Development & Evaluation of Flexibility Requirements on Suppliers

A Case Study

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Abstract

The market for industrial robots has seen exponential growth in recent years, leading to new challenges for industrial robot manufacturers. These increases in demand have been fluctuating, and as a way of coping with the new uncertainties, supply chain flexibility (SCF) has become a higher priority for many actors in the sector. For optimal results the SCF initiatives should extend beyond the single organization, and this thesis has focused specifically on the buyer-supplier (B-S) dynamic.

ABB Robotics (ABBR) is an example of a manufacturer affected by the market changes, facing exactly the described challenges. They serve as the basis for this thesis’ case study, which seeks to investigate what flexibility requirements should be put on their suppliers in order to deal with demand uncertainty. The thesis also explores what kind of data ABBR needs from their suppliers to monitor and evaluate the supplier’s flexibility, in turn to increase ABBR’s own ability of responding to demand changes. To achieve this, an extensive literature study has been used in combination with interviews and discussions with ABBR.

Through this, it was found that ABBR currently share their demand forecasts with their suppliers, yet receive very little data back. This leads to a deficiency of information in the decision-making process for their sales and operations planning (S&OP) processes, leading to ABBR being unable to optimally take advantage of the growing market. While it was found that they do have some standards for how much flexibility their entire supplier base should be able to deliver, supplier flexibility information is unavailable to ABBR for practical use.

To combat the issue, a triple sided approach has been developed. Firstly, it is recommended that ABBR use a segmentation model differentiating groups of suppliers that should be required to have differing levels of flexibility. The segmentation is made via criteria on dependency, B-S relationship etc., and results in three segments. Secondly, it recommended that suppliers share information on how much they can deliver above what has been forecast, so-called upside flexibility. Supplier-side information sharing of upside flexibility data is recommended, so that the information reaches ABBR. Incorporating this into databases used in the S&OP processes will enable better planning and decision making for ABBR, especially in situations with rapidly changing demand. Thirdly, a simple, visually intuitive model for saving upside flexibility data over time was proposed. Using past data to continuously monitor the actual upside flexibility at the supplier’s will enable evaluation against the required flexibility as defined in the segmentation model. Through these three recommendations, knowledge of flexibility within the supply chain is expected to increase; facilitating higher overall SCF.

Further research can be done to enhance the proposed guidelines with quantitative, statistical data to determine the effectiveness of local activities (such as those proposed in this thesis) on long term global SCF. It is also relevant to extend the perspective beyond first tier suppliers, which is this thesis’ focal point, in order to get a holistic view of flexibility in the supply chain.
Marknaden för industriella robotar har sett en exponentiell tillväxt de senaste åren, vilket har lett till nya utmaningar för tillverkare på marknaden. Efterfrågan har dessutom ökat oregelbundet vilket gjort att många aktörer vänt sig till värdekedjeflexibilitet som ett sätt att hantera osäkerheten. För optimala resultat bör initiativ kopplade till värdekedjeflexibilitet sträcka sig längre än den egna organisationen, och denna uppsats fokuserar specifikt på dynamiken mellan köpare och leverantör.

ABB Robotics (ABBR) är ett exempel på en sådan tillverkare (köpare) som påverkas av fluktuationerna på marknaden. De utgör grunden för denna uppsats fallstudie, vilken undersöker de flexibilitetskrav som bör läggas på deras leverantörer för att hantera efterfrågeosäkerheten. Uppsalsten utforskar även vilken typ av data som ABBR behöver från sina leverantörer för att kunna bevaka och utvärdera leverantörens flexibilitet, för att i sin tur kunna öka sin egen förmåga att svara på förändringar i marknaden. För att åstadkomma detta har en uttömmande litteraturstudie utförts, kombinerat med intervjuer och diskussioner med ABBR.

Det som återfanns var att ABBR i nuläget delar sina efterfrågeprognoser med leverantörerna, men får mycket lite data tillbaka. Detta skapar en informationsbrist inför beslutsunderlagen som används i ABBRs sälj- och verksamhetsplanering (S&OP), vilket leder till att de inte på bästa sätt kan dra fördel av den växande marknaden. Det finns dock generella standarder för hur mycket flexibilitet varje leverantör ska kunna leverera, men i praktiken är information kring leverantörens flexibilitet inte tillgänglig för ABBR.

First off, the authors would like to extend their most serious thanks and appreciation to Eleonora Boffa at the Department of Production Engineering (IIP) at the Royal Institute of Technology (KTH). Without you supervising our thesis, providing valuable insight and direction, this would not have been possible. A heartfelt thank you also goes out to IIP lecturers Per Johansson & Lasse Wingård for being so accepting of us barging into their office repeatedly, as well as general consultants Christina Ghawi & Julia Creutz. Thank you for helping us navigate this inordinately stressed endeavour, you are all truly irreplaceable.

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Nevertheless, and with all our sincerity: thank you, a huge thank you, to all of you who have helped on this journey.

Elle Edström & Alex Warris
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<td>B-S</td>
<td>Buyer-supplier</td>
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<td>MRP</td>
<td>Materials requirement planning (system)</td>
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1. Introduction

In this section, the area is introduced briefly, followed by problem formulation, purpose, research questions, expected contributions and delimitations. The intentions of the authors are to provide the reader with sufficient preliminary information to understand the thesis.

1.1 Background

Global manufacturing trends toward plants are getting more suited for industry 4.0, and technological advances has made automation by use of robotics a cost-effective option for more and more manufacturers. Many manufacturers have a need for replacing menial or hazardous tasks, all the while meeting requirements such as a speed, tolerances or precision. As a result of the subsequently increased demand and availability of these more effective tools, the use of robotics in production has skyrocketed over the past decades (IFR, 2017). For industrial robot manufacturers, this means new challenges that must be addressed in order to take advantage of the growth in their markets.

For the large robot manufacturing companies, the customer demand is difficult to predict due to rapid and sometimes sporadic market changes. The growth is normally not consistent in the short term, and this unpredictability combined with the previously mentioned large increase puts a strain on robot manufacturers as well as their entire supply chains. Meanwhile, said manufacturers wish to continue to offer their regular and pledged delivery times and services. Dealing with these opposing realities poses challenges and requires heightened flexibility in the entire supply chain, so that necessary changes (both present and future) can be made with speed and cost efficiency.

In practical terms, this means a need for flexibility in production and from suppliers. Management needs to be aware of exactly what the flexibility situation looks like, necessitating certain flows of information, in order to make the best decisions. In large Swedish companies, the knowledge of production capacity and flexibility tends to be satisfactory due to the focus it has received in recent years, but that knowledge is not guaranteed to extend to even the first-tier suppliers. How to increase this to gain flexibility in the supply chain thus remains a challenge for companies competing in the 21st century’s global manufacturing market.

1.2 Problem statement

Going forward, robot manufacturers such as ABB Robotics (ABBR) need to extend their flexibility initiatives to include their suppliers in order to promote better supply chain flexibility (SCF). Today they struggle with on-time delivery, and there is a lack of insight as to how flexible their suppliers are with regards to capacity and adaptation to order changes within reasonable timeframes. This causes a general unawareness of future bottlenecks as well as opportunities, and leads to delivery problems that might be preventable.
1.3 Purpose

The purpose of this thesis is to investigate what flexibility requirements ABBR should have on their suppliers in order to deal with demand uncertainty, and what kind of data ABBR need from their suppliers in order to monitor and evaluate the supplier’s flexibility. The thesis aims to develop guidelines for the approach a robot manufacturer should have when working on supplier flexibility with their supplier, for an increased knowledge of the flexibility potentially spanning the entire supply chain.

1.4 Research questions

1. What requirements on flexibility should ABB Robotics have on their suppliers, with regards to volume and time dimensions?
2. How could ABB Robotics increase supply chain flexibility in order to improve the current state?
3. How should the flexibility at the supplier be monitored and evaluated, and what measurements should be proposed?

1.5 Expected contributions

The work presented in this thesis is expected to contribute with guidelines for how large manufacturers of industrial robots can increase knowledge of their SCF by increasing information sharing and collaboration with their first-tier suppliers. Another expected point of contribution is a deepened understanding and analysis of the area of supply network management from an industrial perspective, as well as a mapping of the SCF concept related to suppliers.

1.6 Delimitations

The scope of this study will cover a range of subjects, from information sharing to SCF, specifically for the industrial robot manufacturer industry and companies such as ABBR. With regards to suppliers, only collaboration with the first-tier suppliers will be investigated, conducted in such a way as to focus on the effects that the collaboration will have on ABBR. Assessing the relevance of different factors is investigated from an angle of SCF in the present and going a few years forward, meaning the timeframe and perspective is relatively short.

This study will not discuss the supplier-side of relationships (with the exceptions of overlapping academia) and their components in general. In brief, this means that aspects such as the need for trust or how to apply a general policy or code of conduct is ignored in favour of strictly focusing on flexibility through volume and time. The same is applicable for the strategic side of the buyer-supplier (B-S) relationship. How the general relationship with the supplier should be managed is considered out of scope, focus is strictly on flexibility in the short to medium term. Information sharing from this perspective is addressed in the form of data points on the supplier’s production, and not general data required, for instance, in the procurement processes.
2. Method

This section provides explanations of the methods used throughout the thesis, ranging from interview design to academic information gathering. It concludes with general comments on the veracity and validity of the methods used.

2.1 Literature study

For the academic section of the thesis work, a literature review was conducted, which later served as a basis for the subsequent empirical part. This review was constructed by use of a systematic approach, covering various sources through a variety of journals, technical reports and books. Initially, sporadic searches were made to get a feel and introductory understanding of the area. This naturally returned a plethora of formal as well as informal results, such as editable online encyclopaedias and non peer-reviewed business reports, which ended up giving the direction of the final literature study. As stated by Collis & Hussey (2013), the use of a rigorous method is unmistakably important when gathering information. Data collection for the thesis was thus accordingly decided to follow a set of guidelines, which were iterated upon if found incomplete. For instance, seeing as the subject matter had no apparent limit in terms of how old research was, with results dating back decades yet still remaining relevant, no restriction was made on how old academic results could be. This, as anticipated, balanced itself out as more relevant research built on older, more unrefined research, proving to be of little concern later down the line. Instead, factors such as region of study, amount of citations, methodology, study design and scope were prioritized. Despite these being used, the thesis is in the end based on qualitative results, meaning that some results were incorporated without having been returned from systemic searches (such as direct recommendations from this thesis’ supervisor or ABBR). Regardless, approaching any results with a critical perspective was essential in order to ensure an academic thread of coherence (Quinton and Smallbone, 2006).

Searches were made through the online search tool KTH Primo, available to the authors through the KTH library and website. A few journals and specific sources were highlighted as more important, partly based on criteria from Quinton and Smallbone (2006) and partly through recommendations from this thesis’ supervisor and other members of KTH staff. Despite this, no discrimination was made with regards to other journals or research papers, and naturally some proved more fruitful than others. The selection itself was made based on keywords and search terms, iterated upon multiple times. These iterations and reiterations changed as new search terms were discovered to be of relevance or were recommended to us. By carrying out the search in this way, through division of searches and keywords, better outcomes could be expected according to Collis and Hussey (2013). While tens of thousands of results were returned on each search, the first 200 were examined in more detail. Here, title and abstract was scanned for selection into the reference list. Data from each scanned source (for example author, link, journal, year of publication and summary) was then collected in a spreadsheet for later internal ranking based on their relevance after the entire article had been read. After a complete screening of the sources deemed relevant, the literary findings were
compiled and analysed on a meta-level, combining sources in order to provide a complete picture of the literary themes (Glass, 1976).

2.2 Case study
A single case study was chosen to explore the master thesis themes in-depth, in a naturally occurring situation. It is not necessary to choose the most representative case in this situation, due to the statistical insignificance of a single case, so what was considered a critical case was chosen (Collis & Hussey, 2009).

For the data collection for the case study, a total of 11 face-to-face interviews were conducted with employees from ABBR. The results of these served multiple purposes. For one, they made possible the presentation and analysis of the current state, as well as served as a reactionary force to suggestions and ideas the authors had during the thesis’ writing. They also allowed for benchmarking against research found through the literature study, and aided in providing meaningful insight and discussion into the multifaceted problem present. Interviews are overall considered suitable for this type of qualitative research, and although they are considered to have a high degree of validity, there can be difficulties in terms of their reliability (Collis and Hussey, 2013). Despite this statement, the results are nevertheless considered dependable as questions were designed to focus on determinable values and technical details about work methods. Any other input that have come from the interviews, such as opinions or other subjective perceptions, have been sought to supplement this focus. Still, a discussion on whether the thesis’ design promotes repeatability is of relevance, especially when considering the use of anonymity among interviewees and the choice not to release transcripts of the interviews. The complexity present when designing a thesis aiming to appease multiple stakeholders made it difficult in finding a perfect solution for all parties. Simply put, no other superior option was available when collecting the information necessary, in terms of pure practicality.

The interviews were semi-structured and conversational, so that interviewees were allowed to elaborate on their answers. The goal was to get information in order to paint a picture of the current state at ABBR, so subjects were only guided when interviewees were trailing off too far or when time became an issue. Questions were centred on gaining an understanding of what was conceived to be the main problem, as well as seeing the different functions and work of the interviewees in relation to said problem. Other areas of interests included the understanding of incentives, contracts and other ascertainable factors concerning the issue. While this lead to, at times, changing questions between interviews, it was not something taken into consideration during the work process. Seeing as this is considered an entirely acceptable work method (Collis and Hussey, 2013), these changes were not of concern, as the purpose of them was not to gather quantitative or statistical data to later lean on, nor was it to contrast or cross-examine collected information to find flaws between interviewees.

