UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master's degree in International Business and Trade

Supply chain disruption and its impact on MNCs business models.

- A Case study of an automotive company facing semiconductor shortage.

Master's degree Project, spring 2022

Graduate School

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Abstract

In the interconnected world we are living in, MNCs have their supply chains located all over the globe. This implies an increased risk for disruptions within the supply chain which impacts rapidly all the parts involved in it. It is therefore crucial for organizations to manage their risks in order to mitigate the consequences of disruptions. This study hereby studies the impact on the supply chain of a global disruption that extends during a long period of time.

To gain a deeper understanding of the perspective of automotive manufacturers toward a global disruption and its impact on the supply chain, a case study was conducted with the participation of one car manufacturer located in Gothenburg. The study was conducted on site at the company's headquarters enriched with internal information from the case company with multiple observations; taking part in meetings and to other relevant documents; but also, through a number of interviews with a semi-structured format with managers of departments daily dealing with disruption issues.

The main findings of this study are that management in the supply chain done upstream permits to mitigate upcoming disruptions. Regarding the impact of disruption in the supply chain on business models, we notice mutual readjustments from the actors of the supply chain in order to meet future goals of the company in their business model. This study contributes to existing knowledge by treating the perspective of a global disruption that extends during a long period of time and by studying the management of risks and of the actual supply chain during a global disruption.

Key words: Supply Chain Risk Management, Extended Global Disruption, Automotive MNC, Supply Chain Management.

Acknowledgements

We have received a great deal of support and assistance when writing this thesis.

Therefore, we would like to express our deepest thanks to our supervisor at the school, Niklas Åkerman, for your support and professional guidance. Your feedback was valuable to bring our work to a higher level. We would also like to express our sincere gratitude to our company supervisor, Christian Söderström, and his team at the case company, for their support and professional expertise through this process.

Furthermore, we also want to express our gratitude to all the respondents that have participated in this study and provided us with valuable insights. It would not have been possible to conduct this study without your participation.

Gothenburg, 26 May 2021.

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1. Introduction

In this introductory chapter, a brief background for this study is presented introducing the importance of a business model and overview of supply chains. It is followed by a definition of supply chain disruptions, introduction to semiconductors and a brief overview of disruptions within the automotive industry. It concludes with a problem discussion, presentation of the research purpose and questions as well as study delimitations.

1.1 Background

During the last decades companies around the world are being more and more globalized and in order to have successful operations they are required to set clear goals and objectives, which are commonly known as vision and mission. But also have a clear business model that is keen to change knowing the industrial development within many sectors. A business model can be described as the core logic that creates value for the company, in the form of generating profits, attracting customers, employees and investors as well as delivering products and services that satisfy demand (Linder & Cantrell, 2000). Business models encompass and span across firms' various business functions in order to create value (Norris, Hagenbeck & Schaltegger, 2021). This includes the management and handling of supply chains, and its processes which are performed to create value for the firm (Trkman, Budler & Groznik, 2015).

A supply chain is a network of organizations where information and materials flow in order to produce goods and services to the customer (Stadtler, 2005). This definition gives a very simplistic view of a supply chain, as the flows are linked by multiple processes, relationships, activities and various information systems (Waters, 2007). Therefore, supply chains, especially within multinational companies (MNCs), are often large in size and have a dynamic and complex nature (Wu, Blackhurst & O'Grady, 2007), with a focus on increasing efficiency and reducing costs. However, this leads to supply chains being vulnerable to disruptions (Stecke & Kumar, 2009), which can have both financial and strategic consequences on the company (Tomlin & Wang, 2012). Companies that manufacture more complex products that contain many different parts and components are particularly vulnerable to supply chain disruptions. If the manufacturer is missing a single part, it will not be able to produce the desired product (Inman & Blumenfeld, 2014). There are many reasons for supply chain disruptions, such as transportation delays, natural disasters, or any other event (Wu, Blackhurst & O'Grady, 2007).

One example is the Covid-19 pandemic, which has impacted the world's economy in its entirety. Many challenges had arisen due to the outbreak of Covid-19, as many companies faced shipping problems, supply difficulties, and lockdowns. However, the effects of the pandemic on the supply chain are industry-specific since different industries rely on the global supply chain in different ways. Industries reliant on highly specific, specialized goods such as semiconductors, face a long return to normal (Ford & Scheck, 2021).

1.1.1 Definition supply chain disruption

In the traditional physical distribution chain, actors within the supply chain were separated in a sense that links between the first production site all the way to the end customer were not interacting with each other. Each actor was focused in its own role, keeping information to itself and acting mainly for its own best interests (Kajüter, 2002). Various disruption risks emerged such as the delay of product delivery, the damage of products during transportation, sending goods to the wrong place, wrong articles delivery and so on. To mitigate those risks, links within the distribution channel; placed orders early, kept buffer stocks and had greater flexibility in lead times. The traditional physical distribution chain was vulnerable and risk management in the chain was therefore managed by each individual company (Paulsson, 2007).

In the modern distribution process, the physical distribution chain is turned into a supply chain. The supply chain expands the chain upstream (to the source of raw material) and different links are deeply integrated with each other. This has created a competition between different supply chains and with an increased globalization, firms on the supply side reduce costs by procuring components, raw materials and services from geographical parts of the world where price and quality are the most favorable (Fine, 1998; Craighead et al., 2007). Another difference between the traditional physical distribution chain and the modern supply chain is that it is more and more common for firms to rely on only one supplier (single sourcing) or two (dual sourcing) of each raw material or service for the purpose of cost-effectiveness.

Disruptions in one part of the supply chain are easily spread to other parts of the chain, indeed a fire in a production plant, a natural disaster (drought, flood) could mean a total elimination of production capacity. The spread of the effects of a disruption from one link of the supply chain to another is called the “domino effect”.

Accordingly, Jütner et al., (2003), affirmed that the domino effect, illustrated in Figure 1, might increase as you get further away from the initial point of the event in the chain. Escalating domino effects are believed to have huge consequences on the individual company in the chain, it is therefore argued by Paulsson (2007), that deeply integrated supply chains might be highly vulnerable for the individual link. In a case that disruption reaches the end market, consumers have the opportunity of changing over to another brand or to another product to fulfill their needs. Disruption can also be caused by quality problems in the product itself and the consequences of those are particularly serious as they can damage the consumer's confidence in the product (ibid).

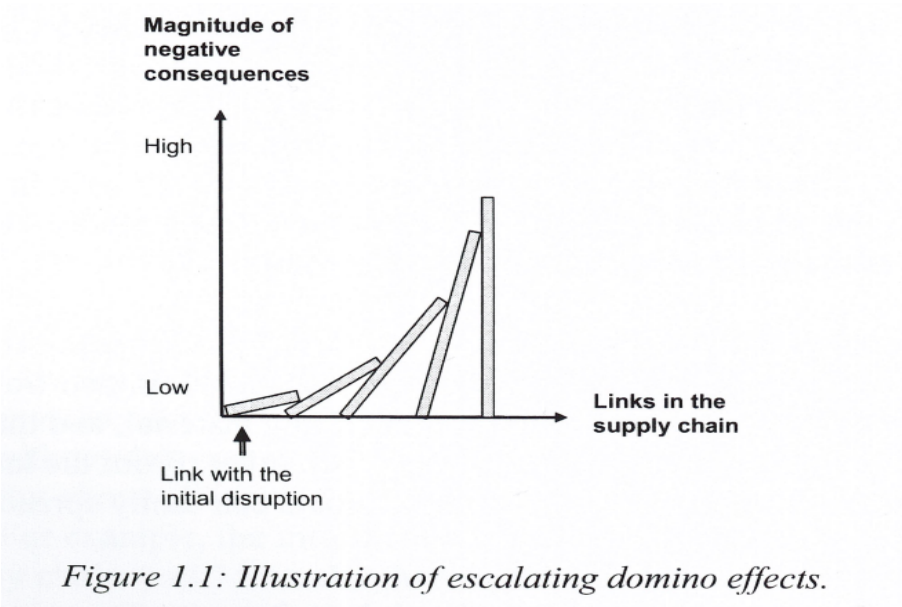

Figure 1.1: Illustration of escalating domino effects.

Figure 1: Illustration of the escalating domino effects. (Paulsson,2007 pp.137).

In this way, researchers had an increasing attention toward disruptions the past years and studied the causes behind them, how to manage them and tried to differentiate them from each other. Craighead et al. (2007, p.132), define supply chain disruption as "unplanned and unanticipated events that disrupt the normal flows of goods and materials within a supply chain". Moreover, Paulsson (2007) developped a model of different risk sources, where terrorism, natural disasters, ordinary disruptions, and ordinary disruptions are five main risk sources of disruptions in supply chain. Trkman & McCormack, (2009) differentiates "only disruptive" events (such as bankruptcy, natural disasters, or the possibility of a terrorist attack) and "turbulent environment" where continous changes occurs due to technology shifts, supplier priorities or customer tastes). It is also stressed by the authors that suppliers are influenced differently to turbulences because they operate in different markets and environment and while

for example a certain supplier strategy is to order large batches to decrease acquisition cost or having single-source suppliers with long contractual commitments may be acceptable in a non-turbulent environment, on the contrary in a more turbulent environment it is less acceptable, for example in the presence of quick technological advances such as microprocessors or large commodity price swings.

The last-mentioned causes join the attempt to gather sources behind supply chain disruptions presented by Kleindorfer & Saad (2005). Indeed, they present different sources, such as operational contingencies (equipment malfunctions and systemic failures, financial distress and human-centered issues ranging from strikes to fraud), natural hazards; earthquakes, hurricanes, and storms (e.g the hurricane in Florida in 2004, hurricane Andrew in 1992 but also the Kobe earthquake in Japan 1995). The last disruption source is terrorism and political instability, with the example of World Trade Center attacks in 2001, sabotage and destructive competitve acts.

Operational disruptions are defined as unplanned incidents that negatively affect the regular operations of an organization (Schmidt & Raman, 2012). According to Blackhurt et al. (2011), OD is the rate at which organizations encounter unforeseen events that obstruct the steady flow of their operations. The examples given as causes for OD by Schmidt & Raman (2012), to firms are transportation interruptions, unscheduled shutdown of plants, shortage of parts, logistics and supplier failure. Based on the arguments above, the current shortage of semiconductors in automotive MNCs can be classified as an operational disruption (OD) or operational contingency as the sudden disruption of microchips is partly due to systemic failures such as unscheduled shutdown of automotive plants, shortage of parts in the shadow of the Covid-19 pandemic (Schmidt & Raman 2012; Kleindorfer & Saad, 2005).

1.1.2 Definition of semiconductors

Semiconductors are components which carry the same properties as conductors and insulators in electrical equipment. Semiconductors are mostly composed of germanium and silicon, with the latter being the most frequently used in the world. Semiconductors are essential parts of integrated circuits (ICs), which enhance the capability and performance of electronic appliances (Hitachi, 2022). Semiconductor chips, which are being used in everyday electronic appliances, are manufactured by melting silicon into ingots, which are then sliced into thin wafers, which are in turn made into hundreds of chips. Manufacturing chips is a complex

process, which involves hundreds of individual steps in a timespan of several weeks (Geng & Zhou, 2005). Because of its qualities, semiconductors are crucial components used by many manufacturing industries in their production today, with 169 industries in the United States alone that are using these components in their products (Voas, Kshetri & DeFranco, 2021). Semiconductors are essential components in modern electronic devices, enabling advances and innovations in healthcare, computing, communications, transportation, clean energy and other areas. Without semiconductors, there would not be any television sets, computers, smartphones or advanced medical equipment (SIA, 2022). Semiconductors are becoming increasingly harder to obtain, and shortages affect most economic sectors in the world, such as phones, television sets, gaming consoles and household appliances (Voas, Kshetri & DeFranco, 2021). This shortage in semiconductors has impacted the supply chain of many MNCs in 2021 and it directly affects product prices for companies using them in manufacturing of their final product. The supply chain disruption forced firms to find temporary solutions in order to satisfy the demand on their products. Reconditioning older chip technologies is a promising solution both for the manufacturing and the engineering side, this is done in the automotive industry where "used" semiconductors equipment are rehabilitated in order to be used in newer models (Wang, 2021).

Chip shortage is a historical issue. In 1988, there was a worldwide shortage of chips, due to factors such as increased demand for increasingly powerful and sophisticated computers, and the 1986 US-Japan semiconductor trade pact (Olmos, 1988). In 2004, there was a shortage of CDMA (Code Division Multiple Access) chips, due to a rapid increase of CDMA networks around the world (Malik, 2004).

Factors that are believed to be causes of the shortage are natural factors and disasters, such as weather and fire. In March 2021 a fire damage happened in Japan's Renesas Semiconductor Manufacturing Co. Ltd. The company produces one third of microcontroller chips embedded in cars globally. Matsuo (2015) portrays the impact of the Tohoku earthquake in 2011, on Toyota's supply chain as the earthquake damages the plant of Naka where semiconductors were manufactured by Renesas. Toyota purchased its MCU (micro controlled units) from several suppliers (first-tier suppliers), and had decreased its dependency on Denso, a global automotive component manufacturer, from 74% of MCU purchases in 1992 to 44% in 2007. However, after the earthquake it turned out that all the first-tier suppliers that Toyota purchased from were purchasing the same MCUs from one single semiconductor company, Renesas

Electronics and from one single factory, in Naka. The Naka plant's recovery was initially planned to take six months, but through a concerted effort from a large group of stakeholders, the plant recovery took only three months. This quick recovery is attributed to the supply chain coordination mechanism of Toyota production system through close collaboration with first-tier suppliers (Matsuo, 2015). Texas-based semiconductor manufacturing facilities were forced to shut down as a consequence of a cold weather outbreak in February 2021 (Voas, Kshetri & DeFranco, 2021).

Also the fact that production of semiconductors requires a lot of water, in 2021 the production hub of Taiwan Semiconductor Manufacturing Company (TSMC) in Taichung Taiwan experienced a serious drought which worsened the shortage and companies in the city were forced to reduce their water usage by 15% this lead TSMC to transport water from other parts of the country using tanker trucks (still the use of a daily quantity of 200,000 tons of water necessary for TSMC production were hardly covered by the transportation of tanker trucks that only carries 20 tons of water). Another factor that is worth mentioning, is the stockpiling of chips done by firms in some countries. In anticipation of US sanctions Chinese firms such as Huawei began stockpiling chips from 2019 which contributed to tight capacity at its main foundry TSMC, Chinese imports of ICs in Q1 2021 increased by more than a third compared to Q1 2020 (Voas, Kshetri & DeFranco, 2021).

