMI)) and downstream side (e.g., Customer Relationship Management (CRM), Collaborative Planning Forecasting and Replenishment (CPFR)). Figure (2.7) shows the difference between these types of collaborations. Literature has suggested several approaches to achieve flexibility, such as supply chain collaboration (Vickery et al., 1999). In this regard, information sharing among supply chain partners is a fundamental form of such collaborations.

Before reviewing previous studies, contributions, and frameworks on the concept of information sharing and its relationship with flexibility and performance, it is important to provide the reader with background information for considering the automotive industry in Sweden as the empirical case of this thesis.

2.7 Information Sharing and Company Performance

Recalling the definition of information sharing by Yigitbasioglu (2010), it can be argued that there are two aspects of effective sharing of information: its level and frequency.

2.7.1 Level of Information Sharing—Types of Information Being Shared

Researchers have identified different types of information sharing between supply chain members at the operational level. Sahin and Robinson (2002) propose a conceptual framework for information sharing in which they identify different types of information, such as production plans, production schedules, stock levels, actual demands, demand forecast, product portfolio, Point-of-Sales (POS) data, and product's launch date. Each type of information plays a different role; for example, first-tier suppliers may pursue an MTO strategy but lack information on demand, thus they may be interested in obtaining information on demand while OEMs might be interested in learning information about the prices of the components. In this regard, Qian et al. (2012) studied the vertical demand information sharing in a two-echelon supply chain formed by many downstream retailers and one upstream manufacturer with a limited production capacity. They found that a discriminated allocation strategy would encourage the retailers to share their demand information. However, supply chain members have different operations, manufacturing strategies, and products. Thus, each company has self-interest in certain types of information that are necessary for its activities.

Information sharing is crucial to a supplier's responsiveness; information is generally shared on a daily, weekly, or monthly basis. The use of information technology (IT) has facilitated fast exchange of information between buyers and suppliers (Yue and Liu, 2006). IT systems have been used to streamline accurate and real-time data and avoid manipulation or amplification of actual forecasts (Prater, 2005). For example, CPFR

and VMI are widely used methods to share information between buyers and suppliers in many industries such as food, retail, and apparel. However, most firms in the automotive industry use the EDI system..

2.7.2 Information Sharing and Responsiveness

MTO strategy requires fast information flow and accurate demand forecasts and plays an important role in facilitating fast exchange of data between buyers and suppliers (Shih et al., 2012). In their study, Shih et al. (2012) claim that uncertainty can be decreased by integrating IT systems in the supply chain network, resulting in lower production cost, shorter lead times, and faster product delivery. Kemppainen and Vepsäläinen (2007) confirm that for any manufacturing strategy to work well, it is necessary to stabilize demand and reduce supply chain uncertainty. In tackling such uncertainty, flexibility requires smooth flow of information sharing across the supply chain members (Datta and Christopher, 2011).

Consequently, MTO is a manufacturing strategy that is usually implemented by firms that work in an agile environment where demand is uncertain and variability is high (He et al., 2014). In such an environment, the demand volumes are likely to fluctuate, making it difficult for suppliers to predict the future demand. In this context, MTO provides first-tier suppliers with the flexibility to produce less or more according to the customer's orders.

In that sense, research has suggested that flexibility is relevant for those industries in which demand is volatile. Flexibility is a broad concept, viewed as “a firm's ability to match production to demand in the face of uncertainty and variability” (Iravani et al., 2014, p. 321). Several studies such as Upton (1994), Upton (1995), Sanchez (1995), Christopher (2000), Sánchez and Pérez (2005), and Gosling et al. (2010), argue that flexibility is a crucial element to increase the competitiveness of the company in an unpredictable business environment (i.e., volatile market). Furthermore, Reichhart and Holweg (2007, p. 1150) emphasize that the “flexibility of manufacturing systems in a supply chain should be regarded as a factor contributing to a supply chain's responsiveness and not vice versa.” Hence, flexibility is viewed as one of the competitive weapons of operations strategy. From a supply chain perspective, the

fundamental focus of flexibility is based on the combination of responsiveness and efficiency of operations strategy (Simchi-Levi, 2010). While responsiveness is concerned with speed such as JIT, efficiency often pertains to cost reduction such as adopting lean production principles (Monden, 2012).

2.7.3 Previous Contributions on Information Sharing in Supply Chain

Although there is abundant research on information sharing in supply chains, it has not been fully integrated into the study of supplier flexibility. While reviewing some recent studies (i.e., a literature survey of the main previous studies concerning theoretical models and empirical investigations on information sharing during the last 15 years), it was observed that most , as reported in Table (2.5), have investigated the impact of information sharing on the performance of the entire supply chain, but not at the supplier level.

In addition, most empirical studies were too broad in terms of investigating many industrial sectors in one single study. For instance, Li and Lin (2006) examine the impact of environmental uncertainty, intra-organizational facilitators, and inter-organizational relationships on information sharing and information quality in the supply chain on several industrial sectors in the USA such as furniture, fixtures, rubber, plastics, fabricated metal, industrial and commercial machinery, electronic, electric equipment, and transportation equipment. In their study, Li and Lin (2006) find that information sharing and information quality are influenced positively by trust in supply chain partners, and shared vision between them, but negatively by supplier uncertainty.

Another example is Bagchi et al. (2005) who identify the underlying factors of supply chain integration in European firms. Their study investigates the role of information sharing and inter-organizational collaboration in many industrial sectors such as: food and kindred products; paper and allied products manufacturing; chemicals and allied products manufacturing; rubber and miscellaneous plastics; fabricated metal products; industrial and commercial machinery; electronic and other electrical equipment;

transportation equipment manufacturing; and measuring, analyzing, and controlling instruments.

Despite their importance, both studies presumed that all supply chains are the same regardless of the industry, therefore these studies tended to generalize the results to all industries. Yet, industrial sectors differ in many supply chain aspects. For instance, the automotive industry can differ from other industries because:

- Supply chain design: The automotive industry is characterized by an agile/lean business environment while the food industry has a different supply chain configuration.
- Level of demand variability: The automotive industry involves a high level of demand uncertainty while the food industry involves less demand variability levels.
- Supply strategy: Supply chain of the automotive industry focuses on being responsive to market changes, while the paper industry focuses on cost-efficiency.
- Intensity of information sharing: In the automotive industry, the level of information sharing in automotive business is high. Information sharing is a critical part of the daily operations between suppliers, manufacturers, distributors, and retailers. In contrast, the level of information sharing between suppliers, manufacturers, and retailers is not that high for the paper industry. The same comparison may apply to different industries as well. Therefore, information sharing may not necessarily play the same role in every industry or supply chain.

These aspects were not considered in the previous studies; hence, generalizability of the results to other industrial sectors might be a main concern. Youn et al. (2014) investigate how supply chain information capabilities are instrumental to achieve performance outcomes on the steel industry. Their study suggests that the Korean manufacturing industry (such as automobile, shipbuilding, construction, and mobile industries) is heavily influenced by the competitiveness of the steel industry in terms of

supply chain information capabilities and supply chain flexibility and firm-level performance outcomes (i.e., customer responsiveness and cost reductions).

Table (2.5) provides a review summary for the findings of previous studies. The table presents a comparison between several aspects. These aspects are the type of study (empirical vs. theoretical/conceptual), methodology and empirical data (qualitative, quantitative), geographic area (specific country vs. general), empirical scope (specific vs. general industry), and level of analysis (supplier vs. supply chain level).

By comparing the type of study, the majority of the studies are based on empirical investigations, in which data was collected by a survey-based technique and analysis with advanced statistical techniques. For instance, Youn et al. (2014) use PLS-SEM to analyze a survey of sample size of 74 cases. Baihaqi and Sohal (2013) also use structural equation modeling to analyze a survey of sample size of 150 cases. Therefore, the extensive use of quantitative techniques in literature reflects the importance of information sharing in supply chains. However, when comparing the scope of these studies, the majority have focused on the role of information sharing on the performance at the supply chain level while very few focus on that at the supplier level. This indicates that there is potential for research opportunities to explore the impact of information sharing at the supplier level, such as in suppliers' flexibility.

The review indicates that there is a lack of studies on the supplier level; hence, the research in supply chain information sharing should consider other research lines related to this issue, such as flexibility. The review also overemphasized the role of information sharing and performance at the supply chain level but not the supplier level.

Table 2.5: Literature survey of previous models on the role of information sharing in supply chain performance during the last 15 years, published in international peer reviewed journals in the field of operations management

Study	Focus	Type of industry	Geographic area	Methodology			Findings
				Type of study	Level of analysis	Type of analysis	
(Youn et al., 2014)	to discuss how supply chain information capabilities are instrumental to achieve performance outcomes, and identifies critical components of supply chain information capabilities in terms of inter-organizational information system capacity and inter-organizational relational competency.	Steel	Korea	Empirical, Survey questionnaire sent via fax, email, and postal mail Sample size: 74 Response rate 56.9%	Supplier-Manufacturer level	PLS-SEM	The Korean manufacturing industry (such as automobile, shipbuilding, construction, and mobile), are heavily influenced by the competitiveness of the steel industry in terms of supply chain information capabilities and performance outcomes, supply chain-level (i.e., supply chain flexibility) and firm-level performance outcomes (i.e., customer responsiveness and cost reductions).
(Zhang and Chen, 2013)	to explore information sharing in a supply chain comprising one supplier and one retailer, in which both the supplier and retailer possess partial information on the demand.	Generic	Generic	Conceptual study	Supplier-retailer level	Mathematical modeling	Information sharing may be detrimental to the retailer, supplier, and the supply chain under some conditions if they sign a wholesale price contract.
(Baihaqi and Sohal, 2013)	to conceptualize and assesses several factors that influence the degree of information sharing in supply chains, namely integrated information technologies, internal	Manufacturing companies	Australia	Empirical Mail and Internet-based surveys Sample size: 150 Response rate: 9.9%	Supply chain level	Relationships are examined using structural equation modeling	Information sharing does not directly relate to organizational performance. Information sharing is essential but insufficient by itself to bring significant performance improvements.

Study	Focus	Type of industry	Geographic area	Methodology			Findings
				Type of study	Level of analysis	Type of analysis	
	integration, information quality, and costs–benefits sharing.						
(Lotfi et al., 2013)	to investigate and reviews the effectiveness of information sharing in supply chain management, in order to increase the efficiency of the organizational performance in the manufacturing sector.	Generic	Generic	Review study	Supply chain level	Content analysis	Significance of information integration in a supply chain has been elaborated in terms of: - Types of shared information in supply chains - Barriers to information sharing - Benefits of information sharing
(Qian et al., 2012)	to investigate the incentives for vertical demand information sharing in a two-echelon supply chain formed by many downstream retailers and one upstream manufacturer with a limited production capacity.	General	China	Conceptual study	Manufacturer-retailer level	Mathematical modeling	A discriminated allocation strategy will encourage the retailers to share their demand information. The study also finds the condition under which full information sharing can be reached. For instance, when the manufacturer cannot satisfy the total order of all the retailers, social welfare, and consumer surplus will be locked by the capacity.
(Datta and Christopher, 2011)	to investigate the effectiveness of information sharing and coordination mechanisms in reducing uncertainty that originates from unexpectedly large demand spikes.	Paper tissue	UK	Single case study Quantitative	Supply chain network level	Analysis of variance (ANOVA)	Central coordination of material flows with supply chain-wide information sharing across different members is found to be essential in managing supply chains effectively under

Study	Focus	Type of industry	Geographic area	Methodology			Findings
				Type of study	Level of analysis	Type of analysis	
(Yigitba sioglu, 2010)	The study examines how the extent of information shared affects buyers' performance in terms of resource usage, output, and flexibility.	Generic (Non-services companies)	Sweden and Finland	Empirical, mail survey Sample size: 221 Response rate: 10.2% for Sweden, 11.5% for Finland,	Buyer-supplier level	Partial least squares modeling with reflective and formative constructs	uncertainty. Environmental and demand uncertainty, and interdependency can, to some degree, explain the extent of information shared between a buyer and key supplier.
(Yu et al., 2010)	to design different information-sharing scenarios to analyze the supply chain performance through a simulation model.	Generic study	Taiwan	Conceptual study	Supply chain level	Simulation	The scenario of demand information sharing is the most efficient. In addition, sharing information on capacity and demand, and full information sharing in general are good practices. Sharing only information on capacity and/or inventory information, without that on demand, interferes with production at manufacturers, and causes misunderstandings, which could magnify the bullwhip effect.
(Zhou and Benton, 2007)	to investigate the integration of information sharing and supply chain practice in supply chain management.	Manufacturing firms	North America	Empirical, mail survey Sample size: 125 Response rate: 18%	Supply chain level		Both effective information sharing and supply chain practice are critical in achieving good supply chain performance.
(Li and Lin, 2006)	to examine the impact of environmental uncertainty, intra-organizational facilitators, and inter-	Furniture, Fixtures, Rubber, Plastics, Fabricated Metal, Industrial,	USA	Empirical – Field survey Sample size: 196 Response rate: 6.3%	Supply chain level	Regression Structural equation modeling	Information sharing and information quality are influenced positively by trust in supply chain partners

Study	Focus	Type of industry	Geographic area	Methodology			Findings
				Type of study	Level of analysis	Type of analysis	
	organizational relationships on information sharing and information quality in supply chain management.	Commercial Machinery, Electronic, Electric Equipment, and Transportation Equipment					and shared vision between supply chain partners, but negatively by supplier uncertainty.
(Bagchi et al., 2005)	to identify the underlying factors of supply chain integration in European firms with particular emphasis on the role of information sharing and inter-organizational collaboration.	Food and kindred products, Paper and allied products manufacturing, Chemicals, Rubber, miscellaneous plastics, Fabricated metal, Industrial and commercial machinery, Electronic and other electrical equipment, Transportation equipment manufacturing, Measuring, analyzing, and controlling instruments	Denmark, Finland, Norway, Sweden, Austria, Germany, Netherlands, and the UK	Empirical, mail survey Sample size: 149 Response rate: 5.7%	Supply chain level	Correlation and multiple regression analyses	Comprehensive supply chain integration is more a rhetoric than reality in most European firms. However, the study found a clear indication of the value placed by the respondents on integration with key suppliers and customers for performance enhancement. In addition, the study finds that most companies are quite cautious when it comes to sharing sensitive data.
(White et al., 2005)	to explore how a number of emergent information systems offer the possibility of both deep integration and increased flexibility.	IT and business software industry	UK, USA Interviews	Exploratory study. Single case study at IBM	Service provider level	Thematic analysis Literature review	The study identifies a set of themes that can frame future studies.
(Fiala,	This study is devoted to	Generic	Generic	Conceptual	Supply chain	Simulation	Supply chain partnership

Study	Focus	Type of industry	Geographic area	Methodology			Findings
				Type of study	Level of analysis	Type of analysis	
2005)	modeling of supply chain dynamics.				level	approach by STELLA software is an appropriate tool for prediction of real supply chain situation	leads to increased information flows, reduced uncertainty, and a more profitable supply chain. The ultimate customer will receive a higher quality, cost-effective product in a shorter time.
(Huang et al., 2003)	to review research on the impacts of sharing production information on the supply chain dynamics to understand the needs to unravel such impacts on the supply chain design and management.	Generic	Generic	Literature review of 100 publications	Generic	Content analysis	A few usable guidelines have been established for the supply chain planners and designers regarding the fundamental questions of what information should be shared, and what activities should be integrated into the supply chain.
(Thonemann, 2002)	to analyze how sharing advance demand information (ADI) can improve supply chain performance, considering aggregated and detailed ADI.	Generic	Generic	Conceptual study	Supply chain level	Mathematical model solving and approximation	All members of a supply chain benefit from sharing ADI. The manufacturer benefits from reduced cost and the customers from lower prices or higher service levels. Sharing ADI also has a drawback as it introduces variation in the base-stock levels and increases the variability of the production quantities.

In addition, not all supply chain members have the same access to information on final demand as other members do. For instance, car manufacturers have much more access to information on the final demand volumes (e.g., for a particular car model) than first-tier suppliers do. Hence, sharing information on final demand becomes highly important to not only reduce the bullwhip effect but also make the demand visible for suppliers and helping them improve their responsiveness to demand fluctuations. In this regard, Chopra and Sodhi (2004, p. 56) emphasize that increasing the visibility of demand information across the supply chain helps companies reduce the repercussions of the bullwhip effect. Continuous replenishment programs (CRPs), CPFR, and other supply chain initiatives also can minimize the bullwhip effect (Chopra and Sodhi, 2004).

It is important to remember that these studies did not investigate the questions—which types of information are most important than others? Who needs these particular types of information more than others? Why and how are these particular types of information affecting the performance? Is it the financial or operational performance? Is it the performance of the manufacturer, retailer, first-tier supplier, second-tier supplier, etc.? Datta and Christopher (2011) propose several combinations of information sharing and coordination mechanisms for reducing the uncertainty in supply chains. However, their study is limited to the MTS supply chain of a single case study of paper tissue manufacturing.

2.7.4 Benefits of Sharing Demand Forecasts and Inventory Data

In their study, Lotfi et al. (2013) have summarized some benefits of information sharing with supply chain members. They mentioned 14 benefits that supply chain member firms could benefit from. Despite its importance, their study brings few queries regarding the generalizability of such benefits. For instance, their review did not specify whether or not these benefits are valid for all types of information or all supply chain members. For instance, they claim that information sharing has a benefit of “significant reduction or complete elimination of bullwhip effect” which is number (4) in their study. However, is this valid for all types of information? In fact, some types of information, if being shared, will not improve the bullwhip effect, such as sharing

design changes of a product. Besides, the improved bullwhip effect will be much more beneficial to upstream supply chain members (i.e., suppliers) than for downstream ones (manufacturers or retailers). Therefore, we adopt the benefits given in Table (1) in their study in a more usable way wherein we removed few benefits and added few more depending on the type of information and applicability to the supply chain member. Hence, the benefits presented in Tables (2.6) and (2.7) are adapted to two types of information sharing (demand forecasts and inventory data) under the assumption that information sharing happens in one dyad direction, from OEM to first-tier suppliers.

Table 2.6: Benefits of sharing demand forecasts (adapted from Lotfi et al., 2013)

No.	Benefits of sharing demand forecasts	Impact horizon	Impact applies to	
			First-tier supplier	OEM
1	Inventory reduction and efficient inventory management	Short-term	x	
2	Significant reduction or complete elimination of bullwhip effect		x	
3	Improved resource utilization		x	
4	Increased productivity, organizational efficiency, and improved services		x	
5	Early problem detection		x	x
6	Quick response		x	x
7	Reduced cycle time from order to delivery			x
8	Better tracing and tracking	Long-term		x
9	Earlier time to market			x
10	Expanded network optimized			x
11	Optimized capacity utilization		x	
12	Cost reduction		x	x
13	Building and strengthening trust		x	x
14	Increasing demand visibility		x	

Table 2.7: Benefits of sharing inventory data (adapted from Lotfi et al., 2013)

No.	Benefits of sharing inventory data	Impact horizon	Impact applies to	
			First-tier supplier	OEM
1	Improved inventory management and stock levels	Short-term	x	x
2	Improved material planning and replenishment system		x	
3	Increased accuracy of production scheduling		x	
4	Early problem detection		x	
5	Enhanced delivery accuracy		x	x
6	Better tracing and tracking		x	x
7	Reduced cycle time from order to delivery			x
8	Enhanced JIT implementation	Long-term		x
9	Increasing visibility significance (or significant reduction of uncertainties)			x
10	Optimized capacity utilization			x
11	Building and strengthening social bonds and trust		x	
12	Cost reduction		x	x

2.7.5 Detriments of Sharing Demand Forecasts and Inventory Data

Despite the benefits of information sharing, there are few drawbacks (or “risks”) associated with sharing demand forecasts and inventory information between OEMs and their first-tier suppliers. Manatsa and McLaren (2008, p. 18) claim that “many firms are reluctant to share information with their supply chain partners due to an unequal distribution of risks, costs, and benefits among the partners.”

These risks are usually associated with an opportunistic behavior that might emerge. For the OEM, several risks might occur, for instance:

- Suppliers may mistreat the demand information in order to prolong the payments due date.
- Suppliers may disclose information to other customers (client’s competitors).

- They may misuse the information to negotiate and reduce prices.
- They may make significant delays for selling more quantities.
- Suppliers may put the OEM in a bottleneck situation if the former knows the latter's stock levels of input materials.

However, there are risks for the supplier as well, for instance:

- The OEM may overestimate the actual demand volumes in order to urge the suppliers to build up extra capacity.
- They may underestimate the actual demand volumes in order to negotiate the price.
- The OEM may push the supplier to produce more components than needed to drive the market prices down.

These risks are most likely when the suppliers or OEMs are interested in asset specificity.

2.7.6 Theoretical Perspectives on Information Sharing

Various theoretical stances have been used to analyze and understand the concept of information sharing in supply chains. In their recently published study, Kembro et al. (2014) have conducted a systematic literature review of published research in 10 peer-reviewed international journals on predominant theories and approaches that can be applied to analyze different aspects of information sharing. The authors find that transaction cost economics, contingency theory, RBV, resource dependency theory, and relational governance theories such as the relational view and social exchange theory are the most used theories. Table (2.8), which is adapted from the study of Kembro et al. (2014, p. 615), presents a comprehensive review of those theories in which the authors connect them with various aspects of information sharing in supply chains, such as why share, why not, what to share with whom, how to share, pre-requisites, barriers, drivers, and governance mechanisms. On analyzing different theoretical perspectives on information sharing offered in Table (2.8), no dominant or unifying theory on information sharing emerges.

Given that the main purpose of this research is investigating the role of information sharing in improving suppliers' flexibility under demand uncertainty, transaction cost economics (TCE), contingency theory, and RBV provide valid theoretical perspectives to address the research problem of this thesis in different ways.

First, TCE and contingency theory address the issue of why information is shared between firms. From the TCE perspective, information sharing with partners (such as suppliers) may reduce demand uncertainty and transaction costs (Tan et al., 2010). From the contingency theory perspective, information sharing improves operational performance (Wong et al., 2012).

Second, TCE and RBV address the issue of how information is shared. TCE argues that information sharing and processing technologies such as EDI can reduce uncertainty and transaction costs while RBV argues that such technologies positively affect firm performance (Tan et al., 2010).

Third, TCE addresses the issue of what and with whom to share. For instance, TCE argues that the degree of demand uncertainty affects the required level of information sharing (Yigitbasioglu, 2010).

Table 2.8: Theoretical perspectives on aspects of information sharing in supply chains (Sources: Adapted from (Kembro et al., 2014, p. 615)).

Theories vs. aspects	Why share	Why not	What to share with whom	How to share	Pre-requisites, barriers, and drivers	Governance mechanisms
Transaction cost theory (TCE)	Information sharing with partners can reduce uncertainty and transaction costs. (Tan et al., 2010)	Maintain information asymmetry to prevent partners from acting opportunistically. (Klein et al., 2007; Yigitbasioglu, 2010)	The characteristics of the transaction (e.g., degree of demand uncertainty) impact the required intensity of information sharing. (Yigitbasioglu, 2010)	Implement new means of sharing information (e.g., EDI) to improve information processing capabilities and thereby reduce uncertainty and transaction costs. (Tan et al., 2010)	Establish formal contracts to compensate partners and prevent opportunistic behavior through incentives and penalties. (Porterfield et al., 2010)	Select governance structure as a strategic response to uncertainty. (Grover and Saeed, 2007)
Relational governance theories	Exchange relationships improve inter-organizational cooperation, which could lead to enhanced operational efficiencies. (Wei et al., 2012)		The relationship context is proposed as the main source of coordination needs. (Grover and Saeed, 2007)		Suggesting norms of reciprocating benefits such that people cooperate under the expectation that they will give and receive from the relationship. (Nyaga et al., 2010)	Select coordination mechanism considering the relationship context as an important dimension of the transaction. (Grover and Saeed, 2007)
Contingency theory	Information sharing improves an organization's ability to perform when they operate under favorable environmental conditions. (Wong et al., 2012)	Partners may suffer from excessive information sharing ("information overload"), which could cause delayed or inappropriate decisions. (Kim et al., 2006)	Avoid "one-size-fits-all"; rather adapt level and scope of information sharing to internal and external environment. (Stock et al., 2000; Grover and Saeed,	Adapt information processing capabilities to the supply chain context. (Kim et al., 2006; Grover and Saeed, 2007)		

Theories vs. aspects	Why share	Why not	What to share with whom	How to share	Pre-requisites, barriers, and drivers	Governance mechanisms
Resource based view (RBV)	Engage in collaborative relationships to secure critical resources that extend beyond the firm boundaries. (Patnayakuni et al., 2006; Hernández-Espallardo et al., 2010)	Increase competitive advantage by protecting firm-specific resources and capabilities. (Holweg and Pil, 2008; Paulraj et al., 2008)	2007; Caridi et al., 2010)	New technologies such as EDI can represent an inimitable resource that may positively affect firm performance. (Tan et al., 2010)	Firms lacking certain competitive capabilities will promote collaborative relationships. (Tan et al., 2010)	
Resource dependency theory		Investing in inter-organizational information systems could increase dependency. (Patnayakuni et al., 2006)	Adapt level of information sharing with supply chain partners based on degree of dependency. (Yigitbasioglu, 2010)	Consider information sharing capability of partners when leveraging relationships (in order to reduce uncertainty and dependency related to scarce and valued resources). (Tan et al., 2010)	Mutual dependence can have a positive influence on integration and commitment; asymmetrical dependence can be expected to be detrimental to inter-organizational relationships. (Vijayasarathy, 2010)	Select governance structure as a strategic response to dependency. (Grover and Saeed, 2007)

2.8 Summary of the Chapter

While Section (2.1) offers an introduction to Chapter 2 (Literature Review). This section presents a brief summary of this chapter. The literature review is focused on contribution of two main areas: “flexibility in supply chains,” and “information sharing in supply chains.” Thus, the structure of this chapter is organized as follows.

Section (2.2) focuses on the underlying concepts and terminologies such as agility, responsiveness, and flexibility. The main conclusion that can be drawn from this section is the fact that agility, responsiveness, and flexibility have been interchangeably used in the supply chain context. This remark indicates that there might be no consensus among researchers on what each term really means. Alternatively, it may indicate that literature is lacking empirical studies that show the differences between their meanings.

Section (2.3) reviews the main contributions on the flexibility of manufacturing firms. The review includes the various types of manufacturing flexibility (e.g., product, product mix, volume, delivery, and other types of manufacturing flexibility), dimensions and levels of flexibility, timeframe, implementation, and uses. This section also addresses the difference between manufacturing flexibility of a firm and supply chain flexibility.

Section (2.4) highlights the main theoretical perspectives that have been utilized to view the concept of manufacturing flexibility. Two main theories have been focused on: Economic and Resource-Based perspectives.

Section (2.5) reviews the importance of manufacturing flexibility as a competitive tool at the strategic level. The section provides a short discussion on flexibility as part of a firm’s operations strategy.

Section 2.6 covers a short review on information sharing, as a form of collaboration in supply chains. The section focuses on information sharing as an enabler of flexibility.

Section (2.7) is devoted to review various aspects of information sharing in supply chains. This includes reviewing different types of information being shared, level of information sharing, direction of information flow, benefits and drawbacks of information sharing in supply chains, and mechanism of sharing information between supply chain partners. The section also reviews the most common theories and perspectives that have been used to view information sharing in supply chains including TCE, RBV, and other theories. The chapter ends with a short summary (section 2.8).

The empiric in this thesis is divided into three studies as will be presented in Chapter 4. For clarification, a brief and concise literature review at the beginning of each study will be presented due to the fact that each study is dealing with a specific research question.

3. CHAPTER III: METHODOLOGY

3.1 Introduction

Researchers generally differ in the ways of undertaking their scientific research depending on the discipline, research questions, research objectives, context, and other factors. This heterogeneity results in different methods and approaches in which scientific research and studies are conducted. Consequently, the epistemological concepts such as research paradigm and research philosophy should be explicitly defined and considered when conducting scientific research (Darlaston-Jones, 2007). These concepts describe the underlying beliefs, perceptions, and assumptions toward a specific phenomenon. Since these concepts can influence the research approach from design to conclusion (Flowers, 2006), to avoid researcher biases, it is important to identify such underlying assumptions and paradigms in this research by using appropriate research methods for collecting and analyzing empirical data. Thus, the aim of this chapter is to provide a rational understanding of the following questions: How was this research designed and conducted? What are the methods that have been used to collect and analyze empirical data, and Why?

Research is traditionally classified into three main types: 1) Exploratory, 2) Explanatory, and 3) Descriptive. Exploratory research is a common research used when there is a lack of theoretical support to the research problem (Sullivan, 2001). According to Phillips and Pugh (2010, p. 51), exploratory research “is involved in tackling a new problem/issue/topic about which little is known, so the research idea cannot at the beginning be formulated very well.” Based on this logic, Study No. 1 can be considered exploratory type research for the following reasons: 1) Its aim was to explore how information sharing between OEMs and first-tier suppliers may affect suppliers’ ability to respond to demand fluctuations, and 2) Lack of adequate theoretical support and literature on RQ1.

Explanatory research usually concerns testing hypotheses or validating or rejecting existing theories. This research type usually involves investigating the causal relationships between

different variables based on both theoretical and empirical evidences. It is a common research type when there is plenty of theoretical support to the research problem or when there is a mature debate in the literature (Sullivan, 2001). Based on this rationale, Study No. 2 can be considered an explanatory study because it involved testing hypotheses and relationships between the proposed variables. However, it can also be classified as an exploratory study because its purpose was to explore the relationships between the variables: volume flexibility, delivery flexibility, sharing demand forecast, and sharing inventory data. Therefore, Study No. 2 represented both explanatory and exploratory research types.

Descriptive research is defined as “Research that attempts to describe existing conditions without analyzing relationships among variables” (Norman and Fraenkel, 2001, p. 517). Based on this characterization, Study No. 3 is classified as a descriptive study as it attempts to explain the results and provides additional information on collaboration practices between first-tier suppliers and OEMs.

This chapter is organized as follows. The chapter begins with a brief presentation of the main types of scientific research, philosophical stance, methodological aspects, and research design of this thesis. The discussion reflects on how the research paradigm, philosophy, and strategy are applied to this particular research problem. Next, the discussion progresses to demonstrate various methods of data collection, which include case studies, interview-based, and survey-based research methods. The discussion also considers some important design aspects, which include the case study design, case companies’ selection, and case sampling, and provides justifications of the methods used. The discussion is extended to describe the methods used for data collection and data analysis in each of the three empirical studies that have been conducted, followed by a detailed explanation of the reliability and validity aspects.

At the aggregate level, this chapter presents and discusses the general methodological framework that has been used to deal with research questions posed in this research.

Therefore, this chapter provides a general presentation of data collection and analysis while the detailed discussion of the methodology for each study is presented in Chapter 4.

3.2 Research Paradigm, Philosophy, and Strategy

The aim of this section is to discuss and present the philosophical standpoint of this research, which is a fundamental aspect because it is associated with the methodological aspects of conducting research. Hence, prior to discussing the research methods, the following subsections introduce the philosophical foundations for this thesis, which are: research paradigm, research philosophy, and research strategy.

3.2.1 Research Paradigm

Paradigm is defined as a set of basic beliefs about the ultimate or first principles (Guba and Lincoln, 1994). According to Guba and Lincoln (1994, p. 107),

It represents a worldview that defines, for its holder, the nature of the “world,” the individual’s place in it, and the range of possible relationships to that world and its parts, as, for example, cosmologies and theologies do. The beliefs are basic in the sense that they must be accepted simply on faith (however well argued); there is no way to establish their ultimate truthfulness.