Employees were purposely sampled (Creswell, 2007) for interviews and offered a spectrum in terms of area of expertise as well as position in the workplace hierarchy. Despite each interview giving a narrow view from a specific angle, enough overlap between them existed to provide a holistic overall view, later checked against supervisors and contacts at ABBR. Interviews themselves lasted approximately one to two hours each and took place on several occasions, on location at the facility of ABBR in Västerås, Sweden. Recordings of every interview was made, both in writing and through audio recording, however none are to be
released per agreement with the firm and affiliates used for the case study. For the concluding analysis of the specific interview material, open coding (Patton, 1990) was used. Overall data analysis of the results was conducted in the within-case manner (Collis and Hussey, 2013).

2.3 Methodological implications

With regards to analysing and evaluating the overall robustness of the methodological choices, a few factors can be considered. As a study’s scientific quality is often measured by its dependability, credibility, confirmability and transferability (Creswell, 2007), it would be fair to examine the study at hand based on the same parameters. Although the dependability of studies based on observational data and interviews usually is low, this one serves as an exception. By keeping the name of the case study company in the report, and by focusing the interviews on painting an existing picture through determinable values and verifiable statements, combined with the cross checking of data with supervising individuals at ABBR, dependability is overall considered high. With regards to the reports credibility, all sources are either taken from peer-reviewed journals with good reputations or from ABB Ltd. themselves (either through interviews or published material). This, coupled with the use of established common practice methods for information gathering, naturally lends itself to a comparably high credibility. Together with all this, the authors of this piece of work has worked to remain open minded and actively sought to remove personal considerations throughout the work process, giving way to what can be considered, at worst, acceptable confirmability. Granted, personal bias and heuristics may well have seeped their way into interviews and the like, but care has been taken (such as the reviewing by peers) to ensure removal of this as much as possible. As with any work using the same study design, these factors are hard to completely rid oneself of, and so little in the way of hard facts can be offered to quell scepticism concerning confirmability. Lastly, on the note of transferability, not much can be said but to point out how this work, through a hopefully transparent and logical methodical approach can find results applicable outside this specific context.
3. Aspects & applications of flexibility

This chapter provides the theoretical framework needed to fully understand the technical details of the thesis. The structure follows a funnel design, starting from broader areas and ending with narrower, more specific subjects or theories.

3.1 Introduction to flexibility in the supply chain

A supply chain can be seen as the procedure where multiple companies convert materials into finished goods (Seebacher & Winkler, 2015), and supply chain management (SCM) is the term used to describe the integration and managing of aspects, actors and activities into this seamless process (Lummus et al., 2003). In a supply chain, as shown in figure 1, the buyers and suppliers enter a relationship wherein the supplier provides for the needs dictated by the buyer in terms of product, quantity, delivery and so on (Das & Abdel-Malek, 2003). This relation is not relative, and is dictated by the perspective of any given actors in the chain, meaning that a supplier is also a buyer of their own supplier. With regards to any agreed interpretation, several academics and practitioners have defined SCM which has led to some ambiguity on the part of its actual definition (Duclos et al., 2003). Nevertheless, most definitions share some overlap, and the Supply Chain Council (1997) overarchingly uses the following:

“The supply chain is a term now commonly used internationally which encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer. Supply chain management includes managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer.”

In the current competitive landscape, markets are increasingly getting more international, dynamic and customer-driven. Higher demands on variety, quality and service are now common, and are coupled with similar expectations for reliability and rapid delivery (Duclos et al., 2003; Seebacher & Winkler, 2015). Together with this, technological advances are made ever faster and more sophisticated, leading to new innovations and improvements of products and processes (Duclos et al., 2003; Seebacher & Winkler, 2015; Beach et al., 2000; Thomé et al., 2014).
With the spread of global competition in the 1970s, responsiveness as a concept emerged to become a new strategic advantage, together with low cost and high quality (Lummus et al., 2003). As buyers and consumers grew more sophisticated in their expectations, demand changed to include more customization and shorter product life cycles. This increased element of change and uncertainty meant a challenge for manufacturers, who found themselves unable to maintain the same large volumes and cost efficiency (Duclos et al., 2003). Organizations thus looked, out of necessity, beyond the limits of their own firms and onto their suppliers, their suppliers’ suppliers and so on to improve value for the customer. As such, the idea of a managed supply chain and its interorganizational capabilities was realized (Duclos et al., 2003; Seebacher & Winkler, 2015). Following the last decades, some key subjects in the field grew in relevance with this change of scope. One of these was the concept of supply chain flexibility, which widened the understanding with regards to the discussion and study of manufacturing flexibility (Thomé et al., 2014). Increased flexibility, often defined as a subset of agility, allowed organizations to move quickly and manage and apply knowledge more effectively (Lummus et al., 2003). Generally seen as an adaptive response, a flexible system was one with the ability to react to uncertainties with little penalty in terms of time or performance (Gosling et al., 2010). Given the effect and importance of SCM and SCF to reach competitive advantage, it may come as no surprise that researchers increasingly look into entire supply chains to understand how maximum flexibility can be delivered to the end consumer. However, most of the earlier and contemporary literature has not focused on supply chain as a whole but instead on manufacturing flexibility, and especially internal manufacturing flexibility. Up to now, studies of flexibility within the context of manufacturing systems had been extensively covered in literature, as has performance within the context of lean and agile strategies (Seebacher & Winkler, 2015; Purvis et al., 2014), neglecting the more encompassing view of SCM. This, quite intuitively, has led to a major limitation of the literature (Duclos et al., 2003; Thomé et al., 2014). Still, despite this disregard of some aspects in SCM and SCF, considerable progress has been made on the topic (Thomé et al., 2014). One example of these is the determination and definition of SCF components, something based on previous studies of internal manufacturing flexibility (Duclos et al., 2003).

3.2 Terminology and descriptions

Flexibility is a multi-dimensional concept with multiple aspects playing a role, however it is usually used in simplified or abridged terms. Generally, it is seen as an adaptive feedback response to some form of uncertainty (Thomé et al., 2014; Gosling et al., 2010). It is more specifically the representation of a system’s ability to react with little penalty, either in the form of time, cost, effort or performance (Gosling et al., 2010). As the use and affiliation of the term varies, and in order to understand the scope of what does and does not constitute flexibility (especially with regards to SCF, manufacturing flexibility and so on), an overview of common concepts, definitions and contributors for this thesis will follow in table 1.
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<th>Term</th>
<th>Example</th>
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<td>Internal &amp; external dimensions</td>
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*Table 1: An overview of the report’s academic definitions and dimensions of SCM.*
3.3 Organizational levels of flexibility

There are numerous ways to categorize and order the various aspects of SCF (Stohr, 2013), and some of the relevant ones are covered here. One good way to view this is by separating the different areas which flexibility can affect, another is to view a company as collection of different functions or levels. Terms such as enablers, types, factors, components, perspectives and dimensions have been coined to describe the different facets of SCF, and each contribute with explanations (Stohr, 2013; Seebacher & Winkler, 2015; Duclos et al., 2003). Stohr (2013) outlines these and the main ideas of a flexible or agile enterprise by a visual framework seen in figure 2, providing a solid overview. By looking at various levels within an organization, enterprise flexibility seeks ways of developing flexibility measures and implementation more efficiently. These levels, in order of macro to micro, are: strategic flexibility, organizational flexibility, business processes & information systems flexibility as well as operational flexibility (Stohr, 2013). In order to maximize the flexibility potential, firms should seek to lift the working level of abstraction to as high a level as possible, from operational to strategic (Duclos et al., 2003). It may also be noted that multiple other types of flexibilities are undoubtedly present within an organization. Aspects such as marketing, finance, IT, R&D and so on each hold their own sets of rules and subcategories (Seebacher & Winkler, 2015). Still, an overall understanding of the area is provided by this framework and thus makes for a good stepping stone. Following is a quick explanation of each level.

**Strategic**
A strategic flexibility offers transformational possibilities on behalf on the entire enterprise or some major part in order to keep said enterprise relevant. This highest level of abstraction concerns large-scale decision making and planning. It also provides dynamic adaptability through transparency, strategic focus and change handling.

**Organizational**
Organizational flexibility is the ability to handle and create change in an organization without sacrificing momentum or continuity in existing projects. Specifically, this puts emphasis on how processes, people and culture can interplay across organizational boundaries.

**Business processes & information systems**
This self-explanatory level of information system flexibility refers to how well systems can change or adapt to new demands, conditions or states, be them internal or external.

**Operations**
On the lowest abstraction level, more pragmatic aspects such as physical processes, manufacturing flexibility and so on are covered. Manufacturing systems and their ability to adapt, much like information systems above, are here utilized as a useful benchmark, where minimum time and effort per change are considered valuable. Other aspects of practical operations, such as marketing or finance, can also be considered to fit here (Stohr, 2013).
**Figure 2**: Setup and relationships of enterprise flexibility levels (Stohr, 2013).

**Side note: maturity**

As the subject of flexibility has evolved into an important part of business excellence, understanding its maturity has become equally important. Throughout the various levels and types of flexibility, this serves to help fully appreciate the complexities involved. It allows for organizations to better handle and execute future plans for flexibility, and thus presents another perspective in terms of competitive advantages and risk management.

In brief, a normal model for flexibility maturity covers a plethora of relevant aspects. Typically, it includes multiple levels where flexibility is of relevance, and may include situation-actor-process frameworks as well as strategic perspectives (Sushil, 2012). With regards to range, maturity levels can go from high levels of individual operational, process or actor flexibility to low levels of expectations or even reduced basic change mechanisms. Although this is only introduced here, a more in-depth look at Stohr’s (2013) maturity model is presented in chapter 3.7, Measurements.

### 3.4 Manufacturing flexibility

When using the term ‘manufacturing flexibility’, one refers to a manufacturing system’s ability to adapt and change by influence of external or internal conditions. By extension, a more flexible system naturally manages to do this with minimum time and effort needed (Gosling et al., 2010; Stohr, 2013). The accepted definition of the term varies, as authors have suggested formulations such as “the ability of a manufacturing system to cope with changing circumstances or instability caused by the environment” to “the ability of the system to quickly adjust to any change in relevant factors like product, process, loads and machine failure”. Despite this, a general consensus seems to exist on the more comprehensive
definition of “the ability to change or react with little penalty in time, effort, cost or performance” (Beach et al., 2000), echoing the definition of Gosling et al. (2010). Studies in manufacturing flexibility has been fragmented, with different research focusing narrowly on any given aspect (Duclos et al., 2003; Thomé et al., 2014; Beach et al., 2000). This means that the understanding of the mechanisms involved when discussing manufacturing flexibility, including (but not limited to) practical usage in SCF, has likewise been fragmented. Manufacturing flexibility has nevertheless somehow kept its high value and strategic element in many manufacturing companies, despite SCF being of more relevance when looking to generate value on a grander scale. Moreover, a holistic perspective complete with explanations and deeper understanding has historically been lacking, and thus the growth of knowledge has been evolutionary at best (Purvis et al., 2014). This fact combined with various recent research, such as the work of Beach et al., (2000), has led to a broader understanding through consolidation of previous ideas. Regardless, manufacturing flexibility and its relation to SCF continues to remain a subject in need of study (Beach et al., 2000). When overlooking empirical research on manufacturing flexibility, different views exist on how many dimensions ought to be included (Purvis et al., 2014). Vokurka & O’Leary-Kelly (2000) highlights a total of 15 dimensions, while Petkova & van Wezel (2006) conclude that at least 49 manufacturing flexibility types should be considered. Other researchers have instead set their sights on inventory, such as Griffiths & Margetts, (2000) or Hines (1998), on warehousing (Abrahamsson et al., 2003; Baker, 2006) and on transport flexibility (Naim et al., 2006) as potential sources of flexibility within a manufacturing system. As of today, a growing body of work serves to develop measurements of manufacturing flexibility and flexibility in general, which provides a stable theoretical groundwork in terms of taxonomy, despite divergence and sporadic contradictions. Rules and recommendation on practical performance, however, still stands as unlikely to emerge before purpose and definitions of the measurements are largely agreed upon (Beach et al., 2000). Together with this, another expanding area of manufacturing flexibility concerns itself with strategic uses and competitive advantage. Nevertheless, this is in some instances still in its infancy and thus more research is required before it can be fully integrated in conceptual frameworks which go beyond the limits of pure manufacturing flexibility and strategy. While the relation between manufacturing and business is well understood, a lacking grasp of other influences on strategy - such as corporate culture or B-S relationships - needs to be established still (Beach et al., 2000).