The current semiconductor shortage is an event that occurred with a sudden high demand of semiconductors that are constantly improved technologically, and this could be seen as a technology shift as mentioned by Trkman & McCormack (2009). Infact, demands for high-performance memory systems have had a direct impact on semiconductors memory intellectual property (IP), the market demand for faster and more efficient memory is driving the development of increasingly complex semiconductors (IRDS, 2020). Furthermore, the Covid-19 lockdowns worldwide caused a rise in demand for PCs, with the working-from-home orders and education going digital (Voas, Ksherti & DeFranco, 2021). Within the automotive industry, semiconductor suppliers are constantly innovating their components to meet demand from automotive MNCs (Burghardt, Choi & Welg, 2017).

The Covid-19 pandemic can also be considered as a main factor, as the subsequent lockdowns temporarily disrupted the shipments; the global demand for electronic devices (PCs, smartphones, upgrades in data centers) surged in response to remote work, remote studies, and

other stay-home trends (ibid). Moreover, the suppliers of semiconductors are few, indeed, four companies are sharing 60% of the world's market share (Flynn, 2021).

In order to understand the shortage that happened in the semiconductor industry it is important to explain how its economic model is organized. The production network of the semiconductor industry became more global in the 1980s with semiconductor designers moving toward outsourced manufacturing. Companies that design, sell the hardware and semiconductor chips but don't manufacture the silicon wafers used in its products are called fabless chip makers. The fabrication of the silicon wafers is outsourced to chip-making factories known as foundries to manufacture the chips. Taiwan Semiconductor Manufacturing Company (TSMC) is the pioneer of the "foundry and fabless" model and East Asia is the heart of fabless manufacturing, about three quarters of the global semiconductor manufacturing capacity as well as key suppliers of key materials are in Asia.

The term "fabless" refers to the company that designs and sells the hardware and semiconductor chips. A fabless company manufactures however not the silicon wafers (chips) used in its products and outsourced it to a manufacturing plant called "foundry" (Schmitt, 2021). It is even more true for the manufacturing of advanced semiconductor devices, indeed 100% of the worlds highly advanced logic semiconductors, (below ten nanometers), manufacturing is done in two Asian countries; Taiwan and South Korea with respectively 92% and 8% of world's production (Voas, Kshetri & DeFranco, 2021).

As mentioned earlier the shortage of semiconductors has impacted many industries and countries are taking measures in order to secure access to semiconductor production.
In order to catch up with the global tech race, the European Union acted the EU Chips Act on February 8, 2022, with a desire to mobilize €43 billion of public funds and private investment until 2030 with an allocation of €11 billion in public funds for the research design and manufacturing of semiconductors (Europa, 2022). This echoes the decision of the U.S administration in February 2022 to seek $37 billion in order to boost chip manufacturing in the US (also called CHIPS act). With an ambition of reducing the dependency of American semiconductors firms supply chain from China (Bose & Hunnicutt, 2022).

As explained previously many industries have been impacted by the shortage of electronic parts, such as sensors and semiconductors, however the punch is not equal, and the automotive

industry is being hit the hardest. Indeed, shortages related to semiconductors have been forecasted to cost the auto industry $210 billion in revenues in 2021 with a production loss of 7.7 million units (AlixPartners, 2021).

As an illustration of the important impact of semiconductors shortage on the automotive industry, the example of Volkswagen can be taken with the cut down of at least 100,000 produced vehicles in 2021 and Renault with a loss of 500,000 produced vehicles in 2021 (Asanuma-Brice et al., 2021). The other industries that have been hit by the chip shortage are the consumer electronics especially due to the increasing demand during the pandemic with students and employees forced to adopt virtual learning and work from home (the worldwide PC market increased by 55% in the first quarter of 2021), the LED and lighting fixtures and turbines and solar (Dooley, 2021). The shortage is a result of merging factors, the demand for microprocessors was high before the pandemic mainly because of the deployment of the 5G but also self-driving vehicles, artificial intelligence, and the Internet of Things. When the pandemic spread from China to the rest of the world, carmakers such as General Motors, Ford Motor and Volkswagen were forced to shut down production lines temporarily, and canceled orders for chips used in car electronics systems like driver assistance and navigation control. Chip manufacturers like TSMC reassigned their spare production capacity to companies in other industries using semiconductors; like smartphones, laptops and gaming devices that experienced a sudden demand during the pandemic lockdowns. However, car sales recovered faster than expected and when carmakers tried to step up production again, they were faced with the incapacity for chip factories to meet their demand given the long lead times needed to schedule orders (SCMP, 2021). The scarcity of semiconductors spilled over into other industries such as consumer electronics and home appliances particularly because of the pandemic's “stay at home” effect that boosted sales.

1.1.3 The automotive industry facing supply chain disruption

Car manufacturers in the automotive industry include various types of production units in their supply chains (e.g., assembly, forge & mechanics). Their production, which can account for several thousands of cars daily, is operated and managed according to the just-in-time (JIT) strategy (Pierreval, Bruniaux & Caux, 2007). JIT is implemented in order for manufacturers to stay competitive, maintain cost efficiency, and to achieve profitability. The supply chain of parts and components are usually based on immediate customer demand. However, the supply

chain management (SCM) does not consider unexpected events, such as disruptions in the flow of materials and components. Therefore, supply chains within car manufacturers have proven to be particularly vulnerable to disruptions (Svensson, 2000). Automotive MNCs also have no safety stocks to rely on when there are turbulences in their supply chains (Thun & Hoenig, 2011).

The automotive industry in particular is a heavy user of semiconductors, with the average modern car containing up to 3000 semiconductor components (Voas, Kshetri & Defranco, 2021). One reason for the automotive industry's heavy usage of semiconductors is how automotive technology has innovated with the help of semiconductors, as well as how more technologies are being incorporated into the mass production of cars. With cars becoming increasingly complex, demand for semiconductors continues to rise (Burghardt, Choi & Welg, 2017).

As defined previously, supply chain disruptions (SCDs) "are unplanned and unanticipated events that disrupt the normal flows of goods and materials within a supply chain" (Craighead et al. 2007, p.132). And, in order to mitigate disruption risks, researchers studied events that happened in specific supply chains within single companies, or single countries (Matsuo, 2015; Kleindorfer & Saad, 2005; Hendricks & Singhal, 2003). In the previous example of 2011 Toyota's supply chain disruption, the fast recovery was possible mainly because of the willingness of stakeholders to quickly recover, the coordination mechanism proper to Toyota and because of the "nature" of the event that caused the disruption. Thus, commonality between those disruptions is that these are events that occur in a specific place in during a limited period of time, the example of natural disasters, financial issues, terrorism, human-centered issues, political instability support this argument.

Trying to have a deeper knowledge of SCDs impact on supply chains, (Craighead et al. 2007; Baghersad et al. 2021), define severity of SCDs "as the number of entities within a supply chain network whose ability to ship and/or receive goods and materials (i.e inbound and outbound flow) has been hampered by an unplanned, unanticipated event" (Craighead et al. 2007, p. 134). Bode & Macdonald, (2017), see severity as a construct that catches the negative effect of SCDs and that (SCD severity) can be measured in terms of costs of SCDs. Consequently, it is argued that a more severe SCD would have a greater negative financial

impact within a supply chain network than with a less severe one (Craighead et al. 2007; Baghersad et al. 2021).

1.2 Problem discussion

It is important for MNCs to analyze risks in order to mitigate them in their supply chain, the situation of the shortage of semiconductors can be defined as a disruptive event happening in a turbulent environment according to (Trkman & McCormack, 2009). Indeed, the authors stress the fact that Supply Chain Risk Management, (SCRM), focuses too often on the prediction of disruptive events instead of the root causes of uncertainties where continuous changes are most of the time ignored (e.g technology shifts or supplier priority). Secondly, bankruptcy, terrorist attack or natural disasters that (Tkrman &McCormack, 2009; Kleindorfer & Saad, 2005; Paulsson, 2007), characterize disruptive events and a parallel could be drawn between those events and the Covid-19 to the difference that the impact of the pandemic has had a bigger impact in terms of disruptions (severity) in many industries, many countries and during a longer period.

As mentioned above, supply chains within the automotive industry are complex and very sensitive to disruptions (Inman & Blumenfeld, 2014; Pierreval, Bruniaux & Caux, 2007; Svensson, 2000). These supply chains have been subjects of numerous research, usually focusing on studying the dynamic performances of automotive supply chains (Turner & Williams, 2004; Riddalls, Bennett, & Tipi, 2000), as well as how semiconductor supply chains are managed in response to fluctuating demand and uncertainty (Nakashima & Sornmanapong, 2013). However, there is little research that address SCD within the automotive industry and the shortage of semiconductors impacting automotive supply chains, with exceptions researching the impact on Japanese automotive industry after the Tohoku earthquake of 2011 (Matsuo, 2015), and aiming to quantify the systemic risk semiconductor shortages have on automotive supply chains (Laschat & Ehrmann, 2021). In addition, there is little research in how the shortage of semiconductors affects automotive MNCs and their supply chains from a global perspective and for a disruptive event that lasts a longer period.
Not knowing the impact of a global extended disruption that affects many industries is problematic in a world that has never been that interconnected and where regional disruption can have a global reach.

Indeed, previous studies have researched the topic within a single country or market, such as China (Wu, Zhang & Du, 2021) and South Korea (Hur, Hartley & Hahn, 2004). There is also little research in how automotive MNCs address SCDs regarding semiconductors. Previous studies have researched SCD in other original equipment manufacturers (OEMs) in countries like China and India (Luan et al, 2009; Shenoi et al, 2018). With the automotive industry steering further towards electric vehicles, autonomous vehicles, connected vehicles and mobility services, with analysts for example projecting that 50 percent of all sold vehicles will be electric by the year 2030, use and demand for semiconductors will rise further (Jones et al, 2019), and it will be of interest to analyze and research which segments of semiconductor technology will be relevant in automotive MNCs' business models.

With the identified lack of knowledge of how automotive MNCs manage global disruptions in their supply chains during a prolonged period of time, and the fact that semiconductors are necessary components in automobile manufacturing today, as well as the pandemic's effect on automotive supply chains, it is of interest from a theoretical and practical perspective to increase knowledge in how automotive MNCs manage risks within their supply chains and how they should ensure a steady supply of semiconductors in the future.

1.3 Purpose and Research Question

The purpose of this study is to gain a deeper understanding of how the shortage of semiconductors has affected supply chains of MNCs within the automotive industry. This study will be conducted in an automotive MNC in a single case study and will be examining the risks and SCRM at the company in face of a global disruption that has occured in an extended period of time. The actual name of the company has been anonymized and is given a nickname; ACG (Automotive Company Gothenburg).

The following research question is formulated based on this research purpose:

- ***How do the automotive MNCs manage their semiconductor supply chain during a prolonged global disruption?***

1.4 Delimitations

The semiconductor shortage does not give an exhaustive answer to the disruption of other components in the automotive supply chains. This will impact the transferability of the findings to other components, sectors, and firms within the automotive industry. Nevertheless, some aspects can be general to all companies dealing with disruption and risks in their supply chain.

2. Theoretical framework

This chapter outlines the theoretical framework applied in this study. It reviews firstly SCM to get a broad overview on how companies manage supply chains in general followed by global SCM to have a MNCs perspective on SCM, SCM within the automotive industry to understand how automotive MNCs manage their supply chain, SCRM and lastly SCM strategies to get a deeper knowledge on how MNCs manage risks internally. This chapter concludes with a presentation of a developed conceptual model that summarizes different theories addressed in this study.

2.1 Supply chain management

2.1.1 Supply chains

Supply chains are defined by Sanders (2012) as the network that includes the actors involved in sourcing raw materials and components, manufacturing, assembling and ultimately distributing the final product to the consumer. Supply chains encompass several integral flows, which include physical flows of components, parts, and raw materials, flows of vital information and data, flows of resources in the form of funds, labor and equipment (Mangan, Lalwani & Calatayud, 2021). As shown in Figure 1, there are three different parts of a linear supply chain; "upstream", which include the suppliers directed towards the "focal firm", and "downstream", which include the distributors, retailers and customers directed away from the focal firm (Sanders, 2012). Supply chain activities upstream are usually divided into tiers of suppliers. First-tier suppliers send materials directly to the focal firm, while second-tier suppliers send materials to the first-tier suppliers. In this case, a manufacturing firm might see the necessary component makers as second-tier suppliers, and sub-assembly constructors as first-tier suppliers that the firm has direct contact and bargaining with (Waters, 2007).

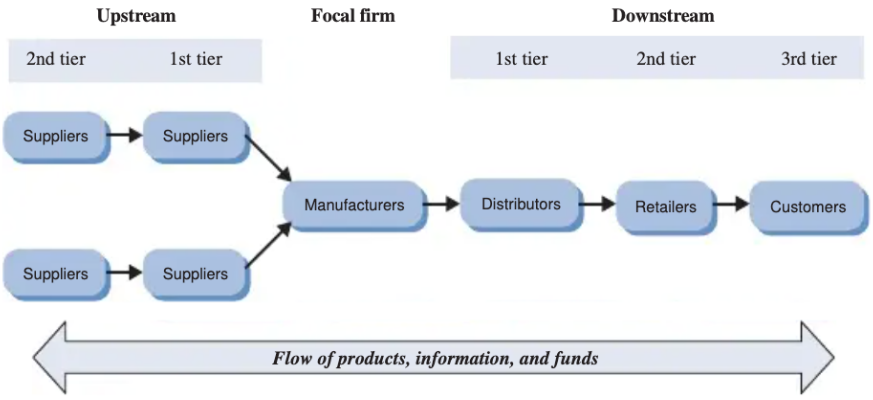

Figure 2: Examples of stages of a supply chain. (Sanders, 2012, pp. 5)

The term “supply chain” presents a rather simplistic and linear view of the process of turning raw materials into finished goods delivered to the customer. The supply chain is structured more like a complex network as shown in Figure 2, with multiple actors and organizations in entwined sets, meaning an interconnectedness between actors in the supply chain. In fact, the supply chain for producing a car contains thousands of different organizations communicating with each other (Sanders, 2012; Waters, 2007).