In this regard, “Positivism” and “Interpretive” might be the most traditional research paradigms in social sciences. Positivism (sometimes referred to as scientific) is originally rooted in empiricism, which is based on the assumption that the knowledge of the world must be derived from facts of experience (Willig, 2001). The positivism philosophy views reality as universal, objective, and quantifiable (Darlaston-Jones, 2007). Additionally, Kirk and Miller (1986, p. 14) regard positivism as “the external world itself determines absolutely the one and only correct view that can be taken of it, independent of the process or circumstances of viewing.” Furthermore, Willig (2001) asserts that the goal of research, according to positivism, is to generate objective knowledge. Therefore, objectivity is based

on a complete detachment for the analysis of the phenomenon observed (Collis and Hussey, 2009).

In contrast to positivism, according to Flowers (2006), Hatch and Cunliffe (2006), and Blaikie (2007), the interpretive paradigm—also known as anti-positivism or post-positivist—considers that individuals and groups decode situations based on their individual experiences, memories, and expectations, resulting in many differing interpretations. Consequently, a researcher with an interpretive perspective considers that interpretations create the social reality. Thus, it is important for the research to discover and understand these meanings and the contextual factors that influence, determine, and affect the interpretations arrived at (Flowers, 2006).

According to the previous discussion on research paradigms, this thesis follows both “Positivism” and “Interpretive” views. For instance, Study No. 1 and Study No. 3 followed the interpretive view, while Study No. 2 followed the positivism view. This was due to the nature of the research problem. As shown in Chapter 1, the research problem was divided into three different research questions where each question was handled in a separate empirical study, each with its own research objective and paradigm.

3.2.2 Research Philosophy

As discussed in the previous sections, it is essential for scientific research to have an epistemological stance. According to De Vaus (2001), an epistemological stance provides a link between knowledge and methods. In this regard, Gray (2014) highlights that scholars have different views and beliefs regarding the philosophy of research and how different research problems should be viewed and tackled. Based on this fact, the relationship between theory generation and empirical evidence is generally classified into three philosophical approaches: inductive, deductive, or abductive.

According to De Vaus (2001), the inductive approach concerns theory building in which a researcher starts by observing a phenomenon and then he or she generates theory or

knowledge from the observation made. The deductive approach concerns theory testing in which a researcher starts by studying the phenomenon from a theoretical perspective and then makes observations in order to test the theory. The difference between the two philosophies is illustrated in Figure (3.1); for instance, observations are used to generate theories in the inductive approach and to test theories in the deductive approach (De Vaus, 2001).

The abductive approach is, however, a mixture of both inductive and deductive views. Therefore, it is important for a research to have a philosophical stance in order to position it within the existing knowledge.

Given the explorative nature of our research problem and questions, and lack of related prior studies, this research aimed at theory building rather than theory testing. This research proposes a conceptual framework to understand the impact of information sharing on suppliers' flexibility. Then, the research progresses to analyze the relationship between various variables and test a set of proposed hypotheses. Hence, the research philosophy of this thesis was grounded on an abductive stance.

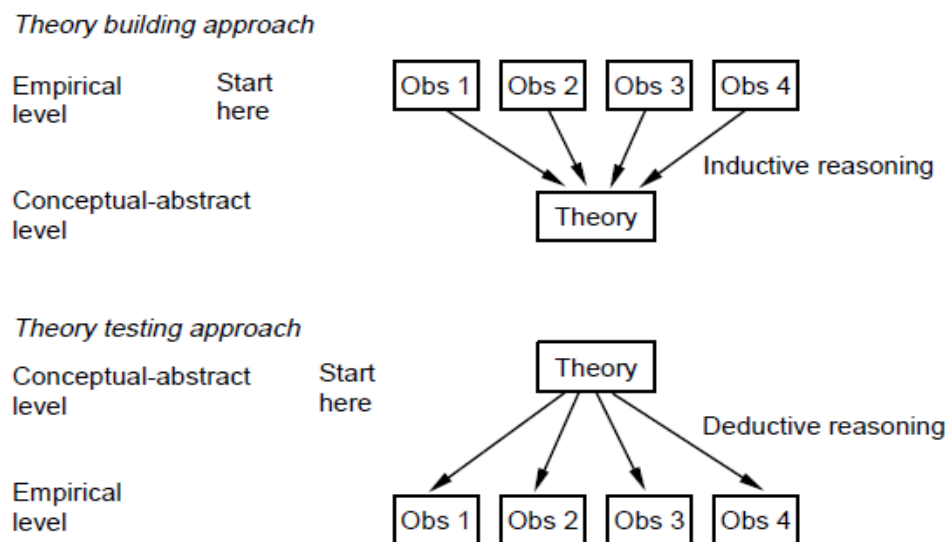


Figure 3.1: Inductive versus deductive research approach (Source: De Vaus 2001, p. 6)

In this regard, empirical studies No. 1 and No. 3 followed inductive interpretations (i.e., based on qualitative data analysis) while study No. 2 followed deductive interpretation (i.e., based on quantitative data analysis). In the abductive research philosophy, various data collection methods can be adopted, which can be considered an advantage.

Having established the research philosophy; the next section discusses the research approach in order to decide on the type of data that is required to answer each research question.

3.2.3 Research Approach

Research is typically categorized into two approaches: quantitative and qualitative (Guba and Lincoln, 1994). Sullivan (2001) suggests that the difference between the two approaches depends mainly on two factors: 1) Extent of our knowledge on a particular topic, and 2) The researcher's assessment regarding the nature of the phenomenon being studied. According to Sullivan (2001), the qualitative approach is usually appropriate for situations where little theoretical support for a phenomenon is available, and thus it is impossible to develop a precise hypothesis. Conversely, the quantitative approach is appropriate for situations where sufficient theoretical support is available for a phenomenon.

The quantitative research approach usually follows the positivism paradigm as it concerns objectivity and casualty (i.e., deductive approach). This is because quantitative research involves collecting quantifiable data and analyses of empirical data (Bryman and Bell, 2011). Besides, quantitative research has the capability to measure and analyze the causal relationships between variables, testing theories and hypotheses, or developing and validating models (Guba and Lincoln, 1994). However, qualitative research generally follows the interpretive paradigm as it has a non-objective perspective or inductive view (Bryman and Bell, 2011). Qualitative research focuses on the observation of human interactions and analyzing the situation or the phenomenon, and provides a deep understanding of the situation or phenomenon (Guba and Lincoln, 1994).

Based on the above discussion, and since this research is based on positivism and interpretive views, this thesis follows a combined strategy of both quantitative and qualitative approaches. In this regard, studies No. 1 and No. 3 followed the qualitative research strategy, which allowed for using various qualitative research methods to collect descriptive, explanatory, or contextual data, which can be appropriate for such empirical studies. However, Study No. 2 followed the quantitative research strategy, which allowed for using quantitative research methods to collect statistical /measurable data, which can be appropriate for this type of empirical study.

3.3 Research Strategy and Design

The research strategy represents a road map or overall plan to systematically explore the phenomenon of interest (Marshall and Rossman, 2016). Based on the type of research question, the extent of control over actual behavioral events, and degree of focus on contemporary events, Yin (1994) suggests five research strategies: experiments, surveys, archival analysis, history, and case study. These research strategies are shown in Table (3.1) below.

Table 3.1: Five research strategies (Source: Yin, 1994)

Strategy	Form of research questions	Require control of behavioral events	Focus On contemporary events
Experiments	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival Analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case Study	How, Why	No	Yes

In addition to Yin's research strategies and their relevant situations, there are other various research strategies that are implemented in several management research disciplines. For instance, conceptualization, orthography, content analysis, simulation, or modeling are

common examples of research strategies in operations research and operations management research.

Based on the previous discussion, it is essential to select appropriate research methods considering the research questions and the nature of the research problem. Figure (3.2) depicts a flow diagram used to guide the research design of this thesis.

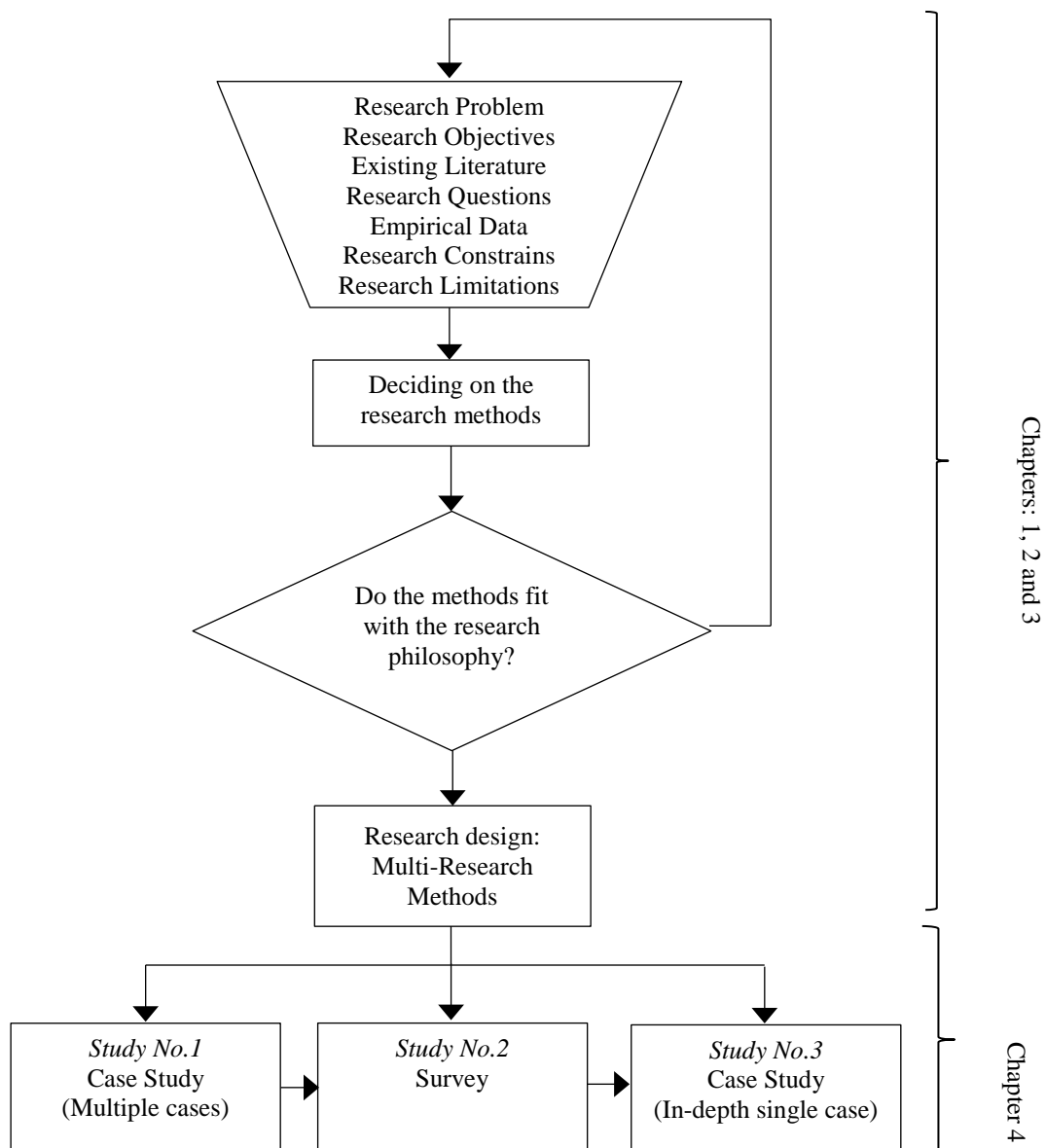


Figure 3.2: Research design for this thesis

This thesis employs two main research methods to collect empirical data: case study-based and survey search methods. The rationality for selecting the multi-methods is fundamentally based on the best fit among the research philosophy, research problem, research objectives, existing literature, research questions, type and availability of empirical data, and research constraints and limitations.

Based on the discussion presented above, it is deemed that the case study method is appropriate for RQ1 and RQ3, while the survey method is suitable for RQ2. The case study and survey methods are discussed in the following subsections.

3.3.1 Case Study Research Method

The adoption of the case study as a research method in recent years has increased within the field of operations management research (Spring and Bonomi, 2015; Ketokivi and Choi, 2014; Voss et al., 2002). According to Rowley (2002, p. 16), case studies “are widely used because they may offer insights that might not be achieved with other approaches. Case studies have often been viewed as a useful tool for the preliminary, exploratory stage of a research project, as a basis for the development of the ‘more structured’ tools that are necessary in surveys and experiments.”

Despite the criticism of lacking objectivity and rigor using the case study method, focusing on design and implementation issues can overcome any shortcomings in objectivity or rigor (Rowley, 2002). In this respect, reliability and validity issues are important when developing a case study.

As mentioned before, the case study method was used for studies No. 1 and No. 3. There are three reasons for this adoption: 1) Explorative nature of the research problem, 2) Type of research questions that are designed in these two studies, and 3) Type of empirical data required to search for evidences. These motives are explained as follows:

1. The main objective of this thesis is to explore how information sharing between the first-tier suppliers and OEMs affect suppliers' flexibility. This kind of research goal has an exploratory nature because it allows for in-depth understanding of the phenomenon (Stake, 1995). In this regard, "the case study is a research strategy, which focuses on understanding the dynamics present within single settings" (Eisenhardt, 1989, p. 534). Thus, the case study is the most appropriate method for this type of research.
2. Research questions such as "Why" and "How" are typically investigated by adopting the case study method whereas questions such as "Who, What, and Where" are usually investigated by using other research techniques (Yin, 1989). In that sense, Yin (1989) suggests that a case study has three characteristics based on which researchers can choose the case study approach amongst other empirical methods. These characteristics are: 1) Type of research question to be answered; 2) Extent of control a researcher has over actual behavioral events; and 3) Degree of focus on contemporary events as opposed to historical ones. Considering these characteristics, and given that studies No. 1 and No. 3 are concerned with RQ1 and RQ3, respectively, which both deal with "how," the case study method is appropriate to investigate these questions.
3. The case study research approach provides multiple data collection methods (Eisenhardt, 1989, p. 534). Patton (1990) emphasizes that the use of multiple data collection methods enhances data credibility. Furthermore, this approach provides an opportunity to use triangulation of combined data collection methods (Yin, 2003). This triangulation from different sources increases construct validity of the research methodology. Therefore, studies No. 1 and No. 3 consider collecting qualitative data from multiple sources, which include interviews, observations, and documentary evidences. A more thorough discussion for each data collection method is introduced in Chapter 4, "Empirics."

Therefore, the case study research approach is appropriate for addressing both RQ1 (covered in Study No. 1) and RQ3 (covered in Study No. 3).

Schell (1992) defines four basic types of case studies on two design parameters: number of case studies, and number of data sources. As shown in Figure (3.3), Type 1 concerns the situations where there is a single case study and a single unit of analysis. Type 2 concerns the situations where there is a single case study and multiple units of analysis, which are embedded in that single case. Type 3 is concerned with the situations where there are multiple cases but only a single unit of analysis. Type 4 is concerned with the situation where there are multiple cases and multiple units of analysis.

	Single case designs	Multiple case designs
Holistic (Single unit of analysis)	<i>Type 1</i>	<i>Type 3</i>
Embedded (Multiple units of analysis)	<i>Type 2</i>	<i>Type 4</i>

Figure 3.3: Basic types of design for case studies (Source: Schell, 1992, p. 7)

It is important to consider the proper application of each type. Type 3 is used in Study No. 1 because it is appropriate for a holistic cross-comparison between the case companies (i.e., there are eight companies in Study No. 1). However, Type 2 is used in Study No. 3 because it provides in-depth investigation of the multiple units of analysis (i.e., first-tier suppliers) that are impeded in a single case study (i.e., the OEM case company). The detailed design aspects are explained in Chapter 4 under the methodology section of each empirical study.

3.3.2 Survey-Based Research Method

The survey-based research approach is used in Study No. 2 due to the quantitative nature of RQ2. This research is a commonly used method in quantitative research. It allows the researcher to collect empirical data on the phenomenon under investigation. The survey-based method has several advantages and is considered a powerful technique as it allows for using various data analysis techniques such as descriptive statistical analysis, inferential statistical analysis, and hypothesis testing. It is also of high objectivity and allows for measuring the reliability and validity, and hence improves the generalizability of the results (Forza, 2002).

The survey-based method includes systematic phases that must be followed. These phases include designing and distributing the questionnaires, collecting the responses, preparing datasets, analyzing data, and reporting the results. In each step, consistent analysis and replicable results must be ensured to consider the validity and reliability issues.

During the design phase, for instance, the researcher must decide about the number of questions to be included, type of questions, types of answers, scale items, respondents, number of variables, number of constructs, type of constructs, relationships between variables, length of the questionnaire, sample size, population, response rate, and many other design aspects (Pallant, 2011). Therefore, during the design phase, it is important to consult the theory, revise the argument or hypothesis if necessary, change the scale items, or revise the type and wording of questions accordingly (Hair et al., 2011). This procedure is usually done by a pilot study (Forza, 2002).

During the questionnaire distribution, it is important to decide the collection method of responses, whether by regular mail, phone, or web-based survey. Each method has its own advantage. For example, web-based surveys are a fast and easy way to distribute questionnaires and collect responses from participants. However, their response rate might be lower than that of regular mail. It is also important to direct the survey to the right

participants by referring the survey to the correct e-mail or postal address of the person, organization, or company.

When collecting responses, it is important to remind and urge the participants who have not responded to answer and return their responses. This reminder is usually done after two to three weeks by telephonic communication or writing a reminder letter. The aim of this procedure is to maximize the response rate by increasing the number of responses.

Before starting to prepare the dataset, it is important to use a proper version of the software package for data analysis, define any missing cases or responses, eliminate any sources of errors or ambiguity, define the variables, and assign appropriate scale items. When analyzing data, it is a common practice to conduct preliminary descriptive statistical analysis before analyzing the data. The aim of this step is to check the normality of data, frequencies, means, and outliers. Choosing the proper analysis technique depends on the research question and the statistical power of the sample, which is determined by the sample size and several other factors.

All the aforementioned criteria were considered carefully while developing the survey questionnaire for Study No. 2, considering most suggestions recommended by Forza (2002), Saunders et al. (2009), Hair et al. (2011), and Pallant (2011). However, given the time constraint, it was not possible to conduct a pilot study prior to the survey. This was countered by significantly focusing on the survey design aspects and revision by experts in the field. In addition, the common method bias was checked for to ensure a rigorous design of the survey.

The following discussion explains the methods used for collecting the empirical data required for each study.

3.4 Data Collection and Analysis

As mentioned in Chapter 1, the main research problem is divided into three research questions. Each research question is addressed by its own research methods as shown in

Table (3.2). Therefore, this thesis employs a multiple-method research approach to answer these emerging research questions. This combination of different research methods stems from the nature of each respective research question.

Table 3.2: Overview of the research methods employed in this doctoral thesis

Research characteristic	Study covered			
	Literature review	Empirical Study 1	Empirical Study 2	Empirical Study 3
Research questions covered	Development of RQ1, RQ2, and RQ3	RQ1. How does information sharing between OEMs and first-tier suppliers affect the latter's responsiveness to fluctuating demand?	RQ2. What is the relationship between information sharing of OEMs' demand forecasts & inventory data, and suppliers' volume & delivery flexibility?	RQ3. What factors should OEMs consider to improve the sharing of demand forecasts with suppliers?
Type of research		Explorative	Explorative Explanatory	Descriptive
Research approach		Qualitative	Quantitative	Qualitative Quantitative
Research method and approach	Conceptual/theoretical approach	Multiple case study	Survey questionnaire	In-depth single case study
Method of data collection and source of data	Semi-structured literature review Peer-reviewed journal articles, books, book chapters, conference proceedings	<ul style="list-style-type: none"> • Focused literature review • Semi-structured interviews • Documentary analysis/ Archival records 	<ul style="list-style-type: none"> • Focused literature review • Survey questionnaire • Focused literature review 	<ul style="list-style-type: none"> • Semi-structured interviews • Documentary analysis/ Archival records • Field visits/ Direct observation
Method of data analysis	Synthesis and argument development	Thematic analysis through cross-case comparison	PLS-SEM	Comparative analysis
Unit of analysis	--	First-tier suppliers main business unit	First-tier suppliers main business unit	First-tier suppliers main business unit
Level of analysis	--	Operational plant level of the main business unit	Operational plant level of the main business unit	Operational plant level of the main business unit
Participants	--	16 managers of supplier firms in Sweden	52 supplier firms in Sweden, response rate 26.5%	10 managers from OEMs based in Sweden

The following sections present the general descriptions of the methods, which were used to collect and analyze the data in each empirical study. However, the detailed discussions are presented in Chapter 4.

3.5 Data Collection and Analysis for Study No. 1

For Study No. 1, a multi-case study approach was used to address the research problem due to the explorative nature of the research question (RQ1). Multiple sources of data were utilized to search for chains of evidences among the interviews and documentary evidence. The aim of adopting multiple sources of data was to allow searching for consistent patterns of evidence across the company cases. The following data collection methods were used in Study No. 1.

3.5.1 Interviews

Data were collected through semi-structured interviews with eight automotive supplier firms located in Sweden. The selection criteria are discussed in Chapter 4. Each interview lasted between 60 to 90 minutes. The interview questions were developed based on a logical reasoning of the underlying concepts of the research question as well as insights from literature. During the interviews, participants were asked to answer open-end questions to reflect on their experience and views regarding a set of questions. The main aim of an interview is to understand the meaning of interviewees' statements/answers (Kvale, 1996).

The interview questions were designed to be rational and systematic in order to increase the reliability of the interview method. The questions were derived from a proposed framework given in Study No. 1, and guided by the main research question. They were then revised based on the literature. Attention was taken to revise the questions in order to check and eliminate any ambiguity or misinterpretation. Then, the questions were finalized and the interview guide was created. The final version of the interview manual is shown in Appendix (A).

A total of 12 companies were contacted (the rationale for selecting this number is discussed in Study No. 1 in Chapter 4). From these, eight companies agreed to be interviewed. For the purpose of validity and reliability, two persons in each company were selected and interviewed. Thus, in total, we had 16 participants including two managers from each supplier firm. The case companies were selected based on different characteristics such as the size of the firm (small-medium-large companies based on the number of employees), which reflects the production capacity, and degree of complexity of the main product(s). These participants were general managers and other managers directly involved in the operations. Interviewing managers in these positions should increase the validity of the data collected by this method. The participants were asked if they could be contacted again for further clarification about their answers and reflections. This approach (i.e., standardized interviews) provides a good way to analyze and compare responses.

The interviews were recorded and then transcribed in order to eliminate any ambiguity or misinterpretation of the answers. Audio recordings can also provide unlimited opportunities to refer to a particular interview, and hence avoid researcher bias and error (Saunders et al., 2009). More detailed information on the case companies, case profile, and interviewees' job role is listed in the methodology section of Study No. 1 in Chapter 4.

3.5.2 Documentary Evidence/Archival Records

Documentary evidence is a research technique that involves analyzing data and information in written documents from the case companies, such as letters, agendas, progress reports, and annual reports. It also includes investigating the archival records such as delivery records, organizational charts, operation strategy, and operational process flow. The aim of using this research technique is to gain an insight into how the collaboration process between the first and second tier suppliers works in reality. For instance, this method allows the researcher to map supply chain activities for each unit (i.e., supplier) as well as the relationships between supply chain members. Thus, this method provides an

opportunity to support the interview analysis. However, it was not possible to obtain such documents due to the company's policy in some case companies.

The data were analyzed using cross-case analysis approach as suggested by (Yin, 1989, p. 56), which is depicted in Figure (3.4). Following the academic norms and scientific ethics, the data were coded and the names of companies were not visible.

The interview scripts were coded and supported by documentary evidence to develop themes and categories using the cross-case analysis approach, where the common unit of analysis is the factory level. Thematic analysis is defined as the process of encoding qualitative information in order to determine patterns and themes that are useful to describe, and organize possible observations or interrupt aspects of a phenomenon (Boyatzis, 1998). Generally, themes can emerge inductively from the raw data or deductively from theory or previous research.

A cross-case analysis between different cases was conducted to improve the external validity of the study as it allows searching for common evidences. This method of cross-case analysis approach is thoroughly discussed in Study No. 1 in Chapter 4.

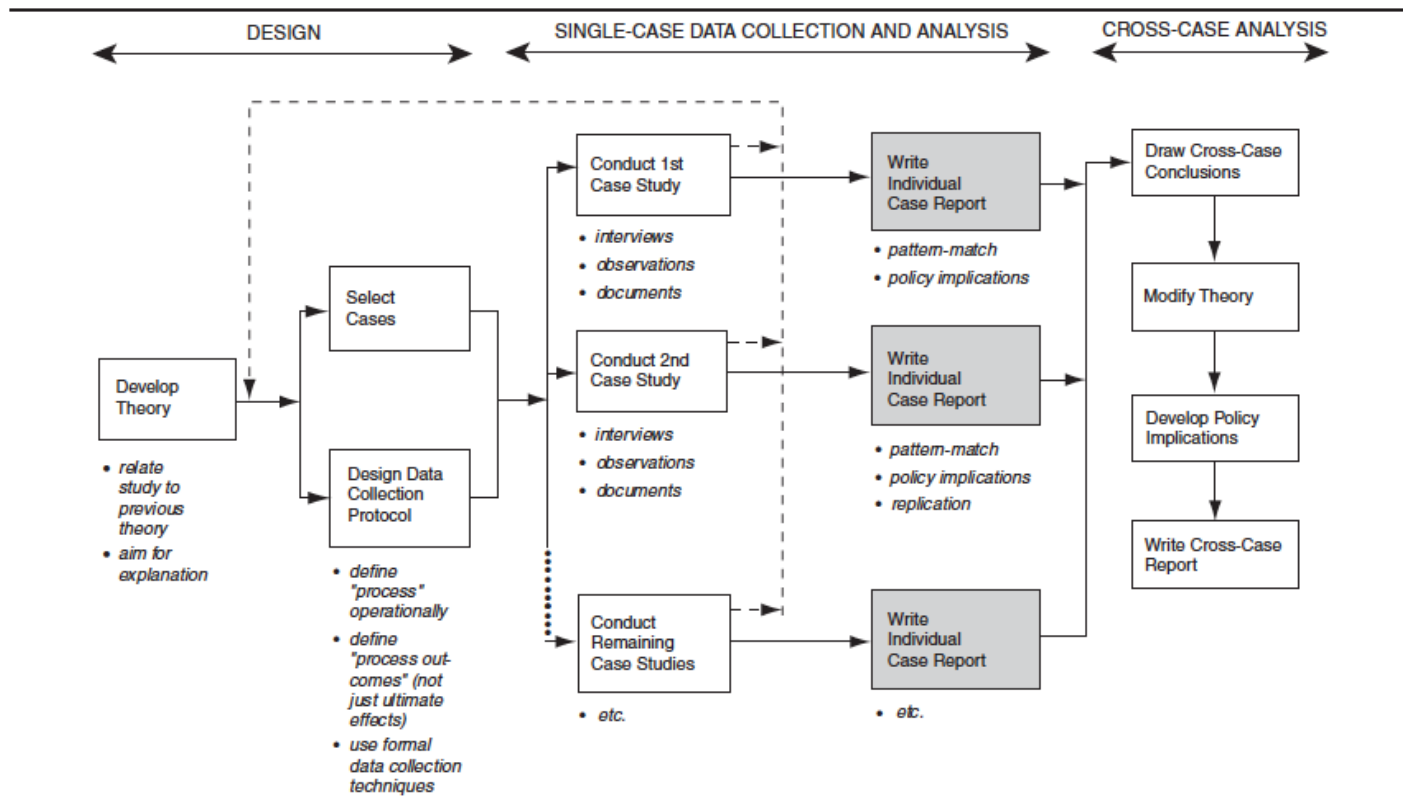


Figure 3.4: Process of conducting a case study research (Source: Yin, 1989, p. 56)

3.6 Data Collection and Analysis for Study No. 2

For Study No. 2, as mentioned earlier, a survey-based questionnaire (shown in Appendix B) was developed and forwarded to 203 automotive suppliers in Sweden. The selection criteria are discussed in detail in Chapter 4. There were 52 responses, making the response rate 26.6%. This response rate can be adequate for an online survey given the fact that such surveys “are much less likely to achieve response rates as high as surveys administered on paper” (Nulty, 2008, p. 302). In this regard, some studies such as Nulty (2008) and Watt et al. (2002) showed that the average response rate for an online survey is 33% while others showed that the average response rate for online surveys is 25% according to a scientific website fluidsurveys.com² (Penwarden, 2014). Consequently, the response rate depends on many factors such as length of the survey, types of questions, timing of the survey, and other factors such as sample size and population.

Since the sample size is relatively low, PLS-SEM can be the appropriate technique to analyze the data. PLS is a variance-based structural equation modeling technique, which is preferred to covariance-based structural equation modeling when the sample size is small (Chin and Newsted, 1999). Although the use of PLS has been criticized, Ringle et al. (2012) highlight that its use has noticeably increased in several management and social research studies in the last 10 years. Dijkstra and Henseler, (2015) and Henseler et al. (2009, 2014) suggested using consistent PLS (abbreviated as PLSc), which is an improved version of the traditional PLS.

Several software packages are available to handle PLS and PLSc analysis; the most common being Smart PLS (Ringle et al., 2015) and ADANCO (Henseler and Dijkstra, 2015). Smart PLS and ADANCO were used to analyze the empirical data in Study No. 2 since they offer unique features such as partial least squares path modeling including reflective and composite measurement models; advanced bootstrapping; and estimation of

² <http://fluidsurveys.com>/ available at: <http://fluidsurveys.com/university/response-rate-statistics-online-surveys-aiming/> (accessed 30 August 2015)

direct, indirect, and total effects. A full description of the PLS-SEM method is presented under the methodology section of study No. 2 in Chapter 4.

3.7 Data Collection and Analysis for Study No. 3

A single in-depth case study was conducted in an OEM truck company in Sweden. This company manufactures buses, trucks, and other types of heavy duty vehicles for the construction industry, civil defense, and fire department. The main unit of analysis is the truck business unit in which multiple units of analysis embedded in the case company were considered. The multiple units here mean different types of first-tier suppliers.

Empirical data on the collaborative forecasting practices between suppliers and the OEM as well as data on suppliers' delivery permanence was collected from the case company. Both qualitative and quantitative data were collected by different means including semi-structured interviews, documentary evidence/archival records, and direct observation.

3.7.1 Semi-structured Interviews

Due to limited number of targeted participants within the case company, 10 semi-structured interviews with functional managers in the case company were conducted. This included several discussion meetings to gather information about collaboration practices with suppliers, regarding supplier delivery performance, material requirement planning, demand forecasting, and purchasing and recording of parts and materials. The participants were encouraged to talk freely and reflect on their experience and views regarding the above mentioned issues. Several open-ended questions emerged during the discussions.

Some interviews were followed up by clarifying questions through either emails or phone calls. Each interview lasted between 50 to 70 minutes depending on the time and availability of the interviewee. The interviews were conducted with participants having adequate knowledge and practical experience in the automotive business. For instance, all participants had at least seven years of practical experience within the area of production

and operations management of automobile parts and components. Therefore, the interviews were conducted with job roles that represented executives from production, material planning, logistics, and management. The answers were noted for further analysis along with other sources of data.