A wide range of reasons as for why journeying into manufacturing flexibility are positive for organizations have been suggested by multiple scholars (Beach et al., 2000; Naim et al., 2006). Arguments include sustaining competitive advantage, better managing of uncertainties, and handling of unpredictability in manufacturing environments (Frazelle 1986), improved development of production technology (Slack 1983) and accommodating fluctuations in outside factors such as energy prices or interest rates (Gunnigle and Daly, 1992). Usual priorities mentioned in these bodies of work are product quality, cost and delivery dependability, which seem to stem largely from a subset of various flexibilities found in manufacturing environments such as in routing, volume, expansion, operation and so forth (Beach et al., 2000). Furthermore, a considerable amount of work has been dedicated to specifically the operational factors of manufacturing flexibility with little attention given to methods of delivery. There does still seem to exist a deficiency in understanding the enablers of said flexibility, meaning aspects such as labour competence, process design and especially information technology (Beach et al., 2000).
3.5 Supply networks

As the concept of flexibility shifts towards a broader view than pure manufacturing flexibility, the entire supply *network* has to be considered. This means the inclusion and study of aspects outside the explicit supply chain, such as logistics, supply sources, suppliers hereditary flexibility and so on. While flexibility is conceptually most often seen as a simple adaptive response, many scholars have suggested that its effect on the broader system, meaning not only the supply chain, should be studied (Thomé et al., 2014; Beach et al., 2000). More recent research has thus left the realm of pure manufacturing flexibility to instead focus on broader SCF. As such, many models of this have been suggested, categorized and contextualized (Purvis et al., 2014). The majority of these differentiate between the internal and external elements (i.e. flexibilities), defining their differences as those that affect internal system behaviour versus those which are observed externally, such as by customers and the like. Manufacturing flexibility research, being too narrow in its scope, is unsuited to fully explain the nuances and broader contexts of the supply chain and supply networks at play (Swafford et al., 2006). However, SCF as a subject has still not fully matured, and so consensus on scope, terminology and taxonomy has not yet been established. It is nevertheless the superior perspective when studying flexibility, and so has been adopted by most academics. Much in a similar vein, firms too have begun changing their focus over the decades, now starting to see their entire supply chain as a possibility for increased overall flexibility.

In order to get a holistic view of the supply chain and processes involved, understanding supply networks is imperative (Purvis et al., 2014). As mentioned before, numerous academics have proposed models, many of which are reliant on or influenced by the research by Gosling et al. (2010) (Swafford et al., 2006; Purvis et al., 2014). In their model, a denotation of *vendor* flexibility and *sourcing* flexibility is made in an attempt to integrate the previously mentioned internal and external elements of the supply chain and SCF. By observing how a grander SCF can be built on and developed by either vendor flexibility, sourcing flexibility or a mix of the two, they argue that these were fundamental aspects and the key dimensions in supplier selection and relationship development (Stohr, 2013). Gosling et al. (2010) thus proposes a simple framework can be used for improved understanding, seen in figure 3 below. Through this type of model (where flexibility is the focus of interest), flexibility in itself acts a determinant for the design of effective networks (Gosling et al., 2010), leading to a broader awareness of its prevalence throughout the entire supply network (Thomé et al., 2014).
In brief, this model’s division seeks to cover all aspects relevant to the supply network and allow for a more strategic outlook. By separating the network into two essential nodes, vendor and sourcing, deeper insight into potential interplay and practical uses of the supply network is made possible. Moreover, in combining the vendor and sourcing concepts, one can see the importance of either aspect (Gosling et al., 2010; Purvis et al., 2014). This view overlaps with older studies from Squire et al. (2009) within a similar resource-based view, in which both internal and external capabilities are considered when studying performance of the SCF. Thomé et al., (2014) suggests, based on earlier research by Gosling et al. (2010), that the supply network expressed like this serves to show how distinguished the two types of flexibility are. The internal flexibility capabilities of vendors within the network are here a necessary but not sufficient element in achieving total SCF; external conditions and configurability, sourcing, does also have a considerable effect. Furthermore, rationalizing the supply network this way, with two separate value streams, allows for the different requirements and varying levels of customer satisfaction to be more easily understood. As a result, the need for strategizing becomes apparent (Purvis et al., 2014), especially as the relation between them grows to be more understood. The usage of this terminology and taxonomy thus emphasises the importance of adopting a network perspective for organizations seeking to increase flexibility (Gosling et al., 2010), while providing a simple overview of the network.

**Vendor flexibility**

The term vendor flexibility refers to the flexibility within specific, individual suppliers (vendors) within a supply network. These suppliers may be in manufacturing, warehousing, freight transportation, electricity or any other industry related to the supply chain, with each vendor holding its own flexibility capabilities (Purvis et al., 2014; Gosling et al., 2010). Gosain et al. (2005) presented a similar view, seeing this capability as a type of “offering flexibility”, suggesting it be the node’s ability to handle changes in products or services as a response to changing business environments. Gosling et al., (2010) argues that consideration of vendor flexibility serves an important function in rationalizing the supply chain overall and in constructing it to cope with high levels of uncertainty in a flexible and agile manner. Meanwhile, Thomé et al., (2014) explores the various contributions scholars have made towards this view, such as research focused on studying supplier alliance under uncertainty,
and on how firms should avoid tight relationships in exchange for higher flexibility via switching suppliers. In brief, a large body of research exists, leading to both a plethora of perspectives and a certain level of ambiguity as taxonomy and terminology evolves. Despite this fact, general ideas and concepts remain the same (Purvis et al., 2014).

Sourcing flexibility

Sourcing flexibility refers to the ability of a supply system’s coordinator to re-configure a network through supplier selection (Purvis et al., 2014). Fundamentally, it is the ability to change around the network’s source of supply with as little effect as possible. This enables improved systems composition from the buyer’s perspective. As with vendor flexibility, there exists a limited amount of literature on the specifics of sourcing in supply systems. Purvis et al., (2014) rationalize it as something conceptual; an overarching term to use based on previous research by Duclos et al., (2003) and Gosain et al., (2005). Also building on their definitions, Tachizawa and Thomsen (2007) necessitates sourcing flexibility to include a large supplier base as well as a constant redesigning and reconfiguration of the supply chain to maximise utility. Other researchers still argue on similar grounds, but with other terminology such as ‘re-configuration flexibility’ or ‘flexible sourcing’. (Thomé et al., 2014; Gosling et al., 2010). Generally, the consensus seems to be that an agile and flexible supply chain sourcing strategy is a legitimate method of handling high levels of uncertainty within an industry (Gosling et al., 2010).

Agile versus lean in the context of flexibility

Although the terms ‘agile’ and ‘lean’ are often used within the context of flexibility, and sometimes used interchangeably, a clear distinction is made between them in academia. The existence of both phenomena is derived from the conflict between standardization and customization. Standardization benefits from lean, while customization requires the ability to make efficient changes in an agile way. However, modern phenomena such as mass customization seems to combine the two, demanding leanness to achieve quality and eliminating waste, but the supply chain also needs to respond quickly to market changes and have high product and service variety. Hence, efficiency has to be supplemented with agility to cope with new market conditions (van Hoek & Harrison, 2001). Despite a relatively large pool of available research on the effects of lean and agile strategies on manufacturing processes, a noticeable confusion still exists between the two terms. These express the views of different paradigms in terms of content and methods of implementation (Purvis et al., 2014), and therefore warrant a deeper explanation.

Whereas lean and leanness seek to minimize internal and external variation, agility instead places emphasis on flexibility and market responsiveness (Naylor et al., 1999). The definitions can at times differ, with Han et al., (2017) describing flexibility as a subset of agility claiming agile organizations be able to rapidly move and choose appropriate responses to any given situation. Others, such as Swafford et al. (2006), see agility as a capability and flexibility as a competence and define the relationship in a slightly different way. Despite these varying perspectives, a general consensus seems to exist on how agility as a concept is linked specifically to flexibility and speed (Purvis et al., 2014). A common emphasis is on being able to perform some task (adapt, apply knowledge, manoeuvre obstacles and so forth) quickly and effectively (Lummus et al., 2003). Moreover, the term flexibility commonly refers to, and is used at, a more operational level in comparison to the overarching business wide perspective of the term agility (Purvis et al., 2014). This nuance lends itself well to
discussing the fit between an organization’s competences and its needs in a rapid, demand driven marketplace (Chiang et al., 2012). Lean on the other hand, while similar in its relationship to the term flexibility, is consistently associated with cost cutting, cost effectiveness and eliminating waste (Purvis et al., 2014).

With regards to combining the lean, agile and the mix (also known as leagile (Naylor et al., 1999; Purvis et al., 2014)), a modelled categorization can be found in available literature. In general, with flexibility seen as a performance capability, distinctions can be made between lean, agile and the leagile supply systems (Naylor et al., 1999), here shown in figure 4. This leads to various strategic applications and requirements for said terms, such as more rigid flexibility controls on lean systems or more robust adaptability incentives for agile systems. One model commonly cited, by Purvis et al., (2014), proposes looking at them from a case-by-case perspective, ranking aspects such as volume mix and markets responsiveness. In this, four different scenarios arise (lean, leagile with vendor flexibility, leagile with sourcing flexibility and agile systems) and are modelled in combination with a supply network approach.

![Figure 4: Model of lean and agile systems combined with a supply network view (Purvis et al., 2014).](image)

**Scenario 1: Lean systems**
Suitable for commodities & functional items with longer shelf lives. This necessitates focused lean practices in terms of both sourcing and vendors, leading to a supply chain heavily influenced by lean in terms of pure efficiency. As an example, Purvis et al., (2014) mention a case with easy forecasting based on historical data, where demand and volume adjustment rarely exceeded 10%. Through this, sourcing commitment could easily be made up to 12 months in advance and low labour cost would be the main driver. High volumes and predictable demand also meant a simplified process for continuing partnerships and with suppliers.

**Scenario 2: Leagile with vendor flexibility**
Here, medium term levels of responsiveness are priority, making it suitable for a relatively normal level of market uncertainty, shelf life and supply chain responsiveness. A dependency on the flexibility of individual vendors combined with lean sourcing practices acted as a foundation for this scenario. Demand is monitored consistently and supplemented by a daily analysis to recognize changes. In order to reduce risks, smaller volumes and more frequent order delivery can be made. This, in turn, puts pressure on the vendor’s ability to manage
their volume flexibility. For reference, one example would have vendors keep a range of order cancellation (-100%) up to multiple times the order size (300%) for certain products. The range of the products too was very wide, offering multiple variations per product. Here, the B-S relationship would often evolve to a more collaborative one, where one of the buyer’s objectives was to develop their supplier’s own business. Consequently, a vendor would see personal benefits in the form of preferential treatment or partnership. For both parties, information sharing would be seen as a prime reducer of costs.

Scenario 3: Leagile systems with sourcing flexibility
A mid-term perspective, similar to that above, is utilized here. It differs, however, in terms of how sourcing practices are used, instead requiring an agile sourcing strategy combined with vendors exhibiting leanness. An illustrative example from Purvis et al. (2014) had biannual decisions on material acquisition based on information from various stakeholders and influenced by seasonal market changes. Forecasts would be generated based on history, and trend analysts would enhance these with supplementary information. The contracted suppliers in these cases were identified by their high labour intensity and small average plant size, combined with a low emphasis on volume flexibility. In an effort to reduce costs, larger volumes and smaller volume variations were agreed upon through informal agreements.

Scenario 4: Agile systems
Short term responsiveness and an unstable market demands defines this scenario, putting heavy emphasis on rapid systems over cost effective ones. Based on high levels of uncertainty, and exacerbated by non-standard products with very low shelf life, agile strategies are necessary both in terms of sourcing and vendors. In this case agility is a must to handle the market instability and reach the level of speed needed. Forecasting would be impossible here, indicating trend-following, breakneck pacing and a high risk of obsolescence.

3.6 Modelling supply chain flexibility
SCF is the ability of the supply chain to exhibit flexibility, meaning its ability to change according to environmental uncertainty in an agile manner. Much like other parts of SCM, SCF can be divided into internal or external aspects (Gosling et al., 2010; Chang et al., 2006). As flexibility in itself is purely a representation of a system’s adaptability and speed, and can be viewed from any number of perspectives. This goes for internal and external factors (sometimes called measurements) of flexibility as well, where an aspect is most easily defined based on its visibility to the customer. Internal aspects are thus those which are invisible to the customer, tied to flexibility of machines, processes, operations and so forth. It encompasses all things internal to the manufacturing process or organization. Meanwhile, external aspects are those which are visible to customers, e.g. product flexibility, delivery flexibility and so on (Gosling et al., 2010). For the broader concept of SCF, these are put on a level matching the supply network perspective, yet placing both vendor flexibility and sourcing flexibility as internal (Seebacher & Winkler, 2015; Chang et al., 2006). External elements are seen as adaptive outputs from the system, such as the previously mentioned volume flexibility, product mix flexibility, access flexibility, access flexibility and so forth. All of these serve to provide and accommodate for customer needs, either in terms of pure products or delivery dates, and express the supply chain’s ability to cope and adapt to changes in the environment (Gosling et al., 2010).
Many scholars have proposed models and frameworks for studying SCF (Duclos et al., 2003; Thomé et al., 2014), leading to a wide spectrum of perspectives. A number of researchers see and define SCF as an important performance parameter (Stohr, 2013). Works by Gosling et al. (2010), Duclos et al. (2003), Vickery et al. (1999) and Beamon (1999) have laid a foundation in discussions on the identification and classification of SCF and many of its components. Beamon (1999) defined and perceived it as the proficiency with which a system reacts. Building on this, Vickery et al. (1999) argue for the now common view of flexibility measures in the form of product, volume, mix, delivery etc. Other important work argues for the importance of evolutionary growth in an evolving business environment and have pointed to the common paradigm of speed, flexibility and productivity, as well as the use of SCF as an important performance indicator of the entire supply chain (Chang et al., 2006; Stohr, 2013). Still, research is fairly young, first appearing in the late 1990’s (Thomé et al., 2014), and has seen fragmented views. Together with various difficulties in scope, these have led to a sometimes lacking nuance. This has been addressed by others, showing that flexibility in itself does not always lead to higher profits but must instead be aligned with other requirements for the supply chain. Moreover, much pressure is put on organizations seeking to increase their flexibility, as they often need to develop cross-functional and inter-organizational strategies for handling the performance (Thomé et al., 2014). Many studies have accepted the ideas of relating components found in literature on manufacturing to a wider view of supply chain and SCF (Moon et al., 2012). Of these, Vickery et al. (1999) highlight the five components most commonly adopted in the current customer-oriented paradigm, namely flexibility of volume, product, distribution, access and new product introduction. Here the first two spring from manufacturing systems, the following two investigative marketing, and the final is connected to R&D. However, despite these attempts to broaden the scope of SCF to multiple departments or processes within an organization, they all stem from internal factors of a firm (Moon et al., 2012) and thus lack the external elements. In summary, most of the current approaches are limited either to the study of very specific flexibility types or are hindered by their use of subjective criteria to evaluate SCF (Seebacher & Winkler, 2015).