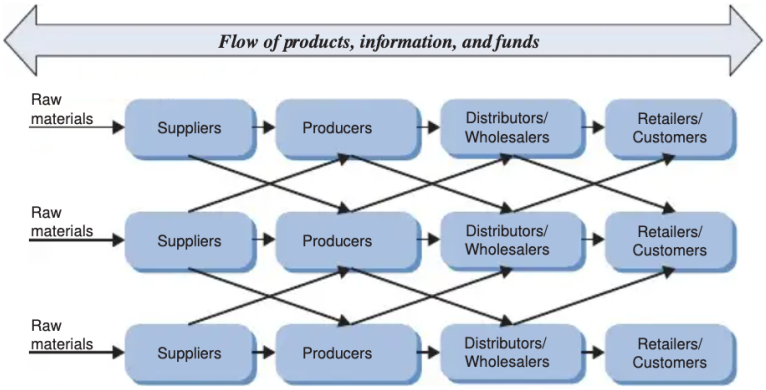

Figure 3: The supply chain network. (Sanders, 2012, pp. 5)

Companies located more downstream in a supply chain, with the buyer having a central role in, is called triadic supply chain. Indeed, the structure of this kind of arrangement is the buyer (focal company), establishing direct relationships with both its supplier and customer and where the supplier and customer are disconnected from each other (Swierczek, 2020). According to Mena et al. (2013), there are three types of triadic supply chain structures. Open triad is a traditional supply chain where there is no direct connection between the buyer and tier 2 suppliers and through which information flow is linear. The second type, a closed triad, depicts the situation where the buyer has an already established and direct connection with tier 2 suppliers. Finally, a transnational triad is a state between these two; in which the buyer reaches out to the tier2 supplier in order to become a close triad and build connections, this can be done through direct sourcing and providing training.

2.1.2 Definition of Supply chain management

Supply chain management (SCM) is defined as the complex process of uniting and linking all the different entities of a company’s supply chain, such as the suppliers, customers, shippers, into a coherent supply network that makes effective use of the company’s time and resources (Zuckerman, 2002). The primary objective of SCM as a business function is to manage the

flow of materials from the suppliers through to end-users across multiple functions and multiple supplier tiers (Buckley, Enderwick & Cross, 2018). SCM takes an "end-to-end" (E2E) perspective from the upstream to the downstream end of a company's supply chain (Mangan, Lalwani & Calatayud, 2021). Usually, companies have many supply chain planning activities that are separate but do not connect well with each other. Therefore, E2E planning allows information to be shared on a need-to-know basis across the supply chain network, which prevents costly inventory buffers and allows the supply chain network to better respond to a fast-changing environment and match supply and demand (Sweeney & Waters, 2021).

SCM is a dynamic process that involves coordinating all the activities in the supply chain in order to maximize profitability and satisfy the end customers. Common activities with SCM include coordination, information sharing and collaboration (Sanders, 2012), which will be further elaborated upon in the following sections.

2.1.2.1 Coordination

Coordination usually involves coordinating the movement of goods through the supply chain, from the material supplier to the final customer, but also flows of funds and various financial agreements between actors (Sanders, 2012). By coordinating with both the upstream and downstream actors in the supply chain, cost reductions and competitive advantages can be achieved (Min et al, 2001; Porter, 1985). According to Fugate, Sahin and Mentzer (2006), coordination activities within the SCM can therefore be divided into three categories; price coordination, which include buy-back policies and two-part tariffs, non-price coordination, which involve allocation rules and quantity flexibility contracts and flow coordination, which involves managing flows of information and products.

2.1.2.2 Information sharing

Within the area of SCM it is important to share relevant information among the actors of the supply chain, both upstream and downstream. This includes information regarding for instance sales forecasts, inventory levels and sales data (Sanders, 2012). Information sharing within the supply chain can improve coordination of processes, reduce costs, and enable efficient material flow (Li & Lin, 2006).

2.1.2.3 Collaboration

Collaboration between actors within the supply chain is imperative for effective SCM, by, for instance collaborating on how to reduce costs and improve processes throughout the supply chain (Sanders, 2012). The focal firm needs to comprehend customer demand further downstream as well as the current real-time constraints of their supplier further upstream in order to optimize their own operations (Horvath, 2001).

2.1.3 Selection of suppliers

Having reliable and trustworthy suppliers is vital for an efficient supply chain. When choosing suppliers, focal firms take many factors into consideration, such as product quality, location, flexibility, lead time, price and ability to deliver on time (Joyce, 2006). By making the right choices in suppliers, firms can reduce risk and establish an effective supply chain system. Traditionally, firms have chosen suppliers solely based on price level, but that selection process has proven to be inefficient (Pal, Gupta & Garg, 2013). In the automotive industry, MNCs value consistency over the financial aspects, and choose suppliers based on potential of a collaborative, long-term relationship, as well as the ability to deliver quality products (Choi & Hartley, 1996).

2.2 Global supply chain management

All organizations and companies today operate in a global environment, with many companies serving an international market (Sanders, 2012). With the rise of globalization companies seeking competitive advantage by employing suppliers around the world, so has the number of global supply chains, which stretch beyond a single country's borders and where focal firms source from offshore suppliers and manufacture as well as distribute in different countries (Koberg & Longoni, 2019). It is apparent that SCM is not a domestic issue, as supply chains extend across national boundaries and pose a challenge to supply chain managers in the face of companies globalizing. Global supply chains are more difficult to manage in comparison to domestic supply chains, considering that geographical distance can cause increased transportation costs and lead-time in the supply chain (Meixell & Gargeya, 2005).

According to Caniato, Golini & Kalchschmidt (2013), global SCM is the combination of three processes: global sourcing, global manufacturing, and global distribution. These processes will be further discussed in the following sections.

2.2.1 Global sourcing

The process of global sourcing is defined by Trent & Monczka (2005) as integrating and coordinating materials, technologies, and suppliers across buying and operating locations. The reasoning for companies to progress from domestic buying to international purchasing and finally to global sourcing usually stems from seeking advantages in terms of cost reduction and efficiency (Contractor, 2021). Two common activities within global sourcing are offshoring and outsourcing. Outsourcing means that activities are carried out by external partners of the focal firm, and offshoring means that the firm itself is carrying out activities across national borders. Offshored activities can either be in-house or outsourced (Manning, Lewin & Massini, 2008). Companies can achieve comparative cost advantages by for instance manufacturing and procuring certain materials in-house, which is known as domestic in-house sourcing (Kotabe & Murray, 2004).

2.2.2 Global manufacturing

Global manufacturing: managing the different manufacturing activities across multiple locations around the world (Caniato, Golini & Kalchschmidt, 2013). For focal firms, particularly in the realm of manufacturing, deciding locations of manufacturing activities around the world is a vital part in their strategic decision-making process (MacCarthy & Atthirawong, 2003). There is a rise in manufacturing firms that pursue a global manufacturing strategy that stretches across national borders and takes advantage of capabilities and resources across the world. These strategies involve global networks of self-operating autonomous units that have a shared responsibility for procurement, manufacturing, and distribution (Jiao, You & Kumar, 2006).

2.2.3 Global distribution

Global distribution is the process of how firms are managing sales and distribution channels worldwide (Caniato, Golini & Kalchschmidt, 2013). Firms often optimize their distribution channels together with their manufacturing channels in order to maximize profit and obtain

substantial advantages. This practice is called Aggregate production-distribution planning (APDP) (Aliev et al., 2007).

2.3 Supply chain management in the automotive industry

In the automotive industry, having efficient and effective SCM is a must for global manufacturers, as fluctuating market demand, increasing customer preferences and tough competition requires automotive manufacturers to become more flexible and responsive to demand in order to achieve success. During the last decades, SCM in the automotive industry has worked towards a lean supply chain to minimize waste and costs, an agile supply chain to respond to rapid changes in demand and, in recent times, a combination of both (Ambe & Badenhorst-Weiss, 2010).

2.3.1 Lean supply chains

A "lean" supply chain's focus is to reduce waste, which relates to activities in the supply chain that offer no value. Waste can range from materials and goods that are stored for too long without moving forward due to increased lead times or underutilized employees (Myerson, 2012). Within the area of management, it is important to distinguish resource efficiency from flow efficiency. Resource efficiency means that the organization makes the most out of its resources available, while flow efficiency focuses on the "unit" (such as a customer with preferences) and how it is processed through the organization within a specific time. The period in question is referred to as the time when a customer's needs are identified to when they are met. One key concept associated with the lean supply chain is the just-in-time (JIT) philosophy (Ambe & Badenhost-Weiss, 2010) with elements that include reducing inventories at all levels of production, and only producing what is needed (Vokurka & Lummus, 2000). Within the automotive industry, Toyota had shifted to flow efficiency in production, by purely focusing on what the customer wanted and eliminating inventory (Modig & Åhlström, 2013). A lean supply chain is possible to apply if there is predictable and stable market demand, and so product delivery is based on forecasts. However, with fluctuating demand and turbulent market conditions, a lean supply chain is often difficult to apply in a company's operations (Ambe & Badenhorst-Weiss, 2010).

2.3.2 Agile supply chains

An “agile” supply chain is essential for a focal firm in order to quickly meet changing customer demands. The term “agile” means that firms are able to manufacture new products that meet volatile demand, as well as reacting effectively to changes in delivery requirements (Tarafdar & Qrunfleh, 2017). A primary objective of agile supply chains is to keep inventory as generic as possible, a concept known as postponement. Postponement involves moving the product differentiation at the decoupling point closer to the end user in order to increase supply chain efficiency. The decoupling point is a point in the supply chain where the supply-driven and demand-driven orders of components meet (Qamar, Hall & Collinson, 2018). Postponing allows firms to decrease the risk of running out of stock and avoiding keeping stock of unnecessary components (Fan, Xu & Gong, 2007). A key component of agile supply chains is mass customization, which means customizing usually mass-produced products into various finished products. The automotive industry is a keen user of mass customization, with many model offerings from different brands often sharing the same platforms and components. A key example of this is the cooperation between Toyota, Peugeot, and Citroën, which resulted in the Aygo, 107 and C1 models respectively (Mangan, Lalwani & Calatayud, 2021).

2.3.3 Leagile supply chain

A “leagile” supply chain is a combination of lean and agile supply chain approaches that is formed to better respond to volatile demand downstream as well as maintaining efficient and less wasteful flows upstream (Ambe & Badenhorst-Weiss, 2010). A leagile supply chain framework within the automotive industry is further visualized in Figure 4, where the positioning of the decoupling point is explained in terms of the lean and agile supply chain. It has been proven that a balanced leagile supply chain strategy in times of uncertainty can improve business performance (Fadaki, Rahman & Chan, 2020).

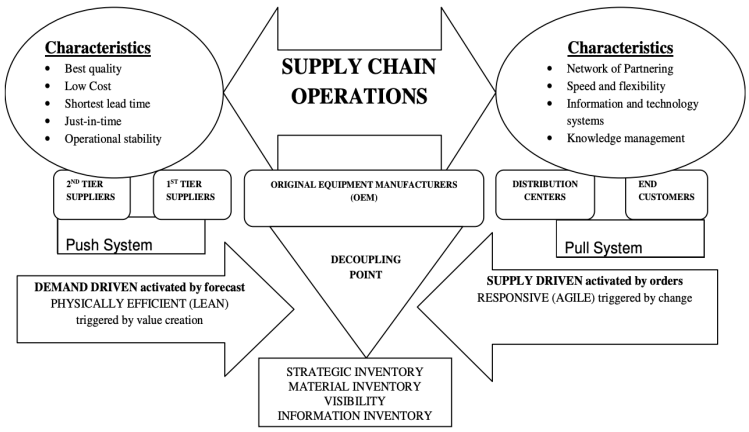

Figure 4: Framework for a leagile supply chain in the automotive industry. (Ambe & Badenhorst-Weiss, 2010)

2.4 Supply Chain Risk Management

2.4.1 Definition of Risk and SCRM.

In order to understand the term risk, a theoretical review is necessary. Risk is defined as "the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge" (Paulsson, 2005). Harland et al. (2003), enumerate many types of risks such as strategic-, operations- and supply risk. Supply risk is defined as a risk that "adversely affects inward flow of any type of resource to enable operations to take place". This definition echoes the definition of (Trkman & McCormack, 2009; Ritchie & Brindley 2007) where risk is defined as the likelihood of the occurrence of a particular event or outcome; consequences of the event or outcome occurring and the causal pathway leading to the event. This interpretation of risk is different from the definition done by other authors such as (Yilmaz & Flouris, 2017; Stoneburner et al. 2003) where risk is viewed as a deviation from the expected outcome and may therefore include negative or positive consequences.

In this study the definition retained is neutral and doesn't distinguish between positive and negative effects of risk. Nevertheless, the focus in the section below lies on why risk management is important to reduce potential negative outcomes as consequences of negative outcomes could be translated to disruptions within the supply chain of MNCs.

2.4.2 Supply chain risk management in MNCs

Regarding supply chain risk management, there is no clear consensus on the definition of SCRM (Sodhi & Son, 2012; Tand & Musa, 2011). Indeed, SCRM is defined by Carter and Rogers (2008) as "the ability of a firm to understand and manage its economic, environment, and social risks in the supply chain" this implies the adoption of contingency planning and having a resilient and agile supply chain (Musa, 2012). Similarly, Borge (2011) defines risk management as "[...] taking deliberate action to shift the odds in your favor- increasing the odds of good outcomes and reducing odds of bad outcomes". The difference between those two last mentioned definitions is that the latter mentioned is more focused on actions/measures that can be taken within a firm in order to mitigate risk. This joins the definition given by Tang (2006), "the management of supply chain risk through coordination among the supply chain partners so as to ensure profitability and continuity", where the author separates mitigation approaches into supply, demand, product, and information management.

In order to clearly define SCRM the term risk needs to be defined. Supply risk is defined by the highly cited Zsidisin (2002, p.14-15) as "the potential occurrence of an incident associated with inbound supply from individual supplier failures or the supply market, in which its outcomes result in the inability of the purchasing firm to meet the customer demand or cause threats to customer life and safety". To be able to handle risk, risk management is needed. Risk management is defined as "the process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence" (Paulsson, 2005). As reported earlier in the paper, supply chain's objective is to match customer requirements with the flow of material from suppliers by balancing the paradoxical goals of high service level, low inventory investment and low unit cost (Walker and Alber, 1999; Sinha et al. 2004).

Accordingly, in order to have an efficient supply chain all entities must be well coordinated, although each entity is subject to different types of risks. The major factors that contribute to supply chain risk are lack of trust, withholding information, dependence on outsourcing and standardized contracts (Sinha et al. 2004; Harland et al. 2002).