3.7.2 Documentary Evidence/Archival records

Documentary evidence is also an important data gathering approach to analyze data in written documents. The researcher had access to some company documents including EDI messages, meeting minutes, operations procedures, and operations strategy. The list of documents is provided in Study No. 3. In addition, the researcher was given access to some documents concerning order quantities, supplier delivery performance, forecasting schedules, and databases. The purpose of using this method is to look for and establish a chain of evidences that support other sources of data.

3.7.3 Direct Observations and Field Visits

Direct observation is one of the oldest and most common qualitative methods in scientific research (Trochim et al., 2015). The aim of this method is to look for further evidences to support those obtained from the interviews and archival records. According to Trochim (2000), direct observation provides a detached perspective in which a researcher is observing certain situations or people, or process without participating in the context being observed. This method was used when conducting the field study (i.e., case study). Direct observations were utilized to illustrate the work procedure, understand the process, and eventually search for the evidences.

In this regard, several field visits, meetings, and office work observations were employed to understand what and how the collaboration is being implemented at the truck production facility. This included three field visits to the OEM facilities such as production lines and inbound logistics centers. The visits were guided with two people: a materials planner and a production engineer. Each visit was three hours long and included observing the work,

assembly, production, materials handling, and inspection. Observations were noted and inquiries were directed to employees working in different areas.

3.8 Research Quality: Validity and Reliability Measures

Establishing research quality is a fundamental step in the research process. Validity and reliability are the most common aspects of research quality. Validity is commonly known as the extent to which a research or concept or construct measures what it is supposed to measure. Reliability is defined as “the degree of consistency with which instances are assigned to the same category by different observers or different occasions” (Silverman, 2013, p. 302). Research has suggested several quality criteria to assess the quality of the qualitative case study methods. The most common quality criteria are: internal validity, construct validity, content validity, external validity, and reliability.

Internal validity refers to the ability of research to measure what it intends to measure. It concerns the relationship between results and variables (Gibbert et al., 2008). Hence, it can be enhanced by establishing a strong connection between data analysis and theoretical development. Gibbert et al. (2008, p. 1466) propose three measures to enhance internal validity: 1) Formulating a clear research framework, 2) Pattern matching between the empirically observed patterns and the predicted or established ones, and 3) Theory triangulation.

Construct validity refers to the ability of the research to use appropriate operational measures for concepts. It can be improved by establishing strong connections among the theoretical underpinnings, concepts, arguments, and the mechanisms used to collect the empirical data. For instance, in case studies, construct validity of a case study based-research can be improved by using multiple sources of evidence and clearly established chains of evidence (Schell, 1992).

Content validity refers to the ability of research to cover all facets or aspects of the attribute being measured. According to David M. and Meredith (1993, p. 245), content validity “concerns how the construct is measured.” Thus, it is important during the data collection

phase, especially when designing the draft instrument. Content validity can be enhanced by examining the literature and having some experts review the instrument. In other words, the interview questions should postulate the underlying theoretical concepts and research questions.

External validity-is concerned with the generalizability of the results. External validity can be enhanced by conducting multiple case studies or an in-depth single case study with embedded units of analysis or by increasing the sample size.

Reliability refers to the extent to which results are consistent over time and provide an accurate representation of the total population. It is an important measure because according to Merriam, (1995), it examines whether the same findings are obtained when the study is replicated. However, reliability assessment in quantitative research differs from that in qualitative research. In qualitative research, reliability is difficult to measure because of its interpretive nature. Qualitative research involves many perspectives and possible interpretations, in which “there is no benchmark by which one can take repeated measures and establish reliability in the traditional sense”(Merriam, 1988, p. 170). In this regard, Merriam (1995,) emphasizes that the replication of a qualitative investigation will not yield the same results as in case of quantitative research. Therefore, Merriam (1995) asserts that, instead of reliability, one can strive for “dependability” or “consistency” concepts suggested by Lincoln and Guba, (1985, p. 288). Based on this, Merriam (1995) highlights that reliability can be enhanced by : 1) Triangulation of multiple sources of data, 2) Seeking peers or expecting examination, and 2) Audit trail, which was suggested by Guba and Lincoln (1981).

During the research process of the three empirical studies, several quality measures and procedures were considered to ensure an acceptable level of validity and reliability. Such measures varied among the three empirical studies depending on the purpose and nature of the research question in each study. For instance, quality criteria for qualitative-based research (such as in Studies No. 1 and No. 3) are different from the statistical-based research of Study No. 2. These quality aspects are described below.

3.8.1 Validity and Reliability in Study No. 1

In Study No. 1, the interview questions were initially reviewed by experts and supervisors to eliminate any ambiguity and to ensure good content validity. The questions were then revised accordingly. To enhance reliability and avoid the possibility of researcher bias or misinterpretation of answers, the interviews were recorded and then transcribed (Gibbert and Ruigrok, 2010). According to Gibbert and Ruigrok (2010), this documentation procedure as well as the interview protocol can enhance the reliability of this type of study. Besides, it allowed the researcher to revisit the interviewees' answers at any point during the analysis phase.

For validation purposes, the transcripts were resent to the interviewees for further checking and some case companies were followed up with through telephonic conversations for further clarifications or data verification. This approach increased the internal validity of the study.

3.8.2 Validity and Reliability in Study No. 2

Compared to qualitative research, it is easier to assess validity and reliability issues in quantitative research. This is due to the objective nature of quantitative analysis. For instance, validity and reliability tests in statistical surveys generally have cut-off values or thresholds for the acceptable validity and reliability levels.

Depending on the statistical technique used in the data analysis, there are several tests in statistical surveys that can be used to verify validity and reliability. These tests may include: face validity, construct validity, discriminant validity, convergent validity, Fornell-Larcker criterion, Cronbach's alpha, and composite reliability. Depending on the data analysis technique, there might be other quality tests such as overall goodness-of-fit and Heterotrait-Monotrait (HTMT) ratio of correlations (Henseler et al., 2015).

Validity and Reliability in Study No. 3.

3.8.3 Validity and Reliability in Study No. 3

In Study No. 3, it was possible to access multiple sources of data within the case company. This approach allows for triangulation of data as it plays an important role in validating the results. For example, the use of triangulation of data among interviews, company documents, field visits, and observations to search for chains of evidence strengthens the validity and reliability of the study. Table (3.3) exemplifies the quality measures that were taken to enhance the reliability and validity aspects in this thesis.

To ensure internal validity, most questions in the interview were designed based on the underlying concepts of the research question RQ3 while some other questions were more about general facts and working procedures to allow for searching of evidences. Furthermore, the questions were reviewed by two experts—a professor in operations management and a supply chain expert from the automotive industry. Since this is a type of semi-structured interview, other questions emerged while interviewing, allowing the participants to interact by adding more information and reflecting upon their answers. The study was conducted from November 2014 to May 2015.

Table 3.3: Overview of the quality measures to enhance the reliability and validity aspects in this thesis

Research Quality Aspect	Study No. 1	Study No. 2	Study No. 3
Internal validity	✓ Enhanced by theoretical conceptualization of the research question RQ1	✓ Enhanced by theoretical conceptualization of the research question RQ2	✓ Enhanced by theoretical conceptualization of the research question RQ3
Construct validity	✓ Enhanced by using multiple sources of evidence: Interviews and documentary analysis	✓ Assessed by discriminant validity, Fornell-Larcker criterion, and convergent validity test	✓ Enhanced by using multiple sources of evidence: Interviews and documentary analysis, and observations or field visits
Content validity	<ul style="list-style-type: none"> ✓ Enhanced by examining the literature ✓ Enhanced by having some experts review the interview questions and research question 	<ul style="list-style-type: none"> ✓ Enhanced by examining the literature ✓ Enhanced by conducting peer-reviews and expert opinions regarding the model operationalization, constructs, and questionnaire items 	✓ Enhanced by examining the literature
External validity	✓ Enhanced by conducting multiple cases studies	<ul style="list-style-type: none"> ✓ A reminder was sent to participants after two weeks. Responses increased from 46 to 52 ✓ The study only targeted first-tier suppliers in Sweden 	✓ Enhanced by conducting in-depth single case study with embedded units of analysis
Reliability	<ul style="list-style-type: none"> ✓ Enhanced by documentation of data and procedure ✓ Recording the interviews, transcription, and taking notes. 	✓ Results were assessed by Cronbach's alpha and composite reliability tests	<ul style="list-style-type: none"> ✓ Enhanced by documentation of data and procedure ✓ Recording the interviews, transcription, and taking notes ✓ Triangulation of data

4. CHAPTER IV: EMPIRICS

4.1 Introduction

This chapter includes three empirical studies. Each study analyzes one research question using its own methodological approach. Study No. 1 covers research question RQ1, Study No. 2 covers RQ2, and Study No. 3 covers RQ3. As shown in Chapter 3, different research methods for collecting and analyzing data, from different sources, were used to address the research questions.

4.2 Study No. 1

4.2.1 Introduction to Study No. 1

The automotive industry, like many industries, has recently been characterized by high demand uncertainty, which causes fluctuation in production volumes (Tachizawa and Thomsen, 2007; Laurent Lim et al., 2014). This setting has forced OEMs to urge their suppliers to respond rapidly to fluctuating volumes. As a result, OEMs often reduce their safety stock level (Fliedner, 2003), urge their suppliers to reduce the minimum lot size but supply more frequent deliveries (Cousins et al., 2008), and create procurement orders with many last-minute changes (Chang et al., 2008). Thus, suppliers' production schedules as well as optimum lot size decisions are affected. To reduce inventory management costs, suppliers often seek large orders, less frequent deliveries, and less product variability to achieve optimality and take advantage of the economy of scale.

Effective inventory cost management requires the OEM and their suppliers to share information in a timely fashion. However, first-tier suppliers usually lack information on the market demand of the final products, and rely on OEMs to provide them with actual demand data. Thus, first-tier suppliers may not have the ability to forecast demand fluctuation and respond to changes in the marketplace. Inadequate response can be costly for suppliers operating in an agile business environment where flexibility is a key competitive priority. In this respect, lacking information can negatively affect the ability of a first-tier supplier to respond to changes in demand. For instance, lacking

information on demand forecasts (due to poor forecasting) will result in the bullwhip effect (Lee et al., 2004). The bullwhip effect is usually reflected as oscillating volumes (e.g., overestimated or underestimated demand schedules) at the supplier side, resulting in several production planning problems; for example, it may affect production capacity planning, production scheduling, workforce planning, inventory and materials planning, or may even lead to outsourcing decisions (Choi et al., 2013). Consequently, lack of coordination and inaccurate information flows result in inflexible production planning and control (Rupp and Ristic, 2000).

One way to overcome this problem is to encourage information sharing on demand forecast, price changes, time to market, and inventory levels. Despite the vast amount of literature on information sharing and supply chains, the study of information sharing on the flexibility of first-tier suppliers has been overlooked. Therefore, given that the specific aspects of first-tier suppliers are identified (i.e., first-tier suppliers encounter fluctuating demand volumes, implement MTO strategy, and lack information on demand), this study aims to propose a conceptual framework to understand how information sharing affects the first-tier suppliers' responsiveness capabilities. Particularly, the study explores the following research question:

RQ1: How does information sharing between OEMs and first-tier suppliers affect the latter's responsiveness to fluctuating demand??

The remainder of this study is organized in the following structure. Section (4.4.2) reviews the most relevant theoretical concepts and contributions within the boundaries of the study, and establishes its specific research question. Section (4.4.3) explains the methods and techniques that have been used to design this research study (i.e., methods used in conducting the literature review, collecting, and analyzing the empirical data). Section (4.2.4) discusses the results in relation to the theories presented in the literature section; this includes proposing a theoretical framework. Section (4.2.5) summarizes the main conclusions of this study. Section (4.2.6) presents the conclusions and implications of this study. The study ends with Section (4.2.7) where the limitations and future research directions are briefly discussed.

4.2.2 Literature Review

A brief literature review is provided in the following section. The concepts and issues are comprehensively presented and discussed in Chapter 2. Hence, this section presents a brief review of previous models, frameworks, and contributions. The focus of this review is directed to analyze how information sharing can affect suppliers' responsiveness through flexibility where suppliers' responsiveness is eventually assessed by delivery performance.

4.2.2.1 Responsiveness through Flexibility

Responsiveness can be achieved through various types of flexibility. As discussed in Section (2.3.2) of Chapter 2, responsiveness is linked to four types of flexibility: product, mix, volume, and delivery (Reichhart and Holweg, 2007). This study covers only volume and delivery flexibilities as key elements of suppliers' manufacturing responsiveness. Manufacturing responsiveness is based on three main dimensions: products, volumes, and processes (Holweg, 2005). According to Upton, (1994, 1995b), the products' dimension is concerned with the ability to introduce new product ranges or models; the volume dimension is concerned with the ability to increase or decrease production volumes, and the processes dimension is concerned with the ability to quickly manufacture, assemble, and deliver products (Holweg, 2005).

The term volume flexibility has been defined in various ways emphasizing different aspects. Some definitions focus on the profitability, some on adaptability while others focus on responsiveness, efficiency, or quality. For instance, Hyun and Ahn (1992) define volume flexibility as the ability to accelerate production and operate profitably at different production volumes. Similarly, Chryssolouris and Lee (1992) define volume flexibility as the ability to operate profitably at different production volumes. New (1996) and D'Souza and Williams (2000) have also focused on the cost and profit aspects of volume flexibility. Observably, these definitions focus on the profitability aspect of a manufacturing system (i.e., ability of changing the production volumes without losing profitability), which means that a manufacturing firm must be able to maintain high profitability when operating in high or low production volumes. However, these definitions do not reflect the agility aspect of the flexibility strategy in

the sense that they ignore the time dimension of the flexibility concept. Although profitability is essential to retain competitiveness, the central role of the volume flexibility strategy is to focus on being adaptive and responsive to changes in the business environment without losing other competitive priorities (Cousins et al., 2008). Suarez et al. (1996) define volume flexibility as the ability to vary production volumes without scarifying the quality of products or efficiency of the process. This definition has led to considering other competitive criteria like quality and efficiency. Volume flexibility, therefore, cannot be attained by sacrificing other competitive priorities. In connection to this, Oke (2003, p. 1499) has also empathized with competitive criteria of a manufacturing plant. Hence, he re-defines volume flexibility as “the capability that a manufacturing system has to vary its output level for a given product mix within a given time period without any unacceptable effect on cost and other competitive criteria of the plan.” The above definitions are supported by Cousins et al. (2008) who define volume flexibility as the ability of the supplier to manage variations from the buyer firm without significant trade-offs with other competitive priorities. This definition is more contemporary because it creates a transition of the concept from a manufacturing system’s perspective to that of a supplier.

The study of flexibility is generally rooted in the manufacturing strategy theory, and refers to the seminal work of Slack (1987) and Upton (1994). In their studies, they assert that flexibility of a manufacturing system can be expressed in terms of four types: product, mix, volume, and delivery flexibility. Thus, there is a considerable amount of research on manufacturing flexibility aspects such as volume, product, and supply flexibility, for instance by Backhouse and Burns (1999), Koste and Malhotra (1999), Das (2001), Vokurka and O’Leary-Kelly (2000), Jack and Raturi (2002), Zhang et al. (2003), Koste et al. (2004), Holweg (2005), Bernardes and Hanna (2009), More and Babu, (2009), Tachizawa and Gimenez (2010), Schütz and Tomasgard (2011), Oke (2013), and Purvis et al. (2014). Nevertheless, most of these studies have been analyzed either from a manufacturer’s or supply chain perspective (Pujawan, 2004). In addition, there has been little empirical research on how volume flexibility is understood by first-tier suppliers. In that sense, Oke (2003, p.1497) emphasizes that “there has been a dearth of empirical research on the concept and there are many unanswered questions

requiring empirical investigation —what is volume flexibility, when is it required, and how can it be implemented.”

Oke (2003) finds that demand variability, regardless of differences in the sector, product, and other plant characteristics, is the major driver of volume flexibility requirements in manufacturing plants. He also finds that demand uncertainty, short product life-cycle, short product shelf life, supply chain complexity, and actions of competitors are the major drivers of volume flexibility. Although this study is a unique attempt to identify the drivers and requirements of volume flexibility for a manufacturing plant in different sectors, it does not show whether the same factors are applicable to other kinds of firms (e.g., first-tier suppliers). Furthermore, the study does not consider the automotive industry as one of the industries that involve high demand variability. Besides, it is still unclear how flexibility can be achieved. Raturi and Jack (2004) postulate a conceptual framework for achieving volume flexibility. In their study, they propose a guideline to implement volume flexibility as a way to resolve the dilemma of demand variability and last-minute changes in purchase orders. Although their study provides a significant in-depth insight into understanding how firms can implement volume flexibility, their proposed framework considers manufacturers but not suppliers. Hence, their proposed framework might not be applicable or generalized to first-tier suppliers unless it is tested empirically on supplier firms.

Table (4.1) summarizes additional recent contributions related to the concepts of volume and delivery flexibilities. While these are all valuable studies, none explores or suggests studying the supplier’s flexibility. For instance, regarding the scope of these studies, it can be shown that six studies have analyzed volume flexibility in relation to other types of flexibility while seven investigated other types such as mix and product flexibility. Regarding the unit of analysis, 10 studies focus on supply chain flexibility, three on the manufacturer level, but none considers the supplier level. Although the review presented in Table (4.1) is not a comprehensive one of all the available literature in the last 15 years, the numbers indicate a gap in the literature on the supplier’s volume flexibility.

Table 4.1: Review of the main studies on flexibility during the last 15 years (i.e., between 2000 and 2015)

Study	Contribution/Purpose	Level of analysis				Scope of the study	
		Supplier	Manufacturer	Supply chain	Delivery flexibility	Volume flexibility	Other types of flexibility
Purvis et al. (2014)	Explore the meaning of flexibility in the context of lean, agile, and leagile.			✓			✓
Gosling et al. (2013)	Propose a four-step framework for achieving appropriate flexibilities to mitigate the uncertainties experienced in supply chains.			✓			✓
Mourtzis et al. (2012)	Use Penalty of Change (POC) method to study product and volume flexibility in a production system in terms of changing the required production volume.		✓			✓	
Gosling et al. (2010)	Study two aspects of flexibility at the supply chain level—sourcing and vendor flexibility			✓			✓
Lin and Chen (2009)	Explore hedge-based inventory and volume flexibility.			✓		✓	
Gong (2008)	Propose an economic index that combines labor flexibility, machine flexibility, routing flexibility, and IT.			✓			✓
Salvador et al. (2007)	Investigate the factors that enable or hinder the simultaneous pursuit of volume flexibility and mix flexibility within a supply chain.			✓			✓
Sawhney (2006)	Studies the implications of various flexibilities on supply chain performance.			✓			✓
Raturi and Jack (2004)	Propose the guideline to implement volume flexibility as a method to resolve the problem of demand variability and last-minute changes in purchase orders.		✓		✓	✓	
Das and Abdel-Malek (2003)	Investigate the effect of creating supply contracts.			✓			✓
Garavelli (2003)	Explores the assignment of configurations to plants and suppliers.			✓			✓
Oke (2003)	Explores the conditions under which volume flexibility is required by manufacturing plants.		✓			✓	
Sabri and Beamon (2000)	Study volume and delivery lead-time flexibility.			✓		✓	

4.2.2.2 Flexibility through Information Sharing

Generally, a considerable body of literature has discussed flexibility of manufacturing systems and information sharing. However, the link between these two concepts is not clearly investigated. Yigitbasioglu (2010, p. 551) defines information sharing between firms as “the information shared between a buyer and key suppliers that is detailed enough, frequent enough (Carr and Smeltzer, 2002; Humphreys et al., 2004; Krause and Ellram, 1997), and timely enough (Dyer, 1997; Krause and Ellram, 1997; Leek et al., 2003) to meet a firm’s requirements.”

Flexibility requires fast information flow and accurate demand forecasts; information flow plays an important role in facilitating fast exchange of data between buyers and suppliers (Shih et al., 2012). In their study, Shih et al. (2012) claim that uncertainty can be decreased by integrating IT systems in the supply chain network, resulting in lower production cost, shorter lead times, and faster product delivery. Kemppainen and Vepsäläinen (2007) confirm that for any manufacturing strategy to work well, it is necessary to stabilize demand and reduce supply chain uncertainty. In tackling such uncertainty, flexibility requires smooth flow of information sharing across the supply chain members (Datta and Christopher, 2011).

To be flexible in responding to demand uncertainty, MTO is a manufacturing strategy that is usually implemented by firms operating in an agile environment where demand is uncertain and variability is high (He et al., 2014). As was indicated previously, research has suggested that flexibility is relevant for those industries where demand is volatile. For instance, Song and Yao, (2002, p. 3) highlight that

“Changes in the marketplace are forcing automobile manufacturers, whose production has traditionally been driven by demand forecasts, to transform their production into MTO systems. This transformation necessitates a new manufacturing strategy since demand variability can no longer be hedged against finished goods inventory. One strategy to address demand variability in this MTO environment is to invest in flexible manufacturing capacity.”

In such an environment, the demand volumes are likely to fluctuate widely, which make it difficult for suppliers to forecast the future demand. MTO provides first-tier suppliers with flexibility to produce less or more according to the customer's orders. In this regard, flexibility is viewed as a "firm's ability to match production to demand in the face of uncertainty and variability" (Iravani et al., 2014, p. 321).

Research has validated the contribution of information sharing to performance improvement. Wu et al. (2014) find that information sharing has a partial mediation effect on supply chain performance while Prajogo and Olhager (2012) confirm that there is a positive relationship between information integration (i.e., information sharing and information systems between firms and suppliers) and logistics performance. Hill et al. (2012), and Datta and Christopher (2011) investigate the effectiveness of information sharing and coordination mechanisms in reducing uncertainty. In their empirical study, Datta and Christopher (2011) find that information sharing across different members is essential in managing supply chains effectively under uncertainty. Despite their importance, these studies have focused only on the supply chain level but ignored the supplier level. Besides, these studies did not specify the information to be shared or with whom to be shared.

Based on this, one can argue that there are two aspects for effective sharing of information—the type or level and frequency of information sharing. These two aspects are explained below.

Type of Information

Researchers have identified different types of information sharing between supply chain members at the operational level. Sahin and Robinson (2002) propose a conceptual framework for information sharing in which they identify different types of information such as production plans, production schedules, stock levels, actual demands, demand forecast, product portfolio, POS data, and product's launch date. In practice, each type of information affects suppliers and OEMs in a different manner. For instance, in a volatile demand environment, first-tier suppliers are usually interested in obtaining

information on demand forecast while OEMs are interested in learning information about the prices of the components and raw materials.

In this regard, Qian et al. (2012) investigate the vertical demand information sharing in a two-echelon supply chain formed by many downstream retailers and one upstream manufacturer with a limited production capacity. In their study, Qian et al. (2012) found that a discriminated allocation strategy will encourage retailers to share their demand information. However, supply chain members have different operations, manufacturing strategies, and products; thus, each company has self-interest in certain types of information that are necessary for its activities. For example, compared to OEMs, suppliers in the automotive industry usually lack information on demand of the final product (i.e., vehicles).

Sharing sensitive information (i.e., demand forecasts, prices, etc.) may depend on other factors not included in this thesis. For example, sharing of information may depend on the level of trust between OEMs and suppliers, and the type of business relationship with suppliers (e.g., strategic and non-strategic suppliers).

Information Sharing Frequency

Frequency of information sharing is crucial to a supplier's flexibility; information is generally shared on a daily, weekly, or monthly basis. The use of IT has facilitated fast exchange of information between buyers and suppliers (Yue and Liu, 2006). IT systems have been used to streamline accurate and real-time data and avoid manipulation or amplifications of actual forecasts (Prater, 2005). For example, CPFR, and VMI are widely used to share information between buyers and suppliers in many industries such as food, retail, and apparel. However, most firms in the automotive industry use EDI. EDI is a system used widely in the automotive business to facilitate communication between buyers and suppliers regarding order quantities, demand schedules, inventory level, last-minute changes, delivery time, and lead-time. It provides an efficient way for information sharing between OEMs and suppliers; especially, for those who use the MTO strategy.

4.2.3 Conceptual Framework Development

The certain type of flexibility required to achieve responsiveness is “contingent upon the system’s structure and environment” (Holweg, 2005, p. 608). Based on the earlier discussion in Chapter 2, it can be argued that a supplier’s responsiveness to fluctuating orders may rely on three generic capabilities: inventory planning, temporary workforce planning, and production capacity planning. As shown in the proposed framework in Figure (4.1), these capabilities are necessary for responding to fluctuating volumes. This argument is built on the seminal work of Ojha et al. (2013). In their study, Ojha et al. 2013 (p. 2919) highlight that:

“If customer demand increases, and an organization does not have sufficient resources (i.e., volume flexibility) to meet the increased demand, then the lack of capability to meet the higher demand creates a backlog of orders. Backordering results in reduced average throughput time and fewer on-time deliveries. Therefore, a greater capability to adapt to the demand variability results in more control over the workflow speed and variability. This increased control over the system workflow allows an organization to achieve reduced variation, higher workflow speed, and improved operational performance.”

The delivery performance, which is used here to quantify the level of responsiveness, can be measured by the delivery time and delivered quantity (i.e., order fulfillment). The level of responsiveness is, however, different from one supplier to another depending on the complexity of the product and the frequency of the last-minute changes.

Product complexity (in terms of functionality and manufacturability) affects the supplier’s responsiveness ability. Complex products require additional processing and consume more resources. This means that the machine set-up time as well as lead-time of final products will increase if the products produced by suppliers are complex. Thus, the supplier takes more time in responding to large orders of highly complex products. However, prior material planning and accurate production scheduling might lower this impact. For this, early and accurate demand forecasting is required.

Supplier's flexibility capabilities

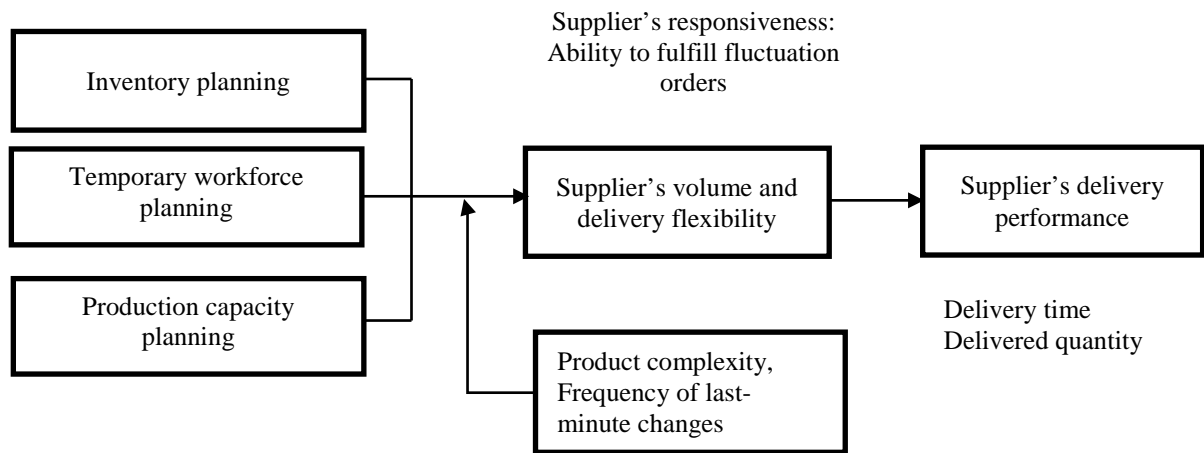


Figure 4.1: Tentative framework of suppliers' responsiveness

Last-minute changes affect the supplier's responsiveness. When the number of changes increases, the ability of the supplier to respond to them will decrease. The customer's orders with frequent changes will create conflicting production schedules to the supplier's factory. As a result, the supplier will change inventory plans and working shifts, which will probably lead to a low response. The impact can be lowered by urging customers to reduce the number of last-minute changes and provide accurate demand schedules in a timely fashion.

This tentative framework was tested by empirical data collected from eight case companies, mainly through interviews. The constructs and their predictors were conceptualized by the interview questions. As shown in Table (4.4), several themes emerged. A cross-analysis between the themes among case companies was conducted to establish a chain of evidences. The framework was revised according to the findings. The following section discusses the detailed methodology.

4.2.4 Methodology

The following two sub-sections summarize the methods used to collect and analyze empirical data. The "Data Collection" subsection presents the rationale of the research

approach, the nature of the material, and the case selection and access. The “Data Analysis” subsection presents the methods for arranging and analyzing the data. The author has altered names and other identifying information to protect confidentiality.

4.2.4.1 Data Collection

Since the purpose of this study is to propose a conceptual framework to explore the role of information sharing, we used the case-study research method. According to Sodhi and Tang (2014), the empirical case-study research method is appropriate for framing and awareness, which fits the purpose of this study. In this regard, we carried out eight exploratory case studies based on 16 semi-structured interviews with supplier firms based in Sweden. The study was conducted between October 2013 and September 2014.

The supplier firms, shown in Table (4.2), were selected from a list obtained from the FKG. The case companies were selected based on some different characteristics such as the size of the firm (small-medium-large companies based on the number of employees), which reflects the production capacity and degree of complexity of the main product(s). Although these firms are mostly classified as first-tier suppliers, in few cases they might be considered second-tier as well depending on the type of products delivered. However, for the purpose of this study, we only analyzed the firms’ main business units in which they are considered first-tier suppliers. It is worth noting that all these case companies supply products to some common OEMs such as Scania and Volvo.

Table 4.2: Profiles of case companies (i.e., supplier firms)

Case company (supplier firm)	Main product(s)	Firm size³	Revenues in million €	Main supply strategy	Supplier tier category
A	Crankcase ventilation filters	100	30	MTO/ATO	First-tier
B	Electric wires and cables	1000	60	MTO/ATO	Mostly first-tier, but sometimes second-tier
C	Pipe bending, silencers, advanced emission control equipment for heavy vehicles	1000	Data not available	MTO/ATO	First-tier
D	Interior textiles for the automotive industry such as seats, covers, fabrics, and beds for trucks	1100	Data not available	MTO/ATO	Mostly first-tier, but sometimes second-tier and rarely third-tier
E	Metal components and sheets	460	80	MTO/ATO	Mostly second-tier, but sometimes first-tier
F	Plastic blow molded parts and systems (e.g., fuel tanks, fluid containers, oil filler pipes, and engine pipes)	130	21.5	MTS/ATO	First-tier
G	Seat belts, airbag systems, and safety products	650	Data not available	MTO/ATO	Mostly first-tier
H	Pneumatics, and valves for truck and bus engines	350	75	MTO/ATO	First-tier

In total, I interviewed 16 executives (i.e., two managers from each company) with different job roles representing different functional areas. For instance, we interviewed people with job titles of CEO, account manager (or sales manager), procurement manager, and product/production manager. I interviewed people with these designations to maximize the utilization of information collected through the interviews. Table (4.3) presents a summary of the informants' job roles.

³ A company with 1-50 employees is considered small, one with 50-250 employees is considered a medium company, and one with greater than 250 is considered a large company. The company size was measured by the total number of employees of the supplier using the European Union categorization. (Directorate General for Internal Market, Industry, Entrepreneurship, and SMEs- European Commission, 2014).

Table 4.3: Job roles of informants

Case Company	Interviewee position/designation				Total number of interviews
	CEO/Managing Director	Account Manager	Procurement Manager	Production/Operations Manager	
A	X			X	2
B		X		X	2
C	X	X			2
D		X		X	2
E		X		X	2
F	X			X	2
G	X		X		2
H	X			X	2
Total number of interviews	5	4	1	6	16

The interview questions were guided by the information sharing and responsiveness, and flexibility literature. Afterwards, the questions were forwarded to two professionals in the automotive business for further review; and were then revised accordingly to eliminate any ambiguity. This procedure was followed to improve the quality of the conceptualization or operationalization of both the research questions and the relevant concepts (i.e., to improve the construct validity).