Dividing SCF into a set of components allows for closer analysis and, in doing so, a deeper understanding the emergent effect of SCF. This is a common academic method of breaking down complex issues. In general, six flexibility components of SCF are widely agreed upon that can be identified from available research (Duclos et al., 2003; Thomé et al., 2014; Chang et al., 2006). These six are shown in figure 5, and originate from studies in manufacturing flexibility, strategic flexibility and more recently SCF. The aim is to explore the entirety of SCF, ranging from ability in aligning operations and assets, to how well a supply chain can alter information systems technology. The components are: operations flexibility, market flexibility, logistics flexibility, supply flexibility, organizational flexibility and information systems flexibility (Duclos et al., 2003; Lummus et al., 2003; Thomé et al., 2014; Moon et al., 2012; Bertrand, 2003). These comprise the overarching view, which is dependent on and affected by all components. For instance, while pure operations and logistics processes can provide a substantial amount of flexibility for a supply chain, the total SCF may nevertheless be hindered in the absence of organizational commitment or failures on behalf of information systems (Lummus et al., 2003; Thomé et al., 2014). Following all this is figure 5, based on the research by Duclos et al. (2003), supported by explanations of each component.
Operations flexibility
Sometimes referred to as operations systems flexibility, this component is characterized by manufacturing and service operations (Lummus et al., 2003; Thomé et al., 2014). In essence, it covers the ability to arrange assets and operations to respond to trends in each point (or node) of the supply chain (Duclos et al., 2003). It does in the practical sense share similarities with the subject of manufacturing flexibility, and many dimensions are categorized as extensions of pure manufacturing flexibility. Those are thus included in this component, here instead connecting the dimensions to a specific company or actor in the supply chain. Some examples of characteristics necessary on the operating side are the abilities to adapt assets along changing customer needs, to change processes with demand and to adjust capacity (Lummus et al., 2003).

Market flexibility
In brief, this details the supply chain’s ability to respond flexibly to market conditions and customer demands. It covers the ability of mass customization and close relationship building with customers, including aspects such as design and modification of existing products. Dimensions of the component include introduction of new products, post-delivery support, ongoing trend adherence, customization and so on. This is heavily reliant on various engineering approaches within the nodes of a supply chain, necessitating knowledge from different nodes in order to develop products more effectively, flexibly and rapidly (Duclos et al., 2003).

Logistics flexibility
This component is sometimes referred to as logistics process flexibility (Lummus et al., 2003), and encompasses all abilities related to logistics. Overall, logistics flexibility can be described as the capability of cost effectively receiving and delivering products as environmental factors (such as supply or customers) change (Duclos et al., 2003; Lummus et al., 2003). Logistics flexibility dimensions can be: adjusting to global requirements, serving customer shipping requirements, ability in varying warehouse space and transportation carriers, as well as the ability to manage product postponement. Other examples include documentation, inventory, tracking and transactions (Duclos et al., 2003). Flexibility in
logistics is necessary in order to meet the requirements of different logistics channels. Two instances of this is e-commerce and its expansion, leading to new markets in developing countries as well as how sourcing, manufacturing and distribution has grown more global alongside the general globalization of businesses (Lummus et al., 2003; Stohr, 2013).

**Supply Flexibility**
Supply flexibility, or supply network flexibility (Gosling et al., 2010), is the ability to rearrange the supply chain in accordance with changing customer demands (Duclos et al., 2003; Lummus et al., 2003). This includes aspects such as volume mix or product variations. In order to meet these demands, flexibility in relationships and other factors is required throughout the network, necessitating a supply chain constructed with future change in mind (Lummus et al., 2003; Das & Abdel-Malek, 2003). A number of elements play into this, such as the ability to add, vary or remove suppliers (sourcing flexibility) or in selecting suppliers who can respond to changes rapidly (vendor flexibility) (Lummus et al., 2003, Gosling et al., 2010).

**Organizational Flexibility**
This component covers the ability of aligning labour skills with the needs of the supply chain, in order to accommodate demand further down the line (Duclos et al., 2003). Because of its managerial outlook, it takes on a role more focused behind-the-scenes. Organizational design flexibility is highly dependent on the structure of the organization, which might either facilitate or impede progress in the form of relationships within and with other organizations (Lummus et al., 2003). Organizational flexibility, as a component of SCF, is used in order to acknowledge the fact the arrangement and adjustment of operations will only be as effective as the flexibility of the organizational structure itself allows (Duclos et al., 2003). A number of factors are closely connected to this, beyond the structure itself, and need to be considered when studying the component. These include the human resource perspective, workforce capabilities, company culture (which is separate in each node in the SC) as well as the ability to create and maintain links with other nodes in the supply chain (Lummus et al., 2003).

**Information Systems Flexibility**
Information systems flexibility simply refers to the capability of aligning IT-systems and IT-architecture with the supply chain and its corresponding organization, as a response to changing demands by customers (Duclos et al., 2003; Stohr, 2013). Under this category, aspects like information visibility, information sharing and informational symmetry are considered. In order for the supply chain to react efficiently, and to maximize SCF, all nodes must be informed and aware of changing requirements. As such, failure to establish sufficient informational symmetry may inhibit flexibility in the chain. This also goes for inter-organizational and inter-firm business practices, as complete data sharing can cover all partners involved (Lummus et al., 2003).

### 3.7 Measurements
The question of measuring flexibility has come into interest at the same time as the general interest in measuring performance in the supply chain, though measuring flexibility has turned out to be a very complicated topic (Seebacher & Winkler, 2015; Kurien & Qureshi, 2014; Hugos, 2011; Stohr, 2013). Measurements can be applied on different levels, depending on which kind on flexibility one wants to measure, and they might also be specific for
capabilities, overall performance effect or how well the supply chain copes with a certain type of uncertainty (Seebacher & Winkler, 2015; Stohr, 2013). The levels on which they can be applied include the manufacturing system level, organizational level, and supply chain level, wherein each level two categories of flexibility are considered: range flexibility (being able to vary volume or extent of operation) and response flexibility (how easily range can be varied with regards to time and cost) (Kurien & Qureshi, 2014). Response flexibility is by some scholars defined as responsiveness and efficiency (Hugos, 2011) and is very important for the big picture SCF (Seebacher & Winkler, 2015). However, measuring flexibility across the different supply chains with sweeping general metrics is considered very difficult and unable to provide an accurate picture of the overall flexibility. Because of this a set of metrics suited for the specific type of flexibility one wants to measure at every level is necessary (Kurien & Qureshi, 2014; Stevenson & Spring, 2007).

At an aggregated organisational level, some all-encompassing measurements has been attempted for measuring strategic flexibility or SCF (Seebacher & Winkler, 2015). These typically evaluate flexibility by translating it into a monetary value or a time measurement, and there exists a multitude of contributions academically. Some examples include maximum profit (Gong, 2008; Das, 2011), minimal total cost (Kesen et al., 2010), total cost (Chan & Chan, 2010), absolute and relative profit (Solvang et al., 2003), order lead time (Peng & Chen, 2005; Das & Abdel-Malek, 2003) and delivery time (Wu & Liu, 2008). Any compilation of these into a set can be applicable on isolated fragments of the supply chain as well as any larger part of the total chain. (Seebacher & Winkler, 2015).

In much the same way, one might want to measure smaller, more specific, elements of flexibility. Similar to the aggregated level, there are different uses of metrics when isolating very specific types of flexibility. An example of this is demand flexibility, which is of great importance to manufacturing companies, yet difficult to quantify in and of itself (Stevenson & Spring, 2007). Instead, it is affected by business operations such as demand forecasts, inventory management, procurement and production scheduling. Thus, when seeking to understand the broader demand flexibility, specific measurements of this can be used bottom-up (van Hoek & Harrison, 2001; Kurien & Qureshi, 2014). These can be applied either to different nodes in the supply chain or on the entire supply chain. For instance, upside flexibility (measured in percent) measures what volume percentage increase that can be accommodated for the chain. On occasion it can be measured in absolute terms of time as well, in such a case meaning the extra time it would take to accommodate a given increase in volume. Other types and dimensions of flexibility have other specific measurement items, and can utilize this switching of perspectives, as well (Hugos, 2011; Moon et al., 2012; van Hoek & Harrison, 2001). A list of the most common ways of measuring demand flexibility, according to Hugos (2011), follows.

**Activity Cycle Time**
Time needed for order fulfilment, product design, product assembly and so on.

**Upside Flexibility**
Increase over the expected demand that can be accommodated without delay.

**Outside Flexibility**
Ability to quickly provide customer with additional products outside of the bundle of products normally provided.
Since flexibility is a coping mechanism for uncertainty, measurements related to these specific uncertainties can also be used. This is applicable mostly on a level of lower complexity, such as the manufacturing systems level (Kurien & Qureshi, 2014). There, the flexibility types are: mix, changeover, modification, rerouting, volume, material and sequence (Stohr, 2013; Gerwin, 1987). In these cases, the supply chain and SCF can be evaluated by how well they cope with these uncertainties in terms of range and response (Stohr, 2013; Kurien & Qureshi, 2014). Different types correspond to different uncertainty, so if one is interested in a particular uncertainty dimension, for instance volume fluctuation uncertainty, the metrics need to be calibrated for this (Gerwin, 1987). Generally, measuring flexibility focuses on the supply chain’s capability to deal with different situations related to non-expected changes or uncertainties, so measurements are in many cases expressed in that manner (Stevenson & Spring, 2007; Stohr, 2013).

When evaluating SCF, other tools can be used in addition to specific flexibility measurements. Stohr (2013) describes a maturity model, where overall capabilities in different areas decides what level of flexibility is attained in the overall supply chain. The hierarchy is shown in figure 6 below and contains the following levels (Stohr, 2013).

![Maturity model pyramid](image)

**Figure 6**: Maturity model pyramid (Stohr, 2013).

*Maturity level 1. Flexibility in individual processes*
Creation of options and change mechanisms separately in various operational processes. This allows for lone flexibility present in minor processes.

*Maturity level 2. Flexibility in interaction of processes*
The different operational processes can interact with each other in a flexible and agile way. Here, the processes from level 1 interact flexibly.
Maturity level 3. Flexibility in actors
On this level, there is a link between processes and actors promoting sustainability and organisational vitality. Maturity has evolved beyond simple or interactive processes to instead be managed by independent actors. Furthermore, these actors need to be open, learning oriented and responsible.

Maturity level 4. Strategic flexibility
This is the highest level within the organizational context, allowing for broad strategic decisions with regards to flexibility. Here, the organisation exhibits strategic flexibility to manage paradoxes, such as the issue of globalization-localization.

Maturity level 5. Operational flexibility in value network
Processes and systems are created to enhance flexibility of interactions with partners. This step is only attainable if all partners are flexibly aligned and on a level 4, and can be facilitated by information sharing and communication technologies.

Maturity level 6. Strategic flexibility across the ecosystem
The highest level of mature flexibility within an enterprise. Strategic flexibility is inculcated in the entire network, including all possible stakeholders and enhancing performance of all actors in the ecosystems (for instance society, government, customers and so on).

3.8 Buyer-supplier relations
In a supply chain, buyers and suppliers make up the driving and pushing forces along the chain, and so the B-S relationships and human factors associated are important to consider. Generally, a manufacturer of any product is dependent on a satisfactory supply of the needed product components. In a supply chain, these components normally come from an outside entity, the supplier. The relationship between the two is dependent multiple aspects, such as business politics, human interaction, technology and various other factors, making managing this a complicated challenge. Of these influences, market demand uncertainty has a profound effect on B-S relations. It primarily raises the need for flexibility and agility in the relationship, requiring robust management to handle changes in order quantity and changing lead times. If handled well, a flexible relation will experience smaller fluctuations in the procurement price or availability under the changing conditions (Das & Abdel-Malek, 2003). To ensure this, the relationship is usually regulated through some form of contract, either with legally binding or informal components. Mixing these two, both formal and informal factors, is not especially uncommon in a B-S relationship.

To ensure a level of safety for the buyer, a supplier is regularly evaluated by the procurement department in the buying company. Specifically, this is done in order to retain and develop good suppliers, and improve those that are unsatisfactory. Performance metrics vary, but commonly consist of attributes such as on-time delivery, quality, price or cost targets, level of professionalism, responsiveness to customer needs, and long term relationships with the buyer (Das & Abdel-Malek, 2003; Mummelaneni et al. 1996). The relationship itself combined with the supplier’s commitment to the buyer also tends to act as indicators of the supplier’s flexibility towards the buyer (Das & Abdel-Malek, 2003). Thus, from the buyer’s side, supplier management and relation handling is very important for the overall flexibility in the supply chain, especially for delivery and volume flexibility (Das & Abdel-Malek, 2003).
As mentioned earlier, buyer and supplier are bound together in various ways. Das & Abdel-Malek (2003) describe these as divided into two parts: an information link and a supply contract. The information link is the data flowing between buyer and supplier, providing information on a work centred week-by-week basis. It covers production order, delivery dates, quality reports, inventory levels, accounting data and so on. This information is crucial for cooperation, and the recent explosion of available technological has greatly facilitated B-S relations on a global level, both for buyers and suppliers worldwide (Das & Abdel-Malek, 2003). On the other hand, the contract defines the foundations for the collaboration, for instance how risk is shared or the legal parameters within which they work. Once it has been written, a contract thus acts as a sort of forceful compliance which limits the supplier’s freedom in a way different to that of the buyer. This can serve to hinder progress and cooperation between B-S. The buyers often find themselves as having the upper hand when writing the contract, resulting in sometimes unrealistic expectations on things like short term delivery flexibility. This seems to certainly be the case when a supplier has multiple buyers, all with their own requirements. In reality, however, the supplier tends to pool the uncertainties to maximize capacity utilization, meaning that if all buyers wanted more capacity at once, the supplier would be unable to deliver (Bertrand, 2003). This undoubtedly puts both buyers and suppliers at risk. Thus, with regards to compliance through contracts and as Bertrand (2003) puts it, the voluntary compliance of a supplier is a more realistic assumption and superior goal under a supply contract.