The importance of supply chain risk management is crucial for MNCs in a world where supply partners are located all over the globe. Indeed, MNCs have located activities of their value

chain in different countries and many factors lie behind the decision to do so. IT advances, higher market integration (lower trade barriers and FDI restrictions), product modularization techniques (IT department divided into countries with different time zones, making 24 hours working possible), intensified global competition, improved market institutions i.e intellectual property right protection e.g the TRIPS agreement for the pharmaceutical industry, industry standards e.g ISO 16949 in the automotive industry, are factors that encourages MNCs to relocate globally (Benito et al., 2020). However, with activities of the value chain spread in different countries comes a risk of disruption caused by factors within supply chains (SCs) but also outside environmental forces (Trkman & McCormack, 2009). Supply chain risk management (SCRM) is therefore a field that brought more and more scholars to investigate and is directed to developing approaches to the identification, assessment, analysis and treatment of areas of vulnerability and risk in SCs. It is believed that the increased use of outsourcing, globalization, reduction of the supplier base, reduced buffers, increased demand for on-time deliveries or shorter product life cycles are trends that enhance exposure to risks (Trkman & McCormack, 2009).

Different models of risk management have been presented in order to understand it management, Knemeyer et al. (2009, identify risk management as a procedure of risk analysis followed by risk perception. Manuj and Menzer (2008), argue that risk management is composed of the process of identification, evaluation, and mitigation. These analyses brought Musa (2012), to present a SCRM model, presented in Figure 5, of two main elements namely, supply chain risk analysis and supply chain risk control. Comparably, the risk management model presented by Paulsson, (2007) as shown in Figure 6, incorporates risk analysis, risk evaluation and risk reduction/control which resembles Musa's (2012), SCRM model.

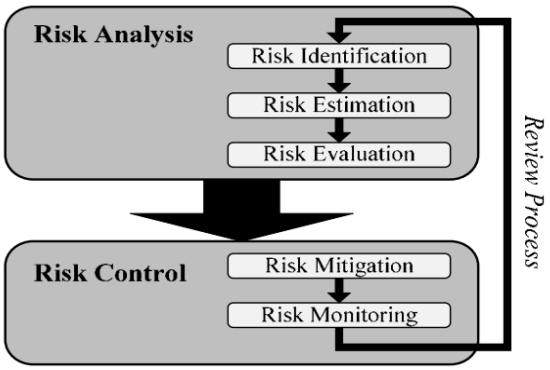

Figure 5: SCRM process (Musa, 2012).

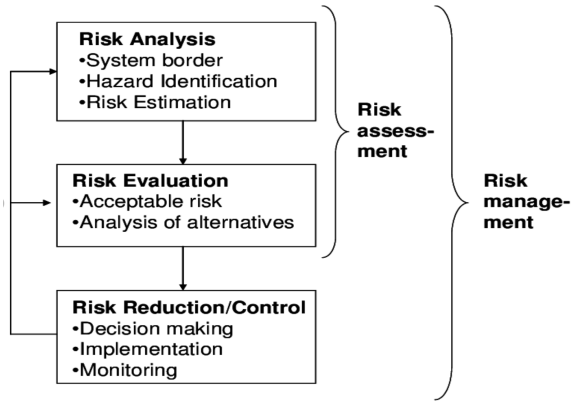

Figure 6: A risk management model (Paulsson, 2007).

2.5 Supply chain management strategy

With supply chains becoming increasingly volatile and prone to risk (Wieland & Wallenburg, 2012), there is a greater interest in companies to develop effective strategies (Manuj & Mentzer, 2008). Most companies view SCM as a strategic tool in of itself in order to create competitive advantage. In this strategic view, the concept of SCM is encapsulated in the much broader concept of "supply chain strategy", which is defined as the approaches of integrating the supply chain actors, in order to minimize costs and creating value (Qrunfleh & Tarafdar, 2013).

2.5.1 Sourcing strategies

As explained previously, firms source activities in order to increase efficiency and reduce costs (Contractor, 2021). In order to manage the supply chain successfully in response to volatile demand, an effective sourcing strategy is needed. There are three types of sourcing: single sourcing, dual sourcing, and multiple sourcing (Yu, Zeng & Zhao, 2008). Single sourcing means that the buying firm enlists a single supplier when other suppliers are available (Larson & Kulchitsky, 1998). With the trend of increased focus on core competencies as well as shifting value creation toward the suppliers, it has become common for buying firms to form cooperative single sourcing relationships with suppliers (Blome & Henke, 2007). However, dependence on a single supplier increases the risk of supply chain disruption for focal firms, and therefore, dual sourcing is usually seen as an effective tool to manage disruptions (Yu, Zeng & Xhao, 2008). Dual sourcing means that firm's source from its necessary components from two suppliers simultaneously rather than source from one risky supplier (Guo, Lee &

Swinney, 2016), and has also been shown to be an effective measure to mitigate risks in the supply chain (Tummala & Schoenherr, 2011).

2.5.2 Proactive and reactive strategies

In order to mitigate risks and respond to disruptions in the supply chain, firms can either adopt a reactive or proactive approach. In a reactive approach, the firm makes no attempt to decrease any uncertainties, but rather react to them as they are and attempt to maintain the same efficiency in their operations. Reactive strategies include improving capacity by keeping safety stock of components and having several suppliers, much akin to multiple sourcing (Angkiriwang, Pujawan & Santosa, 2014). It is common for managers to ignore potential risks in their supply chains and make a reactive response when any unforeseen events occur. However, it is problematic having a reactive approach to supply chain disruptions because it is too slow and great harm can be done to the firm's operations before the reactive action can have any effect. That is why it is preferred to have a proactive strategy when managing the supply chain and mitigating risks (Waters, 2007). A proactive approach addresses risks and problems early on, and planning steps and strategies to mitigate their impact (Meng, 2020). Proactive strategies within SCM range from redesigning products, processes, and the supply chain network (Angkiriwang, Pujawan & Santosa, 2014).

2.6 Conceptual Model

In order to generate knowledge and to fulfill the purpose of the research question and particularly regarding the impact of disruptions on the supply chain in an automotive MNC, the following concept model has been constructed. The model in Figure 7 gives a holistic view and summarizes the different theoretical frameworks that have been brought up in this study. It is built on the studies of (Jütner et al., 2003; Paulsson 2007; Trkman & McCormack 2009) on SCD, Sanders, (2012) on SCM, Ambe & Badenhorst-Weiss, (2010) on SCM in the automotive MNCs, (Sodhi & Son, 2012; Tand & Musa, 2011) on SCRM and (Manuj & Mentzer, 2008; Qrunfleh & Tarafdar, 2013) on SCM strategies.

In the conceptual framework the risk sources are exemplified with three underlying risks that can cause disruption within the supply chain. These are operational contingencies, natural hazards and political instabilities (Jütner et al., 2003). MNCs have many supply chain planning

activities that are separated and usually not connected to each other it is therefore important to have a planning that allows information to be shared, they need also to have a continuous coordination involving all the activities in the supply chain and finally an effective collaboration between actors within the supply chain in order to reduce costs and improve processes throughout it (Sanders, 2012). Accordingly, in the automotive industry the SCM is typically organized using a so-called lean supply chain where waste and costs are minimized or an agile supply chain in which the changes in demand are satisfied rapidly but also a combination of both with a leagile supply chain optimal to respond to a downstream volatile demand and maintaining efficient and less wasteful flows upstream (Fadaki, Rahman & Chan, 2020). The above mentioned SCM influences directly the SCRM that is indispensable to mitigate the impact of risks through risk analysis and risk control (Musa, 2012; Paulsson, 2007). In its turn risk analysis and risk control appeal for a SCRM strategy and the examples brought by Qrunfleh & Tarafdar (2013), in this field are sourcing strategies and whether the company has reactive or proactive measures to mitigate risks.

The theoretical approaches mentioned above indicate that disruptions within firms can have a considerable impact on the management of the supply chains, their strategies, and their organizations.

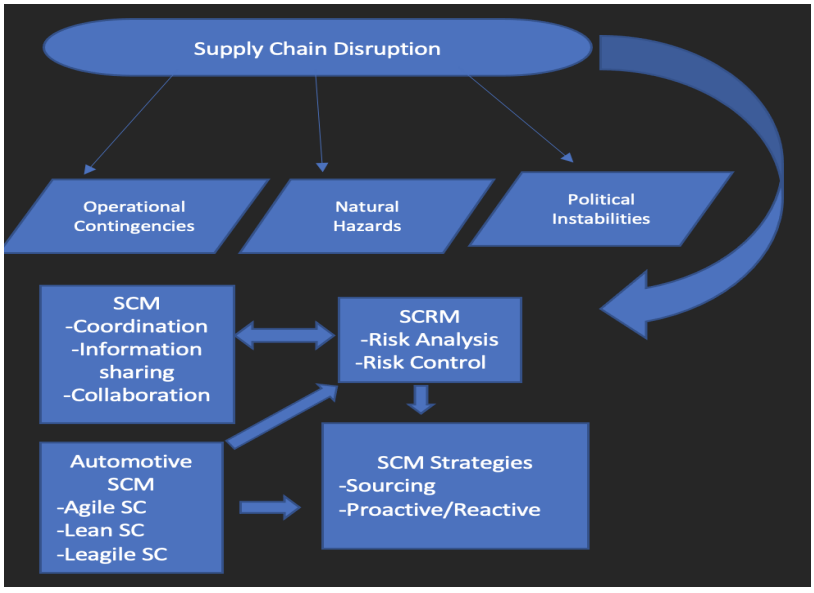

Figure 7: Supply chain disruptions and risk management model developed for this study (Own illustration).

3. Methodology

This chapter explains how this study has been conducted. First, the research strategy that outlines the study, followed by an explanation of what is an abductive approach and why it has been chosen in this study, followed by a description of a qualitative research method. Furthermore, the research design and data collection are outlined. Lastly, sampling and selection, and data analysis are presented.

3.1 Abductive approach

In this study, an abductive research approach has been conducted. An abductive research approach is a combination of an inductive and deductive approach. In an inductive research approach, the theory is formed based on the empirical findings. A deductive approach is the opposite; the empirical data is structured and formed based on the established theory (Bell et al., 2019). Similarly, to inductive and deductive approaches, the abductive approach is used to make logical conclusions. But it is a way to overcome the limitations of deductive and inductive approaches, for example the deductive reasoning has a reliance on a strict logic of theory-testing and the problem here is that it is not clear how to select the theory to be tested. In an inductive approach the difficulty is that building a theory requires a high amount of empirical evidence which is often hard to gather (Mantere and Ketokivi, 2013).
Some researchers see the abductive approach as different from a mixture of deductive and inductive approaches. They argue that the abductive approach is useful if the objective of the research is to discover new things, other variables, and other relationships. The main concern is therefore more related to the generation of new concepts and development of theoretical models rather than confirmation of existing theory (Dubois and Gadde, 2002).
Furthermore, it is argued that studies relying on abduction have an original framework that is successively modified in part as a result for anticipating empirical findings but also in order to reflect the theoretical insights gained during the research process. This combination developed through a mixture of established theoretical models and new concepts derived from the confrontation of reality is called cross-fertilization and is very effective according to Dubois and Gadde (2002).

In our case, the theoretical framework has been generated through a literature review and theories related to the research area that we were interested in investigating. Based on that, a

knowledge gap has been found and theories were revisited through the study to finally include SCRM, Global SCM, lean- agile- and leagile- supply chain and supply chain disruption.
A particularity of case studies is that they rely on analytical inference and not on statistical inference, and the main priority is to achieve an appropriate matching between reality and theoretical constructs, sampling becomes more as a continuous process than a separate stage in the study on which data collection is based (Pfeffer, 1982; Dubois and Gadde, 2002). In line with this particularity, we have constructed data collection in the study by combining interviews with concerned managers within the case company, attending to meetings and having access to internal resources and continuously reviewing and adapting our theoretical constructs based on the information we got. According to (Pfeffer 1982; Glaser and Strauss, 1967), a good theory is characterized by logical coherence and in case studies it has to do with the adequacy of the research process and the empirical grounding of theory.

3.2 Research Strategy

The purpose of this study is, as explained earlier, to gain a deeper understanding of how the shortage of semiconductors has affected the supply chain of MNCs within the automotive industry. And in order to answer the research question the authors chose to conduct a qualitative research approach with a case study design since the scope of a comparative study would have been too broad.

3.3 Qualitative research method

The purpose of this study is to research how automotive MNCs manage risks in the semiconductor supply chain, and so, a qualitative research method is carried out. A qualitative research strategy is used in order to study the world in the eyes of the research respondent with an emphasis on context and processes (Bell et al., 2019). As the purpose of analyzing how automotive MNCs manage risks when facing a global disruption is a subject that seeks to develop understanding, a qualitative research approach is the most appropriate. To provide trustworthiness in qualitative data the researcher must carefully consider the literature in order to build probing questions, justify the methodology chosen, executing the chosen methodology in its natural setting (field study), choosing sample of participants for relevance to the breadth of the issue, choosing sample participants for relevance, developing and including questions that reveal the exceptions to a rule or theory (Cooper & Schnidler, 2011).

Considering the above-mentioned details and with the research question being “How do the automotive MNCs manage their semiconductor supply chain during a prolonged global disruption?” conducting a qualitative research approach is believed to provide us with the more accurate results in our empirical findings and thus answer the research question.

Cooper & Schindler (2011), argue that the qualitative approach is a methodology used in business research in order to understand how and why things happen, to the opposite of the quantitative research methodologies where the purpose is to understand only what happened, or how often things happened. Quantitative research is often used to test theory which implies that the researcher maintains a distance from the subject studied to avoid interfering in the results, on the other hand, qualitative research is sometimes labeled as interpretive research since it seeks to develop understanding through detailed description and is often built on theory but rarely tests it (Mariampolski, 2001; Collis & Hussey, 2014).

3.4 Research design

A case study was conducted to research how automotive MNCs mitigate semiconductor shortage in their supply chains. A case study design is a widely used research design in business research, as it considers the complex and broad nature of a particular business case (Bell, Bryman & Harley, 2019).

Yin (1994, p.13), defines case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. Cooper & Schindler (2011), define case study as research where researchers extract information from a company brochure, annual reports along with interview data from participants that are usually done together with direct observation in the participants “natural” setting. The objective of this kind of research method is to obtain an observation of multiple facets of a particular organization, event, situation, or process at a point in time or over a period and this is done to understand processes. Furthermore, the authors divide case study into two different categories, descriptive or explanatory study which are typically translated as respectively how and why research problems (Eisenhardt & Graebner, 2007; Cooper & Schindler 2011).