As shown in Appendix (A), the interview comprised five sections in which a set of certain questions were asked in each section. For instance, Section (I) included the interviewee's general information such as job position/title, name, years of experience, contact information, etc. Section (II) included general questions about the company such as number of employees, annual revenues, main products, production facilities, contact information, etc. Section (III) included five questions on the companies' supply strategy concerning response to fluctuating demand. Section (IV) included seven questions about information sharing between OEMs and suppliers, such as the most important types of information being shared, aspects of effective information sharing, benefits and obstacles, mechanisms of sharing information, and impact of information

sharing. Section (V) included eight questions concerning suppliers' flexibility capabilities, with focus on volume and delivery flexibility. In total, the interview manual comprised 30 questions (i.e., 10 general questions belonging to sections I and II, and 20 to sections III, IV, and V).

To take the advantage of the interview duration, answers to the general questions, which belong to sections (I) and (II), were obtained from the company website or by phone. This allows the researcher to dedicate more time to the questions of sections (III), (IV), and (V). Then, the same open-ended questions were asked to all managers; the interview length ranged from 60 to 90 minutes.

All interviews were audio recorded and then transcribed for further documentation and analysis. Transcription is important for both transparency and replication, which are key aspects of the reliability of the case study method (Gibbert and Ruigrok, 2010). According to Gibbert et al. (2008, p. 1468), "Transparency can be enhanced through measures such as careful documentation and clarification of the research procedures" while "Replication may be accomplished by putting together a case study database, which should include the case study notes, the case study documents, and the narratives collected during the study." Hence, the interview script, audio files, notes, and company reports were gathered and documented to prepare the data for analysis.

4.2.4.2 Data Analysis

Interview scripts were coded to develop themes and categories using the thematic analysis approach where the common unit of analysis is the factory level. Thematic analysis is defined as the process of encoding qualitative information in order to determine patterns that are useful to describe and organize possible observations or interrupt aspects of a phenomenon (Boyatzis, 1998). Generally, themes emerge inductively from the raw data or deductively from theory or previous research. In this study, the themes were inductively identified based on the data collected from the semi-structured interviews. The emerged themes, as shown in Table (4.4), were coded according to common tags/labels. Subsequently, the themes were interconnected to develop a conceptual framework, which addresses the research question RQ1.

Table 4.4: Data coding used in the thematic analysis

Main theme	Description	Tag/label
Supplier's delivery flexibility	The ability of the supplier to quickly respond to delivery changes	Lead time reduction, Number of lost orders
Supplier's volume flexibility	The ability of the supplier to fulfill the customer orders that involve last-minute changes in the quantity.	Order fulfillment ratio Fluctuating volumes
Production capacity planning	The ability of the supplier to increase or decrease production capacity in accordance with the fluctuating orders coming from OEMs.	Number of production lines/machines, Number of shifts, Product mix, Run length
Temporary workforce planning	The ability of the supplier to hire and lay off temporary workforce without additional cost.	Ratio of temporary workers
Safety stock and inventory planning	The ability of the supplier to maintain continuous production by holding a certain amount of inventory of complements, parts, or raw materials.	Safety stock level, Reorder point, buffers, MTS
Sharing of information	The ability to obtain OEMs' own demand forecasts and schedules.	Quality Aspects: Accuracy of data, speed of sharing, frequency of obtaining the data, updating frequency, availability of data
Suppliers' delivery performance	The ability of the supplier to meet delivery precision targets set by the OEM	Delivery precision (delivery time and delivered quantity)

Using these themes, a cross-analysis between different individual cases was conducted. This step improves the external validity of the study as it allows for searching common evidences; thus, reducing the subjectivity in the data analysis. Based on the analysis of the empirical case studies, the results of this study are presented and discussed in the next section.

4.2.5 Results and Discussion

The study explores how information sharing between OEMs and first-tier suppliers affects the latter's ability to respond to fluctuating volumes. In answering the research question, the study has the following findings:

Finding #1: The analysis shows that sharing of some types of specific information by OEMs with first-tier suppliers may help the latter improve their ability to respond quickly to fluctuating volumes. These types of information are listed as follows

according to their importance: 1) Demand forecasts for each vehicle model, 2) In-stock and work-in-process inventory levels of components, 3) New design changes (i.e., new specification), and 4) Expected date of launching new vehicle models.

Table (4.5) shows how the eight case companies differ with regard to the importance of the above types of information. The scores for each case company ranked on a scale from 1 to 4, where 1 represents the most important and 4 the least important. The cross-analysis shows that most companies agreed that “demand forecasts” and “inventory data” constitute most important information that affects suppliers’ responsiveness, while new “design changes” and “launch date” are less important.

Table 4.5: Ranking of the relative importance of the information being shared by OEMs with suppliers

Case company (suppliers)	Type of information			
	Demand forecasts for each vehicle model	In-stock and work-in-process inventory levels of components	New design changes (i.e., new specification)	Expected date of launching new vehicle models
A	1	4	2	3
B	1	3	2	4
C	1	2	3	4
D	1	2	3	4
E	2	1	3	4
F	1	2	3	4
G	1	2	4	3
H	1	2	3	4

Consequently, demand forecasts and inventory data constitute the most important information that affects suppliers’ flexibility capabilities.

Finding #2: The analysis indicates that sharing OEMs’ demand forecasts and inventory data influences three main capabilities of first-tier suppliers: safety stock and inventory planning, temporary workforce planning, and production capacity planning. As discussed below, these are considered key capabilities of suppliers’ responsiveness to fluctuating volumes.

- ***Safety stock and inventory planning***

The analysis shows that first-tier suppliers maintain certain levels of safety stock not only to ensure continuous flow of production or to avoid out-of-stock status, but also to increase responsiveness to customers' fluctuating orders. For instance, regarding this aspect, the managing director of the case company "A" said:

"In principle, to follow a customer's fluctuating volume, we do have a certain stock of components so that we can assemble them upon order, and of course we ship delivery schedules to our suppliers, which reflect the delivery schedules of our customers, so that our suppliers know—more or less—what they should deliver us on a monthly or weekly basis."

Generally, first-tier suppliers use the MTO/ATO strategy and maintain the least amount of inventory (i.e., raw material or components, finished products) in order to minimize total holding costs. Apart from the inventory costs, maintaining a certain safety stock level of components and parts serves as a buffer to feed the production machines when the demand increases. The analysis reveals that information sharing on demand forecasts and OEM's inventory level affects the way in which first-tier suppliers manage their own buffers. This point is illustrated in Table (4.6).

- ***Temporary workforce planning***

The analysis indicates that most first-tier suppliers (i.e., cases) used temporary hiring and firing when demand volumes fluctuate up and down. For instance, one-third of the total workforce in case company "C" comprises temporary workers with a two-week temporary work contract, while in case company "E" the percentage is 15%. The analysis shows that first-tier suppliers hire more temporary workers when the demand is high in order to accommodate the sudden increase in the quantity. These companies were running on multiple shifts; for example, case company "A" was operating three shifts in addition to the weekend shifts when demand was suddenly high.

Table 4.6: Impact of sharing OEMs' changes in demand forecasts and inventory data on suppliers' responsiveness capabilities-based on cross-analysis

Case company (supplier)	Suppliers' main capabilities affected by sharing OEMs' demand forecasts and inventory data		
	Safety stock and inventory planning	Temporary workforce planning	Production capacity planning
A	Maintains buffers as stock components. The company uses MTO	Uses temporary labor to cope with sudden increase in volumes	Uses three working shifts in addition to the weekend shift when demand was suddenly high
B	The company's reorder-point for components is affected by changing order quantities. The company uses MTO	Ratio of temporary manpower is adjusted if the changes are less than 20% and only for a single item	If the changes are more than 20% and for many parts, then the company increases its total capacity by adding extra machines or even production lines
C	Keeps inventory minimum to avoid unnecessary costs. The company uses MTO	33% are temporary workers because of extreme changes in demand	Uses multiple shifts to cope with short term demand changes while increasing the number of production machines if the demand changes are long-term horizon
D	It is important for the company to plan our inventory. This is highly affected by what we receive from our customers. The company uses MTO	The company is sensitive to changes in demand schedules and inventory data when it comes to hiring and lay-off of temporary labor.	Reschedules production orders and prioritizes them according to the amount of changes.
E	Although the company uses MTO, keeping a safe level of buffers can help if the demand is constantly changing. The company uses MTS	15% are temporary workers because of extreme changes in demand	Outsources the shortage in the capacity to other competitors
F	Having a precise amount of buffer is important. The company needs accurate information from our customers to be able to respond to their orders. The company uses MTS	The ratio of temporary workers can dramatically change up or down.	The company's product mix is affected. Production plans need to be adjusted
G	The company's plans for inspection, sorting, handling, and storage of components and other incoming material are updated frequently. Any change will affect these plans. The company uses MTO	Approximately, 8% of the company's total manpower is hired on a short-term basis because of the huge order changes from the customers	Production run length is affected. The number of idle machines will increase when demand schedules decrease or change to low levels, but the number of utilized machines will increase if the demand schedules increase or change to high levels
H	The company uses MTS in certain cases but mostly MTO	The temporary workforce can increase/decrease by 5% when the company faces unusual changes	Uses night shifts, and sometimes weekend shifts to cope with changes in demand volumes

The cross-analysis shows that this approach is preferred by most case companies to accommodate sudden changes in the demand only when demand fluctuates on a short-term basis. Conversely, when the demand drops again, the companies usually lay off temporary workers. Other examples are illustrated in Table (4.6).

- ***Production capacity planning***

The analysis indicates that information sharing affects the production capacity planning. Sharing information on demand forecasts helps first-tier suppliers in planning the required resources, such as to determine the required number of production machines or number of production lines, the required utilization of production capacity, and the number of work shifts. The level of flexibility increases as long as these capabilities are maintained to a high extent because the ability of the first-tier supplier to respond to the fluctuating orders depends on the ability to increase or decrease the production capacity. This flexibility requires accurate and timely information sharing between OEMs and first-tier suppliers.

However, developing these capabilities requires considerable investment in resources and technology. This investment may include adding extra capacity or renewing the production machines or production lines, replacing old machines with new ones with less setup time, and training of the employees. Nevertheless, investing in production capacity is considered a long-term strategic decision, used by first-tier suppliers who have long-term contracts to supply major customers with huge volumes. In this regard, the production manager of the case company “B” confirmed:

“If the orders involve volume changes for a single part with less than 20%, then it is normal, we can adjust the use of the manpower, but if the changes are more than 20% and for many parts, then we have to increase our total capacity by adding extra machines or even production lines. Of course, we have agreements with our customers regarding our capacity.”

These three flexibility capabilities affect the consequent operations such as production scheduling and manufacturing. Hence, the delivery performance (which is an important measure of suppliers’ volume flexibility) is affected as well.

Finding #3: The analysis of the interviews shows that reliability of information is a key aspect for improving flexibility capabilities. As shown in Table (4.7), sharing “timely,” “accurate,” and “up-to-date” information on demand forecast and inventory data are critical factors for effective sharing of such information. Moreover, information on demand forecasts and inventory should be available all the time. Besides, the more accurate (and reliable) schedules they receive, the more the ability in responding to fluctuating volumes can be realized. Conversely, sharing inaccurate information on demand forecasts will negatively influence the first-tier suppliers’ volume flexibility.

Table 4.7: Quality aspects of information sharing between OEMs and first-tier suppliers

Case company (supplier)	Quality aspects of information sharing				
	Accuracy of data	Speed of sharing data	Frequency of sharing data	Updating frequency of data	Availability of data
A	✓✓	✓✓	✓✓	✓	✓
B	✓✓	✓✓	✓	✓	✓
C	✓✓	✓	✓✓	✓✓	✓
D	✓	✓✓	✓	✓	✓
E	✓✓	✓	✓	✓✓	✓✓
F	✓✓	✓✓	✓✓	✓	✓
G	✓	✓✓	✓	✓✓	✓
H	✓✓	✓	✓✓	✓	✓
✓: Emphasized in one interview, ✓✓: Emphasized in both interviews					

When an OEM creates purchase orders, it usually provides its first-tier suppliers with initial demand forecasts through the EDI system. After receiving the schedules, the supplier starts building up capacity accordingly. In some cases, the OEM may provide too optimistic demand forecasts in order to urge the supplier to build up more capacity. Afterward (i.e., after production takes place at the supplier facility), the OEM most likely asks for changes in the ordered quantities. In such cases, the overestimated or underestimated schedules would negatively affect the supplier’s production and inventory plans preventing them from investing in flexibility.

In this respect, most interviewees emphasized the significance of sharing accurate data. For instance, the managing director of the case company “A” highlighted:

“What we would like to have is more accurate data on demand schedules and demand forecasts, and I will explain what I mean by accurate. Because it’s of

course impossible for a customer to give us 100% accurate schedules, because also their world is changing. We do see that some customers have “Schedule behavior”; one example is of customers who are constantly placing 20% higher demand than they actually will need, to give us the impression that—what I think is—they want to secure their own delivery volume, and when we are getting to the exact delivery date they are constantly bringing those schedules down by the overestimated 20%, so we constantly know that they are giving us too optimistic schedules. Some of our customers fluctuate the volumes a lot, so that we sometimes get completely crazy figures.”

In this regard, Cachon and Lariviere (2001) claim that sharing credible information on demand schedules is critical for effective supply of components and parts. Thus, when a first-tier supplier trusts the OEM's schedules, the former becomes more willing to invest in their own flexibility such as adding new production lines or machines, which improves flexibility capabilities.

In addition, most interviews confirmed that the frequency of sharing information from the OEMs is critical for flexibility capabilities. First-tier suppliers usually obtain demand schedules and other types of information through EDI systems. OEMs usually update the data on a daily, weekly, or even monthly basis. The analysis shows that the earlier the OEMs share demand schedules or other potential last-minute changes with first-tier suppliers, the more rapid are the responses of first-tier suppliers to fluctuating volumes. For instance, the managing director of the case company “A” said:

“Some customers are updating their forecasts every day (every weekday), but it doesn't mean that the quality becomes better, because in one of the cases I mentioned about, the volume fluctuates $\pm 52.1\%$, and this is from the customers who were updating the volumes every day. So it doesn't mean that the quality is better automatically just because you do that every day.”

It is worth noting that sharing timely, accurate, and updated information on demand forecasts and inventory data requires collaborative forecasting teams from both the

OEM and the supplier. The purpose of creating collaborative forecasting teams is to involve the first-suppliers in the forecasting activities. This would offer improved forecasting accuracy (i.e., decreasing the forecasting errors, which represent gaps between forecasted volumes and forecasted actual volumes). Furthermore, most interviews confirmed that fast communication between OEMs and first-tier suppliers is important. Early communication of potential changes and sharing them on a real-time basis will allow for a quick response.

Finding #4: Based on the analysis of the empirical case studies and the aforementioned results, a conceptual framework to relate information sharing (between OEMs and first-tier suppliers) to volume flexibility aspects has been developed. The framework, shown in Figure (4.2), emphasizes that demand uncertainty on the downstream side of a supply chain is the main driver of demand variability, which in turn is reflected by fluctuating orders at the upstream side.

The framework suggests that sharing timely and accurate data on production schedules, inventory, and demand forecast have short-term and long-term implications on the supplier's volume flexibility-related decisions. In the short-term, it affects the supplier's ability to respond to fluctuating orders; particularly, it helps improve production capacity planning, workforce planning, and safety stock and inventory planning.

The framework also shows that suppliers' ability to respond to fluctuating orders differs from one supplier to another, depending on two controlling factors: the complexity of the product and the frequency of the last-minute changes. In the long term, however, information sharing affects decisions on the outsourcing or capacity expansion, such as creating several partnerships with other suppliers. In this regard, the analysis shows that information sharing on demand forecasts and data inventory may indirectly affect outsourcing decisions, especially when the supplier's total production capacity is not able to serve high volumes.

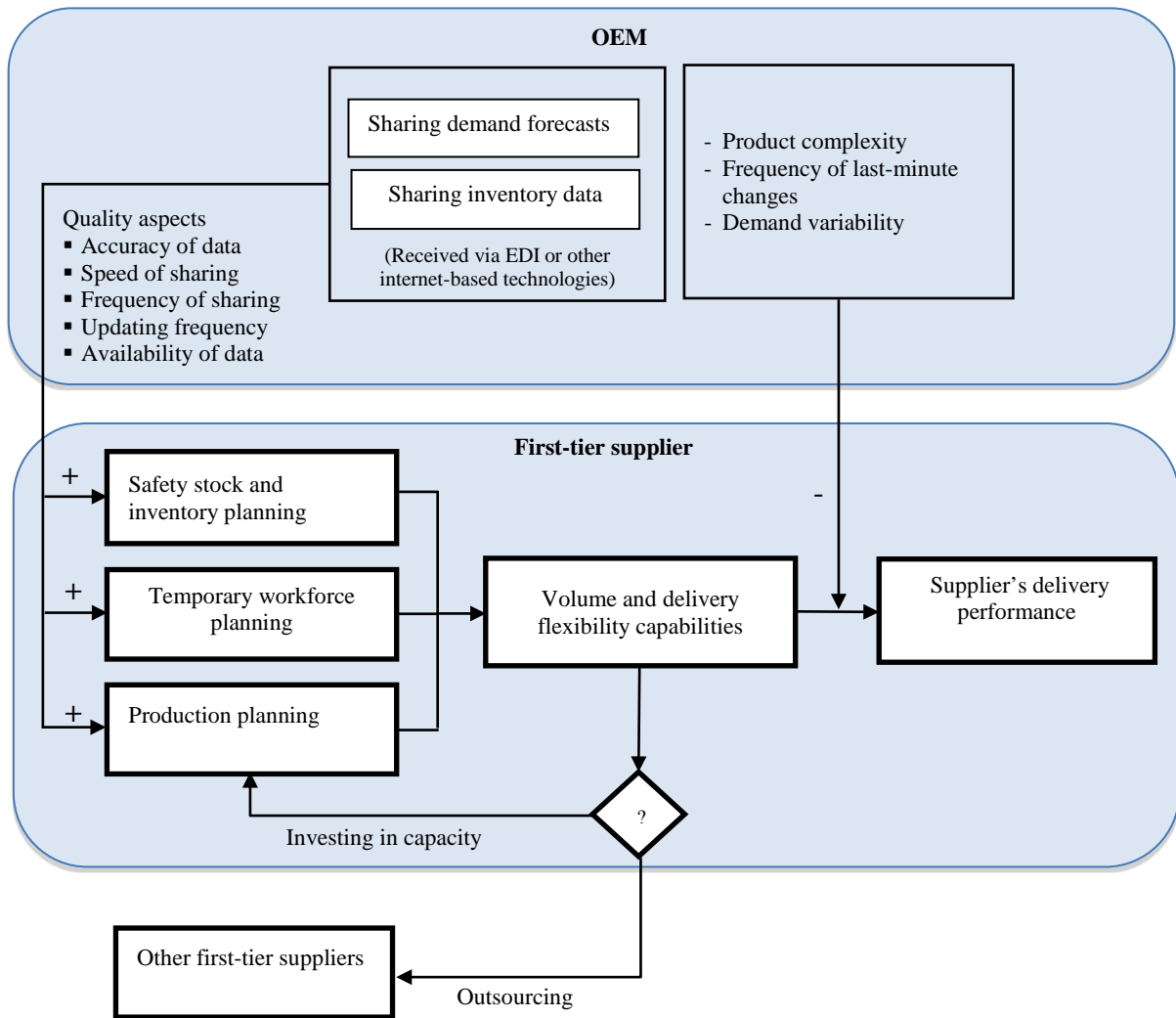


Figure 4.2: Revised conceptual framework

In this setting, the supplier would ask other first-tier suppliers to supply the rest of the quantity to avoid shortage. In this scenario, the supplier must have established several outsourcing agreements with other suppliers or even competitors. According to Qian et al. (2012), an allocation strategy is required in case the total order exceeds the supplier's capacity. Some suppliers consider this a part of their supply chain contingency plan. For instance, the account manager of the case company “D” asserted:

“If we need to adjust our production capacity, we have agreements with several different companies—I think it’s maybe eight different companies outside our company where we constantly have some production. This is part of our

contingency plan because in the automotive industry, we need to have contingency plans in case we have an accident or something happens.”

The analysis also shows that the OEM must approve such outsourcing decisions taken by first-tier suppliers. For instance, the sales and marketing manager of the case company “E” emphasized:

“We cannot outsource without our customer’s approval, but that’s something we work with to outsource production. We need to check that with our customers because they need to approve it. This is how it works in the automotive business.”

Therefore, establishing tier relationships with other first-tier suppliers who deliver similar products may help improve outsourcing decisions and thus improve suppliers’ volume flexibility.

4.2.6 Conclusions and Implications

This study explored how sharing certain types of information between OEMs and first-tier suppliers, affects the latter’s responsiveness to fluctuating demand. Based on empirical data collected from eight case companies (mostly first-tier suppliers) in the automotive industry in Sweden, the study analyzed the ability to respond to fluctuating orders. The study revealed that sharing information helps improve suppliers’ three internal operations—safety stock and inventory planning, temporary workforce planning, and production capacity planning, which are the key aspects of volume and delivery flexibility. However, lacking accurate information on actual demand may affect the way in which first-tier suppliers manage their buffers (i.e., as a result, they may have excess or shortage of inventory). Consequently, inventory costs may increase dramatically since the first-tier suppliers use the MTO strategy.

This conclusion is supported by previous studies; for instance, Prajogo and Olhager (2012) have identified several benefits of information sharing between supply chain

partners. In their study, they claim that sharing information on point of sale history “helps suppliers to successfully forecast demand, which subsequently improves the service level and efficiency to their customers,” while sharing information on real-time inventory “helps suppliers plan their replenishment and delivery schedules; thus, improving service levels and reducing inventory costs.” Conversely, sharing inaccurate information on demand schedules and forecasts will eventually devastate the trust between OEMs and their first-tier suppliers. As a result, it would prevent suppliers from investing in their own flexibility.

This study suggests improving the process of information sharing by building trust between OEMs and their first-tier suppliers. Building a trust requires OEMs to share accurate data and the first-tier suppliers to show commitment. Piderit et al. (2011) find that information sharing is important to improve trust between OEMs and suppliers and vice versa. Hence, if the demand schedules are accurate and creditable, the supplier will have an incentive to install or add more capacity. Moreover, Wu et al. (2014) confirm that trust and commitment will positively affect information sharing in the supply chain while information sharing positively affects supply chain performance. Thus, the study suggests that sharing timely and accurate information will build trust, which is an important requirement for a first-tier supplier to invest in its flexibility. The study also showed that information sharing might affect some outsourcing decisions, particularly those related to short-term production capacity.

4.2.7 Limitations and Directions for Future Research

The study has a few limitations worth noting. First, it focuses on first-tier suppliers in the automotive industry. Hence, the results cannot be generalized to other types of suppliers (e.g., second-tier or third-tier suppliers) or other different industries such as electronics, food, chemicals, and so forth. Second, the study follows a qualitative research approach using a case-study research method; thus, the subjectivity of the analysis might be a concern. Therefore, we do not aim to generalize the results or the proposed framework to other industries or other types of suppliers; instead, we consider the results as imperative signs to understand how first-tier suppliers practically perceive

the importance of information sharing in improving flexibility and responsiveness-related decisions. However, results might be generalized to some similar industries where the demand fluctuation is high and requires responsive first-tier suppliers. Based on that, we recommend future researchers to conduct a quantitative research approach to survey a larger sample from different industries, including different types of suppliers such as second-tier and third-tier suppliers or system providers.

4.3 Study No. 2

4.3.1 Introduction to Study No. 2

Information sharing in supply chains has attracted the attention of many researchers and practitioners in the last two decades. Wu et al. (2014) confirm that information sharing in supply chains indirectly affects firms' performance. In their study, Wu et al. (2014, p. 129) assert that supply chain collaboration mediates the effect of information sharing on the achievement of supply chain performance. Chu et al. (2012), Skipper and Hanna, (2009), and Closs et al. (2005) assert that information sharing is considered a crucial element to supply chain responsiveness. As shown in Chapter (2), the concept of responsiveness has been recognized as broad business strategy to cope with uncertainties, especially for those industries operating in agile supply chains in which demand volumes are volatile, such as the automotive industry. Research has suggested that "flexibility" is one of the most doable approaches to compete in agile supply chains in which many manufacturers and suppliers adopt flexibility as an operation strategy to cope with demand fluctuations.

An examination of the extant literature suggests that little is known about the relationship between information sharing and flexibility, especially at the first-tier supplier level in the automotive industry. This gap in the literature is reflected in two main areas. First, most studies have investigated the role of information sharing on the company's financial performance, but have not explored its effect on the operational performance such as delivery performance or responsiveness to fluctuation volumes. Second, most studies have focused on the OEMs' perspective (Duclos et al., 2003; Pujawan, 2004), but ignored the supplier perspective. Therefore, this study focuses on first-tier suppliers in the automotive industry.

Focusing on suppliers has been recognized as a new way to research supply chain management (Rota et al., 2002). Suppliers are responsible for 70% to 80% of the total value creation in the automotive industry (Bennett and Klug, 2012; Harrison and van Hoek, 2008). Additionally, according to a recent report from the FKG (2014), 60% of new technology comes from the suppliers, which implies that they invest as much as the

OEMs in R&D. Most importantly, first-tier suppliers possess some unique characteristics (compared to other tier suppliers) that make it difficult for them to respond to demand fluctuations. For instance, they usually lack information on demand forecasts due to the large number of last-minute changes received from OEMs or due to poor communication with OEMs regarding information on orders, shipment delivery schedules, or quantities. Furthermore, first-tier suppliers use minimum levels of buffers to avoid the high cost associated with holding stock in inventories. Besides, first-tier suppliers produce customized products while other tier suppliers produce standardized ones.

The automotive industry has been recently characterized by high volatile demand in which demand volumes are constantly fluctuating. Many professionals, consultants, and academicians have attributed the demand variability to the global financial crisis that affected many economies worldwide in 2008 (Campello et al., 2010; Cattaneo et al., 2010; Pavlínek and Ženka, 2010; and Dooley et al., 2010). Hence, the financial crisis has been the primary driver of fluctuating demand. Furthermore, the new environmental legislations, such as the Euro 6 legislation, are the second most important drivers of fluctuating demand. These legislations require changes (such as new design changes to the components of current or existing versions of engines, gearbox transmission, or other parts) in the production processes, which in turn create demand fluctuations for all business partners in the supply chain, especially first-tier and second-tier suppliers.

Drawing on that, the increasing concern of demand uncertainty in the automotive sector has created a need for highly responsive suppliers than ever before. Hence, in order to survive in the agile market, first-tier suppliers must be flexible enough to respond to such an environment at the operational level. However, they usually lack information on demand forecasts due to the large number of last-minute changes from the OEMs. Therefore, it would be difficult to predict the actual demand quantities. Furthermore, since a lot of value has been added to products, it is expensive for first-tier suppliers to use buffers as a strategy to enable responsiveness. Alternatively, first-tier suppliers may keep minimum levels of inventory and avoid the high cost of holding inventories by pursuing operations strategies such as MTO.

To address the aforementioned gaps, this study explores the role of information sharing as a new approach to enable the supplier volume and delivery flexibility. Particularly, the study explores the following research question: *What is the relationship between information sharing of OEMs' demand forecasts and inventory data, and suppliers' volume and delivery flexibility?*

The rest of this study is organized as follows. Section (4.3.2) provides a theoretical foundation for the study. Section (4.3.3) proposes a research model to relate four variables. In this model, five hypotheses are developed, followed by a theoretical operationalization of the constructs. Section (4.3.4) provides a detailed illustration of the methods for the survey design, data gathering, and data analysis techniques. Section (4.3.5) presents the main results and findings in light of the previous research. Finally, the study ends with Section (4.3.6) where the conclusions and implications of this research are presented.

4.3.2 Literature Review

For the purpose of reviewing, a brief literature review is provided in the following section. This review is extracted and presented from the literature review chapter (Chapter 2). The concepts and issues are comprehensively presented and discussed in the mentioned chapter (see Chapter 2). In this brief review, the focus is directed to develop theoretical arguments for the proposed measurement model presented in Figures (4.3) and (4.4) in this chapter.

4.3.2.1 Volume and Delivery Flexibility

Hult et al. (2006, p. 460) define responsiveness as a “product-specific action taken as a function of the knowledge generated and disseminated in logistics operations.” However, responsiveness is still a broad concept and can be defined in different ways. In this study, We focus on the study by, Holweg (2005, p. 605), who defines responsiveness as the “ability to react purposefully and within an appropriate time-scale to customer demand or changes in the marketplace, to bring about or maintain competitive advantage.” This definition suggests that a firm must possess certain

abilities to react quickly to changes in demand volumes. Such abilities refer to the manufacturing-flexibility capabilities that enable the supplier to manage production volumes and delivery schedules (increase or decrease production volumes) without a significant trade-off between time, cost, and quality of the products (Cousins et al., 2008).

This study limits the focus on only two main aspects of manufacturing flexibility—volume and delivery flexibility. Reichhart and Holweg (2007, p. 1147) provide a holistic view of the flexibility concept. They classify flexibility into two types—internal and external. Internal flexibility includes seven categories: Machinery, Material handling, Operations, Routing, Expansions, Program, and others. External flexibility, on the other hand, comprises four types—product, mix, volume, and delivery flexibility. In their model, they also relate flexibility to the “responsiveness” concept. They claim that product, mix, volume, and delivery flexibility constitute “responsiveness.”

Volume and delivery flexibility are key enablers of the responsiveness strategy. According to Christopher, (2000), they are key characteristics of an agile organization. In this regard, Reichhart and Holweg (2007) investigate the relationship between flexibility and responsiveness. In their study, they assert that responsiveness is only concerned with the external dimensions of flexibility (i.e., product, mix, volume, and delivery flexibility).

Duclos et al. (2003) provide an integrated conceptual model to analyze the components of supply chain flexibility. They claim that the flexibility strategy must go beyond a firm as supply chain management extends. Reichhart (2006) examines supply chain flexibility across multiple tiers. In particular, he investigates how flexibility propagates through the supply chain network. Based on his results, several research propositions were developed to link flexibility dimensions to product variety and modularity. His first research proposition is that flexibility dimension (i.e., types) can convert into each other, mix flexibility was found to transform into volume flexibility at various stages in the supply chain. He finds that this transformation can create severe constraints for the supply chain. His second research proposition is that flexibility levels fluctuate along the supply chain. He finds that the propagation of flexibility was subject to flexibility

increases or losses. His third research proposition is that the ratio of required to potential flexibility can vary in the same supply chain. In this regard, Reichharts' study is a rigorous attempt; it involves empirical investigations and data collected from multiple tiers (i.e., suppliers, manufacturers, and retailers).

Research has suggested that flexibility is a highly important competitive priority for those companies where demand is volatile, in which several studies argue that flexibility has been recognized as a key enabler for supply chain performance. For instance, Koste and Malhotra, (1999); Koste et al. (2004); and Narasimhan et al. (2004) emphasize that flexibility is essential in accommodating uncertainty. Competitive priorities refer to the strategic emphasis on developing certain manufacturing capabilities that either sustain or enhance a plant's position in the marketplace, and such emphasis may guide decisions regarding the production process, capacity, technology, planning, and control (Ward et al., 1998). Generally, competitive priorities are expressed in terms of at least four basic components—cost, quality, delivery, and flexibility (Cai and Yang, 2014; Díaz-Garrido et al., 2011; Boyer and Lewis, 2002; Ward et al., 1998). Hence, flexibility is considered part of the operations strategy for competitiveness. Several studies, such as Upton (1994), Upton, (1995), Sanchez (1995), Christopher (2000), Sánchez and Pérez (2005), and Gosling et al. (2010), argue that flexibility is a crucial element to increase the competitiveness of the company, especially for those companies operating in an unpredictable business environment (i.e., volatile market).