Different approaches of compliance are more or less effective depending on the situation, as stated by Chang & Huang (2012). The options for influencing supplier delivery flexibility are: coercive methods, requests, or non-coercive methods. Coercive methods include threats (e.g. loss of future business), legalistic pleas (referring to contract) and promises (of rewards etc.), request are simple questions or demands given to the supplier with little or no explanation, and non-coercive methods are recommendations or information exchange. Naturally, the trust between buyer and supplier, affected by factors like level of surveillance, is something of importance when building successful cooperation. This, as well as how much of a shared vision buyer and supplier have, are powerful tools that determine which effect the various influence methods and strategies have on the actual outcome of the situation, as shown in figure 7 below (Chang & Huang, 2012).
Further findings show that although methods and promises of rewards are very effective in increasing delivery flexibility under high trust, it can in some instances decrease delivery flexibility when shared vision is high. This occurs due to possible mismatches in strategy. Thus, any organizational purchasing manager should have this in mind when presenting incentives. Requests on the other hand, should consistently be handled with care, regardless of trust levels or shared vision. A request is often seen from the supplier side as a hostile demand that negatively impacts the collaborative relationship. In some cases, it can even cause the supplier to behave in a less flexible way in the future, leading to the requests having a decreasing effect on delivery flexibility rather than an increase. Regarding the non-coercive methods, their effectiveness is also highly dependent on trust and shared vision. Under high levels of shared vision, recommendations are expected to positively affect delivery flexibility, but information exchange has lesser effect. On the other hand, when trust is high, non-coercive methods should be avoided altogether as it may foster opportunistic behaviour. The two, trust and shared vision, can to a certain degree then be interchangeably replaced by each other instead (Chang & Huang, 2012).

In general, a segmentation of the suppliers is an effective way of defining which suppliers should be managed, and how. This is especially important in situations where resources are limited, and where prioritization is critical (O’Brien, 2014; Dyer et al., 1998; Hofmann et al., 2012). The segmentation should be done by cross-functional teams that have great knowledge of the supplier base, but even a simple segmentation can be enough to aid in making decisions about supplier management. Using visual aids to present the supplier can be helpful when making sense of a complex situation, as most buyers commonly have a plethora of suppliers (O’Brien, 2014). Segmentation of suppliers generally has three components: the criteria, the process and the resulting intervention plan for when the segments are determined. The criteria can differ greatly depending on the reason for the segmentation being made (O’Brien, 2014,
Hofmann et al., 2012), but most can be sorted into one of five archetypes, shown in figure 8 below. After the identification and classification of suppliers has been done, the segmentation then finalizes as a result of the categories referred to by O’Brien (2014), as hurt, help or hero, also shown in figure 8.

This model presents three overarching categories, each having different profiles with self-explanatory titles. Suppliers in the hurt-category has the potential to hurt the buyer, i.e. the buyer is dependent or the supplier carries a lot of risk. The help-category includes suppliers that can be of help to the buyer, for instance in how it is familiar with the buyer’s business or has a well-developed relationship. The heroes-category covers suppliers that can be of considerable benefit to the buyer, through aspects like innovation or extensive facilitation of the buyer’s future plans. Granted, there are numerous other possible classifications apart from the three aforementioned, that can incorporate the same criteria along with other aspects such as general importance, how much money is spent on a supplier, strategic importance, and even potential new suppliers. The segmentations, criteria and classification can all be tailored to suit any specific reason needed by the buyer, as it lays the groundwork for a follow-up action plan (O’Brien, 2014).

An action plan is needed to handle the managing of supplier segments, and is built on the aforementioned segmentation. Most commonly, this is produced internally via a strategic branch of the buying organization. As an example, an action plan can contain information on how to employ incentives with supplier segments to increase flexibility and agility, or how to handle unsuitable suppliers (Dyer et al., 1998; Hofmann et al, 2012; O’Brien, 2014). With situations like quantity flexibility, a problem for both the buyer and supplier is risk, and for
optimal supply chain collaboration this risk needs to be shared. However, since neither party wants to carry risk, it is common for an uneven distribution to be done, leaving one party to carry high risk and the other low. In terms of B-S relations this can mean the buyer not committing to buying any volumes in the future, whilst simultaneously demanding that the supplier deliver forecasted quantities as well as surplus buffer capacity to cover possible last-minute demand fluctuations. An increased flexibility on behalf of the supplier can thus be met with incentives lowering the supplier risk (O’Brien, 2014; Tsay, 1999). In practical terms, this can be achieved through tools such as the quantity flexibility contract (QFC). QFC allows for various advantages in many action plans, such as specifying flexibility limits for the supplier (meaning how many percent above the forecasted demand they are obliged to supply), whilst shifting some risk to the buyer via having them commit to buying a set percentage of the forecasted demand. This type of agreement incentivizes the buyer so as not to overshoot in the forecasts, and the supplier to reserve extra capacity for the buyer (Tsay, 1999).

3.9 Information sharing

Sharing information in the supply chain has been proved time and time again to be a key element of success, both in performance measurement and in coordination and collaboration (Thomas et al., 2015; Yu et al., 2010; Byrne & Heavey, 2006; Sohn & Lim, 2008; Ganesh et al., 2014). A company is able to increase its profits by simply redesigning its information sharing strategy, and this works for all steps of the supply chain (Yu et al., 2010; Lee et al., 2000). However, just as with the majority of SCM strategies, there is no “one size fits all” approach. It is important that the information sharing policy is tailored to the specific needs in the supply chain as well as other initiatives, such as forecasting methods (Sohn & Lim, 2008). The data can then primarily be used on three different levels: strategic, tactical and operational. On the strategic level, the right data will help top management on deciding what to do, on the tactical level it will help middle management decide how to do it, and on the operational level it will help people to actually and practically carry out the tasks involved (Hugos, 2011).

Performance in the supply chain is best when all decisions are aligned and the supply chain is coordinated, necessitating a robust informational flow. This can only occur when decision makers have close to complete information and when incentives are aligned with system-wide objectives. However, even then, sub optimization can occur. This means that in order to reap the benefits of information sharing, individual objectives need to be aligned with the overall supply chain strategies (Yu et al., 2010; Kelle & Akbulut, 2005). The type of information and data shared also affects performance in the supply chain, and so categorizing or classifying them is important (Yu et al., 2010). There exist different methods of classifying information for use in the supply chain. Lee et al. (2000) presents such a method, specifically to be used in SCM. It includes aspects such as inventory level, sales data, order status, sales forecast, and production schedule. The system through which these data points are collected also seems to have an effect on performance in the supply chain, especially when combining forecasting methods with an information sharing policy (Sohn & Lim, 2008). Using these allows for a pragmatic approach to the information shared. The policies can be classified as either decentralized (if information is not shared between buyer and supplier), centralized (if information is completely shared) or separated (if buyer and supplier forecasts demand separately, with the supplier using buyer orders as input) (Sohn & Lim, 2008).
Although there are many positive effects of information sharing on the performance of the supply chain, some problems can occur. In particular, information distortion is a problem (D’Amours et al., 1999). An example of this being closely related to future demand information sharing in the supply chain, is the bullwhip effect (Byrne & Heavey, 2006; Yu et al., 2010; D’Amours et al., 1999). This effect occurs when demand uncertainties are increasingly amplified for every tier going upstream in the supply chain. Lee et al. (1997) explains this as being due to multiple levels of information processing. As mentioned previously, certain types of performance metrics information are often shared in the supply chain with affiliates, such as capacity. Information on specifically capacity has the ability of reducing risk of bullwhip effects and can also mitigate potential peaks and valleys in the demand (Lee & Whang, 2000). Another problem is false reporting, where actors report false figures in order to enhance their own utility or get other advantages. To avoid these types of problems, the information sharing system needs to be robust and adapted to its surrounding situation (D’Amours et al., 1999; Thomas et al., 2015).

In practical terms, the information sharing is generally carried out via use of an information system covering one or more of the actors in the supply chain. The system itself needs to be able to adapt to the businesses’ needs, in order for it to provide information flexibly in supporting the overall SCF, with tool most commonly used being some enterprise resource planning (ERP) or materials requirements planning (MRP) system (Stohr, 2013). Said system is a software able to integrate internal processes and functions, and can be designed in various ways. Generally, it covers many of the traditional functions of an overarching planning tools, such as sales, production scheduling and inventory management, and collects their different data into a single system. Because of its structure, an ERP system might either help or hinder supply chain integration and information sharing between buyers and suppliers. A buyer can improve its production scheduling and delivery by being allowed access to their supplier’s data, and vice versa, the supplier can plan deliveries more favourably when given access to the buyer’s inventory levels. Through the collection and distribution of order status information and performance metrics, the ERP system can help supply chain partners to improve customer service quality, provide cost savings, and identify and overcome problems in the supply chain (Kelle & Akbulut, 2005; Edwards et al., 2001). However, it is somewhat limited when it comes to supporting an extended business model across the supply chain (Edwards et al., 2001), and it can be a challenge to provide it with the right data at the right time (Harrold, 2001).
4. Current state at ABB Robotics

This section of the thesis aims to explain the current state at ABBR Västerås. The information herein is based solely on material provided by the company, such as interviews, internal reports and other documents, and thus cannot be cited publicly in the thesis’ reference list.

4.1 The ABB Robotics organization

ABBR Västerås is a robotics manufacturer and a significant actor within its industry. It is a large supplier of industrial robots, software, equipment and complete application systems, and has over the last decades installed upwards of 300 000 units worldwide. In their plant, located in Västerås, Sweden, they assemble completed components into industrial robots, which vary in size (from a reaching range of half a meter to over 4 meters) and payload ability (from a few kilos to half a ton) and have a range of applications. In addition to providing a wide range of ready-made robot solutions, ABBR also houses customization options for their customers. The focus of ABBR lies heavy on quality, with terms like efficiency, safety and productivity being the selling points of the automated setups offered by the company. The situation of the overarching proprietary enterprise of ABB ltd. also allows for a large and global network of suppliers, sales, support offices and other functions. Today, the company offers a product range consisting of equipment specialized in everything from industrial pressing, pumping and painting, to application tools for welding, loading or optics.

Organizationaly, the company has multiple branches and operations globally. Their sales branches currently exist in 53 countries, with the total number of employees spanning more than 100 countries, and the company runs three manufacturing plants for assembling the robots. These three are located in Sweden, China and most recently the US, with each focusing on a specific set of the product range. Sweden covers most of big and medium size robots, supplemented by the US, while China produces more of the smaller models sold. None of the plants of ABBR (locally or globally) has any component manufacturing being done in-house, instead they are all in the business of assembling robots. The three plants have separate procurement functions, meaning staff is divided, and have a high level of ongoing collaboration. Despite this, however, problems have been known to occur based on things such as shared dependence on global suppliers or through insufficient strategic planning between them. Steps have been taken to combat this, with suggestions covering increased communication and new strategic coordinators.

4.2 Market overview and challenges

While most of the robots produced by ABBR are multi-axled industry robots, or IRB’s, for use in automotive industry, some new segments and demands have recently put pressure on the market. These are referred to as the general industry to contrast the forerunning automotive industry, and are mainly related to 3C industries (computing, communication and consumer electronics), with specific requirements and uses for smaller and lighter robots. The rapid increase in production technology in these industries has led to fast growth and volatile
demand fluctuations for companies such as ABBR. Today, ABBR are facing a rapid increase in demand and so far this is causing order backlogs and long delivery times during busy periods. The backlogs may take months to eliminate, and subsequently on-time delivery can dip below desired levels. Concisely, the current work methods and systems are not adequately equipped to handle this in a satisfactory way, something made worse by the demand changes in the short and long term.

While mature market segments, such as the automobile industry, have acted as the foundation in automation sales, the new 3C industries are causing significant changes. The vehicle market is already automated to a very large extent, and their investments in robots are part of larger, more structured plans, allowing companies like ABBR to plan accordingly. On the other hand, the 3C actors from the general industry are only beginning to show their purchasing power. These are starting to automate their production lines at a fast pace, which causes a great demand for the smaller industrial robots. This industry is a fast moving one, with short times to market and constant new investments that need quick implementation. Together with this, the level of confidentiality is very high, due to the competitive market, so demand from customers is unpredictable. This also means that 3C industry customers consider delivery time critical in their choice of supplier (being, in this case, ABBR).