This is in tune with the objective of the research that we are conducting, namely observing the impact of a global shortage in a multinational company and its impact on the company's business model. Having the research question on how do the automotive MNCs manage their semiconductor supply chain during a prolonged global disruption, it can be concluded that the research is exploratory according to (Eisenhardt & Graebner, 2007; Cooper & Schindler 2011). Achieving understanding in case study research usually involves the utilization of multiple research methods as for example triangulation. Triangulation often includes the use of direct observation by the researcher within the environment of the case and secondly, probing by asking case participants for explanations and interpretations of "operational data" (Woodside, 2010). In this context operational data includes spontaneous conversations of participants in a case, activities engaged in and observed by the researchers and documents written by the participants. However, critics note that case study research is not generalized to a population; the case included in each case study is so unique that it represents a singular context. Indeed, a respondent is limited in reporting the details necessary to learn to deeply understand the process being studied but also the fact that the objective of a case study research is not to generalize to a population but rather to investigate theory. (Campbell, 1975; Yin, 1994)

3.5 Data collection

A combination of both primary and secondary data will be collected for this study. Primary data is data collected by the researcher, while secondary data is gathered by someone else (Bell, Bryman & Harley, 2019). Information was extracted from annual reports, through interviews, and direct observations in a natural setting, as stressed by Cooper & Schindler (2011), as the study was conducted at the company's headquarters.

3.5.1 Primary data

Primary data will be primarily collected through semi structured interviews with senior managers operating in different departments within ACG, and through observations by attending meetings within and between departments involved in SCM. ACG was selected by the authors as it is a global automotive company with an actual issue of semiconductor shortage. The shortage is hitting the automotive industry at most, so it was therefore interesting to study the shortage within the company. It was also made easier for the authors to conduct the study on site as ACG is located in Gothenburg.

Furthermore, primary data was collected through attending internal meetings within the procurement department and by observing daily measures undertaken by the department in order to manage the issue. The authors attended approximately 2 to 3 meetings per week where the situation has continuously been updated and discussion on how to proceed going forward, as illustrated in Table 2. The first contact with the case company was made first by email to a business procurement assistant, who then directed us to the primary contact person. First contact with him was done through LinkedIn, with a subsequent Teams meeting, where he introduced us to his team at the company who was operating around the semiconductor shortage. Complete access to the organization, office and databases was given, with the contact person becoming our supervisor at the company.

After the first meetings with the Software and Electronics procurement department a mind mapping of the thesis research purpose was done together with the Global Category Manager Procurement and two category buyers daily working with the semiconductor shortage.
The objectives of the study were further clarified during the mind mapping and a dual consensus was found including objectives covering both the scientific- and the practical approach of this study.

The questions asked during the interviews were designed after reading a considerable number of articles and taking part in meetings and having discussions with managers within the software and electronics department that is handling the semiconductor issue. The type of question prepared for the interviews were a mix of open questions, closed questions, and probes (Collis & Hussey, 2014). During the interviews both authors were asking questions and minor notes were taken during the interview in order to build supplementary questions to the interviewee. The interviews conducted in this study were semi-structured as mentioned earlier with an event-based format, where questions are asked in order to get a description of a particular incident and complementary questions about the incident (Cassell, 2015). In our case the "event" in question here is the current shortage in semiconductor within the automotive industry.

3.5.1.1 Sampling and Selection of respondents

Contact persons within the departments that were relevant to the study were provided (Software and Electronics procurement, Constraints team and Capacity team).

Contact was made with pertinent persons within each department and the responsiveness has always been fast and positive. The only downside came from the Capacity team (providing macro analysis and commodity forecasts), which didn't provide any response despite several attempts to contact persons within the department. The purpose of taking part of insights from the above-mentioned team was to have a nuanced understanding of the long-term strategy related to semiconductor shortage and other shortages in general from a macro perspective. We have finally managed to get answers from other managers that explained how the overall strategy was at the case company and their answers were valuable to our study.
In total, 5 interviews were conducted with managers within the above-mentioned departments. Most of the interviews were conducted via Teams and the interviewees were requested regarding the possibility of recording the interview and the response was always positive.

Since the subject studied was subject to flexibility mainly because of the fact that it is a recent and ongoing shortage, it has been decided to conduct semi-structured interviews which are the most suitable in our case. Indeed, semi-structured interviews provide flexibility and offer to have an open discussion with the respondents (Bell et al, 2019).

The interviewees chosen in this study are working in different departments within the case company. They were brought out after mind mapping the phenomena of the shortage within the MNC and dividing different departments involved in solving the issue into short, mid & long-term perspectives. However, after interviewing different departments it turned out that some departments were involved in solving the shortage at a short-term perspective but also setting bases for the future configuration of the supply chain. The minimum number of interviewees in qualitative research is not dictated by any guideline, it is rather the quality of the sample that is the most important with interviewees that can directly address the research question and provide informative responses to what is studied (Cassell, 2015). This explains why the number of interviewees is relatively low (compared to other case studies).

The interviews were for most of them conducted online via a communication program using video telephony, the program includes a transcription feature enabling audio recording to be translated directly into text with a good level of accuracy required for data analysis (Cassell, 2015). With the consent of interviewees, the interviews have been recorded and this helped us correct wrong transcriptions done by the program, transcriptions were done after each interview and interviewees have been anonymized to protect confidentiality.

The respondents were located using a combination of purposive and snowball sampling methods (Collis & Hussey, 2014). The data collection process was planned on location with the supervisor, who facilitated contact with the best-suited respondents within the organization who operate towards Tier 1 and Tier 2 suppliers respectively, as well as within constraints and strategies. By interviewing respondents who work in different teams within SCM, risk management and strategies, and who have different experiences, it was possible to gain a broad understanding of how the teams operate in terms of semiconductor risk management and strategies. Some of the respondents suggested other contacts that might be of interest for this study. One criterion when choosing respondents was that the respondent's duties must include SCM towards tier 1 and/or tier 2, risk management or strategies, especially around the issue of semiconductors.

Respondent	**Position**	**Team**	**Date**	**Type of Interview**	**Length**
R1/Andre	Junior Manager	Core & Zone Controller	March 22nd	Teams	57 min
R2/Bernard	Senior Manager	Global Procurement Software & Electronic	March 25th	On location	55 min
R3/Nicolas	Senior Manager	Constraints	March 30th	Teams	47 min
R4/Jacob	Senior Manager	Core & Zone Controller	April 1st	Teams	66 min
R5/Michael	Senior Manager	Constraints	April 11th	Teams/on location	50 min

Table 1: Summary of respondents

Meeting	**Weekday**	**Length**	**Type of meeting**
Stand-up	Mondays	30 min	Teams/on location
Procurement Semiconductor Secure Capacity	Mondays, Wednesdays, Fridays	50 min	Teams/on location
Team meeting Core	Tuesdays	90 min	Teams/on location

& ZF			
GCM meeting Core Computer	Thursdays	90 min	Teams/on location

Table 2: Summary of meetings

3.5.2 Secondary data

The secondary data were collected in this study and were mainly coming from ACG's internal website but also from the public website where information about the company and the issue studied were examined. Secondary data are data that have been collected through primary sources for some other purpose than the primary user (Juneja, 2022). Accordingly, the data available from ACG's internal website included updated reports on; commodity prices, global situation, forecast on future demand, among others. Other department-specific information such as the list of suppliers they are working with, and semiconductor supply chain were made available for us by the interviewees.

3.6 Data analysis

The interviews were recorded, and the primary data was transcribed with the help of a transcription tool. The transcriptions were downloaded and gathered in a separate document in order to gain easier access to them. The respondents gave very long and broad answers to the questions, and so the raw information had to be reduced in order to make it more interpretable (Eriksson et al., 2015). This is done by coding the data into different labels, inspired by the theoretical framework, as well as removing answers that carried no relevance to this study. The labels in turn were presentation of the case company, its global presence, the case company and its supply chain, relationship with suppliers, the company managing risk, mitigation of risk and disruptions within the company, and lastly measures to manage future shortages.

The analysis of the collected and coded data was done by examining the aforementioned labels in terms of relevant theory in the theoretical framework. We interpreted the collected data in terms of how the company manages their supply chains, their relationship with their suppliers, how they manage risk, which risk mitigation strategies they conduct and what they consider, as well as any learnings they have gained from the semiconductor shortage.

3.7 Literature review

The literature has been collected via an approach that firstly was to identify previous research and articles that have been treating the issue of disruption of supply chain in MNCs from different databases such as GU Supersearch and Google Scholar. The main purpose of gathering articles was to get a deeper understanding of what has been studied before and helped us in identifying a knowledge gap in order to contribute to existing knowledge and of course with an international business perspective. When identifying interesting articles, we searched for articles/research that handles the issue of a disruptions impact on supply chain, risk management within MNCs, SCRM, SCM, supply chain configurations.

A high number of articles were found and in order to narrow down and choose the articles that are relevant we used search words such as “supply chain management automotive”, “disruption supply chain automotive”, “risk management automotive”, “operational disruptions”.
Based on the findings that we got from the research we removed articles that were not dealing with disruptions, automotive MNCs, SCRM or risk management.

3.8 Quality of Research

When conducting a qualitative research study, it is vital that the results correctly reflect the reality that had been studied (Yin, 2013). Bell et al. (2019) list three criteria for research quality, which are reliability, replicability, and validity. These criteria will be further elaborated upon in relation to this study in the following sections.

3.8.1 Reliability

Reliability in research concerns whether the results can be repeated if the same study is conducted again (Eriksson et al., 2015; Bell et al., 2019). A researcher conducting a quantitative study can be concerned if the results stay the same when conducting the study multiple times, with the same questions and questionnaires. However, since this study followed a qualitative research approach, the results are not expected to stay the same if this study was conducted again. The results might change if this study was focusing on another essential component or if the study’s scope was broader and focused on the entire procurement function.

In order to increase reliability of this study, the respondents were given information about the purpose of it, and it is assumed that the respondents have a knowledge of the scope of this study as it was conducted on-site at the case company's headquarters during the spring term. Furthermore, during interviews, the respondents were given questions based on their departments and knowledge of themes in the interview guide. Also, because the study stretched between different teams, it can be difficult to decide if the respondents share the same views and have the same perceptions of the situation. This can impact the reliability of this study. However, because the different departments and teams work in a cross-functional way, it can be assumed that they share the same perceptions and ideas in managing supply chains.

3.8.2 Replicability

Replicability in research concerns whether the study can be replicated, meaning that it can be done again by another researcher (Eriksson et al.,2015; Bell et al., 2019). A major factor in replicability is whether the research method is explained in detail, which was done here in this study. However, because the study explored a timely issue, which was the semiconductor shortage, it is unlikely that any future research replicating this study will have this shortage as a focus area. By that time, the semiconductor shortage might be resolved. This study can be replicated by focusing on a different component, or by increasing the research scope to how supply chains are managed in general.

3.8.3 Validity

The validity aspect of research quality refers to the extent to which conclusions drawn in research give an accurate description or explanation of what happened. Schwandt (2001) says that to be able to say if the research findings are valid is to say that they are true and certain. The findings accurately represent the phenomenon referred to and that they are supported with evidence which means that they are certain. Furthermore, it is explained that common procedures for establishing validity for research are analytic induction, triangulation, and member check. Triangulation is the process of using multiple perspectives to refine and clarify the finding of the research. In this paper the triangulation of theories and data has been conducted as theories are several used in explaining, understanding and interpreting the case. Secondly, data has been triangulated as evidence from multiple empirical sources are used (e.g interviews, observations, reports), to cross-check information (Glaser and Strauss, 1967).

However, the generalizability of the study beyond the specific case is limited, as this paper treats one specific company.

3.9 Ethical considerations

Ethical considerations were followed in line with the guidelines set by the Swedish Research Council (2017). The first guideline is the issue of transparency and openness. Before the research began, ACG was given full information about the research purpose and the data collection process was planned in accordance with the supervisor and his team at ACG. This allowed the supervisor to suggest different departments and interviewees that were suitable for this study. Before the interviews, the respondents were given information about the research purpose in order for them to answer the questions accordingly. Ensuring secrecy and professional secrecy is of importance when conducting ethical research (Swedish Research Council, 2017). Because the case study was conducted on site at ACG's head office, sensitive information was given, and company secrets were shared. This study was required to be published, and so discussions with the supervisor at ACG were made on how to translate the sensitive information in the study in order not to spill any company secrets. This was done by anonymizing the interview respondents and the case company, in accordance with the supervisor and consent from the respondents. To ensure anonymity, the respondents were also asked for consent before recording the interviews and ensuring them that the transcribed data will not be accessed by any unauthorized party.

4. Empirical findings

This chapter presents the empirical findings collected from both interviews and observations done at ACG. It begins with a presentation of the case company ACG and its global presence, continues with empirical findings, and then concludes with a summary of empirical findings. It has been decided to anonymize the interviewees names and to assign them fictitious names. R1, R2, R3, R4 and R5 will be named Andre, Bernard, Nicolas, Jacob, and Michael.

4.1 Presentation of ACG

ACG is one of the fastest growing automotive manufacturers in the world, with sales to over 100 countries. ACG was founded in Gothenburg, Sweden, where its headquarters is also located. Aside from the original factory in Gothenburg, the company has operations in Europe, Asia, and North America, and during the data collection process in the spring of 2022, the company had approximately 41 000 employees (Annual Report, 2022a).

4.1.1 Global presence

Across its operations in Europe, the Asia Pacific region, and the Americas, ACG has its headquarters in Gothenburg, regional headquarters in China and the United States, R&D and design centers in the United States, Sweden and China, as well as production facilities in the US and Belgium and various cities in China (Annual Report, 2022a). Aside from its operations, ACG has 2300 retail partners across the world and makes approximately 700 000 retail deliveries every year. The distribution of global retail deliveries per market is visualized in Figure 7, where it is apparent that the largest deliveries are directed towards the European market (Annual Report, 2022a).

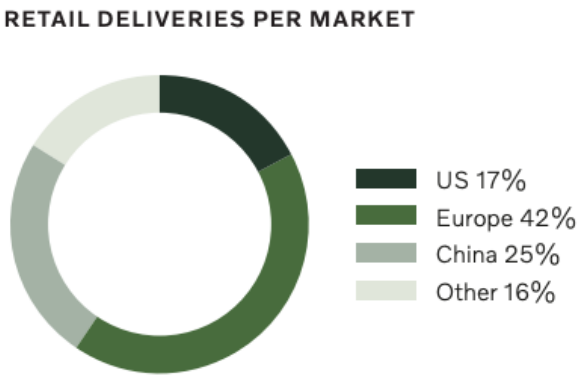

Figure 7: Global distribution of retail deliveries (Annual Report, 2022a).