Nevertheless, flexibility requires considerable development in two main aspects: flexible technologies—information and communication technology (ICT) (Wu et al., 2014; Lotfi et al., 2013; Datta and Christopher, 2011; White et al., 2005). Flexible technology refers to flexible production systems (FPS). FPS is characterized by low set-up time, low switching time, rapid production, high product variety (Spear and Bowen, 1999), and high quantity. FPS helps accommodate various product quantities and varieties. Several studies, such as (Upton, 1994; Sanchez, 1995; Gosling et al., 2010; Christopher and Holweg, 2011; Povarava and Porovkova, 2012; Gosling et al., 2013; Purvis et al., 2014), have argued that flexibility is a crucial element to increase the competitiveness of a company in a volatile market. Similarly, IT systems facilitate the

information flow and exchange with customers and suppliers; allowing companies to share real-time data on demand forecasts, production schedules, inventory levels, and other kinds of information. For instance, EDI is one of the most powerful IT tools for exchanging data between different supply chain members (Min et al., 2005), such as business partners in the automotive and electronic industries. Nowadays, most purchasing and order transactions are completed via EDI or Internet-based systems such as real-time data exchange systems.

4.3.2.2 Information Sharing in Supply Chains

Usually, OEMs share their demand forecasts, production schedules, or inventory levels with their suppliers through different means. Thus, sharing of information can be accomplished by formal or informal means. Formal sharing of information is usually accomplished through EDI or other real-time data exchange systems through the Internet, or via e-mail or fax. Information sharing is a central element in any type of collaboration (Zhang and Chen, 2013). According to Zhou and Bentonjr (2007, p. 1351), “high performing firms had a higher percentage of information exchanged via EDI with customers and suppliers.”

Generally, information sharing is classified into two types—intra-firm and inter-firm information sharing. Intra-firm information sharing is between two or more departments within the firm; for instance, exchange of production schedules between the sales and production departments, or sharing the bill of material or between production and procurement, or procurement and executive management, executive management and sales, and so forth. Inter-firm information sharing is the external exchange of information between different supply chain members or organizations. According to Zhou and Bentonjr (2007), information content can be classified as that of suppliers, manufacturers, customers, distribution, and retailers. This study covers only one direction of inter-firm information sharing, which is the information that OEMs share with their first-tier suppliers. Information sharing is usually necessary to coordinate operations among different functions or departments within a firm. Depending on the type of contracts and relationships between OEMs and suppliers, the content of information to be shared as well as the way that information is being shared can vary.

Supply chain members, such as OEMs and suppliers, do exchange a huge amount of information every day or even every single hour. For instance, they may share and exchange information on product prices, product cost, product design, product specifications, stock levels, demand forecasts, sales forecasts, production quantities, product volumes, product delivery times, order status, and product delivery destinations (Lee and Whang, 2000). Although all types of information are essential for the decision-making process (Davenport and Beers, 1995; Chu and Lee, 2006), this study investigates only two types of information: sharing demand forecasts and inventory data. Demand forecasts refer to production schedules and customer orders of the final products (i.e., vehicles). They represent data on demand schedules and quantities over different time horizons. Depending on the product and industry, the demand forecasts can be seasonal, causal, or stable. It also can be short-term, mid-term, or long-term. Inventory data refers to the inventory level, safety stock, work-in-process, and buffers of the input materials (i.e., parts and components). Nevertheless, the quality of the information is considered a fundamental aspect of effective information sharing, meaning that the data must be reliable, accurate, available, complete, and updated frequently (Zhou and Benton, 2007). In fact, many OEMs overestimate or underestimate their actual demand and thus share inaccurate numbers with their suppliers. Inaccurate information could create scheduling problems (including problems in material and production planning) for first-tier suppliers, which in turn interrupt and perhaps delay the delivery schedules of the OEMs. Thus, OEMs must report any changes quickly and ensure that the forecast information contains no missing data.

4.3.3 Research Hypotheses and Model Conceptualization

4-3.3.1 Hypothesis Development

Yigitbasioglu (2010) confirms that information sharing improves buyers' performance with respect to resource usage, output, and flexibility. In addition, he finds that environmental and demand uncertainty, and interdependency can, to some degree, explain the extent of information shared between a buyer and key supplier. Despite its insights, Yigitbasioglu's study is a generic study on flexibility because it did not show

what types of flexibility have improved, or what kind of information sharing improves flexibility. Furthermore, demand uncertainty creates variations in all production systems (ODETTE, 2012). Hence, it is a common practice that the buyer firm (OEM) requests many changes concerning the quantity or delivery schedules of the ordered materials or components from suppliers. These changes often occur after placing the purchasing orders. Such changes require the supplier to increase or decrease production and reschedule production orders. When the OEM shares information demand forecasts and inventory data with the supplier, the latter can respond to changes quickly, allowing fulfilling the purchase orders within the requested time. Thus, this type of collaboration (i.e., information sharing between OEMs and suppliers) can also be beneficial to both the OEM and supplier. Based on the discussion on this aspect, five hypotheses are drawn to construct the model given in Figure (4.3).

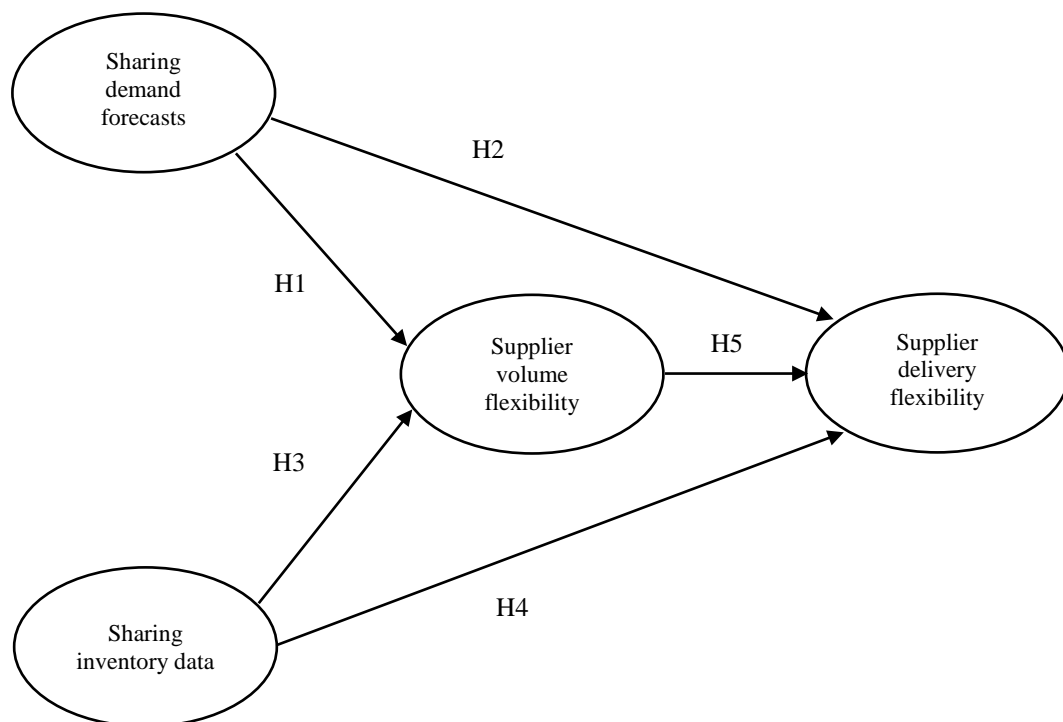


Figure 4.3: Research model and proposed hypotheses

Prajogo and Olhager (2012) confirm the positive relationship between information integration and logistics performance. In the automotive supply industry, the demand forecasts of car parts and components have a causal relationship as production of these components depends on the number of cars produced by the OEM. Thus, the demand

forecasts for the final products are one of the most important types of information that first-tier suppliers need to know in order to plan their own production and inventory.

Ojha et al. (2013, p. 2919) argue that “if customer demand increases and an organization does not have sufficient resources (i.e., volume flexibility) to meet the increased demand, then the lack of capability to meet the higher demand creates a backlog of orders. Backordering results in reduced average throughput time and fewer on-time deliveries.” Conversely, sharing excessive information with partners, according to Kembro et al. (2014) and Kim et al. (2006), could result in product delays, delivery problems, or inappropriate decisions. Suppliers either obtain the demand forecasts from their customers (OEMs) or they forecast demand on their own. If OEMs share demand forecasts with suppliers, the latter can then compute potential changes in components demanded by the OEM. Therefore, sharing demand forecasts can improve the ability of the supplier to respond to any change in the demand faster and utilize their capacity to accommodate the changes in product volume or delivery. Hence, two hypotheses (H1 and H2) are drawn, where:

- H1: Sharing demand forecasts positively affects supplier volume flexibility*
- H2: Sharing demand forecasts positively affects supplier delivery flexibility*

Inventory data involves safety stock, amount of finished products in stock, work in process, amount of raw material in the stock, out-of-stock status, reorder point, and reorder quantities. These types of data are critical for production planning, scheduling, and product delivery schedules. Lotfi et al. (2013, p. 300) highlight that: “*Partners like to share inventory information the most. This is because sharing inventory data can help going out of stock and stock repetition. It also reduces the total stock level and stock cost allowing more accurate forecasts and decisions to be made.*” However, the customer’s inventory data are not always available to the first-tier suppliers depending on the terms and conditions of supply agreement or on the nature of the business relationship between them. As shown in Study No. 1, sharing OEMs’ inventory data with first-tier suppliers may help the latter secure the required raw materials, plan their procurements, production schedules, number of working shifts, production capacity, and delivery schedules. Thus, one can argue that sharing inventory data between OEMs and

suppliers will improve the latter's delivery and volume flexibility. Hence, two hypotheses (H3 and H4) are drawn, where:

H3: Sharing inventory data positively affects supplier volume flexibility

H4: Sharing inventory data positively affects supplier delivery flexibility

Delivery flexibility is defined as the ability to change the planned or agreed delivery time and destination (Slack, 1987). Since the primary objective of supply chains is to meet customer needs, "inability of suppliers to deliver the required material, components, or products will have detrimental effects on the supply chain's ability to serve its customers" (Chen, et al., 2013, p. 2188). For example, delivering defective materials or components will require the supplier to do additional rework or reprocess, which results in delivery delay to the OEM orders, thereby increasing the production lead-time. However, when the supplier is able to change delivery times or destinations for the requested components, then the response performance in terms of product lead-time and transportation time will probably be improved.

Volume flexibility is the ability to increase or decrease the aggregated output of the system (Slack, 1987). According to Ndubisi et al. (2005), volume flexibility directly impacts customers' perceptions because it prevents out-of-stock conditions, especially for products that are suddenly in high demand. Demand uncertainty can create imbalance points among partners in a supply chain network. For instance, if the actual demand is higher than the forecasted demand, shortages occur. Conversely, if the actual demand is less than the forecasted demand, it results in excess inventory, obsolescence, inefficient capacity utilization or price breakdown, and inefficiency in the supply chain (Sodhi and Lee, 2007; Chen et al., 2013; Zhang and Chen, 2013). Considering this, the primary purpose of a supply chain is to match supply with demand (Cohen and Kunreuther, 2007). Accordingly, volume flexibility becomes an enabler to respond to changes in product delivery and fulfill OEM orders. Hence, the following hypothesis (H5) is drawn, where:

H5: Suppliers' volume flexibility positively affects their delivery flexibility

Following the above discussion, the next subsection presents the theoretical development of the proposed measurement model, which includes development of the variables and constructs of the model.

4.3.3.2 Conceptualization of the Proposed Model

All four constructs in the proposed model—“delivery flexibility,” “volume flexibility,” “level of information sharing on demand forecast,” and “level of information sharing on inventory data,” are presumed to have reflective indicators. The indicators used in this study were selected based on previous studies as well as evidence from practitioners (Rexhausen et al., 2012). The individual items, which were used to measure the constructs, are described in Figure (4.4). The constructs and their indicators are described below.

Delivery Flexibility

Delivery flexibility measures how quick a first-tier supplier responds to demand fluctuations in terms of delivery. Hence, delivery flexibility measures the ability of the supplier to change delivery schedules (i.e., delivery time, delivery data, and delivery place). This definition is based on Slack, (1987), who defines delivery flexibility as the ability to change the planned or agreed delivery time and destination. Despite its importance as a foundation of the concept, some studies claim that Slack’s definition is out-of-date as it does not reflect on the current logistical changes that surround the delivery flexibility of suppliers. Hence, the term may have to be updated to include other indicators. This study argues that the following measurement scales should be used to measure the level of delivery flexibility of a supplier: delivery load flexibility, delivery priority, delivery size flexibility, mode of transportation, and transportation time.

Delivery Load Flexibility

The delivery load has an impact on the delivery flexibility. Being able to mix different products into a single shipment indicates that delivery load would not be a constraint for the delivery promises to customers. This kind of flexibility allows the first-tier supplier to benefit from combining other products into the same consignment, which may result in significant cost and time saving in the logistic operations.

Delivery Priority

Delivery priority is also another important aspect of delivery flexibility. In this study, delivery priority refers to the ability of the first-tier supplier to prioritize delivery schedules. This capability requires categorizing customer orders and managing variations in production scheduling and material requirement planning as well. Prioritizing delivery schedules is a challenging task, and it may result in delaying delivery promises. Delaying delivery promises might result in disputes with customers or even require some penalties. Therefore, delivery priority is an indicator of how good a first-tier supplier is at managing the delivery process.

Delivery Size Flexibility

As explained earlier, we presume that product delivery is the sole responsibility of the first-tier supplier. Thus, we define *delivery size flexibility* as the ability of the first-tier supplier to deliver products in various batch sizes to customers. Being able to dispense various batch sizes into a single shipment indicates that the batch size would not be a constraint for the delivery promises to customers, which implies that the delivery process would be flexible.

Mode of Transportation

Many firms use fast modes of transportation to handle quick delivery and urgent orders. This allows for quick delivery of products, enabling flexible delivery schedules. Pujawan, (2004) used this indicator in his study as a measure of delivery flexibility of a supplier. According to Pujawan, (2004, p. 87), “a delivery system should be able to economically employ different modes of transportation, different delivery policies as well as different service level targets for each customer or customer segment.” Hence, regardless who is responsible for transporting the goods, it is fundamental for the supplier to be able to use fast modes of transportation when required, especially for urgent delivery orders (Kutanoglu and Lohiya, 2008).

Transportation Time

Transportation time refers to the time needed to ship the product to the customer’s premises. In some cases, it is the supplier’s responsibility to deliver the products to the

OEMs' factories, but in other cases, it is the customer's responsibility to pick up the products (parts or components) from the supplier's premises. In both cases, this activity is contracted to Third Party Logistics (TPL) providers who usually transport the products. TPL offers a range of logistic services such as fast delivery and special packaging. However, in this study, it is assumed that delivery is the responsibility of the supplier; hence, the shorter the transportation time, the more responsive the first-tier supplier will be. It is noteworthy that the transportation and delivery times are not the same. The transportation time refers to the time taken to transfer a product from two given nodes in the supply chain, for instance between the supplier and OEM sites. The delivery time, however, may include both transportation time and production lead-time.

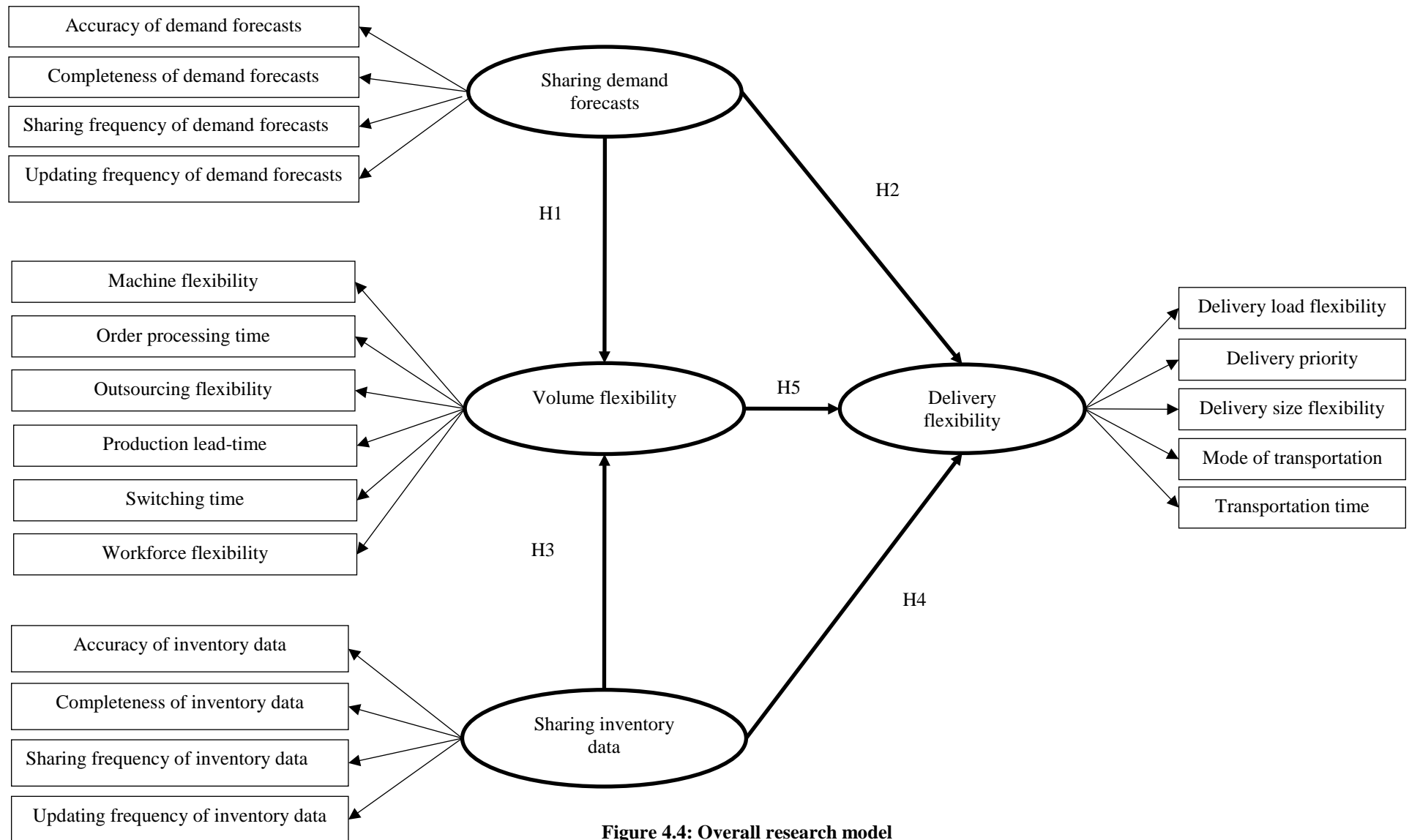


Figure 4.4: Overall research model

Volume Flexibility

Volume flexibility measures the ability of the supplier to react to the fluctuating demand by increasing or decreasing the production volumes. Fundamentally, the ability of the production system to operate profitably under inconstant demand volumes is related to the optimal utilization of the total production capacity. Hence, the greater the production flexibility, the higher is the level of volume flexibility that can be reached. Hence, this study argues that the following measurement scales are used to measure the level of volume flexibility of a supplier: Machine flexibility, Order-processing time, Outsourcing flexibility, Production lead-time, Switching time, and Workforce flexibility.

Machine Flexibility

It is the ability of the production machines themselves to operate in various production scenarios in terms of increasing or decreasing production volumes. In other words, production machines are able to accommodate any sudden change in demand by adapting its production capacity accordingly. Nowadays, many suppliers and manufacturers use modern machines such as Industrial robots, Computer Numerical Control (CNC), Computer Aided Design (CAD), and Computer Aided Manufacturing (CAM) in their manufacturing facilities. These technologies and other types of automated machines can handle sophisticated tasks easily, and offer high flexibility in terms of production volumes and product customization. Besides, these types of machines can be reprogrammed or reconfigured to accomplish different tasks; for instance, some robot arms are equipped with multi-task manipulators used for welding, drilling, painting, or holding. Accordingly, a flexible machine is a principal contributor to realizing volume flexibility.

Order Processing Time

It is the time required to process the order (i.e., time from receiving the purchasing orders to releasing the corresponding production order). Thus, the order processing time is related to how well administrative workers are performing. It also offers an indication of how fast the white-collar employees (in sales and purchasing departments) are in

dealing with orders; changes in quantities, specifications, prices; and negotiation with customers and second-tier suppliers. The shorter the order-processing time, the more responsiveness the first-tier supplier will achieve.

Outsourcing Flexibility

This is the ability of first-tier suppliers to outsource production of some product quantities when they are unable to satisfy the sudden increase in the demand. For instance, when first-tier suppliers receive orders beyond their total capacity, they may need to outsource the out-of-capacity orders to another supplier, called Contract Manufacturer (CM). Usually, this kind of outsourcing is uncommon in the automotive industry, but if it happens, the outsourcing decision is taken together (in agreement) with the customer, implying that the OEM shall approve the contracted supplier, outsourced quantity, quality, and delivery time. Outsourcing flexibility depends on whether the first-tier supplier has strong partnership agreements with other competitors (i.e., other first-tier suppliers who produce and sell similar products). It also depends on the relationship with the OEMs and of course on the terms and conditions of the contract between the OEM and the first-tier supplier. Consequently, outsourcing flexibility helps realize volume flexibility when the volumes are unexpectedly increased, but it does not help when the demand decreases. It is worth noting that the concept of outsourcing flexibility should not be confused with the classical meaning of outsourcing as a strategic decision. In this study, outsourcing flexibility is considered a short-term capability.

Production-Lead Time

It is the time needed to produce a single unit of the product. It encompasses the time elapsed in production or manufacturing processes such as cutting, welding, drilling, turning, molding, assembly, packaging, etc. This time aspect may depend on various factors including the production capacity, number of available machines, number of workers, number of working shifts, complexity of the product, and the layout of the factory. Numerous management tools, such as Lean Production; JIT; Single-Piece Flow (SPF), and Value-Stream-Mapping (VSM), have been used by manufacturing firms

(i.e., OEMs and suppliers) to reduce the production lead-time. Thus, the shorter the lead-time, the more responsiveness the first-tier supplier will achieve.

Switching-Time

It is the time needed to switch production from one product to another; it can also include the set-up time for machines, calibration time, and the machine warm-up time when starting operation. Switching-time is related to the type of technology first-tier suppliers use in their own factory. Nowadays, many manufacturing companies adopt modern technology and machines in their factories, such as Flexible Manufacturing Systems (FMS). FMSs provide flexibility in producing different volumes and different products, with substantially short switching-time. The shorter the switching time (the machines have), the more responsiveness the first-tier supplier will achieve.

Workforce Flexibility

It refers to the ability of the first-tier supplier to increase or decrease the number of employees in accordance with the demand fluctuations. Usually, these employees are blue-collar workers operating as temporary labor. They work only when the demand is at a stage when their help is needed. Typically, manufacturing plants have a constant ratio of temporary workers to be used during periods of fluctuating demand. In our study, the results show that 67% of the suppliers use temporary labor in their manufacturing facilities to cope with fluctuating demand, and the average ratio of temporary workers is 12.5%. In conclusion, suppliers use temporary workers not only to reduce the operational cost associated with production, but also to realize volume flexibility targets.

Sharing Demand Forecasts

“Sharing demand forecasts” measures the level of information sharing on demand information between an OEM and a first-tier supplier. In this study, demand information refers to the OEM’s demand forecast volumes, which have been shared with the first-tier supplier. This construct is measured by averaging the items, in which each item is measured on a five-point Likert scale. These items are data accuracy, data

completeness, frequency of sharing data, data updating frequency, availability, and sharing speed of data.

Accuracy of Demand Forecast

It refers to the degree of correctness of the demand schedules. The accuracy of such data is an important aspect of information sharing on demand forecasts. Inaccurate demand schedules may negatively affect the supplier's production schedules. The accuracy of demand schedules is usually measured by forecasting error, which is generally defined as the difference between the actual and predicted demand over a certain period. If the forecasting error is high, then there is a high risk that the data is inaccurate.

Completeness of Demand Forecasts

It implies that the data are not missing any information on demand. In other words, demand forecasts, which are being shared with first-tier suppliers, shall include all expected quantities, corresponding production schedules, with a certain error margin for a certain period. This aspect helps improve the reliability of the information sharing process.

Sharing Frequency of Demand Forecasts

It denotes how often OEMs share their demand forecasts with their first-tier suppliers. Some OEMs share their data on a daily, weekly, or monthly basis, while some companies do not share at all. Hence, the more frequently OEMs share their information on demand forecasts with the suppliers, the better the quality of the information sharing process might be. In the automotive industry, demand forecasts, production schedules, and purchasing orders are generally shared using the EDI databases, which allow for fast (and secure) interchange of real-time data.

However, some companies (i.e., OEMs and suppliers) do not use the EDI technology; alternatively, they use e-mail or fax to communicate with each other. Regardless of how they share their data, the faster the communication, the better is the quality of the information sharing process. In this respect, Zhou and Benton (2007, p. 1351) specify

that “high performing firms had a higher percentage of information exchanged via EDI with customers and suppliers.” It is worth noting that if the data being shared is complete, shared very often, updated frequently, and shared on a real-time basis, it does not mean that the data is accurate; rather, it means that the quality of the sharing process is acceptable.

Updating Frequency of Demand Forecasts

Updating demand forecasts can be another important indicator of the level of information sharing. For instance, sharing up-to-date demand forecasts with suppliers frequently could affect the significance of the information sharing. It measures the level of availability and freshness of data. Data must be available whenever it is needed. Suppliers have different processes, products, production schedules, delivery schedules, cash cycles, and even MRP systems. For instance, the supplier X may require demand forecasts in week 17 while supplier Y may need the same demand forecasts in week 23 or supplier Z may need the demand schedules in week 43. Therefore, OEMs should make the data available to suppliers all the time. Hence, updating the frequency can be an indicator of the level of information sharing on demand forecasts.

Sharing Inventory Data

Similarly, the same logic applies to “sharing inventory data.” Sharing inventory data measures the level of information sharing on inventory information between an OEM and a first-tier supplier. In this study, the inventory data refers to the OEM’s inventory level, safety stock, reorder point, and economic order quantity, which have been shared with the first-tier supplier. Since the flow of both kinds of information is the same, the same latent variables will be used to measure information sharing on inventory data. Therefore, this construct is also measured by averaging four items (i.e., variables), in which each item is also measured on a five-point Likert scale. These items are accuracy of inventory data, completeness of inventory data, sharing frequency of inventory data, and updating frequency of inventory data. Table (4.8) summarizes the proposed indicators and constructs based on the understanding and examination of some previous studies in the literature.

Table 4.8: Operationalization of the model constructs

Item No.	Indicator	Literature references	Belong to construct
Q1	Delivery load flexibility	(Pujawan, 2004), (Shin et al., 2000)	Delivery flexibility
Q2	Delivery priority	(Li et al., 2006), (Gerwin, 1993)	
Q3	Delivery size flexibility	(Pujawan, 2004), (Jin et al., 2014)	
Q4	Fast mode transportation	(Kutanoglu and Lohiya, 2008), (Bagchi et al., 2005) (Pujawan, 2004) , (Rota et al., 2002), (Cooper et al., 1997)	
Q5	Transportation time	(Reichhart and Holweg, 2007), (Tachizawa and Thomsen, 2007), (Rota et al., 2002)	
Q6	Machine flexibility	(Gong, 2008), (Chang et al., 2003), (Das, 2011), (Jin et al., 2014)	Volume flexibility
Q7	Order processing time	(Byrne and Heavey, 2006), (Ngamsirijit, 2008), (Shieh, 2010), (Lu et al., 2006), (Moattar Hussein et al., 2006)	
Q8	Outsourcing flexibility	(Dabhilkar and Bengtsson, 2008), (More and Babu, 2009), (Chang et al., 2006)	
Q9	Production lead-time	(Moattar Hussein et al., 2006), (Shin et al., 2000), (Yu et al., 2010), (Narasimhan et al., 2004)	
Q10	Switching time	(Moattar Hussein et al., 2006), (Reichhart and Holweg, 2007), (Prater et al., 2001), (Vokurka and O'Leary-Kelly, 2000), (Alexopoulos et al., 2005)	
Q11	Workforce flexibility	(Raturi and Jack, 2004), (Sawhney, 2006), (Ward et al., 1998), (Oke, 2013)	Sharing demand forecast
Q12	Accuracy of demand forecast	(Barut et al., 2002), (Childerhouse et al., 2003), (Yu et al., 2010), (Yigitbasioglu, 2010), (Wong and Hvolby, 2007), (Jin et al., 2014), (Wu et al., 2014)	
Q13	Completeness of demand forecast	(Zhou and Benton, 2007), (Wu et al., 2014)	
Q14	Sharing frequency of demand forecast	(Jin et al., 2014), (Wu et al., 2014)	
Q15	Updating frequency of demand forecast	(Wu et al., 2014), (Yigitbasioglu, 2010)	Sharing inventory data
Q16	Accuracy of inventory data	(Jin et al., 2014), (Carr and Smeltzer, 2002), (Wu et al., 2014), (Yigitbasioglu, 2010)	
Q17	Completeness of inventory data	(Zhou and Benton, 2007), (Wu et al., 2014)	
Q18	Sharing frequency of inventory data	(Jin et al., 2014), (Wu et al., 2014)	
Q19	Updating frequency of inventory data	(Jin et al., 2014), (Wu et al., 2014), (Yigitbasioglu, 2010)	

4.3.4 Methodology

The following subsections provide an overview of the design issues and methods used to collect and analyze the empirical data.

4.3.4.1 Survey Design and Instrumentation

To test the hypotheses of the research model, a web-based survey was designed. The questionnaire comprises two main parts. The first part comprised 19 questions; all rated on a five-point Likert scale. These questions were developed based on an understanding of the preceding literature review. The first part contains questions about the supplier operations; logistics and production flexibility capabilities; and delivery performance in terms of the delivery time, lead-time, and response time. It also contains questions about information sharing on demand forecasts and inventory data, such as the method and level of information sharing, frequency of information sharing, and accuracy of the information. The questions are used to develop multi-item reflective measures for the four constructs of the research model—“sharing demand forecasts,” “sharing inventory data,” “supplier volume flexibility,” and “supplier delivery flexibility.” Since the unit of analysis is the supplier’s main business unit, the second part of the survey covers general questions on the supplier’s main business unit, in which the respondents were asked to reply on behalf of the supplier and not as individuals. This part includes six general questions about the supplier size and supplier tier-category, respondent job role, and work experience (as measured by the number of years). In total, the survey comprised 26 different questions.

To ensure that respondents understand the survey questions correctly, the first draft of the questionnaire was forwarded to six experts to review the wording, length, and consistency of the questions for ensuring correct interpretation by the readers. These experts include two professors in operations strategy and four professionals in the automotive industry. This step aims to increase the content validity of the questionnaire items (Pallant, 2011). Content validity is defined as the extent to which the measure encapsulates the concept being measured, as seen by the experts. Therefore, the survey questions were revised accordingly to eliminate any ambiguity that may affect their understanding.