4.3 Demand forecasting processes
Accurate demand forecasting and an effective sales and operations planning (S&OP) is essential for the ABBR organization, affecting everything from procurement to manufacturing and financial matters. The forecasting process begins with ABBR’s sales branches, sometimes called product distributors, who compile a monthly sales forecast for the geographical area they are responsible for. This forecast from the sales branches represent the expected customer demand and is thus regarded the revenue plan, later to be used as a basis for procurement of materials and in planning the production. While the forecast is done monthly, its horizon is each time set to 18 months. After receiving the forecast, ABBR continue by involving the S&OP process. Here, some manual changes are made to the sales forecasts based on aspects such as historical data and how accurate ABBR considers the specific sales branch’s predictions to be. The accuracy of these changes, as well as the original sales forecasts, are later followed up on to ensure reliable estimations. After modifying the forecasts, they are subsequently loaded into ABBR’s ERP system, where the aggregate demand can be seen and sorted by product or per part. In addition to the manual changes imposed on the forecasts due to internal experience, already known demand (such as when customers having long term projects that ABBR is aware of) can also be added into the ERP system. A few months ahead in time, the forecast will contain a mixture of received orders, large orders not yet specified, and a forecast volume which has not yet been linked to orders. Naturally, the forecast experiences greater uncertainty the further ahead one looks due to the decreasing proportion of confirmed orders. This leads to the upcoming demand being seen as call options, and therefore considered open spaces for potential orders. When a customer order is received, these spaces are thus changed from opened to closed spaces. In addition to the forecast S&OP and revenue plan, a materials plan is made to calculate the materials needed to meet demand. In brief, this plan seeks to even out demand fluctuations (for both ABBR and suppliers), which generally is done by adding around 10% interest to the revenue plan as a materials buffer.
For practical purposes involved with procurement, the ERP is linked to an MRP system. The forecasts show ABBR’s planned net requirements, further needing to be broken down per part for suppliers to plan their activities (e.g. purchasing materials or building up for buffer storage). As the sales branches’ forecasts only show demand on volumes of the different models, and not the different variations or components of the models, some internal translation work is needed. This is done by having demand for a product be divided into a bill of materials in the ERP, allowing for every demanded product to also be viewed as a list of specific, required parts. Naturally, any variation of a specific model has a great impact on procurement and production planning, since it may require different parts or production time. Since no data on variation are supplied through the demand forecast, the ERP system is using a set of percentages to divide the demand into smaller, more tangible demand of components or volumes of product variations. These probability percentages are derived from historical data from ABBR sales and production, and are manually updated every couple of months.

The MRP also gathers historical data on flexibility over time which, together with other tools, aids in suggestions for planning of procurement. This is mainly done via the so-called flexibility staircase, seen in figure 9, depicting how supply flexibility grows from low in the short term to higher in mid to long term. Through is, the MRP can make a purchasing suggestion of the required components for an order at the latest possible time, allowing for some internal flexibility on behalf of ABBR. Furthermore, the suppliers have access to the full forecasted 18 months of each forecast sent by ABBR, but there exists no system of confirmation. This means that ABBR cannot know whether their suppliers have seen the forecasts or not. Apart from the MRP system, a tool called iPlanner is used in the process of receiving orders. It checks if the plant has the production capacity and materials required to fulfil an order, and from this it results in a recommended course of action. However, it is used supplementarily, since if there is incorrect data in the ERP to begin with, this tool becomes unreliable. It is therefore common practice to manually check orders daily in order to confirm on which terms the order can be accepted.

Figure 9: The flexibility staircase showing how flexibility changes over time.
Upon having received the monthly forecasts, a series of meetings are held in ABBR to plan upcoming production. These fall into two categories: a regular S&OP meeting being held every month in accordance with the 18-month sales forecast, and a smaller mini S&OP weekly. Of these, the regular S&OP meeting is where various parts of ABBR (such as from sourcing, production, financing or marketing) gather discuss future actions both locally and globally. While other aspects are also discussed, such as recent problems or upcoming changes, the result from the meeting is a production plan for one year ahead. A previous challenge in these meetings has been coordinating the three different plants and their needs, since they share certain suppliers and can thus at times compete for the same materials. This has since been addressed, with work being put into creating a function dedicated to promoting cooperation and avoiding suboptimal planning. However, the position is currently still being worked on and is not yet completely implemented. Another point of importance is the loss of information happening between the purchasing department and the S&OP process where, at times, decision makers seem to lack information that their subordinates have. Regardless, some improvements have been made to the meetings recently, with further increasing collaboration and communication globally, but the time horizon for decisions made in these meetings tend to be short. Since there are such a large number of tasks to do the first 3 months of a production plan, the focus on inconveniences down the line may get deprioritized. Still, a significant amount of effort is being put into continuously improving this. Despite the short time frame and limited options when dealing with for instance a supply problem, ABBR has the goal of lifting their gaze to deal with problems up to 12 months in advance. However, many levels of uncertainty are nevertheless providing the decision-making process with difficulties. According to interviewed employees, while the process is described as simple and straightforward, the resulting decisions are hard to make. Information on suppliers’ flexibility, capacity or buffer stock processes is believed to greatly facilitate this decision-making process, and would also lead to minimizing the amount of (albeit qualified) guesswork.

4.4 Supplier management

Due to a vast amount of available suppliers, ABBR utilizes a variety of policies, practices and KPI’s to ensure quality. These range from mixing written contracts with informal agreements and focusing on trust in the B-S relationship, to getting involved early in new technology and broadening SCM practices to a global level. The perspective of involvement is perpetually long term, so accepting suppliers is a serious undertaking. Besides being able to meet requirements on logistics and availability, as well as KPI’s related to on-time delivery, speed and quality, the suppliers are preferably also able to cope with the recent developments connected to the robotics industry. This means that when ABBR faces a need for rapid upscaling, suppliers must be capable to supply. The complexities involved in such cases, make it impossible to ask for a standard flexibility rate from suppliers. At the same time, ABBR does not commit to forecasted volumes which means they assume no responsibility of their suppliers’ actions. The future forecasts instead serve as indication of what suppliers can expect of the upcoming months, so they can plan accordingly. While this might sometimes place suppliers in a difficult situation, ABBR’s work method is to consistently notify suppliers if there are significant changes or updates in the forecasts.

ABBR, being a manufacturer focused on assembly, experiences a direct link between their own flexibility and the flexibility of suppliers. From the perspective of ABBR, the flexibility is affected by three factors: internal manufacturing processes, capacity at supplier and competition in the market. With regards to in-house manufacturing processes, affecting things
like lead time, cycle time etc., most are considered good enough in the current state. Still, the lead time for ABBR is in a direct influenced by the lead time of components they need from suppliers. Supplier capacity, in much the same way, affects ABBR’s supply of components, making the relationships with suppliers crucial. A strong relationship enables flexibility for ABBR through development of the supplier, for instance so that they may be able to buy new machinery and expand capacity. Lastly, with regards to competition in the market, ABBR generally aims to take up 15-20% of the supplier’s total production. This allows for ABBR to be a significantly large customer, but not have the supplier’s survival hinge on ABBR. This also allows for competition of other buyers seeking service from the supplier, meaning possible flexibility problems for ABBR in times of rapid market growth since all similar buyers will want to ramp up production at once. Besides this, ABBR are also affected by suppliers providing components to buyers from different industries, for example bearings, which can be used in both robots and automobiles. What happens in these unrelated markets may then have a significant effect on ABBR’s own flexibility.

Beyond capabilities of flexibility, dependence on suppliers is also important for ABBR to consider. Of their many suppliers, no distinction or ranking is made for suppliers. Instead, ABBR works on a basis of equal treatment, regardless of size or importance. Despite this however, it is only natural that ABBR need to lean more heavily on some suppliers than others. This can be because of shortages of material, few available suppliers, limited technology or high switchover costs. Regardless, dependence on a supplier is a factor that ABBR tries to minimize. With a low dependence on a supplier, ABBR can gain flexibility by sourcing strategies and business allocation, but when faced with high dependence, mutual agreements are the only way to manage the business terms. For factors like flexibility, this usually has negative implications because of common practice methods of limiting freedoms of B-S like specifying set percentage of business.

With regards to how ABBR works towards supplier management, a number of global and local responsibilities are divided among employees. At the advanced materials planning and sourcing departments, work is conducted on multiple levels. The employees range from global level value chain managers, to local category manager handling commercial aspects, to operational purchasing and quality engineers. These, and others in between, have contact with suppliers at different layers. The mode of contact naturally varies, and the employees convene on a regular basis to keep information and practices up to date.

In handling suppliers as well as production components, ABBR use various categories for easier managing i.e. presentation, purchasing, handling of suppliers etc. Internally, components are divided into a multitude of groups. These groups are denoted based on their area of function, and have varying attributes in terms of required flexibility, availability and spare parts. They can change, and are sometimes considered different depending on one’s organizational position within ABBR, yet mostly remain the same and cover areas as motors, bearings, gears, gearboxes, cables and harnesses, sheet metal, electronics and so forth. Suppliers are divided into these as well and are at times put in other categories such as machining or casting depending on what they supply to ABBR. The amount of suppliers included in each category varies, as does the share of business each supplier gets, with one example category being covered to about 90% from 10-15 suppliers. This can, however, wildly differ as some groups do not have the luxury of multiple sourcing options, instead being dependent on a handful of suppliers worldwide. Generally, the dependence hinges on two factors: availability of suppliers and complexity of the sought component for ABBR. Bearings or sheet metal, for instance, are abundant commodities that are easy to produce and
find. As such, there exists a plethora of sourcing options. On the other hand, electronics, gearboxes and other complex parts need high levels of quality testing and other assurance practices before they can be produced, meaning switching costs will be higher for ABBR.

Exactly how much information the supplier shares with ABBR depends on factors like country of origin, culture and on how big of a customer ABBR is to the particular supplier. The strategic purchasing department can occasionally (but never continuously) data on capacity and shifts, but they are never provided insight into contingency plans or touchy information like inventory, buffers and so forth. This may change if the B-S relation is deepened, but is not put into any typical agreements. Moreover, its necessity also varies in accordance with factors like dependence or flexibility requirements. For a standardized approach, a so-called supplier’s handbook is issued from ABBR to suppliers, containing general requirements. However, as of today, no regular follow-up is made with suppliers.

In terms of how ABBR practically manages their suppliers, a mix of official (meaning legally binding) and unofficial agreements are utilized. With new suppliers, contracts cover a larger part of the relationship and relational aspects, while established suppliers with longer relationships see a greater amount of handshake deals and informal arrangements. These can include anything from face-to-face get togethers to factory visits, with focus being on sustaining and building the relationships. In their supplier’s handbook, ABBR provide some basic flexibility requirements for suppliers, but these cannot be considered a binding agreement. Instead, more pragmatic expectations on the supplier are developed throughout the relationship, where experience of how the market behaves acts as a foundation for handling fluctuations and building trust. Trust is an aspect that is emphasized greatly in ABBR supplier management practices, and collaboration is seen as the optimal policy. Through this, multiple beneficial relationships and projects have developed with many suppliers. For instance, ABBR does in many cases use vendor managed inventory (VMI) to increase flexibility and fluidity in operations. The VMI’s in particular have been worked out to contain 4-8 weeks of buffer stock of raw materials, however demand fluctuations can sometimes make this impossible to guarantee. ABBR also regularly update their plans for the coming years in terms of development, investments, new technologies and so forth, which necessitates communicating this with the suppliers. To that end, ABBR also use quarterly reviews every 3rd month, as well as management business meeting once or twice a year to keep suppliers in the loop.
5. Guidelines for flexibility initiatives

In the following chapter, the developed models and guidelines derived from the data gathering will be presented. The structure abides by the chronology of the research questions presented in chapter 1, and is intended to be kept short and concise.

5.1 Supplier segmentation and flexibility requirements

The flexibility required from a specific supplier is dependent on a variety of factors, such as ABBR’s internal buffer stocks or quality of B-S relationship, and need to be organized for easier understanding. In order to simplify the mapping and evaluation of the requirements on flexibility, ABBR should implement a supplier segmentation. Through this, an overview and necessary actions will easier to see, as each segment will have a set of guidelines attached that will assist ABBR with elements like B-S relations and S&OP processes. The segmentation criteria are focused on ABBR’s overarching need for flexibility and is based on factors like their level of dependency of a supplier, ABBR’s demand uncertainty, buffer stocks and ABBR’s future plans, among others. These are chosen to combat the current problem and guide ABBR in taking appropriate steps and to assess their suppliers. For instance, a high dependency on a supplier implies risk for ABBR, so the best-case scenario in such a case (if the dependency cannot be lowered) is that the supplier also shows high flexibility to match the dependency. If not, ABBR might choose to take other action. The proposed segmentation results in three groups: A, B and C, seen in tables 2 and 3, to be further explained below.

This segmentation is focused exclusively on the most important factor in solving this, upside flexibility, and it is suggested that further developments be done by ABBR to find a flawless fit. The reason for solely considering upside flexibility in this model is based on how ABBR operates with regards to its suppliers. ABBR does not commit to volumes, which means downside flexibility at the supplier is not relevant for the segmentation. Furthermore, the segmentation only aims to explore upside flexibility requirements in short and medium term (0-18 months). With regards to the build of the model itself, ABBR are recommended to continue construction to remove any flaws or blind spots that may appear in the future. Although the segmentation is considered robust and valid, as it is based on reviewed literature as well as interviews with key personnel at ABBR, it is still recommended (in accordance with literature findings) that it is further developed by teams at ABBR. This mainly due to the vast knowledge of the supplier base and deep understanding of work methods and internal practices present within ABBR. Further exploration of the model will also facilitate the finding of newer, more concrete flexibility requirements, such as exact upside flexibility percentages needed, which are currently impossible to do in this thesis due to a lack of statistical data.