With their operations and sales networks spread throughout the globe, ACG also has complex and geographically dispersed supply chains for every essential material and component. The complexity of these supply chains will be elaborated upon in the following sections, with a particular focus on the semiconductor supply chains.

4.2 ACG and its supply chain

ACG relies on a global network of nearly 9700 suppliers located in 1700 manufacturing locations in order to source raw materials, parts and components (Annual Report, 2022a). The semiconductor supply chain network is very large and complex with many global actors for each individual semiconductor component, as is affirmed by Bernard and Jacob. The semiconductor supply chain is structured in a way that the company collaborates with their tier 1, and to some extent, their tier 2 suppliers. Direct procurement of components though is done through the tier 1 suppliers, and direct communication with tier 2 suppliers is limited, almost to none. Andre further explains:

"I would say it's almost zero. Typically, we have no direct contact with tier 2s, especially not at a buyer level. On an R&D level, we might interact with some tier 2s at the early stage. But all direct contact is going through the tier 1s. The tier 1s have direct control over the supply chain going downward."

ACG also procures semiconductor components from brokers, which are actors that technically exist outside of the supply chain. They act as an intermediary between the focal firm and for the company unknown supplier of necessary components. Brokers are regarded as a viable

option for procuring necessary components. ACG is scouting the broker market in order to mitigate the semiconductor shortage (Nicholas, Michael), and has already formed relationships with 10 to 15 broker companies they feel they can trust. Jacob explains further:

*"Brokers are like Blocket, right? The broker market acts as distributors that connect the seller and the buyer. They don't keep stock. If for instance, a broker says they have 10.000 units of component X, they don't keep it themselves. Instead, they can buy it from a source we at **** [1]don't know about."*

ACG is not purchasing more than what they need, and they are following the lean model of SCM. They are generally avoiding stockpiling components for safety, and when they do, it is kept at a minimum, because storing all types of semiconductor components would be impossible (Bernard; Michael). Respondent Michael explains further; *"The lean model is definitely not going the right way. We would like to have small storages, and a low level of safety stocks."*

There is an entire team that focuses on managing the semiconductor supply chains that was formed in response to the semiconductor shortage. In early 2021, this task force was formed around this issue with external support from a consultancy firm (Bernard). Even before the semiconductor shortage began, a tier X team was formed with the intention of locating and analyzing future business opportunities and improvements in semiconductor technology. It coincided with the semiconductor shortage, and although the shortage was not the main reason for forming this team, it was a motivating factor (Jacob).

[1] ****: Company's name put in asterisks in order to maintain confidentiality.

4.2.1 Suppliers

When choosing the right suppliers, ACG takes many dimensions into consideration. The company carries out a 360-degree review of a potential tier 1 supplier in which they investigate every possible angle. Historically, reviewing a supplier was purely based on cost efficiency, but in the present time aspects like sustainability, quality and historical performance are considered. Bernard continues; *"We use a symbolic briefcase when we are reviewing a supplier. In this briefcase there are the different kinds of dimensions that are being considered in a sourcing decision."* ACG takes a more strategic approach when choosing the proper tier 2 suppliers. Potential tier 2 suppliers are identified by reviewing the tier 2 suppliers they have, which suppliers they have knowledge of, and take into consideration what potential innovation there is within their ICUs (Andre). Changing a supplier that is not cooperating well enough occurs, but that does not happen very often, and it is mostly for reasons such as a change in the core model or to save costs. Also, swapping a supplier is very costly (Bernard).

Information sharing towards the company's tier 1 suppliers is structured in a way that ACG shares its capacity with the tier 1 suppliers, and the tier 1 suppliers are obliged by contract to fulfill that capacity. Jacob explains further; *"We are showing every supplier our capacity every time we enter business with them. We lay clear our intentions and what volume we expect them to secure for us. The suppliers also need to make the necessary investments and the security of the supply line that is structured in a way that it can support us."* Information sharing towards the tier 2 suppliers is frequent, with weekly discussions with the suppliers. The frequency of discussions is dependent on the size of the suppliers and which topics are on the agenda. Andre continues: *"The information we share to the tier 2 suppliers include volume forecasting, what projects they are involved in, and also when it comes to negotiating for future projects as well."*

To ACG, being as transparent as possible towards their suppliers is vital (Andre; Bernard). If ACG were to include tier 2 suppliers in any kind of partnership or project, the tier 1 suppliers must be informed (Andre). As far as information transparency is concerned, ACG procures "black box" components from their tier 1 suppliers. "Black box" means that ACG is purely procuring a function for a specific component, but the tier 1 supplier is responsible for sourcing the necessary parts and designing the components (Bernard). ACG does not know how the

component is set up or designed, so they are very dependent on the tier 1 supplier to carry the necessary information on which components are necessary. Respondent Andre continues.

"So, We are buying something. We have no idea how it works or how it's set up or anything like that, which means that we are very dependent on a tier 1 supplier in order to do anything."

There is a noticeable lack of information sharing from the tier 1 suppliers. For instance, ACG does not obtain the bill of materials for semiconductor components, which contain information on how and where they are produced. With that information, ACG hopes to assess risks and develop strategies on how to mitigate them. Bernard continues:

"We need the bill of materials in order to assess where the risks are and how they can be mitigated. For instance, there are certain semiconductor components that are single sourced in one facility somewhere in Asia, and that of course is a huge risk for us. We need to know where the risk is."

For ACG, strategic collaboration with suppliers is more prevalent towards their tier 2 suppliers rather than with their tier 1 suppliers. The company is collaborating with their tier 2 suppliers in their goal of bringing semiconductor component design in-house, by gaining technical roadmaps and including tier 2s in their discussion of which features, and components will be applied to future vehicles (Andre; Jacob). Although the company is taking a bigger responsibility of designing the necessary components and software, they do not regard the tier 2 suppliers as competitors. Jacob explains further.

"We are not intending to build our small computers ourselves. We still want to use our traditional suppliers and sometimes venture into new suppliers that are mainly just building what we provide them with. And so we are not taking that away from anyone, and we are pushing our suppliers in our direction. This helps the tier 1 suppliers understand where they need to make their investments, where they need to shine."

ACG believes that the relationship with their tier 2 suppliers is helping them achieve their goals in bringing component and core computer design in-house, to determine which components will be applied in future car models and understanding which technologies will be necessary to design core computers (Andre; Jacob). Today, ACG carries discussions regarding volumes and

short-term or middle-term issues in deliveries, and are seeking to do technical road-mapping, to determine which applications they wish to have in future vehicles. They wish to include the tier 2 suppliers in the technical road-mapping, because the tier 2 suppliers carry the necessary expertise (Andre). When looking to design the core computer, the relationship with the tier 2 suppliers is allowing ACG to map down the potentials they see for the common core platforms, understand the direction the suppliers want to go and align them with ACG's ambitions (Jacob).

4.3 ACG managing risk

ACG manages risks in their supply chains with the help of their Constraints team. The Constraints team identifies any potential issues in vehicle production, such as delivery of components, shortages, or any other issues. When these risks become apparent for a supplier that can impact ACG's production, the Constraints team steps in (Nicolas). Michael explains further; *"When everything else is fucked up, we act. We are stepping in when there is a high risk of production at any of our global plants halting due to various reasons, such as the issue of semiconductors."* The Constraints team does not normally conduct any short-term strategies for mitigating risks, but due to the semiconductor issue they have been focusing on securing the necessary semiconductor parts and components (Nicolas).

The Constraints team is a global team, with units in Europe, China, and the United States with a close-knit collaboration. Allocation of tasks is dependent on where the constraints are taking place, but if it is a global issue, all teams collaborate. This strategy taken in order to mitigate risks when facing a shortage of a component that has previously been reported by procurement departments is analyzed by the Constraints team that is further forwarded to the regional team because of their proximity with the concerned supplier and their ability to quickly deploy solutions on field. Michael explains further; *"We have a team here in Europe, we have a team in China, and a team in the US, and we are all working together. But it of course depends on who is the best person to take it. If the constraint is regional based, and the supplier is in China, then a Chinese colleague is best suited for the job. But if the constraint is global, then any team in the world can take it."*

The actions that the Constraints team take to mitigate risks in the semiconductor supply chain are dependent on the information they receive from procurement departments at ACG, for

example when a supplier sends a force majeure letter to ACG (Nicolas) or that a tier 1 supplier is informed by the semiconductor manufacturer that they cannot supply the number of units agreed upon. The location of the shortage, the impacted supplier and whether the shortage is regional or global is also taken into consideration (Michael). Michael continues; *"Let's say that we have a supplier in China, who are seeing a shortage because of a decommitment from a semiconductor supplier. They have a commitment of 10,000 pieces per week. Then the Chinese supplier is contacted by the semiconductor supplier who informs them that they cannot provide them with the agreed amount. So, the first step is getting a broad understanding, the supplier is located in China, and are they supplying us globally or regionally?"*

In the case of a component shortage involving delays of delivery and when the safety stock of a particular component is critical, some urgent measures are taken. First by being reported to the Constraints team that delegates the issue (if possible) to the regional team present near the supplier in question and then by trying to reactively allocate the supply to the concerned plant. As explained by Michael:

"[...] they are not receiving enough parts, or they backlog as we call it. And backlog basically means can they follow our normal EDI [...] So if the plant calls off from Europe into China, there is a lead time for sea transport. Then there is a safety stock in the plant. So, then we can immediately stop sending parts with normal transports and just make sure that the plants in that region are supplied and then we start to find solutions."

The Constraints team also investigates which type of component there is a shortage in and collaborates with the R&D department in order to receive more knowledge of components and their processes. Nicolas explained:

> First, we need to understand in detail. What is the issue? What semiconductor shortage are we talking about? We need to understand a bit more about the semiconductor process and supply chain if it goes through a distributor or distributed directly and what is the supply chain within the semiconductor industry. Where are the wafers coming from? Where is the back end, front end testing? To understand this, we also need to understand which cars we are talking about, which cars in our portfolio are affected. It might be specific models, or entire platforms (Nicolas, 30 March 2022).

After identifying a shortage in components, the Constraints team must research when the shortage will have an impact on ACG and its production facilities. The supplier keeps track of components needed through backlogging in order to follow the company's EDI (Electronic Data Interchange). Key factors within the EDI are lead time of transport and safety stocks in the company's plants, which indicates the time the company must find alternative freight solutions to make sure that the plants suffering from shortage are supplied until they can find solutions (Michael). Michael clarifies; *"If we say that there is nothing in backlog, then we know immediately from a constraints point of view that we have quite a lot of time to act because there is lead time involved, calculating with for instance eight weeks of transport and two weeks of safety stock. In that time, we can utilize air freight, for example, mitigating the time with many weeks. So, then we can immediately stop sending parts with normal transports and just make sure that the plants in that region are supplied so we can find solutions."*

When there are not enough parts and components available, ACG must prioritize allocating components to factories and produce different models of cars (Nicolas; Michael). When the Constraints team is deciding on allocation, they hold internal meetings, prepare an allocation plan and present to the highest management (Nicolas). Nicolas explains further; *"For instance, we need to reduce the number of cars produced in this factory and reduce the number of cars produced in another. Our goal is to allocate together with the supplier because they are not allowed to decide where to [2]send the parts. It is **** who tells the suppliers how many parts they should send. For example, a factory needs 2500 units, but we only have 2000, so we tell them to send 500. This is how we work with allocation on a daily basis. An internal alignment is necessary."*

This view is also shared within the Software and Electronics procurement department as a short-term risk mitigation strategy. Bernard emphasizes:
"if it is short term then then we talk about for example optimizing the production plan versus the constraint in material so we optimize the production it can be that we allocated between our plants we maybe reduce some speed in one plant to improve in another so internal allocation between our plots when possible it could be this finding alternative components on the short term [...] "

[2] ****: Company's name put in an asterisk in order to maintain confidentiality.

ACG works daily with the Constraints team that has 12 managers dealing with constraint flows and doing reviews on which components are facing shortage and how they should prioritize (Nicolas; Michael). Michael explains; *"And when we face such a situation, we must decide how we should prioritize, how we should secure all plants, and if some suppliers affect globally or regionally. That might not be fixed but we try to agree on how to allocate material in a way that is best for *[3]***. That is why in our team it is important to have a daily call where we align exactly what the situation looks like globally."* The Constraints team hold internal discussions on what might be the best solution, depending on where the components are produced, if they are shipped from one region to another and if the shortage is localized. The Constraints team then presents their proposal to higher management at ACG on how to for instance reduce the production in a particular plant by a certain number of cars. This proposal is then brought to a higher management meeting where the final decision is taken (Nicolas).

Even if ACG is forced to make prioritizations on which models to produce in the face of semiconductor shortage, the company is committed to keep producing BEV (battery electric vehicle) cars in line with their strategy and commitment to become an electrified brand (Bernard; Nicolas). However, the company must also consider the state of the market in order to determine which models are most profitable (Nicolas). Nicolas explains further; *"When it comes to prioritized cars, that might be cars with a higher margin, but of course the BEV cars are really important to the company due to our strategy and our commitments. So, we are trying to protect the BEV cars, but sometimes the market situation is a deciding factor. If there is a specific market for specific cars, we need to produce at least some cars for this market in this location. So, it's a combination."*

When asked if ACG follows a particular scheme or model to analyze risks in the semiconductor supply chain, the respondents claim that it is difficult to follow a specific predetermined model because there are many different types of risks and many actions to handle them. It is often many different departments at ACG who identify the risks and notify them to the Constraints team (Nicolas; Michael). However, ACG analyzes risks according to a model that begins with identifying risk and ends with analyzing risk, depending on the type of semiconductor component, both short and mid-term. They must be flexible when it comes to risk analysis and testing of alternative components (Nicolas). Nicolas explains further; *"In the short term, we*

[3] ****: Company's name put in an asterisk in order to maintain confidentiality.

might have alternative components like automotive grades, non-automotive grades and sometimes microcontrollers. For the mid-term, we are collaborating with R&D in order to redesign the printed circuit board assembly (PCBA) to be more flexible and be able to use much more semiconductors from the same family, or even different families."