Generally, the reliability of a questionnaire represents how consistently individuals respond to a set of questions. Thus, a measure is defined to be reliable if it produces a consistent score from one occasion to another. Using SPSS, the “Corrected Item Total Correlation” test was considered to check if any item in the questionnaire is inconsistent with the average behavior of other items. A value equal to or greater than 0.3 is considered a good indication of an item’s reliability (Field, 2013, p. 713; Pallant, 2011, p. 100). The results obtained show that all questionnaire items are above the threshold, and hence no item was discarded. The questionnaire is shown in Appendix (B).

4.3.4.2 Target Population

This study focuses on first-tier suppliers in the automotive industry in Sweden. The Swedish automotive industry is considered an important part of the economy of Sweden. As mentioned in Chapter 1, the FKG report indicates that there are a total of 1000 to 1100 suppliers in Sweden, of which 50% are classified as small companies (i.e., having less than 3 million €turnover).

4.3.4.3 Sampling

The membership list of the FKG provides the sampling frame for this study. There are in total only 203 suppliers that are of interest (i.e., they are mostly first-tier suppliers that produce/assemble and deliver physical products and/or systems to OEMs). Hence, the online survey was forwarded to 203 suppliers located in Sweden. The e-mailing list was obtained from the official webpage of FKG. Since the unit of analysis is the supplier’s main business unit, the target respondents for these firms would be the plant manager, general managers, managing directors, production manager, and supply chain or sales executives. Individuals in these positions are familiar with the operational issues such as the firm’s operations strategy, information exchange within the supply chain, and delivery performance. The names and e-mail addresses of the contacts were obtained from a list published on the FKG website. This survey was conducted during the period of January to March in 2014.

The sample obtained comprised 52 responses (i.e., cases or observations). This sample was used to fit the research model depicted in Figure (4.4). It was determined by means of a sensitivity analysis, using the G*Power 3.1 software, that a sample of 52 will

achieve a power of 80% in detecting an R-Square of 0.16 or more with a level of significance of 5%. Furthermore, according to exhibit (1.7) shown in (Hair et al., 2013), the minimum recommended sample size to use PLS-SEM for a static power of 80% at a significance level of 5% and R^2 of 0.50 is 45, given that the maximum number of arrows pointing to a construct is 5. Hence, our sample size of 52 can be suitable for using PLS-SEM.

4.3.4.4 Data Collection and Response Rate

An invitation letter along with a brief summary of the survey's objectives and the web-link of the questionnaire were e-mailed to one senior manager of each firm. Since the unit of analysis is the supplier's main factory, it is believed that the targeted senior managers can represent the following positions: plant manager, general manager, managing director, production manager, supply chain manager, and sales or operations manager. In total, 55 responses were collected, among which three were judged as incomplete, and thus excluded from the analysis. Hence, the effective response rate is 25.6%. In business surveys, where general managers or CEOs have limited time to answer a survey and given the fact that web-based surveys usually have poor response rates, this percentage is considered adequate for the analysis. Petchenik and Watermolen (2011) and Archer, (2008) highlight the average response rates of the online surveys as 11%, which is less than that of mail and phone surveys. Furthermore, many similar studies such as Yigitbasioglu (2010), Bagchi et al. (2007), and Bagchi et al. (2005) obtained comparable or even lower response rates from Sweden or Scandinavia in general.

4.3.5 Results and Discussion

The data analysis involved the following types of analysis: First, profiling the descriptive statistics of the sample. This includes analyzing the frequencies of the respondents to the questionnaire in terms of the company size, respondent's designation and work experience. Second, testing and validating the model using PLS-SEM. This includes estimating the parameters of the research model, verifying the reliability and validity of the constructs, and testing the hypotheses of the model.

4.3.5.1 Sample Characteristics

Based on the statistical descriptive analysis of the empirical data, Table (4.9) summarizes the sample characteristics. The results show that 26.9% of the sample comprises small-sized companies, 48.1% are medium-sized, and 25.0% are large-sized enterprises. This indicates that majority of the respondents are medium-sized suppliers.

Table 4.9: Profile of the sample

Company size (no. of employees)	Frequency	Percentage
Less than 50	14	26.9
50 to 250	25	48.1
More than 250	13	25.0
Respondent's job role		
Top management	25	48.1
Sales/Marketing/Customer services	16	30.8
Production/Inventory/Logistics	9	17.3
Finance/Purchasing/Strategic planning	2	3.8
Experience (in years)		
1 to 5	2	3.8
6 to 10	6	11.5
11 to 15	8	15.4
More than 15	36	69.2
Total	52	100

The company size was measured based on the total number of employees of the supplier using the European Union categorization. A company with 1-50 employees is considered a small company, with 50-250 employees is considered a medium company, and greater than 250 is considered a large company (Directorate General for Internal Market, Industry, Entrepreneurship, and SMEs- European Commission, 2014). Regarding the respondents' position, 48.1% are top management executives (i.e., general managers, CEOs, managing directors, president, and vice presidents), 30.8% are sales and marketing executives, 17.3% are production managers or logistics managers, and 3.8% are financial or purchasing managers. Accordingly, the analysis demonstrates that approximately 69% of the respondents have more than 15 years of practical experience in the automotive supply industry while only 4% have an experience of less than five years. These results confirm that respondents were qualified enough to answer the survey questionnaire correctly.

Method biases are one of main sources of measurement errors, which may result in inaccurate conclusions (Podsakoff et al., 2003, p. 879). Therefore, it is important to check the common method bias problem in this study. Common method bias was checked using Harman's single factor test for common method bias. Harman's single-factor test is a widely used technique by researchers to address the issue of common method variance. With the help of the SPSS software, the test is done using the exploratory factor analysis procedure by examining the unrotated solution when all variables are loaded on one single factor (Aulakh and Gencturk, 2000). The results show that the extraction sum of squared loadings of the single factor is explained by 34.9% of the variance. Hence, no substantial extent of common method variance is present (Aulakh and Gencturk, 2000). Thus, the results suggest that common method variance is not of great concern.

4.3.5.2 Testing and Validation of the Research Model

SEM is an advanced multivariate statistical technique that is widely applied to estimate complex conceptual models in the areas of social and business research (Ronald and Raschke, 2007). The literature suggests two types of SEM: Covariance Based Structural Equation Modeling (CB-SEM) and PLS-SEM. The use of PLS-SEM has a long history in management information research (Ringle et al., 2012). Hair et al. (2011), clarify the distinction between the two techniques. They highlight that CB-SEM is used when the research objective is to test and confirm the theoretical relationships between constructs, while PLS-SEM is more appropriate when the research objective is to predict and develop theories. Furthermore, PLS is a nonparametric estimation procedure in which "its conceptual core is based on an iterative combination of principal components analysis relating measures to constructs and path analysis capturing the structural model of constructs" (Eggert and Serdaroglu, 2011, p. 175). Nonparametric estimation implies that PLS is useful when the distribution is not normal, and sample size is small.

Since our sample is relatively small, it is not possible to use CB-SEM. In general, it is not advisable to use CB-SEM when the sample size is less than 100. Some scholars argue that the sample size should be at least 200 in order to use CB-SEM. Hence, following the logic of PLS, this study employs the PLS-SEM technique.

In this study, the PLS-SEM analysis involved two steps: 1) Assessment of the constructs by using the measurement model, which includes reliability and validity analysis, 2) Fitting of the structure model, which includes path analysis, and estimation of the model parameters. The data analysis involved the use of Smart PLS 3.2.1 software package.

4.3.5.3 Measurement Model: Reliability and Validity Analysis

Reliability and validity of the constructs are fundamental statistics that must be considered when assessing reflective measurement models (Hair et al., 2011). The aim of this step is to examine the internal consistency and validity of the constructs of the model. The internal consistency is assessed by Cronbach's Alpha and composite reliability while the validity is assessed using convergent and discriminant validity tests. The reliability of the constructs can be measured using reliability statistics such as Cronbach's Alpha and Composite reliability coefficients. Cronbach's Alpha is one of the most widely used tests for measuring internal consistency of the constructs. As a rule of thumb, a Cronbach's Alpha of a value greater than 0.7 is a good indicator of reliability (Hair et al., 2009). The results reported in Table (4.10) show that all constructs are reliable since Cronbach's Alpha values are above the 0.7 threshold. Hence, the results indicate acceptable internal consistency of the indicators.

Composite reliability is also used to estimate the internal consistency of a construct in which it "prioritizes indicators according to their reliability during model estimation, making it more suitable for PLS-SEM" (Hair et al., 2011, p. 145). Generally, a value of 0.7 or greater is considered a good indication of composite reliability. The composite reliability is also reported to verify the internal consistency of the constructs. The results reported in Table (4.10) show that the composite reliability values are greater than the threshold of 0.7 for the constructs. Therefore, the reliability of the constructs is confirmed.

Table 4.10: Results of reliability and validity analysis

Construct	R ²	Cronbach's Alpha (α)	Composite Reliability	AVE
Delivery flexibility	0.733	0.841	0.891	0.626
Volume flexibility	0.177	0.817	0.866	0.523
Sharing demand forecasts		0.784	0.859	0.603
Sharing inventory data		0.954	0.961	0.859

The validity of the measurement is an important aspect that must be considered. Convergent validity and discriminant validity analysis are commonly used measures to quantitatively assess the validity of indicators and their constructs in the model. Convergent validity is defined as “the extent to which a measure correlates positively with alternative measures of the same construct” (Hair et al., 2013, p. 102). The convergent validity of a construct provides an assessment of how well the indicators of a construct are correlated with its “own” construct (i.e., the item reliabilities).

The convergent validity test demonstrates how an indicator correlates positively with alternative indicators of the same construct by observing the values of the outer loadings. The convergent validity is verified by observing the Average Variance Extracted (AVE) or sometimes referred as to Fornell and Larcker’s Test. The rule of thumb is that if AVE is equal to or greater than 0.5, then it indicates good validity of the construct (Bagozzi and Yi, 1988). The results shown in Table (4.10) indicate acceptable levels of convergent validity for the constructs: delivery flexibility (AVE=0.626), volume flexibility (AVE=0.523), sharing demand forecasts (AVE=0.603), and sharing inventory data (AVE=0.859). Hence, the convergent validity is confirmed.

Discriminant validity refers to how well the indicators of a construct are correlated with those of other constructs in the research model. According to Fornell and Larcker (1981), the discriminant validity, for a construct, can be established by calculating the square root of the AVE of the construct and then comparing this construct AVE to its correlations with the other constructs in the research model. As a rule of thumb, the value should be larger than other correlation values between the latent variables. By comparing the AVE square root values with other correlation values among the latent

variables, the results shown in Table (4.11) indicate that discriminant validity is well established.

Table 4.11: Discriminant validity check (Square root of AVE is shown on the diagonal in bold)

Construct	Delivery flexibility	Sharing demand forecasts	Sharing inventory data	Volume flexibility
Delivery flexibility	0.791			
Sharing demand forecasts	0.657	0.776		
Sharing inventory data	0.202	0.197	0.927	
Volume flexibility	0.767	0.419	0.055	0.723

Table (4.12) summarizes the PLS estimation of the measurement model. The factor loadings of the reflective indicators imply an acceptable level of validity of the outer model. The loadings, which are reported in Table (4.12), were obtained by calculating the PLS algorithm with the default settings of 300 iterations and Path analysis as the weighting scheme.

The outer loading values were obtained by the “Path Analysis Procedure.” There are several rules of thumb depending on the discipline and type of research. In general, a value equal to or greater than 0.7 is preferred (Hair et al., 2013). However, a value of 0.4 or higher is acceptable for an exploratory research (Hulland, 1999). Since this study is considered an exploratory research, the 0.4 rule of thumb is used to assess the reliability of the indicators. The results confirm that all indicators have loadings higher than 0.4, which signify an accepted level of reliability.

The results also confirm that the indicators have loaded on the proposed factors. It is important to explore the outer model by checking the T-statistic. If the T-statistics are greater than 1.96, the outer model loadings are highly significant. As shown in Table (4.12), all indicators are highly significant.

Table 4.12: Estimation of outer model (i.e., Measurement model)

Constructs and indicators	Outer loadings	
	Point estimation	T-values
1 Delivery flexibility ($\alpha=0.841$, AVE=0.626, CR=0.891)		
Delivery load flexibility	0.897	26.214
Delivery priority	0.793	16.560
Delivery size flexibility	0.895	32.710
Fast mode transportation	0.763	11.943
Transportation time	0.558	4.145
2 Volume flexibility ($\alpha=0.817$, AVE=0.523, CR=0.866)		
Machine flexibility	0.743	9.351
Order processing time	0.745	4.585
Outsourcing flexibility	0.823	13.743
Production lead time	0.730	4.383
Switching time	0.528	3.317
Workforce flexibility	0.738	9.958
3 Sharing demand forecasts ($\alpha=0.784$, AVE=0.603, CR=0.859)		
Accuracy of demand forecasts	0.774	12.184
Completeness of demand forecasts	0.769	11.856
Sharing frequency of demand forecasts	0.781	11.530
Updating frequency of demand forecasts	0.781	11.110
4. Sharing inventory data ($\alpha=0.954$, AVE=0.859, CR=0.961)		
Accuracy of inventory data	0.902	4.200
Completeness of inventory data	0.955	4.575
Sharing frequency of inventory data	0.899	4.189
Updating frequency of inventory data	0.951	3.415

α : Cronbach's Alpha; AVE: Average Variance Extracted; CR: Composite Reliability

4.3.5.4 Structural Model

As shown in Figure (4.5), with the coefficient of determination, R^2 being 0.733 implies that 73.3% of the variance in the “delivery flexibility” latent variable can be explained by the three latent variables “volume flexibility,” “sharing demand forecasts” and “sharing inventory data.” The inner model suggests that “volume flexibility” has the strongest effect on “delivery flexibility” (0.600), followed by “sharing demand forecasts” (0.387), and “sharing inventory data” (0.093).

To complete the examination of the inner model, it is important to verify the path coefficient sizes and statistical significance of the relationships between the latent variables in the structural model. This verification was done by observing the standardized path coefficient (B values) equal to or greater than 0.1 (Eggert and

Serdaroglu, 2011), where a relationship can be considered “statistically significant” if the t-value is equal to or greater than 1.96 at a significance level of 5% (where 1.96 is the two-tailed level of significance). The t-values are obtained through the bootstrapping procedure, which comprises 500 subsamples as the default setting (Hair et al., 2013). The results obtained by the bootstrapping procedure are shown in Figure (4.6).

Observing the standardized path coefficients (B values), T-statistics, and P-values of the inner model given in Table (4.13), the results confirm that “sharing demand forecasts” has a significant positive impact on both “volume flexibility” (B=0.425 and t=3.855) and “delivery flexibility” (B=0.387 and t=5.201). However, “sharing inventory data” has a small negative impact on “volume flexibility” (B=-0.029) but not significant because the t-value is 0.170, and a small positive impact on “delivery flexibility” (B=0.093) but not significant because the t-value is 0.960 (i.e., between -2 and 2 is not significant). The results also confirm that “volume flexibility” has a significant positive influence on “delivery flexibility” (B=0.600 and t=8.152).

Table 4.13: Results of the model fit and hypothesis testing

Relationship	Coefficient (original sample)	Standard error	Significance			Conclusion
			t-value	T- statistics	P- value	
Sharing demand forecasts => Volume flexibility	0.425	0.105	3.855	4.053	0.000	H1 is supported
Sharing demand forecasts => Delivery flexibility	0.387	0.073	5.201	5.271	0.000	H2 is supported
Sharing inventory data => Volume flexibility	-0.029	0.165	0.170	0.175	0.861	H3 is not supported
Sharing inventory data => Delivery flexibility	0.093	0.091	0.960	1.023	0.307	H4 is not supported
Volume flexibility => Delivery flexibility	0.600	0.068	8.152	8.832	0.000	H5 is supported

Given the results of the structural model (i.e., the inner model), it can be concluded that “volume flexibility” and “sharing demand forecasts” are both strong predictors of “delivery flexibility,” but sharing inventory data does not predict “delivery flexibility” directly.

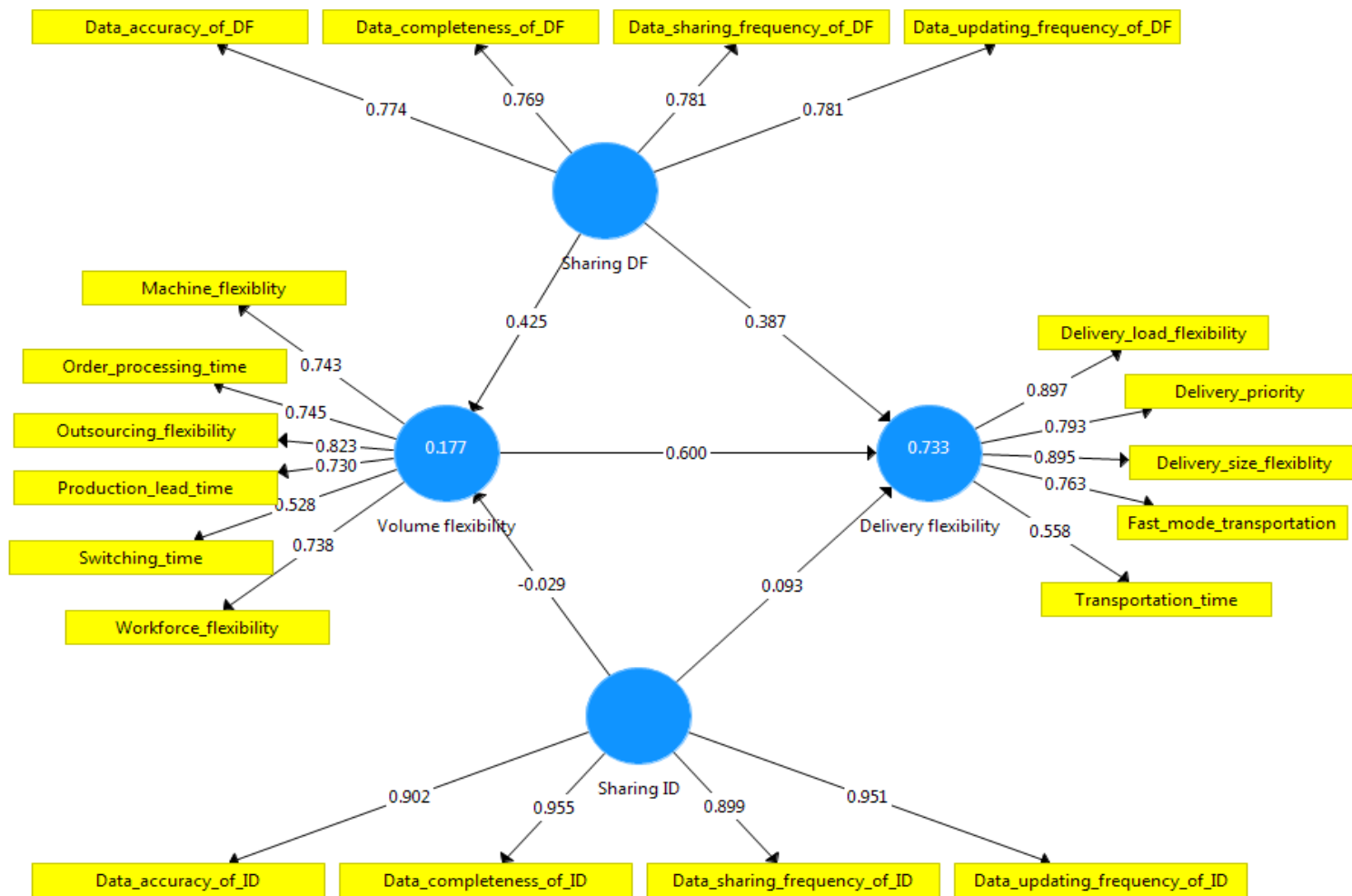


Figure 4.5: PLS path-modeling estimation of the research model

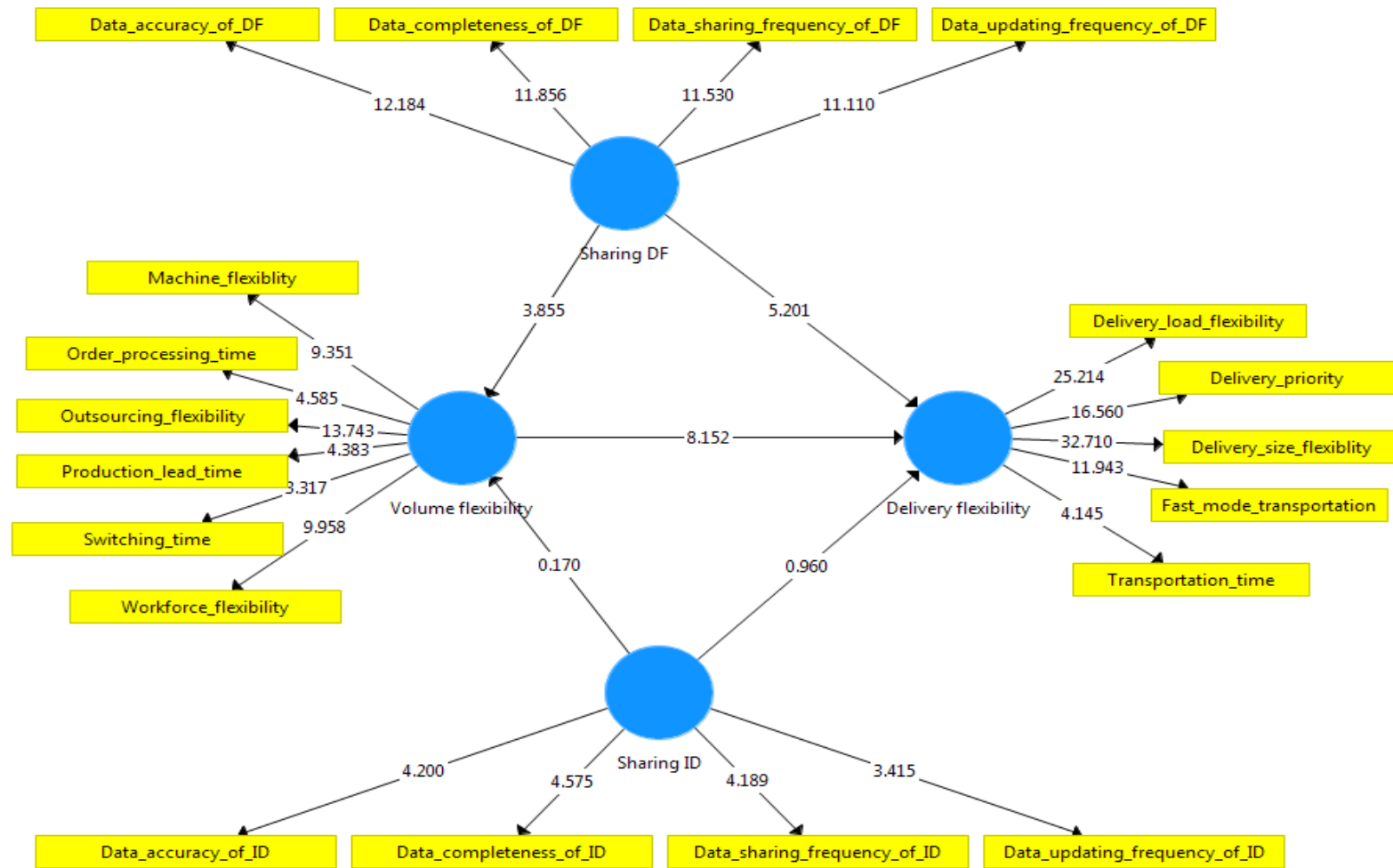


Figure 4.6: Model fit estimation using bootstrapping procedure

Observing the results given in Tables (4.13), the analysis confirms that H1, H2, and H5 are supported. However, H3 and H4 are not supported. A potential justification for this finding is the inventory data, which includes safety stock level, reorder quantity, and reorder point, is usually embedded in the demand forecast calculations. For example, if future demand is perfectly known, the reorder point is equal to the total forecasted demand during the lead-time period. As depicted in Figure (4.7), Dickersbach and Passon (2015, p. 139) highlight that:

“Most of the service parts—especially in the automotive and engineering industries—have an immediate demand, i.e., the service part has to be in stock. Since the forecast is always just an estimation of the future demand, it is necessary to compensate the deviations from the real demand (and the irregularities of the supply) by safety stock.”

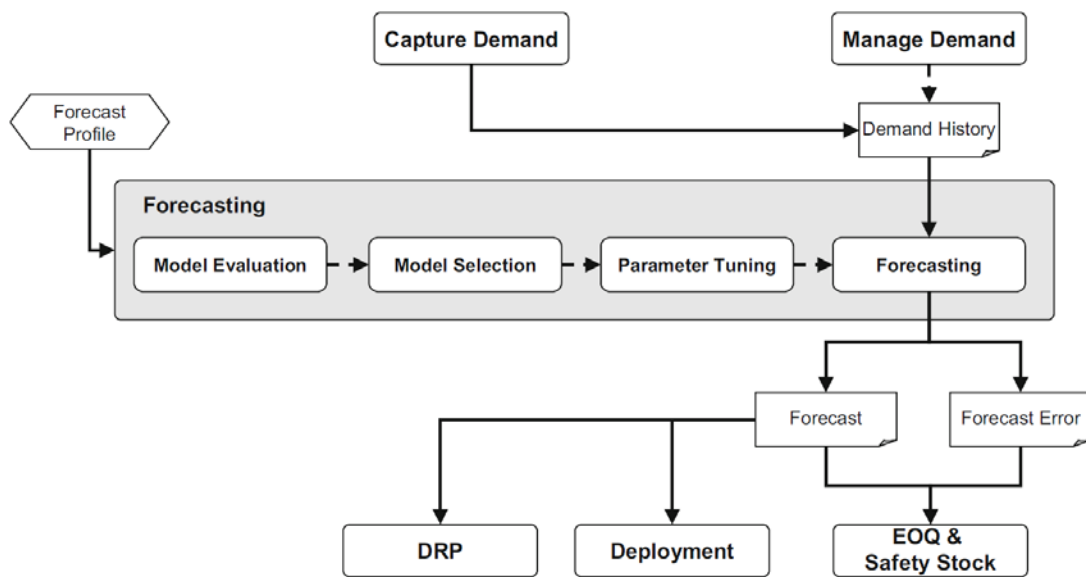


Figure 4.7: Depiction of the demand forecasting process (Source: Dickersbach and Passon, 2015, p. 81)

In this regard, (Oracle, 2013) also emphasized that Material Requirements Planning (MRP) including safety stock, inventory levels, and Economic Order Quantity (EOQ) for all components and subassemblies are outputs to the forecasting system, which generates demand projections. Hence, inventory data is manifested in calculating demand forecasts. This justifies why “sharing inventory data” does not directly affect

volume flexibility (hypothesis H3) or delivery flexibility (hypothesis H4). When an OEM shares demand forecasts with suppliers, the inventory data are already embedded in the demand forecasts.

4.3.6 Conclusions and Implications

The aim of this study is to explore how information sharing can improve suppliers' delivery performance in terms of responsiveness to fluctuating demand. The study proposed a research model to analyze the relationship between two types of information shared with suppliers "sharing demand forecasts" and "sharing inventory data" in relation to two types of manufacturing flexibility, "volume flexibility" and "delivery flexibility." Empirical data were collected from a sample of 52 suppliers among the automotive suppliers in Sweden through a web-based survey questionnaire. The model and subsequent hypotheses were tested through the PLS-SEM technique using the Smart PLS 3.2.1 Software package. IBM SPSS 21.0 software package was also used to conduct some preliminary descriptive and factor analysis.

Effective information sharing has been a critical issue in achieving supply chain performance. Although there is abundant research on the role of information sharing in supply chains, it has not been fully integrated into the supplier flexibility. The study contributes to the body of knowledge by developing four factors to measure the level of information sharing on "demand forecasts" and "inventory data" and suppliers' "volume flexibility," and "delivery flexibility." The important factors that lead to "delivery flexibility" are identified. As shown in the analysis, suppliers are found to care about machine flexibility, order-processing time, outsourcing flexibility, production lead-time, switching time, and workforce flexibility. With loadings of 0.743, 0.745, 0.823, 0.730, 0.528, and 0.738 respectively, they are good indicators of volume flexibility. Company management should not overlook these basic elements of day-to-day operations of volume flexibility because it has been shown to significantly influence the delivery flexibility level. Therefore, their delivery performance is highly influenced by the ability of suppliers to increase or decrease their production volumes without affecting the quality of the products.

The study revealed that accuracy, completeness, sharing frequency, and updating

frequency of demand forecasts are important indicators of the level of sharing demand forecasts, with loadings of 0.774, 0.769, 0.781, and 0.781, respectively. Fulfilling these requirements can improve suppliers' volume flexibility and delivery flexibility. As a result, management should have strong collaborations and communication with OEMs with regard to demand forecasts.

The study also revealed that accuracy, completeness, sharing frequency, and updating frequency of inventory data are important indicators of the level of sharing inventory data, with loadings of 0.902, 0.955, 0.899, and 0.951, respectively. Fulfilling these requirements does not significantly affect "volume flexibility" or "Delivery flexibility" due to its weak effects (-0.029 and 0.093, respectively) in the linkages.

The analysis of the inner model showed that "sharing demand forecasts" and "sharing inventory data" together can only explain 17.7% of the variance in "volume flexibility." This is an important finding because it suggests that managers of the supplier firms should consider other factors. This can be a suggestion for future research exploring other factors that affect volume flexibility.

In answering the research question posed in this study, the findings confirm that effective sharing of information on demand forecasts is a key enabler of the supplier delivery and volume flexibility. This finding has important theoretical and managerial implications. As a theoretical implication, the study showed the significance of the impact of information sharing on suppliers' flexibility. This finding creates opportunities for further research to investigate how demand visibility, through information sharing, could reduce the impact of the bullwhip effect on each tier-supplier. As a managerial implication, the study emphasizes the significance of sharing demand forecasts on the supplier's performance when the demand is volatile. As a key finding, management should only allocate resources to improve communication and collaboration practices with OEMs for effective sharing of demand forecasts but not for sharing inventory data. Hence, by sharing accurate, complete, and up-to-date demand forecasts and consistently making it available for first-tier suppliers, the management of OEMs could save costs associated with late-delivered orders, early-delivered orders, or inaccurate delivered quantities, supplier development and training programs, suppliers'

appraisal, and/or cost of searching for new suppliers or alternatives. Furthermore, suppliers can benefit from sharing demand forecasts by enhancing flexibility levels and response to demand fluctuations, reducing both inventory and procurements costs associated.

Every research study has its limitations (Eggert and Serdaroglu, 2011). The empirical findings are based on data collected from supplier firms within the automotive industry in Sweden. However, the model can be generalized to other industries where suppliers' flexibility is a key characteristic such as the electronics or computer industries. These industries are somehow similar to the automotive industry in which the final product requires many components and complex subassemblies. Furthermore, the demands of the final products as well as their components are characterized by high volume fluctuations. Therefore, such industries require huge coordination and information sharing between suppliers and manufacturers to maintain a high level of flexibility.

4.4 Study No. 3

4.4.1 Introduction to Study No. 3

In today's uncertain world, manufacturing firms subscribing to lean production principles tend to hold fewer buffers of raw materials, parts, or components in their inventory due to the notion that considers inventory as a source of waste. For instance, such OEMs in the automotive industry rely on JIT or SPF tactics for ordering raw materials, parts, or components. On the other hand, suppliers who also would like to avoid holding excess buffers of components and parts stock in their inventory. Hence, the question that may emerge immediately is: who should hold the stock if both suppliers and OEMs avoid keeping them?