The segmentation process begins with evaluation each supplier with the following criteria. Level of dependency is a major factor; therefore, it has three questions associated with it. In order to facilitate the process, they are formulated as questions.
1. Level of dependency
   1. How many other suppliers make this part is available for ABBR, currently on payroll or not, and how much business is allocated to the supplier?
   2. How high are the switching cost and are there any barriers for business reallocation within the supplier base, or are the components specialized to the point of switching costs based on technological incompatibility?
   3. Has ABBR developed the supplier with investments?

2. Level of uncertainty
   1. What is ABBR’s current level of demand uncertainty?
   2. Does ABBR have any future plans that will affect the need for flexibility?
   3. What is the quality of ABBR-supplier relationship?
   4. How big is ABBR’s buffer stock or VMI of the components supplied by the supplier?

To facilitate interpretation of the answers, table 2 gives an indication of which category an answer would fall into. In general terms, a supplier with a majority of A answers thus falls into segment A, a majority of B answers falls into segment B, and a majority of C falls into the segment C. It is important to note, however, is that this table is not supposed to serve as an absolute classification or perfect algorithm. Instead it serves as a reliable tool in guiding an employee at ABBR to understand their situation. The segmentation table should thus always be used in conjunction with practical and operational knowledge of the supplier, preferably by some role closely connected to working with the supplier.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Typical answer for segment A</th>
<th>Typical answer for segment B</th>
<th>Typical answer for segment C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>ABBR can choose between multiple suppliers</td>
<td>ABBR have few other suppliers available in long and short term</td>
<td>ABBR have no other available suppliers now or in the future</td>
</tr>
<tr>
<td>1b</td>
<td>Component is standardized or commonly produced</td>
<td>It is possible to afford the switching cost in the coming years in case it is needed</td>
<td>Switching cost is very high or switching is not possible</td>
</tr>
<tr>
<td>1c</td>
<td>Not at all or very little</td>
<td>A bit, but it could be done with others over time</td>
<td>Very much, developing another to this degree would be very costly</td>
</tr>
<tr>
<td>2a</td>
<td>ABBR is expecting low demand uncertainty</td>
<td>ABBR is expecting medium demand uncertainty</td>
<td>ABBR is expecting high demand uncertainty</td>
</tr>
<tr>
<td>2b</td>
<td>ABBR does not plan anything that can increase the need for flexibility</td>
<td>ABBR are unsure how the need for flexibility be in the future</td>
<td>ABBR plans events that will increase the need for flexibility</td>
</tr>
<tr>
<td>3</td>
<td>Strong cooperative relationship</td>
<td>Solid business relationship, but no additional goodwill</td>
<td>Low trust and cooperation between supplier and ABBR</td>
</tr>
<tr>
<td>4</td>
<td>ABBR has a lot of buffer stock in-house or in VMI</td>
<td>ABBR has some buffer stock and some inventory in the VMI</td>
<td>ABBR has very little buffer stock and no inventory in VMI</td>
</tr>
</tbody>
</table>

Table 2: Criteria for deciding segmentation level.
It is most beneficial for ABBR to have overall low dependence and low need for flexibility from their suppliers, i.e. many segment A suppliers, while many C suppliers might be indicative of problems in supplier management. A complete profile, with recommended actions for the three segments, follows in table 3. The amount of initial flexibility required (expressed as a percentage) is an estimation, commented on further at the end of this chapter.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Low dependency on the supplier</td>
<td>Few resources need to be allocated to the relationship management of this supplier</td>
</tr>
<tr>
<td></td>
<td>Relationship has a satisfactory base to provide built in flexibility</td>
<td>Keep an eye out for new suppliers and utilize sourcing strategies to secure maximal value</td>
</tr>
<tr>
<td></td>
<td>Probable low need for further actions to increase flexibility</td>
<td>Initial flexibility requirement: growing by 3% per month with a starting value of 10% (~25% on the 6th month)</td>
</tr>
<tr>
<td>B</td>
<td>Medium or unsure dependency</td>
<td>Depending on situation, either seek to lower or maintain dependency</td>
</tr>
<tr>
<td></td>
<td>Relationship has some prerequisites for creating a strong relationship with lower dependency and satisfactory flexibility</td>
<td>Either sourcing strategies or vendor relationship strategies may be considered</td>
</tr>
<tr>
<td></td>
<td>A total level of medium flexibility is required for this supplier to ensure optimal performance</td>
<td>Initial flexibility requirement: growing by 7% per month with a starting value of 15% (~60% on the 6th month)</td>
</tr>
<tr>
<td>C</td>
<td>High dependency on supplier</td>
<td>Lowering dependency on the supplier should be a priority</td>
</tr>
<tr>
<td></td>
<td>For a supplier in this segment to perform satisfactory, the supplier needs to exhibit a high level of upside flexibility</td>
<td>Relationship management is very important</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consider the supplier’s flexibility and use strategies commonly associated with high vendor flexibility to maximise use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Initial flexibility requirement: growing by 13% per month with a starting value of 20% (~100% on the 6th month)</td>
</tr>
</tbody>
</table>

Table 3: Profiles for the recommended segment setup.

5.2 Increasing knowledge of flexibility through information sharing

In order for ABBR to increase SCF they should most fittingly focus on supply network flexibility, specifically with regards to its vendors. A way to increase this is via an increase of information sharing and collaboration between buyer and supplier. ABBR already shares data such as forecast information with their suppliers as a part of the S&OP process, under the expectation that the suppliers consider it and comply with it. However, a similar informational flow from the supplier back to ABBR is lacking. The suppliers do not indicate their receipt of the information ABBR provides, nor do they indicate how the forecasts or changes within
them are compatible with their own plans. Naturally, this leads to a difficulty in decision making for ABBR. Increasing information sharing should thus focus primarily on increasing the flow of information between supplier and buyer. It would be beneficial if the supplier shared specifically upside flexibility, or possibly capacity data, over both the short and long term, preferably in a manner suitable to the work methods used by ABBR. In this case, it would be acceptable to include in a spreadsheet software program and sent to ABBR for later unpacking in a data warehouse. The current ERP system and said data warehouse should have no issues with storing and distributing this information for analysis at S&OP etc. The upside flexibility sent from suppliers ought to be expressed as percent of the current prognosis, meaning how many more percent (of the same product mix as in the forecast) above the agreement the supplier might be able to deliver on any given forecast month. In this case, both parties need to be aware that changes in the upside flexibility are to be anticipated over time.

With regards to suppliers equipped with their own in-house stock of components or VMI’s, flexibility calculations are somewhat more complicated. In theory, any reserve of components, whether it be at the supplier’s or in the VMI, provides an immediate boost in short term flexibility as these components are all available at once. However, unlike continuous flexibility, this is a one-time boost that has to be replenished before being used again. This makes it difficult to include when calculating flexibility regularly, because the calculations will differ wildly based on whether said boost has been utilized or is replenishing. As a side note, the flexibility boost of supplier safety stocks should preferably never need to be used, so a good goal would be to plan accordingly. Lastly, certain efforts within ABBR are already being made to make these types of calculations easier. As such, this is considered out of scope and ignored in the flexibility segmentation as well as in the evaluation.

Getting the supplier to collaborate in the proposed way is a long-term development project, so initially focus should be on including supplier that ABBR are highly dependent on, or ones that can cause bottlenecks. The project can overtime be expanded to include all or most suppliers. According to multiple sources within ABBR, it is very likely that suppliers will comply with new initiatives, even though they may be required to carry out extra work in supplying information. The issue can in these cases instead become the quality of the information supplied. However, if the supplier chooses not to share, or shares data of sub-par quality, there are some options for coercing the supplier. One such example is business allocation away from that supplier. ABBR could use the upside flexibility information most notably within the S&OP process, forecasting and decision making for future projects, possible necessitating a new role for maximum efficiency. Preferably, the information could come through the previously mentioned work process involving ERP, but could also be supplied by employees working toward the suppliers. The sourcing department could implement this type of work processes with relative ease, as they have access to various personnel specialized within sourcing while familiar with the problem. Moreover, to facilitate structuring of information flow and reduce risk of entanglement, a higher employee function responsible of strategic planning should be implemented. This could either be its own role or incorporated into another, already existing role. This role would act as an informations coordinator, aggregating information in order to make sure that decisions taken during the S&OP would not be suboptimal for other plants. In other words, this role would be set with a global strategic perspective. While this would be the primary concern, the role could also take on minor tasks still related to the continued
efficiency globally, such as handling how forecasting data or uncertainty analysis is represented between plants.

5.3 Evaluation of suppliers and flexibility over time

In order to monitor and evaluate how flexibility at the supplier changes over time, ABBR needs a two-step process. The first step of this process is to save the upside flexibility data the supplier continually provides through some performance metric system. This will allow for a way of monitoring, graphing and analysing the flexibility over time. Visually representing the current and historical upside flexibility, combined with the segments recommended level of flexibility, will give further insight into the flexibility capability of the supplier, seen in figure 10 and table 4.

![Upside flexibility for an example of A level supplier](image_url)

**Figure 10:** Example showing supplier upside flexibility, graphing current versus average.

The graph is generated from an example data series for an A level supplier. The dotted line is a reference line for how much flexibility a typical A supplier should be required to have. For calculation of the average, see table 4 below. This method provides a comparison between the current upside flexibility and the average upside flexibility over 12 months. The graph will then show how the supplier’s flexibility has developed over time.

<table>
<thead>
<tr>
<th>Month</th>
<th>Upside flexibility 1 month ahead</th>
<th>...2 months ahead</th>
<th>...3 months ahead</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>9% (June)</td>
<td>10% (July)</td>
<td>12% (August)</td>
</tr>
<tr>
<td>June</td>
<td>7% (July)</td>
<td>10% (August)</td>
<td>14% (September)</td>
</tr>
<tr>
<td><strong>Past months (Average)</strong></td>
<td>8%</td>
<td>10%</td>
<td>13%</td>
</tr>
<tr>
<td><strong>July (Current)</strong></td>
<td>11%</td>
<td>14%</td>
<td>117%</td>
</tr>
</tbody>
</table>

**Table 4:** Example showing supplier upside flexibility and calculations of average.
For the second step of the two-step process, the supplier should be evaluated. This will be done by comparing the reported upside flexibility with the segment in which the supplier falls: A, B or C. The evaluation could be made every month in accordance with the monthly planning meeting and S&OP and could, for example, fall within the jurisdiction of the previously suggested global information coordinator or any of the strategic purchasers. In the best case, all segment C suppliers demonstrate high flexibility, segment B at least medium flexibility, and segment A suppliers at least low flexibility. However, the characteristics of a segment’s suppliers make it unlikely that the best cases for B and C would occur on their own. Simply put, having a B or C supplier naturally exhibit vast amounts of flexibility, matching the segments’ recommendations, is unlikely. Comparing the optimal case for a segment with the reality of any given supplier, would then be of use to ABBR. It would allow for ABBR to easily see which suppliers are in most dire need of support, development, or discontinued business. With regards to which exact upside flexibility percentage points corresponds to the levels of A, B and C, that is considered outside of the scope for this thesis. It is instead something ABBR needs to develop through iterative use of the method and internal benchmarking. However, a set of estimated values extrapolated from information, interviews and discussion with ABBR can be used initially for the 6th month, which are: A - 25%, B - 60% and C - 100%.
6. Contextualising the proposals

This chapter provides discussion of the results of the thesis and aims to give a broader understanding of the thesis and its themes, both in academic and practical contexts. Analysis of the results will be presented first, followed by discussion on methodological choices, other factors and conclusions.

6.1 Motivations and examination of the segmentation model

Throughout this thesis, with specific regards to the proposed segmentation model, there are a number of factors in need of discussing. Most notably the reasons behind the model, motivations for its construction and the suggestions found within its segments. These, and the intentions behind them, come from multiple places of possibly overlapping domains and thus will benefit from further analysis and exploration.

The segmentation model was generated from the benefits of segmenting a large pool of suppliers in order to allow for better management procedures. Through such a model, one might be able to better spend and use resources in conjunction with supplier handling. However, too many categories will in itself require more resources to handle, while too few categories will instead negate the purpose of segmentation (through clumping very different suppliers together, in the same category). Based on this, and various other factors, this model uses an accessible three-part segmentation with a total of seven points of criteria. These criteria, also mentioned in the literature review, are crucial to the effectiveness of the segmentation. Focus is here thus solely on dependence, uncertainty, stock and relationship quality in order to build up to the solution of increased supplier flexibility. Similarly, the resulting recommended actions, while being an extension of the selection criteria, are also crucial in themselves. Naturally, there are additional factors affecting the need for flexibility in the short or long term than those making up this model. The ones chosen herein are rather considered to be most applicable for the level of complexity aimed at with this segmentation model. As mentioned earlier in the thesis, segmentation of the supplier base ought to be added upon by some cross-functional team within ABBR with broader and deeper knowledge of the supplier base. These could also see to the incorporation of internal component stocks into the segmentation model, as it currently does not factor in ABBR’s existing inventory when graphing flexibility. While this implies that adjustments to the model are needed, it does not neglect the current one. Since the proposed segmentation model is based narrowly on needs for flexibility requirements, a more general model (such as one constructed by outsiders) is considered adequately applicable. Moving on, the purpose of this case was to determine what requirements on upside flexibility ABBR should have on their suppliers. Recommendations were thus tailored to that end. The empirical data showed a number of factors affecting the actual flexibility for the supplier (such as logistics, supply network or own operations), as well as affecting the need for flexibility from the specific supplier. With that said, however, emphasis was on ABBR’s dependency on the supplier, which was why some factors have been neglected in favour of those related to dependence. The main dependence related factor was in fact considered to be valued as equal to three criteria in the segmentation model. This was deemed sufficient as per the model’s ability to address current problems for ABBR, but does not imply any mathematical precision. Instead, as will be discussed further down, it
serves as a good pointer to where to go or what ABBR should consider next. Like the aspect of dependence, uncertainty was throughout the thesis also stressed as an important part. It can relatively easily be seen as the determinant for future needs for flexibility, and for that reason it was given two points of criteria in the model. Other factors, such as those indicating already existing flexibility, were of course also considered relevant in understanding ABBR’s requirements for supplier flexibility. These include quality of the B-S relationship and whether or not ABBR’s houses significant buffer stocks, and allow for a sort of elasticity within the model so as to reduce unintentional errors by rigidity.