4.4 Mitigation of risks and disruptions within ACG

ACG mainly applies a single sourcing strategy when selecting suppliers and procuring materials. It means that they source from one single supplier for each specific semiconductor component (Bernard). In response to the semiconductor shortage, ACG has considered moving towards a dual sourcing strategy as a risk mitigation option and working more closely with their tier 2 suppliers (Andre; Bernard; Jacob). Respondent Bernard explains; *"With dual sourcing, we see a possibility to source from tier 1, but a bigger possibility on the tier 2 stage. So, I would say absolutely that it is a possible risk mitigation solution to have two possibilities of sources from one component inside the head components or head unit. That of course involves a lot more R&D work, validation work, etc.".*

As explained above, ACG also procures semiconductor components from brokers as a way of mitigating risk (Bernard; Nicolas; Jacob; Michael). For instance, when ACG faces constraints on components, they need to find alternative components of industrial grade or consumer grade (Bernard). Bernard explains further; *"We work with around 10 brokers, with 4 or 5 more closely. The way they are acting on the market is that they buy stocks of components coming from different sources where there is some kind of overstock, such as a tier 1 supplier. The brokers help us in finding ways to resolve all chips which are on the constraint."*

ACG also considers redesigning their products, components and software a viable risk mitigation strategy (Bernard; Nicolas; Michael) A short-term solution to the semiconductors shortage ACG has, is to redesign their printed circuit boards (PCB). In fact, they are reassigning some PCBs that are used in some components. This is done in tight collaboration with the R&D department, which finds solutions for every critical component that is facing a shortage. An example of this is given by Michael.

"From a component perspective, from our end insight together working in understanding. [...] we see this kind of device that we have. What semiconductors are included in this. Do we see

any one of this being at risk? Can we find if we can use multiple or triple different semiconductors already in a proactive way, can we use this in this instead and what do we need to be able to do that?"

In a mid-term perspective this strategy is also considered as being a solution, where the first option is to change components to a pin to pin compatible by taking another shift with a slightly different specification and pin them into another component in order to put the same spot on the PCB as stressed by Bernard:

"[...]you can do another technical solution that's more now or in the mid-term maybe you need to change the components from one to another you need to maybe impact the software you maybe need to impact the PCB layout maybe they're not […] the first option when you change components is to like, pin to pin compatible you just take one other shift maybe a little bit different spec and then they are pinned to pin so you can just put it in the same spot on the PCB but this middle changed it's more kind of massive it could be software impact maybe you need to redesign the PCB [...]"

However, redesigning PCBs is not always an optimal solution as it is not always possible to redesign some components but also because it is impossible to redesign everything as stated by (Nicolas; Michael). Nicolas explains further:
"Sometimes it's not possible, but where is possible and we identified that this might be good. We are working on the midterm solution that we are trying to redesign the PCB to be more flexible, being able to use much more much more."

There is clearly upstream work that needs to be done prior to taking the decision to redesign and prioritizing the components that are at risk. This argument is brought up by Michael.

"Of course, finding the alternatives and how we can do it. But it's also important to understand where and how do we detect what component or what semiconductor in that component is at risk? Because you cannot redesign everything."

This argument builds further on the need of risk analysis regarding the prioritization of which component that needs to be worked on to redesign it or to put a compatible part in it. This analysis is according to Respondent Michael hard to answer as it involves the analysis of components that will be at risk in the future as explained in the following answer.

"I think that there will be a lot of challenges with raw material coming up absolutely, especially due to the war in Ukraine right now. I definitely think there will be a shortage of a lot of raw material as usual. Of course, what happens with the shortages is that prices go up."

It requires a continuous review from buyers that are facing shortages on a day-to-day basis and forward to the competent team that try to find solutions involving departments in different regions and if needed, taking the step further to R&D for the redesigning part. Michael further explains.

"I think that the main thing, at least I think that what we will learn from our team, maybe is how we can jointly work as an organization handling all the risks coming in. Because basically how we have been working is that first of all we are in a constraints team, we have a daily call every day, at the same time completely understanding the picture today, tomorrow, the next coming weeks and that helps a lot if you work."

4.5 Measures to manage future shortages

A key learning ACG has gained from the prolonged semiconductor shortage is that there will be a continued risk even in the future (Nicolas; Michael), and therefore ACG must plan to secure capacity. Nicolas explains further; *"I would say that in the future we still see a risk with those components, and that means we might potentially have to secure the capacities by ourselves. Or at least in another way what we have been used to, purely having discussions with our tier 1s and sometimes to our tier 2s. It is still up to our suppliers to decide how to secure enough capacity of semiconductors and other products. So, what we have learned is that we may have to look more into the future and to look at how to secure capacities in the future."*

Learnings ACG has gained from managing component risks is how jointly they work as an organization handling all the risks coming in, and to act in due time (Michael). Respondent Michael continues by explaining that they are working together on a daily basis, in order to have a greater understanding of the situation tomorrow and the next coming weeks.
He means that it helps a lot when working with different shortages everywhere, especially understanding the surroundings around the situation. He further explains that the daily calls they are having are an opportunity to the buyer and the plants to report how the situation looks like with other suppliers that have other risks.

4.6 Summary of empirical findings

In this section, the most relevant findings from the empirical framework are presented in Table 2 below and will serve as the foundation for the following analysis chapter and conclusions.

Presentation of ACG and its supply chain
- The supply chain is a complex network, with 9700 actors worldwide - The semiconductor supply chain is large and complex, with many actors for each component. - ACG collaborates mainly with tier 1 suppliers, and tier 2 to some extent. - ACG procures components directly from tier 1 suppliers as well as brokers. - ACG procures only what is needed and does not keep stocks. - A task force focusing on semiconductors was formed in response to the shortage.
Suppliers
- ACG does a 360 review of potential tier 1 suppliers. - ACG is strategic in choosing potential tier 2 suppliers. - ACG shares information to tier 1s regarding capacity. - Information sharing towards tier 2s is also frequent. - Transparency towards ACG's suppliers is vital. - ACG is dependent on their tier 1s to know which components are necessary. - ACG is not receiving enough information from tier 1s. - ACG is collaborating strategically with tier 2s. - ACG believes that their relationship with their tier 2s is helping them achieve their goals.
ACG managing risk
- ACG manages risks with their Constraints team. - The Constraints team acts globally. - The Constraints team's actions depend on information received from other departments at ACG. - The Constraints team collaborates with R&D to receive knowledge of constrained components. - The Constraints team research how and when the shortage will impact ACG. - The Constraints team is deciding on allocation strategies. - ACG collaborates daily with the Constraints team. - ACG must prioritize which models to produce in the face of shortage. - ACG analyzes risks by identifying and analyzing depending on the component.
Mitigation of risk and disruption within ACG
- ACG mainly uses single sourcing. - ACG considers moving towards dual sourcing. - ACG scouts the broker market. - ACG collaborates with R&D to redesign products, components, and software.
Measures to manage future shortages

- There will be a continued risk with semiconductors in the future.
- ACG must plan to gain capacity.
- ACG has learned how to better work jointly in the organization to handle risks.

Table 2: Summary of findings

5. Analysis

In this chapter, the empirical findings are analyzed based on the theoretical framework laid out in chapter 2. This chapter follows the logic of the empirical findings by starting with analysis of SCM within ACG. Then it moves on to analysis of risk management, risk mitigation strategies and any learnings gained. This chapter concludes with a revised conceptual model.

5.1 Supply Chain Management

In order to understand how ACG handles a global extended disruption in their supply chain and how they manage risks, the supply chain organization findings will first be analyzed. ACG's supply chain is described as a complex network with 9700 suppliers worldwide. Their semiconductor supply chain on its own is broad and complex, with many actors collaborating with each other for each component. This goes in line with Sanders (2012) definition of a supply chain as a network where all the different actors communicate with each other rather than a linear process. Upstream, ACG collaborates directly with their tier 1 suppliers, with limited direct communication with their tier 2 suppliers. This finding aligns with Sanders (2012) and Waters (2007) definition of supply chain activities upstream, where focal firms procure from and negotiate with their tier 1 suppliers, who in turn procure from the company's tier 2 suppliers. ACG procures directly from their tier 1 supplier, who do not manufacture the necessary components themselves. The tier 1 suppliers procure the finished components from the tier 2 suppliers who produce the needed components. ACG follows an open triadic supply chain structure (Mena et al., 2013), with its limited direct communication with their tier 2 suppliers and linear information flow.

5.1.1 Suppliers

ACG chooses suppliers by using the aforementioned symbolic "briefcase", which includes aspects such as sustainability, quality, cost efficiency, innovation and willingness to cooperate with ACG. This supplier selection process goes in line with Choi & Hartley's (1996) description of automotive MNCs system of selecting suppliers. For ACG, the most important aspect in selecting suppliers is to have a standing long-term relationship with them. Therefore, ACG can be sure that the tier 1 suppliers can deliver according to ACG's capacity and to gain necessary knowledge from tier 2 suppliers in order to achieve company goals.

Information exchange between ACG and their suppliers occurs frequently and as transparently as possible, in terms of capacity, volume forecasting and projects. Following the analysis of Sanders (2012) and Li & Lin (2006), that stresses the importance of information sharing across the supply chain network this, according to the authors, prevents costly inventory and allows the supply chain network to better respond to a fast-changing environment and match supply and demand. Because ACG experiences a lack of information regarding the bill of materials from their tier 1 suppliers, they have few possibilities to assess the risks related to the components.

ACG collaborates mainly with their tier 2 suppliers to achieve their strategic goals and to determine which technologies will be applied to future models. This goes in line with Sanders' (2012) description of collaboration with the area of SCM, which details how collaboration can improve processes within the supply chain. By collaborating with their tier 2 suppliers, ACG can achieve greater control and knowledge of necessary components, and therefore optimize their operations.

5.2 Automotive Supply Chain Management

ACG has a lean supply chain and does not procure more semiconductor components than what they need and does not keep stock of any components. Therefore, ACG employs the JIT philosophy in their supply chain by eliminating inventory and only producing according to market demand, Vokurka & Lummus, (2000), much in the vein of another automotive manufacturer, Toyota. This goes also in line with the Lean manufacturing strategy that is common among automotive manufacturers, which is a way to reduce costs and only produce what is needed to match customers demand (Modig & Åhlström, 2013). Although JIT allows the company to achieve flow efficiency in their supply chain and avoid costly stocks, this philosophy makes ACG's supply chain more vulnerable to disruptions, as they have no safety stocks to rely on when there is a shortage of necessary components. Buffer stocks would be effective against disruptions, but they are costly to manage and because of volatile market demand ACG is not sure when these stocks can be of use.

ACG procures semiconductor components from brokers that exist outside of the supply chain, when necessary, components are constrained. The brokers procure overstock of components from an unknown supplier, which in turn are procured by ACG. This way of operating goes in

line with Ambe & Badenhorst-Weiss' (2010) definition of leagile supply chain, where the focal firm is able to meet volatile demand while at the same time maintaining a less wasteful flow of components upstream. Brokers do not keep stock of any components and collaborate with ACG on how many components are needed. Therefore, brokers can be of help for ACG to eliminate waste and meet demand.

The shortage of semiconductor components and increased demand were motivating factors in forming the semiconductor department at ACG, with the purpose of managing the semiconductor supply chains as well as improving semiconductor technology. This way of operating aligns with a leagile supply chain, where the focal firm can maintain efficient flows upstream and meet volatile demand (Ambe & Badenhorst-Weiss, 2010). ACG has been able to reorganize its operations in response to semiconductor constraints and increased demand.

5.3 Supply Chain Risk Management

When facing the semiconductor shortage which has lasted for a long time and has a global spread, the constraints team have been focusing on securing the necessary semiconductor parts and components by delegating some (if possible) to the regional team where the supplier is located. At a buyer level, it is noticeable that there have been changes in the organization and in their relationship with the suppliers. Indeed, it is stressed by ACG's managers that there is a need for the company to understand in detail what the bought product is and in this case semiconductors. It is also shown throughout the empirical findings that there is strategy from the company to have a closer relationship to second-tier suppliers and it is believed that the utility of it will benefit the company to mitigate risks (in semiconductors) in the long-term.
In fact, coordination here is seen as a harmony between upstream and downstream actors in the supply chain. This is in line with an essential variable of SCM underlined by Sanders (2012), which is collaboration between actors within the supply chain. Which is done in order to reduce costs and improve processes throughout the supply chain. Collaboration has more focus on the downstream part of the supply chain, by the need of understanding customer demand as well as real time constraints of the suppliers in order to optimize their own operations.
Furthermore, Sanders (2012), defines SCM as a dynamic process that involves coordinating all the activities in the supply chain in order to profitability and satisfaction of the end customer. This is done through information sharing as explained previously but also collaboration and coordination across the supply chain. Here, ACG has a clear coordination between its

departments in order to find solution when facing a shortage, it is emphasized by ACG that the close collaboration with R&D and the analysis of cars profitability and sales statistics is primordial in order to decide which features in a car it is possible to switch off without losing an important amount of revenues. The coordination of SCM is also applicable in an upstream-focal firm perspective where the R&D department researches the compatibility of products in order to interchange them and use them in products that have a critical component supply.

It is not made clear what kind of analysis ACG is using, and it is also stressed that the company doesn't make risk analysis following a given analysis model or any particular scheme (at least in the interviewed departments). However, there is some form of risk control that involves risk mitigation and risk monitoring by reporting shortage/issues faced by ACG at a procurement level to a special team that takes measures to solve those. Comparing the findings to Musa's (2012) SCRM process model and Paulsson's (2007) risk management model, there are similarities in the aim of the risk management. For example, in risk control/reduction both models suggest decision making, implementation and monitoring of risk in order to mitigate them and a parallel could be drawn with ACG's mode of procedure when the reporting process occurs but also the measures taken by the Constraints team that monitors risks as they are reported to them and involves their regional teams.

Still, there is some form of global risk analysis done by ACG on a weekly basis that includes macro analysis of what is happening in the world as global short term risk assessments, country risk hotspots, capital market, economic outlook, raw material prices, environment and sustainability and updated information about the automotive industry. It is nevertheless unclear how much of this information is used in a proactive approach. It is however hard to have a proactive approach (risk analysis) in a company that is buying an enormous number of parts and it would be costly to secure every part that is being purchased by ACG.