In previous chapters, it was concluded that collaborative activities, between OEMs and suppliers, require intensive sharing of information. As illustrated in Section (2.6) in Chapter 2, collaboration with suppliers includes many forms of collaborative activities such as production scheduling, supply planning, and new product introduction (Barratt, 2004b). Production scheduling requires sharing accurate and timely production schedules, delivery schedules, and deviations. This entails using a real-time data interchange system to synchronize production data with suppliers. Supply planning requires sharing mid-term and long-term demand forecasts. This requires collaborative teams from both sides to get involved in the demand forecasting process at an early stage. New product introduction requires intensive sharing of design parameters and specifications, and design changes at an early stage. This necessitates involving the supplier in the design process.

It was evident from studies No. 1 and No. 2 that information sharing between OEMs and first-tier suppliers (as a type of collaboration) results in enhanced supplier's volume and delivery flexibility capabilities, which improves their delivery performance. This study focuses on the collaborative activities that usually require sharing mid-term and long-term demand forecasts. It involves three main steps: First, in-depth understanding of the demand forecasting process at the OEM, understanding how information is being communicated, and whether the suppliers' delivery performance can inform us about

their flexibility capabilities. In particular, this study attempts to describe the current collaborative forecasting practices between OEMs and first-tier suppliers and how they affect the suppliers' delivery performance. This study addresses the following research question:

RQ3: What factors/activities should OEMs consider to improve the sharing of demand forecasts with suppliers?

To answer this question, this study conducts empirical investigations based on a descriptive case study at one of the biggest truck manufacturers in the world based in Sweden, and 10 first-tier suppliers. The aim of this study is to describe and explore the activities or practices (concerning sharing of demand forecasts) that OEMs should undertake to improve the sharing of demand forecast and ultimately the delivery performance of first-tier suppliers. To achieve this goal, this study focuses on the collaborative practices implemented in the case company.

This study is organized in the following structure. Section (4.4.2) includes the theoretical frame of reference, and provides a state-of-the-art review of the literature on the types of collaboration practices between suppliers and OEMs, and the benefits and barriers of collaboration. Section (4.4.3) presents the methodology, which describes the methods used to collect and analyze the empirical data. Section (4.4.4) includes the results, which present, report, and interpret the findings in view of the previous studies. Section (4.4.5) discusses the theoretical and managerial implications of the findings. Section (4.4.6) and reflects on the limitations and recommendations for future research.

4.4.2 Literature Review

For the purpose of reviewing, a brief literature review is provided in this section. The concepts of flexibility and information sharing as well as types of collaboration were comprehensively presented and discussed in Chapter 2. Therefore, the aim of this review is twofold: 1) To remind the reader of collaboration practices with suppliers, and

2) To provide background information and a theoretical framework for the research question (RQ3).

4.4.2.1 Collaborative Supply Planning

Collaborative supply planning between OEMs and suppliers is a managerial tool to ensure a steady supply of input materials such as parts and components. To date, researchers have highlighted the strategic role of supply planning. For instance, Spekman, Kamauff, and Salmond (1994) assert that firms must include supply considerations in their planning, development, and operations processes. Examples of such considerations include “developing outsourcing strategies, examining the amount and types of suppliers, moving towards delegated supplier tier and/or the development of supplier associations” (Cousins and Spekman, 2003, p. 21).

Without doubt, securing a steady supply of raw material, parts, or components is a challenging task, which requires a high extent of collaboration between suppliers and OEMs in many aspects. For example, involving first-tier suppliers in the forecasting process at an early stage is one of the mechanisms toward collaborative supply planning. As a result of demand variability, it is not sufficient to communicate the mid-term or long-term demand forecasts or production schedules with suppliers. Suppliers must participate in the day-to-day forecasting process or short term demand forecast. A joint collaboration team should work on calculating actual demands and share and exchange their ideas and thoughts. This can generate a creative environment where the joint collaboration team can develop innovative initiatives.

A well-known example of the collaborative supply planning mechanism is the CPFR. CPFR is defined as “a cooperative management approach that helps improve the abilities of supply chain members to increase their revenue and profit” (Panahifar et al., 2013, p. 1). CPFR is a nine-step business model (Stank et al., 1999), which involves: 1) Developing a front-end agreement, 2) Creating a joint business plan, 3) Creating sales forecast, 4) Identifying exceptions for sales forecast, 5) Resolving/collaborating on exception items, 6) Creating order forecast, 7) Identifying exceptions for order forecast, 8) Resolving/collaborating on exception items, and 9) Order generation.

There exist several related research studies on the adoption of CPFR in the grocery and retail (Simatupang and Sridharan, 2002; Holmström et al., 2002; Chung and Leung, 2005), electronics, agricultural, and healthcare (Panahifar et al., 2013) industries. However, there is a lack of related studies in the automotive industry. For instance, the first study that analyses CPFR's success factors in the automotive industry was conducted in 2013 by Panahifar et al. (2013).

In their studies, Panahifar et al. (2013, p. 6) have identified 10 critical factors for the successful implementation of CPFR in the spare parts industry within the automotive sector: "high level of trust defining mutual agreed objectives, clear communication plan, information security, willingness to collaborate, information readiness, information compatibility across users, competition pressure, strong executive support, and appropriate cultural habits." In addition, Panahifar et al. (2013) highlight that these success factors vary from one industry to another.

Nevertheless, Panahifar et al. (2013) have found that the implementation of CPFR faced some obstacles such as lack of appropriate detailed information regarding the critical success factors. In this regard, Panahifar et al. (2013, p. 1) highlight that "Despite promising results reported by companies that have adopted CPFR, its implementation appears to have encountered some obstacles." Despite these obstacles in the implementation in the manufacturing sector, there are still some benefits of adopting CPFR. For instance, Chung and Leung (2005, p. 571) show that incorporating CPFR in the copper clad laminate industry has several benefits, as follows:

- a) Reduction of inventory*
- b) Reduction in occurrence of out-of-stock*
- c) Improvement in the accuracy of sales and order forecast*
- d) Reduction of obsolescent scrap*
- e) Improve the response to market change*
- f) Reduction of the total lead-time of the pipeline inventory*
- g) Reduction in the running cost*

These benefits should enhance the volume and delivery flexibility capabilities of suppliers, which eventually should enhance the delivery performance. For instance, reduction in the occurrence of out-of-stock improvement in the accuracy of sales and order forecast, reduction of obsolescent scrap, improving response to market change, and reduction of the total lead-time of pipeline inventory are indicators of improved delivery performance for many manufacturing companies. Nevertheless, “none of these outstanding improvements can be achieved unless a successful and proper CFPR implementation is conducted” (Panahifar et al., 2013, p. 2). Regarding implementation, OEMs and suppliers within the automotive industry rely on Internet-based data interchange systems such as EDI and web portals for sharing demand schedules.

4.4.2.2 Supplier’s Delivery Performance

Within the context of collaboration, measuring and monitoring suppliers’ delivery performance is one of the important functions of the OEM’s inbound logistics. For this purpose, OEMs use various Key Performance Indicators (KPIs) to assess suppliers’ delivery performance. Chung and Leung (2005) propose five KPIs in order to improve collaboration and delivery problems. These include: material inventory, order forecast, out-of-stock, and material order lead-time. However, suppliers’ delivery precision is one of the most well-known KPI in the automotive business (ODETTE, 2012). Section (4.4.3) discusses some KPIs that the case company is adopting. As will be shown in the analysis part, this study argues that the supplier’s delivery precision indicator can be used to predict the volume and delivery flexibility capabilities of suppliers. Besides, communicating this indicator directly to suppliers could help understand the strengths and weaknesses of the respective flexibility capabilities.

4.4.3 Methodology and Data Presentation

The study combined both the descriptive and explorative nature of the research question RQ3; hence, it was based on an in-depth single case study with multiple embedded units of analysis in one of the biggest Swedish automotive companies. For the scope of the study, the analysis focused on one product line called the “Chassis Production Unit” and 10 first-tier suppliers. The case company has a supplier base of more than 2000

suppliers (local and global). Due to the time limitation of this study, limited access to data, and availability of participants, this study selected 10 local suppliers. The selection was based on a representation criteria rather than randomness. That is, in order to be consistent with the sample population/scope as defined in studies No. 1 and No. 2, the selected suppliers must be based in Sweden. Each of these suppliers represented a particular product commodity.

The study was based on multiple sources of primary and secondary data (interviews with functional area managers, company documents such as logistics manuals, delivery plans, delivery schedules, delivery agreements, supply contracts, meeting minutes, and supplier EDI data). These multiple sources of data allow for triangulation of data to search for empirical evidences, which in turn provided empirical credibility for the study. This study was conducted between November 2014 and July 2015. The author altered the names and other identifying information to protect confidentiality.

In order to identify the factors/activities that OEMs should consider to improve the sharing of demand forecasts with their suppliers, a cross-case analysis among the selected 10 suppliers was conducted to identify the obstacles in sharing demand forecast. Prior to that, a narrative depiction of the demand forecasting process, demand forecast sharing process, and suppliers' delivery performance evaluation, was provided.

4.4.3.1 Description of the Case Company

The company is operational since its establishment in 1891. Since then, it has built and delivered more than 1,400,000 trucks and buses for heavy transport work. According to the company information, the company has, for more than seven decades, reported a profit every year. Today, the company is one of the leading truck and bus manufacturers not only in Sweden but also worldwide. The company has approximately 42,000 employees and 11 factories in five countries. However, as will be shown in the next section, this study focuses on one production plant located in Sweden, due to availability of resources, access to data, and proximity of headquarters and other production and logistics facilities.

The case company operates in an agile supply chain network, in which the firm sources materials and components from several suppliers from different geographic areas in the world. According to the company, purchased materials and components account for 70% of the total production cost. In this agile business environment, demand and supply are usually uncertain, which creates changes in purchasing orders, product design, product quantity, delivery times, customizations, etc. Thus, assuring customer-responsive suppliers plays a considerable role in increasing the production stability of the company as well as enhancing delivery performance of their suppliers. The company responds to demand changes in various ways. For instance, the case company has been successfully implementing operations strategies such as modular production, JIT, and the continuous scouring approach. In addition, they focus on small and mid-size suppliers in order to leverage their power among suppliers by maintaining long-term relationships with them based on mutual trust. The company's philosophy is to use dual sourcing for all parts and components. However, since having flexible suppliers is a very important aspect in an agile business environment, the case company's approach would facilitate the implementation of customer-responsive strategies that will shorten delivery lead-time of parts and components.

Within this spectrum of strategies, collaboration with suppliers is considered one of the main important functions of the company. In this regard, the company adopts sophisticated technologies (such as EDI and other Internet-based and real-time data exchange systems) and to share information on demand forecasts with suppliers. The aim of adopting such technologies is to improve suppliers' ability to manage variations in design, quantity, delivery schedule, and delivery destination of components and parts.

4.4.3.2 Unit and Level of Analysis

Since the company size is large, it would be time consuming to cover all business areas, products or business units in a single empirical study. Hence, the scope of this study was limited to one single business unit and their suppliers, the Chassis Production Unit located in Sweden. This particular unit of analysis was selected because of availability of resources and access to empirical data. This approach provided two levels of analysis (i.e., the supplier's and OEM's perspectives), which enhanced the methodological rigor

of this study. Thus, the case company and its suppliers are appropriate to investigate how collaborative forecasting practices enhance the latter's delivery performance (i.e., RQ3).

4.4.3.3 Description of Demand Forecasting Process

The sales department is responsible for preparing the demand forecasts of the final product. It is also responsible for preparing gross and net forecasts for parts and components used in each truck model. The department sends the data to the central material planning department, which is responsible for both short-term and long-term material planning of components and parts. The purchasing department is responsible for making contractual agreements with suppliers, bargaining prices, placing the purchasing orders (POs), and managing the legal aspects of procurement contracts. The sales department updates the gross demand forecasts once a week, while the material planning department collaborates with other departments such as production planning and purchasing. Then, the sales department prepares the net delivery schedules. The material planning department then sends the delivery schedules of parts and components to suppliers on a daily basis (for chassis line), or once or twice a week for other production lines (i.e., for production lines with a long final product lead-time). Communication of information is carried out via complex electronic exchange systems and use of multiple databases viable to all departments.

The inbound logistics department is responsible for optimizing material flow, transportation, and shipment of parts and components as well as reverse logistics. For instance, they optimize the best routes, transportation method, truck loads, schedules, and monitor the operations of the TPL in collaboration with material planning. They perform the necessary quality checks to ensure that the quality levels of the received materials, quantities, and schedules comply with Scandia standards.

The sales department then performs market analysis using historical procurement data, historical sales data, market price changes, sales of competitors, customer surveys, and other data types from other functional departments. The data is compiled into a single

forecasting system to calculate demand forecasts for the next 12 months. This market survey on demand is used to forecast the sales, manage the stock, and plan production. To ensure that prediction is accurate enough, the company considers the forecasting error, which is the difference between actual and forecasted demand. In particular, the company uses several performance measurement indicators such as forecasting accuracy index (FAI) and weighted tracking signal (WTS) for measuring forecast accuracy.

These accuracy measurement indicators (FAI and WTS) are widely used in the automotive industry and developed by ODETTE⁴ International. These indicators, as shown in Figures (4.8) and (4.9), are calculated based on the following parameters and equations (ODETTE, 2012, p. 8, 9):

d_0 = Reference value (realized or last forecast)

l_1 = lag 1 forecast: forecast value 1 month prior to realization

l_2 = lag 2 forecast: forecast value 2 months prior to realization

l_3 = lag 3 forecast: forecast value 3 months prior to realization

l_4 = lag 4 forecast: forecast value 4 months prior to realization

Deviations:

$$\Delta_1 = l_1 - d_0$$

$$\Delta_2 = l_2 - d_0$$

$$\Delta_3 = l_3 - d_0$$

$$\Delta_4 = l_4 - d_0$$

Notes:

If Δ_i is positive, lag forecast is too high

If Δ_i is negative, lag forecast is too low

For example, if horizon $n=4$, then: *Weights and weighting factors*: $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_i \geq 0$, where:

$$\sum_{i=1}^4 \alpha_i = 1$$

⁴ ODETTE is an international non-profit organization that brings together supply chain professionals and technology experts to create standards, develop best practices, and provide services that support logistics management, e-business communications, and engineering data exchange throughout the automotive industry.

$$\begin{aligned}
& \text{If: } d_0 \neq 0 \\
& \quad FAI := \alpha_1 \cdot \max \left\{ 0; 1 - \frac{|\Delta_1|}{d_0} \right\} + \alpha_2 \cdot \max \left\{ 0; 1 - \frac{|\Delta_2|}{d_0} \right\} \\
& \quad \quad + \alpha_3 \cdot \max \left\{ 0; 1 - \frac{|\Delta_3|}{d_0} \right\} + \alpha_4 \cdot \max \left\{ 0; 1 - \frac{|\Delta_4|}{d_0} \right\} \\
& \text{If: } d_0 = 0 \\
& \quad FAI := \sum_{i \in I} \alpha_i \quad \text{where } I = \{i \mid \Delta_i = 0; i = 1, \dots, 4\} \\
& \quad \text{for } I = \emptyset : FAI := 0
\end{aligned}$$

Figure 4.8: Forecasting Accuracy Index (FAI) equation (Source: ODETTE, 2012, p. 8)

Where:

- *FAI is calculated as an index ($0 < FAI < 1$) or as percentage ($0\% < FAI < 100\%$)*
- *1 or 100% represents the best value.*
- *If all weighting factors have the same value (i.e., $\alpha_i = \frac{1}{4}$), then all lag forecasts l_1, \dots, l_4 have the same impact on forecast accuracy.*
- *To determine whether lag forecast values are too high or too low compared to the reference value, a tracking signal is required. This indicator is defined as follows:*

$$\begin{aligned}
& \text{If: } \sum_{i=1}^4 \alpha_i \cdot |\Delta_i| \neq 0 \\
& \quad WTS := \frac{\alpha_1 \Delta_1 + \alpha_2 \Delta_2 + \alpha_3 \Delta_3 + \alpha_4 \Delta_4}{\alpha_1 |\Delta_1| + \alpha_2 |\Delta_2| + \alpha_3 |\Delta_3| + \alpha_4 |\Delta_4|} \\
& \text{If: } \sum_{i=1}^4 \alpha_i \cdot |\Delta_i| = 0 \quad WTS := 0
\end{aligned}$$

Figure 4.9: Weighted Tracking Signal (WTS) equation (Source: ODETTE, 2012, p. 9)

Where:

- *The WTS value is between $(-1 < WTS < 1)$*
- *WTS=1: All deviations are positive*
- *WTS=-1: All deviations are negative*

This model is a well-known method among European automotive manufacturers, to improve the forecasting accuracy. This model is used by the case company to enhance the accuracy of their demand schedules, which will then be shared with all suppliers. According to the material planning manager, this model has helped both the case company and most of its suppliers. For instance, FAI and WTS has helped the case company to communicate accurate call-offs to their suppliers. In turn, the suppliers showed enhanced delivery performance.

4.4.3.4 Data Collection and Sources of Primary Data

Data collection was based on multiple sources of primary data using three qualitative techniques—semi-structured interviews, direct observation, and documentary evidence. First, semi-structured interviews were conducted with functional managers, in which participants answered open-ended questions, and reflected on their experience and views regarding the phenomenon. Second, direct observation was utilized to understand whether the collaboration is being implemented in reality. Third, documentary evidence was also an important data gathering approach to analyze the data in written documents such as EDI messages, meeting minutes, operations procedures, operations strategy, etc. This combination of three different data gathering techniques allows for data triangulation, which is widely used in qualitative research to ensure validity of data analysis.

Semi-Structured Interviews

A total of 10 semi-structured interviews were conducted with functional managers in the case company. The interviews were conducted with participants having adequate knowledge and practical experience in the automotive business. For instance, all participants had at least seven years of practical experience within the area of production and operations management of automobile parts and components. Therefore,

the interviews were conducted with job roles that represented executives from production, material planning, logistics, and management. The participants' job positions are listed in Table (4.14).

Table 4.14: Interviewees' job profile

#	Interviewee's Job Role	Functional Unit
1	Material Planner	Material planning
2	Receiving incoming material, Supervisor	
3	Material Planning Manager	
4	Transportation Controller	Inbound logistics
5	Inbound logistics-Nordic tower	
6	Supply Chain Developer	
7	Inbound Logistics Manager	
8	Supply Chain Engineering Manager	Other, production, IT, procurement
9	EDI Developer	
10	Production Engineer	

Some interviews were followed up by clarifying questions by phone calls. Each interview lasted between 50 to 70 minutes depending on the time and availability of the interviewees. As shown in Appendix (C), the interview covered questions on collaboration practices with suppliers regarding supplier delivery performance, material requirement planning, demand forecasting, and purchasing and ordering of parts and materials. The answers and notes were taken for further analysis along with other sources of data.

In addition, six meetings with the supply chain engineering team were conducted during the data collection period. The team comprised the following job positions: material planning manager, supply chain engineer, and supply chain-engineering manager. These participants were encouraged to talk freely and reflect on their experience and views regarding the above mentioned issues, and consequently, several open-ended questions emerged during the discussions.

Documentary Analysis

Utilizing the documentary analysis (or archival records) had allowed the researcher to review and examine official company documents, which allowed searching for evidences in the documents. The author was given limited access to log in to the company's computer system. Specifically, the researcher was given a laptop computer with login information to access some official documents. These documents, as shown in Table (4.15), included various types of information belonging to different functional departments or organizational levels such as corporate policy, work instructions, and reports from different departments.

In addition, the researcher was given limited access to some online databases (such as Webstars, Qlikview, eQuality, and Embassy) concerning the supplier management system including access to the supplier's delivery performance statistics, material ordering, and call-offs.

Observations

Observation was the third data collection technique used in this case study to collect empirical data at the truck production facility. Direct observations were utilized to illustrate the work procedure, understand the process, and eventually search for the evidences. Direct and indirect observations, field visits, and discussion meetings were utilized to collect data. This included five visits to the main truck and bus production sites. The visits were guided by two people: a material planner and a production engineer. Each visit was three-hour long, comprising watching the product assembly, production process, material handling process, inspection, material planning process, and ordering of material and components. Observations were noted and inquiries were directed to employees working in different areas.

Table 4.15: Company documents and sources of evidence within the case company

#	Document inspected	Documents belong to	Type of document		
			Corporate Policy	Work Instructions	Reports
1	Strategy description	Business unit Strategy	x		
2	Commercial operations strategy		x		
3	Logistics manual	Inbound Logistics		x	
4	Transport booking documents		x	x	
5	Delivery precision of 120 suppliers for the past 2 years			x	
6	Delivery deviation handling guidelines		x	x	
7	Demand forecasts process			x	x
8	Company communication policy	Procurement	x		
9	EDI communication procedure		x	x	
10	Order handbook	Material planning and handling	x		
11	Forecast accuracy index			x	
12	Packaging manual		x		
13	New supplier delivery instructions	Production	x		
14	Production schedules			x	x
15	Stock level records		x		x

4.4.4 Results and Discussion

By analyzing and reviewing the interview notes and company documents, the “order to delivery” process in the case company is found to be a cross-functional process. The process comprised several steps and started with volume forecast, sales order management, and allocation and ordering necessary resources. The process covered inventory management, order fulfillment planning, and production planning and execution. When the transport solutions are ready, the products are transferred to the customer. This process, together with financing and invoicing, is also covered in the order to delivery process. According to the “Order handbook,” the foundation of the process is to meet or exceed customer demands according to the principles of customer first, quality, information transparency, delivery time, and delivery precision. In answering the research question (RQ3), the following specific findings were confirmed.

4.4.4.1 Not all demand forecasts are shared with first-tier suppliers through EDI

The case company uses robust information management tools for sharing product demand information with suppliers as shown in Figure (4.10). Most information is shared with suppliers via EDI. EDI is structured and standardized information between two different business parties. As depicted in the graph, suppliers are required to use EDI technology and the supplier portal (SP) of the case company. SP is an important platform for communication and information sharing that provides suppliers access to the case company's standards and manuals, and is the link to their web-based applications. The purchaser in the case company can provide the necessary information and access to suppliers to login to the portal.

The EDI system is also used for internal communication. EDI is connected with several tools for internal information sharing. Such tools are used for various data analysis purposes, such as analyzing supplier performance, transport follow-up, quality reports, etc. The following are some examples of such Internet-based applications/tools: Webstars, Qlikview, eQuality, and Embassy. Webstars is useful for transport booking and follow-up. Qlikview is important for analyzing suppliers' delivery performance. eQuality can be used to report quality or logistics deviations. Embassy is useful for ordering the packaging material on SP.

According to the logistics manual and forecasting process documents, and confirmed by the inbound logistics manager and supply chain engineering manager, the demand schedule comprises two parts: call-offs and forecast. The call-off is a delivery authorization sent by each production unit stating the delivery date and the delivery quantity for each part number. The delivery date is the date the goods must be available for pick-up. The demand schedule is sent by EDI in a frequency decided by the production unit. The demand schedule shows the call-off for batch parts and the forecast for batch and sequence parts up to 360 days. When a supplier delivers to more than one production units, they will receive a demand schedule from each production unit.

As an important finding, it is evident that not every demand schedule is shared using EDI. For example, the call-offs of "sequence products" is shared with different

techniques. This is because the case company uses the “sequence” material control method for certain flows (e.g., expensive parts). For these flows, a separate document is created to describe the set-up of the flow. These documents are called Sequence Deliveries Agreements. In addition, the inbound logistics manager at the case company confirmed that there are several problems due to poor communication with suppliers:

“Although we use a complex system for inter-firm information sharing with our suppliers, we still do have several communication problems. For instance, sometimes we discover that some orders are sent but receive no confirmation. Another example is that we do receive many on-hold signals that are caused by different versions of the product structure database, so having the latest version is important.”

As shown in Table (4.16), it is evident that suppliers with batch call-offs use EDI while those with sequence call-offs use SP. Therefore, this study suggests OEMs to share all types of demand forecast through advanced information sharing tools, which allow real-time data transfer. Besides, the computer software should be synchronized with their suppliers. This can be accomplished by installing the same software for all suppliers or installing an interface between the OEM and its suppliers.

Table 4.16: Cross-case analysis

Supplier	(1) Commodity/Product(s)	(2) Supplier delivery precision			(3) Product call-off		(4) Sharing technology used		(5) CPFR implementation	(6) ODETTE forecasting model implementation (FAI and WTS)
		Equal or greater than 95%	Between 90%-95%	Less than 85%	Batch	Sequenc e	EDI	SP		
<i>S1</i>	Truck body castings & forgings	✓			✓		✓		No	Yes
<i>S2</i>	Axle, gearbox components & brakes		✓		✓		✓		No	Yes
<i>S3</i>	Control technologies & electromechanical components		✓			✓		✓	No	Yes
<i>S4</i>	Forgings & fasteners		✓		✓		✓		No	Yes
<i>S5</i>	Lights and electronics		✓		✓		✓		No	Yes
<i>S6</i>	Lifters, sliders & accessories			✓		✓		✓	No	Yes
<i>S7</i>	Truck/bus body sheet metal			✓		✓		✓	No	Yes
<i>S8</i>	Chassis, components & wheels			✓		✓		✓	No	Yes
<i>S9</i>	Heating & cooling components/systems			✓		✓		✓	No	Yes
<i>S10</i>	Pipeline, fittings, valves			✓		✓		✓	No	Yes
<p>Source of data:</p> <p>Data shown in (1) and (2) are obtained from the Qlikview database of the case company</p> <p>Data shown in (3) and (4) are obtained from the supplier portal system of the case company</p> <p>Data shown in (5) and (6) are obtained from Qlikview and interviews</p>										

4.4.4.2 “When to share” demand forecasts play an important role in supplier delivery performance and forecast accuracy

For suppliers, receiving OEMs’ demand forecasts at the “right time” is considered a critical factor. In this regard, the “right time” for OEMs is not necessarily the same as for suppliers. Suppliers in the automotive industry usually belong to other industries or even different supply chain networks. For instance, some suppliers belong to the “plastics industry” while others to the “electronics” or “steel” industries, which means that suppliers differ in their supply strategies, operations, business models, and many other aspects. Therefore, suppliers do have “planning horizons” and “freeze periods” different than that of OEMs, and this may create delivery overlaps, synchronization problems, delays, etc. The information in the forecast is based on past data and market expectations. However, the closer the current date is to the “End Assembly” day, the more the information in the forecast is based on actual orders.

According to the company documents (e.g., order handbook), the latest demand schedule will always cancel and replace the one sent earlier. The demand schedule is valid from the second working day after its distribution. This means that there can be an increase or decrease from the second day onwards. For instance, increases or decreases are possible from Thursday onwards in a demand schedule sent on a Tuesday.

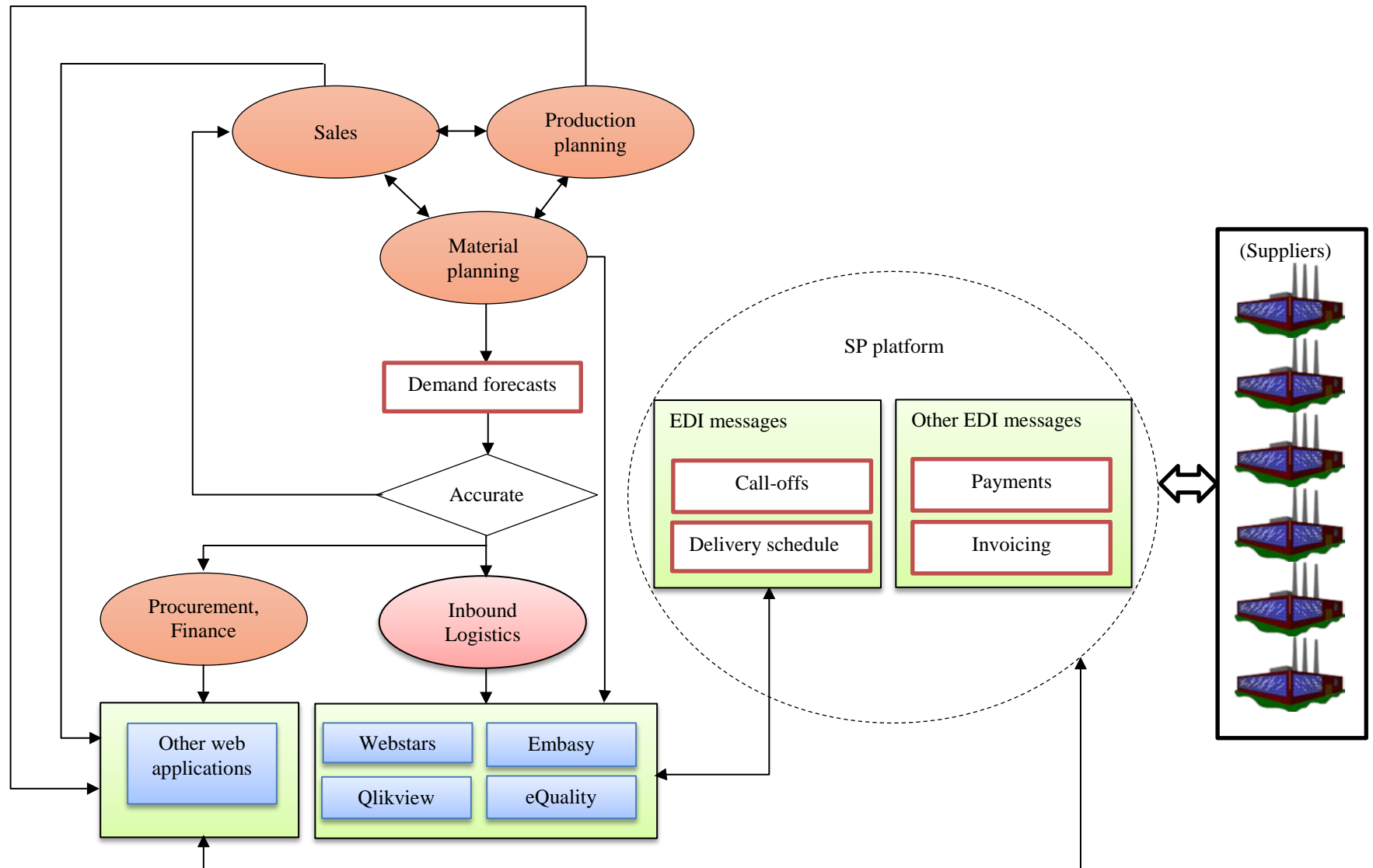


Figure 4.10: Data sharing and communication tools between OEMs and suppliers

Inspecting the company documents and supported by interviews, it is evident that the “right time” is a genuine problem faced by both OEMs and their suppliers. For example, the case company communicates a one-year demand forecast schedule to suppliers every week, and the call-offs every month. Most suppliers have different production planning periods over the same year, which means that material orders to suppliers and their production planning is necessarily happening at the same time. Table (4.17) below provides evidence for the above finding. The table shows the difference in time between the production planning freeze period, production planning, and purchasing of raw material period in which each supplier has its own “lags” with specific requirements.

Table 4.17: Difference in time lag between the call-off period, freeze period, and supplier’s production scheduling

Supplier lag-month												
Supplier	1	2	3	4	5	6	7	8	9	10	11	12
<i>S1</i>												
<i>S2</i>												
<i>S3</i>												
<i>S4</i>												
<i>S5</i>												
<i>S6</i>												
<i>S7</i>												
<i>S8</i>												
<i>S9</i>												
<i>S10</i>												

Production Planning Frozen
 Production Planning
 Purchasing of Raw Material

This finding implies that it is important that the OEMs understand these differences among their suppliers because it affects the demand forecasting accuracy and suppliers’ delivery performance, especially when the OEM has a vast supplier network, which increases the

complexity. In this regard, the material planning manager confirmed that: “*When setting targets, it is common to not match suppliers’ Supply Chain “lags” and it is hard to identify patterns to enable an efficient forecast accuracy follow-up.*”

According to the order handbook, it is evident that the Chassis orders in the case company’s European production can be either *firm* or *open*. The difference between *firm* and *open* orders is that *firm orders* are locked for change once received in the factory order system. The change policy for *firm orders* is strict. If an order change is really needed, a change request could be sent to the factory. *Open orders*, on the other hand can be changed without asking the factory. However, an *open order* has to be made *firm* in order to be produced. This is done using web-enabled sales tools at the case company. Figure (4.11) illustrates the order process.

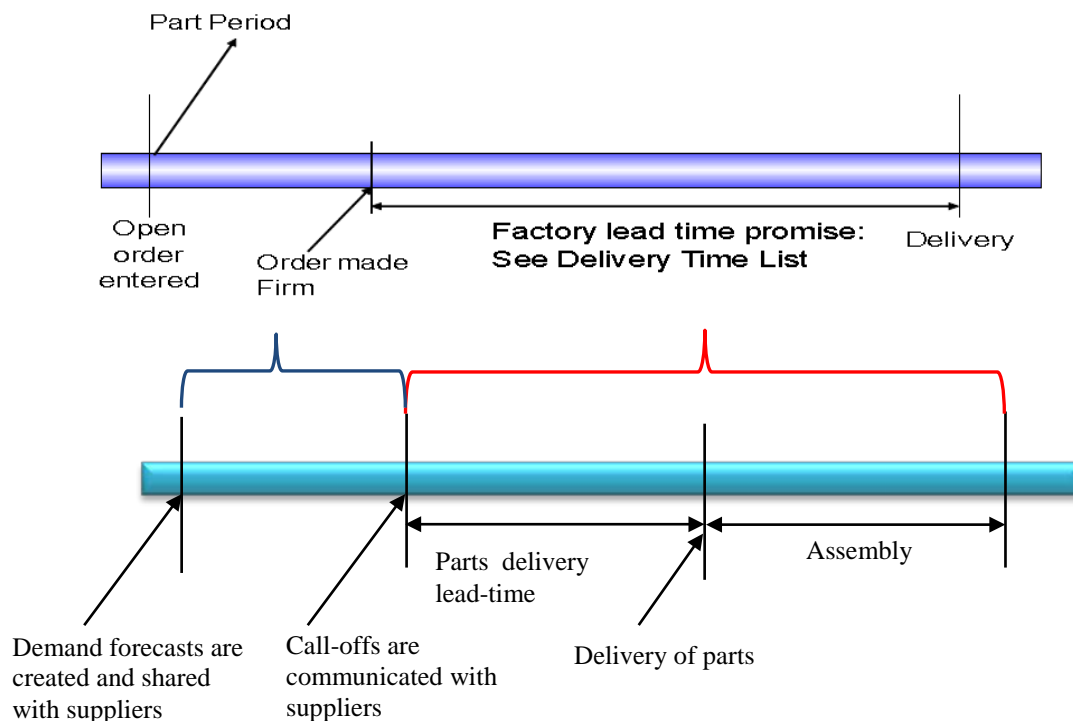


Figure 4.11: Ordering process description from customer order to delivery

Based on this process, the time between open order entered and order made firm is critical for estimating the total demand. During this time, some orders might be confirmed while others might be cancelled. Hence, oscillating orders, which is the actual demand, may lead to forecasting errors. This effect will be probably reflected in the material planning and ordering of input material and components. Hence, sharing these demand variations at that specific time with suppliers' can help synchronizing their own production schedules, and this could be accomplished by having a communication platform linking computers of OEMs and suppliers for planning purposes prior to EDI communication. Numerous benefits also can be obtained by implementing this collaborative forecasting. As a result, the lead-time can be shortened. Thus, it can be concluded that involving first-tier suppliers in the demand forecasting process at early stages can be beneficial.

4.4.4.3 The current way of calculating the supplier delivery precision does not differentiate between accuracy of the delivered quantity or delivered date

As any other company in the automotive industry, the case company uses a delivery precision indicator for assessing suppliers' delivery performance. This indicator is calculated as the percentage of correctly delivered order lines out of the total number of deliveries. The number of deviations is defined as the total number of incorrectly delivered order rows in the selected period. Therefore, the delivery is considered correct if the supplier's delivery and EDI dispatch advice is done exactly according to the call-off, which means the right quantity on the right date. To illustrate this, the following example is considered:

A supplier delivered 10 call-offs to the case company in May 2015. Two call-offs were dispatched two days earlier than ordered, and one was dispatched with one day delay. The other call-offs were dispatched on the correct day, but one of them contained only 90 pieces out of the ordered 100. Thus, four out of 10 deliveries were incorrect and the delivery precision for this supplier for May will be 60%.

Besides, the case company uses software to calculate indicators. The software retrieves the data from the system and automatically calculates the delivery precision for each supplier, and labels each with a specific color based on the three levels. For instance, a green label is given to suppliers with delivery precision value greater than 95%, a yellow label to those with a value between 90% and 95%, and a red label to those with less than 90%. Table (4.16) shows that supplier *S1* had a delivery precision value greater than 95%, suppliers *S2*, *S3*, *S4*, and *S5* had delivery precision values between 90% and 95%, while suppliers *S6*, *S7*, *S8*, *S9*, and *S10* had values less than 90%.

However, determining the specific type of delivery precision and communicating the corresponding delivery performance index directly to suppliers may help understand the flexibility capabilities of suppliers. Unfortunately, this was missing in the case company. For this reason, a specific delivery precision matrix (shown in Figure (4.12)) was developed. The matrix has two dimensions, delivered date and delivered quantity. For the delivered date, a supplier is judged as early, on-time, or late delivery. For the delivered quantity, the same supplier is judged as—supply more than needed, as per call-off, or as less than needed. Based on these assessment criteria, the matrix then classifies the suppliers into nine categories (A, B, C, D, E, F, G, H, and I) within three zones (I, II, and III):

- Zone I includes suppliers in category A, which is given the green label, and represents the suppliers with accepted delivery performance level
- Zone II includes categories B, C, D, and E suppliers, is given the yellow label, and represents the suppliers with critical delivery performance level
- Zone III includes categories F,G,H, and I suppliers, is given the red label, and represents the suppliers with poor or unacceptable delivery performance level

Delivered quantity	over	H	B	I
	as per call-off	D	A	E
	less	G	C	F
		early	on-time	late
		Delivered date		

Figure 4.12: Supplier delivery precision indicator

This matrix can be updated weekly or monthly or based on the volume of transactions between OEMs and suppliers. This matrix was suggested to the management team and is now approved and used by the case company. It was also followed by a diagnostic tool shown in Table (4.18), which was also developed to help understand the root causes and consequences as well as recommendations associated with each supplier category. After categorizing suppliers based on flexibility capabilities, the case company can have a clear picture on the ability of the suppliers to respond to changes. Thus, this will improve flexibility-related decisions such as for supplier development or sourcing.

Table 4.18: Suggested diagnostic tool

Supplier category	Delivered date	Delivered quantity	Consequences on OEM operations	Problem root causes	Recommendations
A	On-time	As per call-off	Accepted level	NA	Maintain trust, collaboration, reward suppliers, keep sharing accurate demand schedules
B	On-time	More than needed	Occupying more space, interrupt other incoming material, need extra resources to handle.	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving overestimate call-offs/demand schedules?	Suppliers need to improve their volume flexibility capabilities.
C	On-time	Less than needed	It will delay production if the remaining quantity is not delivered shortly. Need extra resources to handle shortage.	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving underestimate call-offs/demand schedules?	Suppliers need to improve their volume flexibility capabilities.
D	Early	As per call-off	Occupy space, Need extra resources to handle.	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving early call-offs/demand schedules?	Suppliers need to improve their delivery flexibility capabilities.
E	Late	As per call-off	It does delay production. Need extra resources to follow-up the call-offs.	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving late call-offs/demand schedules?	Suppliers need to improve their delivery flexibility capabilities.
F	Late	Less than needed	Delay production Reschedule production Need extra resources to handle shortage	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving late and underestimate call-offs/demand schedules?	Suppliers need to improve their volume and delivery flexibility capabilities.
G	Early	Less than needed	It will delay production if the remaining quantity is not delivered shortly. Occupy space	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving early and underestimate call-offs/demand schedules?	Suppliers need to improve their volume and delivery flexibility capabilities.

Supplier category	Delivered date	Delivered quantity	Consequences on OEM operations	Problem root causes	Recommendations
H	Early	More than needed	Rescheduling production, occupy more space, need extra resources, interrupt other incoming material	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving early and overestimated call-offs/demand schedules?	Suppliers need to improve their volume and delivery flexibility capabilities.
I	Late	More than needed	Delaying production, occupy more space, need extra resources, interrupt other incoming material	Is it because of the supplier's internal capability/capacity issue? Or is it because of receiving late and overestimated call-offs/demand schedules?	Suppliers need to improve their volume and delivery flexibility capabilities.

4.4.5 Conclusions and Implications

The aim of this study was to explore the activities or practices (concerning sharing of demand forecasts) that OEMs should undertake to improve the sharing of demand forecast and ultimately the delivery performance of first-tier suppliers. The investigations focused on identifying the main obstacles within the collaborative practices that are implemented in the case company. The investigations were based on data collected through a descriptive case study in a truck manufacturer company in Sweden and 10 of its first-tier suppliers.

The analysis of data revealed three main findings concerning potential obstacles within information sharing collaborative practices. Not all demand forecasts were shared with first-tier suppliers through EDI. They were shared based on time requirements of the OEM but not that of suppliers. Supplier delivery performance was evaluated based on a single delivery precision index, which was not shared with suppliers.

In answering the research question RQ3, three main collaborative factors/activities were suggested. First, the study suggests OEMs to synchronize their computers with their suppliers for a real-time sharing of demand forecasts. Second, OEMs should consider the time requirement of each supplier regarding sharing demand schedules. Third, OEMs should communicate the exact delivery precision to their suppliers, specifying the types of delivery problem by providing the exact delivery time precision or delivery quantity precision of the supplier.

As a theoretical contribution, this study provided further understanding and insight into the context of collaborative demand forecasts between OEMs and suppliers as well as its role in enhancing delivery performance within the flexibility capability context. As managerial and practical implications, this study provides a diagnostic tool to predict the level of flexibility capabilities of their suppliers by analyzing the supplier's delivery performance precision. Besides, this diagnostic tool acts as a guideline to identify the root causes of each

particular delivery problem as well as the consequences on OEM operations. In addition, this tool proposes a recommendation for each scenario.

4.4.6 Limitations

This study focused on collaborative activities that improve the sharing of demand forecasts between OEMs and their suppliers in the automotive industry in Sweden. Thus, it does not intend to generalize the findings to other industrial sectors or geographic areas. Due to the descriptive and qualitative nature of this case-based research study, the generalizability of the results to other OEMs and suppliers in Sweden might be a major concern. However, this issue was encountered by cross-analysis of data collected on multiple embedded units of analysis (i.e., 10 supplier companies) from the case company (i.e., OEM company). Furthermore, the data was collected from different sources such as interviews, company documents, and observations/field visits. Multiple sources of data were useful for triangulation of data analysis.

5. CHAPTER V: SUMMARY, CONTRIBUTIONS, IMPLICATIONS, LIMITATIONS, AND DIRECTIONS FOR FUTURE RESEARCH

5.1 Introduction

The aim of this chapter is to summarize the answers to the research questions, findings, contributions, implications, limitations, and directions for future research. Hence, this chapter should not be deemed as repeating the conclusions and discussions presented in the previous chapters.

5.2 Answers to the Research Questions/Research Findings

This thesis intended to explore the concept and role of information sharing, between OEMs and first-tier suppliers in the automotive industry, in enhancing supplier flexibility. Particularly, the research focused on exploring the relationship between sharing OEMs' demand forecasts and inventory data, and suppliers' volume and delivery flexibilities. The thesis has identified the reasons and motivation for sharing information with first-tier suppliers, the types of information being shared, the benefits of sharing demand forecasts and inventory data, resources required for flexibility, and the role and impact of sharing such information on the supplier's flexibility capabilities. The study has also sought to learn whether sharing such information could result in improved delivery performance, particularly for first-tier suppliers. As shown in Chapter 2, as well as in studies No. 1 and No. 3 of Chapter 4, the general theoretical literature on this subject and specifically in the context of first-tier suppliers in the automotive industry is inadequate within the supply chain agility discourse.

The main empirical findings are chapter-specific and were summarized in the respective empirical studies (in Chapter 4). This section synthesizes the empirical findings to answer the three research questions in the thesis, as follows:

1. In answering the first research question, *RQ1: How does information sharing between OEMs and first-tier suppliers affect the latter's' responsiveness to fluctuating demand?*, the following findings were obtained:

Given the results presented in Section (4.2.5) of Chapter 4, demand forecasts, in-stock and work-in-process inventory data, new design changes, and the expected launch date are the most common types of information that suppliers would like OEMs to constantly share with them. Among these four categories, demand forecasts and inventory data were the most important types that affect their ability to respond to fluctuating volumes. Sharing OEMs' demand forecasts and inventory data influences three main capabilities of first-tier suppliers: safety stock and inventory planning, temporary workforce planning, and production capacity planning. They are considered the key capabilities of suppliers' responsiveness to fluctuating volumes. In addition, it was shown that sharing "timely," "accurate," and "up-to-date" information on demand forecast and inventory data are critical factors for effective sharing of such information.

2. In answering the second research question, *RQ2: What is the relationship between information sharing of OEMs' demand forecasts and inventory data, and suppliers' volume and delivery flexibility?*, the following findings were obtained:

Given the results of the structural model presented in Section (4.3.5.4) of Chapter 4, "volume flexibility" and "sharing demand forecasts" are both strong predictors of "delivery flexibility," but sharing inventory data does not predict "delivery flexibility" directly. Furthermore, the results shown in Table (4.13) confirmed that:

- Sharing demand forecasts positively affects supplier volume flexibility
- Sharing demand forecasts positively affects supplier delivery flexibility
- Sharing inventory data does not positively affect supplier volume flexibility
- Sharing inventory data does not positively affect supplier delivery flexibility
- Suppliers' volume flexibility positively affects their delivery flexibility

3. In answering the third research question, *RQ3: What factors should OEMs consider to improve the sharing of demand forecasts with suppliers?*, the following findings were obtained:
- According to the findings presented in Section (4.4.4.1) of Chapter 4, OEMs should consider involving suppliers in the demand forecasting process at early stages.
 - According to the findings presented in Section (4.4.4.2) of Chapter 4, OEMs should consider the different planning horizons and time lag among their suppliers. For instance, production scheduling, call-off period, freeze period, and purchasing of raw material vary among suppliers. These differences among suppliers refer to the fact that the suppliers of automotive components not only belong to the automotive supply chain or automotive business, but also they are parts of other sectors and supply chains.
 - According to the findings presented in Section (4.4.4.3) of Chapter 4, OEMs should consider a precise KPI that is used not only for measuring delivery performance but also should reflect on the specific flexibility capabilities of a supplier's volume and delivery capabilities.

5.3 Research Contribution

Effective information sharing has been a critical issue in improving supply chain performance. Although there is abundant research on the role of information sharing in supply chains, it has not been fully integrated into the supplier flexibility. The goal of this research is to provide insights on how information sharing, between OEMs and their first-tier suppliers, impacts the latter's flexibility in responding to fluctuating volumes. Therefore, this research contributes to the body of knowledge in several ways.

First, this research asserted that flexible first-tier suppliers play an important role in agile supply chains by responding to fluctuating demands. By observing the literature presented in Chapters 2 and 4, it is evident that the impact of information sharing on performance is well studied and empirically validated. However, several studies have focused on manufacturers and ignored the suppliers. Hence, this study provided more insight into first-tier suppliers. To our best knowledge, this research appears to be the first of its kind focusing on the relationship between information sharing and flexibility of first-tier suppliers in the automotive industry.

Second, the particular types of information being shared were identified based on their relevance and influence on supplier responsiveness. The supplier responsiveness was identified by three main capabilities: safety stock and inventory planning, temporary workforce planning, and production capacity planning. These capabilities were found to be time sensitive, accurate, and shared updated information by OEMs. Hence, a conceptual framework was developed to depict the impact of information sharing on suppliers' responsiveness.

Third, this thesis contributes to the academic field of operations and supply chain management by developing a model to explain how information sharing affects suppliers' delivery capabilities. The key variables and indicators were identified and verified. The model provided a measurement scale to quantify the impact of sharing demand forecast and inventory data, between OEMs and suppliers, on the latter's volume and delivery flexibilities. The model also confirmed that sharing demand forecast is a key enabler of the supplier's volume and delivery flexibilities while sharing inventory data is not.

Finally, this thesis contributes to the methods by using a state-of-the-art PLS-SEM algorithm and applying advanced concepts to empirically test the model in Study No. 2. For instance: assessing the measurement and structure models using bootstrapping procedure.

5.4 Managerial Implications and Suggestions for Practitioners

The supplier perspective has been recognized as a new way to conduct research on supply chain management (Rota et al., 2002). Recent research indicates that the automotive suppliers play an important role in the industry. For instance, Harrison and van Hoek (2008) assert that suppliers in the automotive industry account for 70% to 80% of the total value creation. This percentage implies that suppliers are responsible for a significant portion of the total value creation in this industry.

This thesis has several managerial contributions to examine the issue of information sharing and flexibility at the supplier level. For managers, investigating the problem from the supplier's perspective brings some insight into short-term decisions, such as production scheduling decisions, internal production, inventory processes, and evaluating collaborative practices with OEMs. Within this context, this thesis suggests that the management should not overlook the basic elements of day-to-day operations of volume flexibility because it has been shown to significantly influence the delivery flexibility level. Therefore, their delivery performance is highly influenced by the ability of suppliers to increase or decrease production volumes without affecting the quality of the products.

Furthermore, this thesis provides a diagnostic tool for OEMs to predict the level of flexibility capabilities of their suppliers by analyzing the supplier's delivery performance precision. As illustrated in Section (4.4.4.3) of Chapter 4, this diagnostic tool provides a guideline to identify the root causes of each particular delivery problem as well as the consequences on OEM operations. In addition, this tool proposes a recommendation for each scenario.

5.5 Research Limitations

As any other research study, this research has a few limitations worth noting. First, it focuses on one single industry in one country, which is the automotive industry in Sweden. The unit of analysis was mainly first-tier suppliers. The investigation included only

manufacturing firms of discrete parts and components. Service-based supplier firms (such as system providers and software) providers were excluded from the scope of investigation.

However, the OEM perspective is considered in Study No. 3. The results cannot be generalized to other industries such as electronics, food industry, chemicals, etc. and other countries. However, focusing on one single industry and country could be perceived as advantageous to this thesis since it allows for in-depth analysis of an important industry in one of the most advanced industrial nations in Europe.

Second, studies No. 1 and No. 3 followed the qualitative research approach using case study research methods. Thus, the subjectivity of the case study analysis might be a concern. Therefore, we do not aim to generalize the results to other industries or other types of suppliers; instead, we consider the results as imperative signs to understand how first-tier suppliers practically perceive the importance of information sharing in improving flexibility and responsiveness-related decisions.

5.6 Suggestions for Future Research

The findings of this thesis reinforce the need for further research focused on first-tier suppliers. Based on the findings and limitations discussed in this thesis, the following research lines are suggested for future research opportunities:

1. Studying the impact of information sharing on other flexibility aspects, such as product flexibility or product mix flexibility.
2. Exploring the effect of information sharing on outsourcing decisions.
3. Exploring the benefits of adopting an instant sharing of real-time production data such as delivery schedules, in-process inventory, machine breakdown, delays, etc.
4. Identifying other factors that may affect the level of sharing demand forecasts, volume flexibility, and delivery flexibility.

5. Studying the impact of information sharing between first-tier and second-tier suppliers on flexibility capabilities of the former.
6. Quantifying the benefits of involving suppliers in the demand forecasting process at an early stage.
7. Examining the impact of sharing other types of information on a supplier's delivery performance.
8. Considering other industries such as the fashion industry and Fast Moving Consumer Goods (FMCG), in studying first-tier suppliers.
9. Considering a larger sample size and other different geographic areas.

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Appendix (A): Interview Manual for Study No. 1

Introduction

This manual is designed to guide the interviewer to conduct a semi-structured interview where the researcher asks open-ended questions. The purpose of the interview is to collect qualitative data from experts in the supply chain. The questions are designed based on the understanding of research questions of my doctoral thesis. Therefore, some questions, might be revised, rewritten, or restructured in other ways.

Opening clause

I would like to thank you for accepting our request to have an interview with you. I would also like to express my appreciation to you for taking out time to answer the questions raised in the interview.

Confidentiality clause

The collected data and information will be used only for the purpose of scientific research. The company's and interviewees' names will not be revealed or disclosed unless acceptable to either. Your privacy, therefore, will be our highest priority and responsibility. However, results and analysis of this research will be subject to academic publication in the form of academic journal articles, doctoral thesis, and international conference papers.

Recording

This interview will be audio -recorded unless the interviewee refuses it. The purpose of the recording is to help both the researcher and the interviewers to focus on delivering a good interview, so that the former can refer back to the questions at any time. Most importantly, the recorded interview is used for the transcription process. This helps avoid subjectivity and self-bias in analyzing the answers.

Length of the interview

The interview is expected to last between 60 to 90 minutes.

Section I: Interviewee's general information

Interviewee's name
Position (Job role)
Experience (years)
Tel./Mob.
E-mail
Date
Time

Section II: Company's general information

Company's name
Annual revenues
Number of employees
Main products
Tel.
Address
Website

Section III: Supplier's supply chain strategy

1. Based on your company's core business (i.e., main product line), where do you locate your company's position in the automotive supply chain map?
 - a. 1st tier supplier
 - b. 2nd tier supplier
 - c. Other (please specify)
2. Which of the following ERP strategies does your company pursue? And why?
 - a. Make-to-stock
 - b. Make-to-order/Assemble-to-order
 - c. Other (please specify)
3. From your point of view, how do you define 1) manufacturing flexibility and 2) responsiveness? What is the difference between them?
4. How do you reduce the lead-time of your main product? What are the required actions/operations/procedures/decisions/investments that you normally undertake?
5. Was the support you received from your buyers enough to achieve lead-time reduction?

Section IV: Information sharing and exchange

6. Do your buyers share their data and information with you? All buyers or strategic ones?
7. What kind of information would you like your buyers to share with you (e.g., price, cost, inventory level, demand forecast, product design, etc.)? Which is more important for you to know? Why?
8. How frequently do they share such information?
9. Was the data obtained accurate enough?
10. How do you communicate with your buyers to get such information?
11. Is obtaining such data helpful to fulfill customer orders that involve changes in quantities? Can you elaborate on that?
12. How can such data affect your production/outsourcing decisions?

Section V: Supplier's flexibility

13. What does the company do in order to respond to changes in the volume/quantity of the ordered products?
14. What does the company do to measure its ability to respond to those changes?
15. How do you ensure that the quality and delivery time of the product will not change?
16. What are the required investments/costs for adjusting the capacity accordingly?
17. If your company is unable to adjust its production capacity to fulfill customer orders, or when it is unable to accommodate such changes internally, does your company resort to making outsourcing decisions?
18. What does your company do to increase/decrease its production capacity?
19. Do you mind if we get back to you later for further explanations (just in case)?
20. Additional information you may like to add.

Closing statement: I would like to thank you again for your valuable views and answers, and I do believe that your participation will enrich our study. Thank you very much for this opportunity.

Appendix (B): Survey Questionnaire for Study No. 2

Dear participant,

This survey is a part of a doctorate research project conducted in the School of Industrial Engineering and Management at the Royal Institute of Technology KTH in Sweden. It explores the role of information sharing (between OEMs and suppliers) in improving suppliers' flexibility and responsiveness to fluctuating demand. Ideally, the respondent should possess a comprehensive knowledge of production, logistics, and supply chain activities. While filling this questionnaire, please consider only the main product business unit of your company.

All questions are designed to avoid exposure to confidential data; nevertheless, all responses will be treated anonymously and used for scientific research purposes only. The survey will take less than 10 minutes to complete. Please do not hesitate to contact the correspondent researcher for any further information.

Thank you for taking time to fill this survey.

Sincerely,
Corresponding researcher

Part 1: Information sharing and flexibility measurement indicators [Questions 1-19]

On a scale of 1-5, where **1=Strongly Disagree**, **2=Disagree**, **3=Neutral**, **4=Agree**, and **5=Strongly Agree**, how would you rate the following statements regarding your main product's business unit.

Q #		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Question	1	2	3	4	5
1	We deliver various sizes of minimum delivery quantities to all customers					
2	We give priority to the requests from strategic customers					
3	We are able to mix different products into a delivery load without increasing the cost of transportation					
4	We use fast modes of transportation to deliver urgent delivery requests					
5	The total transportation time of our main product is relatively short					
6	The total production capacity of machines is large enough to accommodate any significant increase in demand					
7	The processing time of fluctuating orders is relatively short					
8	In case our in-house capacity cannot satisfy the total demand, we outsource some operations or part of the production					
9	The production lead-time of our main product is relatively short					

Q #		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Question	1	2	3	4	5
10	The switching time between different operations or product lines is relatively short					
11	We use multiple shifts and temporary hiring or lay-offs					
12	The demand forecasts data that we receive from our main customers is quite accurate					
13	The demand forecasts data that we receive from our main customers is quite complete					
14	Our main customers share their demand forecasts data with us frequently					
15	Our main customers update their demand forecasts data frequently					
16	The inventory data that we receive from our main customers is quite accurate					
17	The inventory data that we receive from our main customers is quite complete					
18	Our main customers share their inventory data with us frequently					
19	Our main customers update their inventory data frequently					

Part II: Company and participant information [Questions 20-25]

20. How many employees are working in your main product's business unit?

- ☐ Less than 50
- ☐ Between 50 and 250
- ☐ More than 250

21. How would you classify your main product's business unit in relation to your automotive supply chain?

- ☐ Mostly, we are first-tier suppliers
- ☐ Mostly, we are second-tier suppliers

22. Which of the following best describes your supply strategy?

- ☐ Make-to-order/Assemble-to-order
- ☐ Make-to-stock

23. How would you describe the current business relationship between your business unit and your main customers?

- ☐ Strategic relationship (i.e., Long term supply contract)
- ☐ Tactic relationship (i.e., Short term supply contracts/e-procurement)

24. Which of the following job roles or functions do you belong to?

- ☐ Top management

- Sales/Marketing/Customer services
- Production/Inventory/Logistics
- Finance/Purchasing/Strategic planning

25. For how many years has your main business unit been working in the automotive industry?

- 1-5
- 6-10
- 11-15
- More than 15

Thank you for your kind participation

Appendix (C): Interview Manual for Study No. 3

To help collect the right data needed for developing the case study in Study No. 3, this manual is designed to guide the researcher in conducting the interviews. To ensure internal validity, most questions in the interview were designed based on the underlying concepts of the research question RQ3 while some other questions were more about general facts and working procedures to allow for searching of evidences. Furthermore, the questions were reviewed by two experts. One is a professor in the operations management field and the other is a supply chain expert from the automotive industry. Since this is a semi-structured interview, other questions emerged while interviewing, allowing the participants to interact by adding more information and reflecting on their answers. The study was conducted from November 2014 to May 2015.

Part I: Understand the inbound logistics operations at the case company

1. What is the organization chart of the case company inbound logistics (i.e., structure of the functional units)?
2. What are responsibilities of each unit?
3. Which forecasting model does your company use?
4. Can you describe how the following processes work?
 - Demand forecasting and planning
 - Material flow (inbound)
 - Production planning
 - Information flow (inbound)

Part II: Collaboration with suppliers

1. What are the current mechanisms of information sharing with first-tier suppliers?
2. Are these current mechanisms sufficient for improving supplier delivery flexibility?
3. Do you implement CPFR in your company? With all suppliers?
4. What are the aspects of efficient sharing of information?
5. How can these aspects enhance the supplier's delivery performance?

Part III: Supplier-related questions

1. How do you measure a supplier's delivery performance?
2. How do you categorize your suppliers?
3. What the locations of suppliers? Where? What are the main delivery locations?
4. How do you measure the supplier's delivery precision?
5. What is the delivery lead-time for each product?
6. What were the delivery schedules for the past 12 months?
7. What were the actual delivery quantities for the past 12 months?

Part IV: Orders

1. How often do you order these components?
2. What is the demand forecast for the last 12 months for those parts?
3. What were the production volumes for the last 12 months for those parts?
4. What are the quantity changes (i.e., last-minute changes) in the corresponding purchasing orders (POs)?

Part V: Communication and IT tools

1. How do you communicate your POs?
2. How do you communicate changes in POs?

3. When do you communicate changes in POs?
4. What information do you share with suppliers?
5. How frequent do you share each type of information with each supplier?
6. How accurate is the information being shared?

Appendix (D): List of Acronyms

Acronym	Designation
ATO	Assemble-to-Order
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CB-SEM	Covariance Based Structural Equation Modeling
CNC	Computer Numerical Control
CPFR	Collaborative Planning, Forecasting, and Replenishment
CRM	Customer Relationship Management
CRP	Continuous Replenishment Program
EBSCO	Elton B. Stephens Company
EDI	Electronic Data Interchange
EOQ	Economic Order Quantity
FAI	Forecasting Accuracy Index
FKG	Fordonskomponentgruppen-Swedish Association of Automotive Suppliers
FMCG	Fast Moving Consumer Goods
FPS	Flexible Production Systems
ICT	Information & Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
JIT	Just-in-Time
KPI	Key Performance Indicators
MRP	Material Requirement Planning
MTO	Make-to-Order
MTS	Make-to-Stock
ODETTE	Organization for Data Exchange by Tele Transmission in Europe
OEM	Original Equipment Manufacturer
OOS	Out-of-Stock
PLS	Partial Least Squares
PLSc	Consistent Partial Least Squares
PLS-SEM	Partial Least Squares Structural Equation Modeling
POS	Point-of-Sales
RBV	Resource Based View
SMEs	Small And Medium-Sized Enterprises
SP	Supplier portal
SPF	Single-Piece Flow
SPSS	Statistical Package for the Social Sciences
SRM	Supplier Relationship Management

TCE	Transaction Cost Economy
TPS	Toyota Production System
VM	Vehicle Manufacturer
VMI	Vendor-Managed Inventory
VSM	Value-Stream-Mapping
WTS	Weighted Tracking Signal

Appendix (E): Emerged Working Papers & Conference Presentations form this thesis

Working Papers

Paper 1: Dwaikat, N. Y., (2016), "Flexibility and responsiveness through information sharing: Evidence from automotive suppliers in Sweden". The paper has been submitted to Operations Management Research.

Paper 2: Dwaikat, N. Y, Money, A., Beheshti. H., & Salehi-Sangari, E., (2016), "How does information sharing affect first-tier suppliers' flexibility? The paper has been submitted to International Journal of Operations & Production Management

Conference Presentations

Presentations 1: Dwaikat, N. Y., (2015). "Information sharing with first-tier automotive suppliers: A volume flexibility perspective". The paper was accepted and presented in the 22nd EurOMA Conference, Operations Management for Sustainable Competitiveness, 26 June-1 July 2015, Neuchâtel, Switzerland. (Accepted and presented).

Presentations 2: Dwaikat N. Y., (2016), "What factors should OEMs consider to improve the sharing of demand forecasts with suppliers?" the 27th POMS Annual Conference, 6-9 May, 2016, Orlando, Florida, US. (Accepted for presentation).