When analyzing Musa's (2012) model of SCRM process further, there are two separate SCRM processes that are interconnected and where a review process is done. Those processes are risk analysis which comports risk identification, estimation and evaluation and risk control that comports risk mitigation and risk monitoring. Those two processes could be separated into proactive SCRM measures and reactive SCRM measures, in fact a proactive strategy uses research and preparation to mitigate risks before they occur, and reactive strategies are those that respond to some unanticipated events after they occur (Thompson, 2019). In the case of the

SCRM process model, the proactive process takes place in the risk analysis as it involves measures done before an event occurs and reactive process is the risk control as it happens after an event occurs. ACG utilizes a reactive approach when facing a disruption and in our case semiconductor shortage as measures are taken after events occur. However, taking into consideration the measures taken by ACG in order to mitigate the risks when facing the semiconductor shortage, as the collaboration with the second-tier supplier with an aim to have a closer relationship and a higher control of the supply chain this could be seen as a proactive approach for future semiconductor shortage.

5.4 Supply Chain Management Strategies

ACG mainly uses a single sourcing strategy when procuring components, which means that they source from one single supplier for each component. This goes in line with Larson & Kutchinsky's (1998) definition of single sourcing. ACG uses single sourcing within semiconductor procurement. It is explained by ACG that using their direct suppliers (first tier), they have a contribution in testing components and procuring the right components for the right product. This is in line with Blome & Henke, (2007), who stress the increased focus on core competencies as well as shifting value creation toward the suppliers when applying a single sourcing strategy.

However, ACG is at greater risk of disruptions when sourcing components from a single supplier. The company has opted for a dual sourcing strategy in face of the semiconductor shortage, which means that ACG sources its necessary components from two suppliers simultaneously rather than from one single supplier, in the vein of Guo, Lee & Swinney's (2016) description. By spreading the risk across two or more suppliers, ACG can better mitigate risks of disruption.

ACG considers redesigning their products and components, such as PCBs, as a risk mitigation strategy. When there is a shortage of a certain semiconductor component, ACG redesigns parts and systems dependent on that component compatible with another semiconductor component that is not constrained. This is done in collaboration with the R&D department. This is a reactive strategy, which is defined by Ankiriwang, Pujawan & Santosa (2014), as the focal firm adapting their strategies when disruptions occur. ACG adapts to component shortages by redesigning their products to be less reliant on constrained semiconductor components.

5.5 Learnings

ACG has learned from the semiconductor shortage that the risk of disruption will continue even in the future, and that the company must plan ahead to secure capacity. ACG might have to secure the required capacities by themselves, which is a different approach from having the suppliers decide how to secure capacity. This goes in line with the definition of a proactive approach by Meng (2020), where the firm forecasts risk ahead and develops strategies to mitigate them. ACG forecasts that the semiconductor risks will continue and plans ahead to find new ways of securing capacity in order to be better prepared to mitigate risks.

ACG has learned how to better work together as an organization in order to mitigate incoming risks and shortages and to act in due time. This goes in line with Sanders' (2012) definition of collaboration within SCM, where the actors in the supply chain must collaborate in order to improve processes. ACG improves its risk mitigation processes by collaborating with other departments within the organization in order to better understand the risks around them. Collaboration in this instance includes having daily meetings where production plants and buyers report what the situation looks like with the suppliers.

6. Conclusions

This chapter concludes the findings derived from the analysis and the answer to the research question "How do the automotive MNCs manage their semiconductor supply chain during a prolonged global disruption?". The last sections of the chapter outline the managerial implications, implications for theory limitations of the study and suggestions for future research.

This case study has examined how ACG manages their semiconductor SC during an extended global disruption to have a deeper understanding of how firms within the automotive industry can mitigate an unexpected event. The semiconductor shortage is specific to an extended global disruption as it is a disruption that affects many industries and that occurs under a period of more than two years (and still ongoing) (Stankiewicz, 2022).

With an increasing probability of risks disrupting the entire SC of MNCs in more than one industry the authors developed a conceptual model based on SCM and SCRM presented in Figure 7, while the literature on how prolonged global disruption is meager. The data was collected and analyzed to answer how the semiconductor shortage was managed in the supply chain. Some factors have been identified, such as collaboration, information sharing, reactive and proactive approaches and risk analysis based on areas presented in the conceptual framework: SCRM, SCM, Supply Chain Disruptions, SCM strategies and Automotive SCM.

From the findings of this study, it can be concluded that information sharing between the focal firm and the suppliers is crucial in order to overcome an eventual disruption. Indeed, being continuously updated by the supplier about their disruption gives clear signals to the company about upcoming shortages. This also implies collaboration between departments within the company through continuous communication and decision making, which could imply changes in SCM. This also requires a vertical integration of concerned departments that rapidly anticipates shortages.

This could also have an impact on SCM strategies as sourcing strategy is only appropriate when there is a continued supply of components available. With demand becoming more volatile and supply of components wavering, automotive MNCs are considering moving

towards dual sourcing (or multiple sourcing) and at the same time a closer relationship with second-tier suppliers as a way to spread out risk in their supply chains.

Many automotive MNCs employ the JIT philosophy in procuring materials. However, this traditional way of operating is prone to fragility when facing an unexpected event, such as a global shortage. This could call the procurement strategy of automotive MNCs into question if a global disruption lasts longer than other strategies such as just in case (JIC) can be used to assure a continuous supply. This can be done upstream through an analysis of risk components and stockpiling those in a proactive way.

The study also emphasized the shortage by taking the example of semiconductor shortage and shows the importance of taking harmonized measures within an automotive MNC to meet future goals as well as to properly respond to risk. This is done by a cross-functional way of operating as automotive MNCs have different departments working towards a similar goal. An example is the purchasing department that is directly facing a disruption and collaborating with other departments such as R&D or strategic planning departments in order to overcome an unforeseen event.

The impact of disruption in the company's business model is also a feature to consider as knowing that the company has a clear strategy of moving towards an electrified product line which implies a shift in their business models and knowing their cross-functional operations it can be concluded that both business models and supply chain management are influencing each other.

A revised theoretical framework has been developed, showing that supply chain disruptions have a direct impact on SCM and SCRM of companies that in turn affect SCM strategies of a particular company by involving different departments within it, the revised framework is presented in the following section.

6.1 Revised Conceptual Model

The analysis shows how management and risk management in the supply chain are divided in different processes done by distinct departments. However, these are linked to each other where the information sharing within the MNC is crucial in order to manage upcoming disruption in order to manage them. The analysis also shows that MNCs set the paths for future business models by adjusting the functioning of the supply chain in order to be in line with supply chain management strategies. Even though the continuous readjustment of strategies occurs within the firm it is not sufficient to prevent disruptions within the supply chain, it is therefore important to have a clear coordination, collaboration and information sharing with the suppliers to mitigate eventual disturbances.

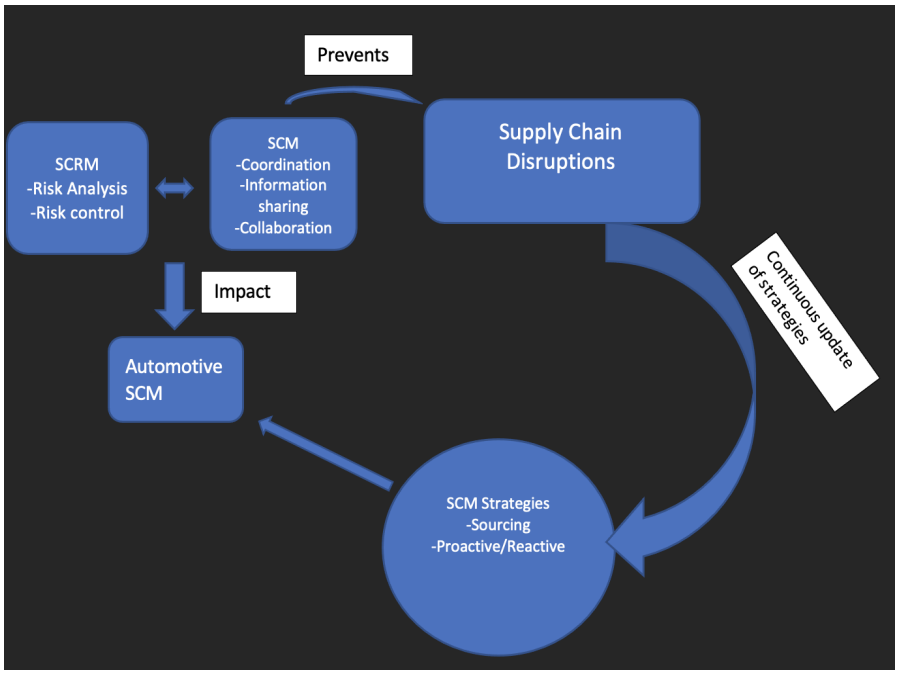

Figure 8: Revised conceptual model (Own illustration).

The conceptual model presented in Figure 8 is a revised model of the conceptual model presented in Figure 7. It shows how a harmonized SCM and SCRM could prevent SCD which suggest an adaptation or readjustment of strategies within the SC with the suppliers that in turn have an impact in the nature of the SCM of the industry in question, here the automotive industry. This model gives a more accurate view of SCM, its link to SCD and further on its impact on strategies within automotive MNCs in order to prevent disruption alternatively deal with disruptions. Previously the conceptual model only looked at SCM and SCRM within MNCs as being measures taken reactively when disruptions occur.

This updated model makes it clearer how the process of management could be done upstream for an eventual forecast of disruptions.

6.2 Managerial Implications

This study shows how automotive MNCs can manage their supply chains during a global extended disruption of components. It can provide insights on how automotive MNCs can improve their SCM processes and strategies in order to mitigate risk. The following table contains factors that can be considered when managing a global shortage of components.
It must be kept in mind that the factors in question are not entirely specific but can be used as guidance for supply chain managers and buyers in developing strategies.

- To get in line with shifting business models, a cross-functional way of operating is important.
- Closer collaboration with internal and external actors is essential to mitigate risks.
- Harmonized measures allow automotive MNCs to reach future goals and respond to risk.
- Multiple sourcing allows automotive MNCs to better respond to disruptions.
- A more agile supply chain is necessary to anticipate future disruptions.
- A Just-in-case (JIC) approach in procuring materials is a possible measure to ensure continuous supply during a global prolonged shortage.

6.3 Implications for Theory

This study increased understanding regarding how automotive companies can manage risks and disruptions within the supply chain, especially a global disruption that affects the supply chain in its entirety and that lasts during an extended period. This thesis was important to conduct since the automotive companies have a vulnerable supply chain that is prone to disruptions due to their traditional mode of operating, e.g., single sourcing and lean manufacturing. This study contributes to the limited theory of how automotive MNCs manage risks in their supply chain, by developing a conceptual framework that shows what implications automotive SCM has on SCRM. That way the existing theory is expanded. Another contribution is on how automotive MNCs create strategies in response to a global extended shortage, with the conceptual framework showing the implications of supply chain disruption on automotive SCM, SCRM and ultimately SCM strategies. The theory is also extended with the role of cross-functional operations within automotive MNCs as a risk mitigation strategy. This study also contributes to the limited research on how semiconductor disruptions are affecting automotive MNCs supply

chain management. This is shown on how automotive MNCs form entire task forces in cooperation with different departments in response to the semiconductor shortage. Another contribution is to previous research that only covers the research topic in a single country or market. This is highlighted in how automotive MNCs manage and allocate their global operations in response to semiconductor constraints.

6.4 Limitations and future research

Even though this study has a general scope in its implication, it has some limitations that need to be addressed. Price et al. (2004), define limitation of a study is the systematic bias that the researcher didn't control (or couldn't control), and which could inappropriately affect the result. They further explain threats that could affect internal and external validity of a study, internal validity and external validity could be threatened by the absence of established validity and reliability. Furthermore, they explain that even though a study is valid and reliable for an instrument on a given assessment it doesn't necessarily mean that the instrument is valid and reliable for all populations.

Based on the argument above, the result of this study may not be applicable to other companies operating in other industries as strategic and operational differences may occur. For instance, lean supply chains and JIT are widely used in automotive MNCs, but it is not clear if these strategies are used by other manufacturing industries. This study's findings may also not be applicable to other companies within the automotive industry. The strategies and operations of ACG might differ from other automotive MNCs.

Additionally, Price et al. (2004) mention attrition as a limitation of a research study and define it as the loss of study participants from pretest to posttest. In our case, this study tried to limit the confidential information given by the case company when they were accidentally given, and we also had a drop out of a department that couldn't attend the interview and their insight could have influenced the findings of the study.

Future research could include more automotive companies and more respondents to increase generalizability, and future studies could overcome the limitation of including only one company by conducting a multi-comparative study. Furthermore, the number of respondents

was limited. Future research in this topic can include more respondents in order to increase generalizability.

This study's primary focus was on the issue of one type of risk component, which was semiconductors. It can also impact the generalizability of this study, because semiconductor supply chains and processes might differ from other types of risk components. Therefore, there would be an interest to study how shortages of other types of components are affecting the supply chain strategy of automotive MNCs, such as shafts or gearboxes. Furthermore, this study focused entirely on direct procurement of materials, which means procurement of materials that are part of the manufactured product, and not taking procurement of indirect materials into consideration. Procurement of indirect materials, which are components used in production of products but not part of them, is also an integral part of SCM. Future research could include indirect material procurement to give a more holistic view of automotive MNCs supply chain operations.

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Appendix: Interview questions

Introduction

- What is your role here at ACG, and how long have you been working here?

Supply chains, Tier 1

- Can you describe how a semiconductor supply chain is structured?
- Can you describe a typical Tier 1 relationship?
- What kind of information sharing do you have with your tier 1 suppliers?
- How do you choose your tier 1 suppliers?
- In what matters do you collaborate with your tier 1 suppliers?

Supply chains, Tier 2

- Can you describe a typical relationship with a tier 2 supplier?
- How do you choose a tier 2 supplier?
- What is the purpose of setting up a tier 2 department?
- How does the relationship with your tier 2 suppliers help you in accomplishing your goals?
- How is information sharing with your tier 2 suppliers structured?
- Will your relationship with your tier 2 suppliers change your business model?

Risk Management

- How do you deal with shortages from shirt, middle and long-term perspective?
- How do you analyze risks in the supply chain?
- How do you work to manage risks in the semiconductor supply chain?
- What are your short-term strategies to mitigate shortage in semiconductors?
- How do you decide which factory is prioritized when allocating more to a plant and not to another?
- Do you follow any particular scheme or model in order to manage risks in the supply chain?

Learnings

- Did you have any learnings from this shortage of sensitive/high risk components?
- Have you faced a shortage earlier in your career?