With specific regards to the segments and the selection of particularly three segments, much was done in to weld accessibility with implementation. To that end, three segments are considered fitting when wanting to differentiate between the different flexibility needs. In order for the segmentation process not to be too resource demanding, an intuitive differentiation of low, medium (or unsure) and high segmentation was used for all criteria. Having a category for both medium and unclear alternatives is primarily regarded as a measure to reduce ambiguity in the low and high segments. The expected results from this is twofold: first, to allow for and improve adjustability of the model, and second, to enable the segments of low and high to give clearer recommendations. Through this, we assume that suppliers placed in categories A or C (low and high respectively) are done so with an overall higher level of assurance on behalf of the employee. By allowing for an employee to essentially be given two choices, either low or high, (with the third option acting as a “non-choice” midpoint between them), the authors hope to reduce unintentional misses or incorrect treatment of suppliers. Still, the trade-off is that there will exist a risk that the B (medium) segment will numerically overshadow the other segments. If such a thing occurs, meaning the B segment would be disproportionately large, that (as well as any other disproportionate share of suppliers in another category) might indicate a need to expand the segmentation model with more segments. What could then be done is to adequately respond to such a change. This could mean increasing the number of segments in order to avoid suppliers with wildly different characteristics being found in the same segment. While this example has only treated the middle segment, B, as potentially being annoyingly large, it would be utterly important to avoid for segments with strong recommendations, like A or C.

Concerning the recommendations found in the segmentation model, most speak for themselves. As the level of dependence and needs for flexibility increase, so too does the resources suggested for allocation. With regards to the relationship and surrounding aspects, it is difficult so give specific suggestions. This primarily due to it being outside scope, but also due to ABBR’s already existing internal knowledge on the subject. Moving on, the sourcing strategies present throughout the recommendations vary their focus from sourcing strategies in segment A, to vendor strategies in segment C. This is due to the nature of the dependence (and in turn flexibility) ABBR experiences from a supplier in any given segment. In A, dependence is low and there exists a plethora of suppliers. It would then be natural to focus more on maintaining the situation through use of sourcing strategies, like keeping order slots open for any one of the available suppliers. In segment C, the roles are reversed. There, ABBR’s focus should instead lie on maintaining or lowering the dependence via vendor flexibility strategies, such as deepened cooperation with the specific vendor. In that situation, ABBR’s options are limited as they will be unable to switch vendors with the same ease found in segment A or B.

Determining how much flexibility should be required from suppliers turns out to be a complex task, but the model is considered to aid in the process. Not only does flexibility have
a volume related dimension, but a time dimension related one as well. Moreover, while there are numerous variables related flexibility, such as the previously discussed dependency and uncertainty, these in themselves also have a plethora of influencing factors attached. To disregard and reduce all these factors down to a precise percentage over a certain time frame is therefore not a plausible goal. Meanwhile, too much complexity is also a problem since although high accuracy can be achieved, it would quickly become unjustifiably demanding for a company with hundreds of suppliers, such as ABBR, to keep track of every element. To attain a balance between complexity and accessibility is therefore seen as the optimal solution. To this end, a segmentation model which sorts suppliers into three segments for which ABBR has different flexibility requirements is consequently regarded as the best solution in terms of optimal performance.

6.2 Comments on information sharing and supplier evaluation

The advantages of choosing upside flexibility as a data point, being a relative measurement, over capacity which is an absolute measurement, are numerous. For instance, it is the supplier that will carry out the evaluation of how much more capacity they have for a specific mix of products before supplying the information to ABBR. This would mean less work needed to be done by ABBR when analysing supplier flexibility. However, to transform capacity into upside flexibility becomes challenging when the product mix is not determined, since different components have their own lead times and processing times within production. Thus, depending on the combination of products demanded, capacity can naturally vary. Choosing to evaluate upside flexibility in terms of a forecasted product mix demand provides a general picture of the available capacity at the supplier’s, but it will not be valid for specific projects where product mix is known. This means that as soon as a mix of products that needs flexible supply is known, new upside flexibility calculations will be needed from the supplier. Clearly it is not the best system imaginable, since it requires some form of maintenance on behalf of the suppliers, but it does provide a solid general indication. Still, one should not consider it a fight between ABBR and the suppliers, in terms of who does what, since rather the opposite is true. The recommendations in the model are for example constructed with no regard for how much ABBR can lower their forecast. This can be attributed to the fact that ABBR does not commit to volumes, meaning that the downside flexibility requirement is essentially 100%. However, in practice the matter is more complicated. Cancelling orders or adjusting the forecast downwards can put a strain on the supplier, so it is in ABBR’s best interests to be mindful of how their utilization and requirements of flexibility affects their supplier. A strong, trusting, and long term relationship with the supplier is usually the most benefitting for both parties, so to collaborate when faced with decreased demand is the best strategic choice. This means that actual downside flexibility is dependent on what the supplier can manage, and thus it is somewhat unpredictable. Lastly, having the suppliers share upside flexibility instead of capacity information also saves ABBR from having an abundance of alternatives when trying to get an overarching view of the current state of supplier flexibility and possible growth potential.

With regards to the evaluation of upside flexibility development over time, it must be remembered that upside flexibility is a perishable good. Conditions and outside factors vary, meaning that a relevant comparison between flexibilities is only possible with relatively current data. This according to both academic texts and ABBR themselves. Thus, the recommendation of this thesis is to save historical data for the last 12 months of any present date, but depending on the preference of the employees reviewing the data this can easily be
adjusted. Still, there is a consistent disadvantage in comparing an average to a current state, namely that seasonal changes or outliers are not compensated for. It is for this reason that the historical data should cover 12 months. A suggestion is then for ABBR to evaluate how they use the data. When data has been accumulated over time, ABBR can examine it to investigate further if the average can be considered an acceptable point of comparison. Most likely, it will be, seeing as the ongoing forecasts and major changes are known. If these are too impactful (and possible to single out) they can be disregarded from a continuous calculation of upside flexibility averages.

By increasing information sharing and collaboration with the suppliers, ABBR can increase flexibility and their current state, leading to an answer to the thesis’ research questions. Sharing information such as upside flexibility at the supplier, provides the S&OP process with a better basis for decision making when deciding which customer order can be taken and how they should be planned. Moreover, information sharing is also correlated with a higher level of collaboration with a supplier, most often leading to a stronger relationship and even more flexibility within the relationship. In the current state, as has been discussed, ABBR is having restricted flexibility against the customer. This is due to uncertainty of whether or not the supplier is able to handle an upscaling of production. As a result, information sharing about the supplier’s upside flexibility should reduce these problems. It is also reasonable to assume flexibility spillover effects on other parts of ABBR. For instance, sharing specifically the upside flexibility is (as discussed earlier) a way to lower the workload for ABBR while still getting the necessary information. A continuous flow of this information from the supplier is seen as a sufficient measure in monitoring the flexibility at the supplier, and it enables evaluation through comparison to historical data as well as to the segment provided by the segmentation model. The sum of the recommendations and guidelines provided in this thesis should thus be sufficient to decrease uncertainty within ABBR, as well as increase information sharing and collaboration with their suppliers, ultimately leading to increased flexibility and monitoring options.

6.3 Implications for ABBR and supply chain flexibility

The recommendations included in this thesis will generally be highly dependent on the cooperation of a supplier. It is therefore important to have suppliers comply and collaborate with ABBR. In the case of any supplier complications, where further implementation and collaboration would be needed from the supplier’s side, incentives can be used. Although the suggestions in this thesis and the required data from suppliers are reasonable requests from ABBR, achieving compliance may at times be difficult. In those instances, various incentives can be utilized, such as commitments of prioritization, specific purchasing agreements or exchange of information, but these are not usually put in practice at ABBR for various reasons. Regardless, this type of negotiations is not as simple as may herein be depicted and is highly affected by outside factors, necessitating a careful case-by-case basis approach. There is no singular end-all solution to this problem, so the most fitting method to use is determined by the relationship (and dependence) between buyer and supplier. In the case of ABBR, they are aware of their size and importance as customer for many of their suppliers, allowing them to count on their supplier’s cooperation. However, if and when the suppliers find themselves in another situation, roles may reverse and other methods for compliance might need exploration.
Overall, the segmentation model is kept at a general level, for multiple reasons. Naturally, this carries with it both pros and cons, yet the advantages are considered to trump the disadvantages. The case study and review of literature, for instance, has led to guidelines that are simple and relatively easy to understand and apply. Their understandability is increased further by visual representation, and the chances of ABBR being able to implement the model are considered heightened because of this. Another advantage of this solution is that, because it is quite general, it has a lot of potential as a starting point to later be adjusted to fit ABBR perfectly. Still, the generality of it is also a weakness. Without adjustments it is not as specialized or reliable as it might become and it can thus supply somewhat shallow analysis and direction in its current state. It should be noted that although the model allows for increased flexibility and simplicity in decision making, it is not a method to directly increase general SCF. It instead works on a more fundamental level of the issue: supporting the information sharing and supply network aspects of SCF. The generality is both a strategic decision (as it leads to increased applicability for more cases than in this specific case study), as well as a consequence of constraints for this thesis in terms of time and data. As has been touched upon previously, more data is needed in order to improve the guidelines in the future. Data directly from suppliers on plans, plants and capacity, as well as historical demand, delivery data, forecasts of future demand and uncertainty are needed. This thesis focused on the qualitative aspects of the subject and case study, defining the aforementioned necessary data and the analysis of it out of scope, but it is highly relevant in future research.

This thesis focuses on a very particular aspect of flexibility in order to further SCF. A supply chain is, just as with any chain, simply as strong as its weakest link, so in theory any increase in flexibility between actors could in fact increase the total SCF. The results in this case has been explicitly focused on sharing flexibility information between actors to support the strategic and operative flexibility, (and to some extent also delivery and volume flexibility) in the ABBR organization. Overall, ABBR exhibits a high maturity in its flexibility, and in several matters they are approaching a level 5 maturity when considering Stohr’s (2013) maturity model, meaning they extend their flexibility initiatives beyond their own organization. However, they are not considered to have completely filled all the criteria of operational flexibility in value network (level 5), and it is unsure if their supply chain partners have reached an adequate level of SCF to support a level 5 organization. As we now know, information sharing and communication technologies can facilitate operational flexibility in the value network, which supports the assumption that information sharing as proposed in this thesis can be used as a step towards a higher level of flexibility maturity. Still, this thesis lacks insight into other actors’ flexibility levels, so it could be the case that the effectiveness of the described initiatives will be affected by these. This means that the observable overall effect in SCF, when implementing the suggestions that this thesis proposes, might be limited.

Lastly, on the note of possible additions to the results and recommendation, certain aspects of international coordination can be improved. An observation made during the case study is that there is room (and need) for increased collaboration and information sharing within the ABBR organization as well. In the S&OP process, the different plants managed by ABBR are sharing suppliers and forecasts with each other, and currently a lack of global perspective prioritization could potentially lead to sub-optimization. A suggestion of implementing a global coordinator is made to improve the situation. Aside from this, having flexibly aligned actors and interaction between them within the organization itself is a prerequisite for interorganizational flexibility. This is most often the case at ABBR, yet minor improvements can still be made. Specifically, there have been some instances where information has been shared locally in the plant in Västerås, for instance between purchasers and the S&OP
process, where data has been lost in translation. This may lead to supply chain managers missing information or not being aware of what their colleagues know, so an additional recommendation is to have ABBR continuously work to improve these factors.

6.4 Methods, choices and method choices

With regards to the method and approaches practiced throughout this work, much can be said. Most overarchingly, there are questions pertaining to the reasonability of using a single case study as any legitimate means of answering the questions presented herein. Despite the purely practical details discussed earlier in the methods section, other topics such as bias or heuristics are also in need of consideration.

With regards to choosing to have single case study, Collis & Hussey (2013) stresses that every case study has a context and interact with the rest of the world, and the case also has a history and a future that must be regarded in order to understand current events. This is applicable to this thesis as well, and the case study at ABBR clearly leaves little inherent value without an understanding of context. Suppliers and supplier management are constantly a subject worthy of analysis, and with good reason: their role and importance in SCM is impossible to ignore. The information presented to the authors throughout this thesis, as well as the general understanding of the issue, has been (and practically must be) seen through the lens of today’s society, and current factors has naturally been affecting the thesis from its inception to its conclusion. These factors or the growth of global interconnectedness, not to mention general industry 4.0 changes or other paradigmal revolutions, may well prove the results presented in this thesis to be of zero worth within the upcoming future. Regardless, even utopias must be built step by step, and so the results and recommendations can (and are) just as well argued to have a relevant effect today. Understanding the recommendation as a product in itself, without including context, can absolutely be done - and has acted as the foundation for many of the methodological choices. In its context, ABBR are expected to have the most use of it, however, the authors of this thesis want to argue that the recommendation and its supplementary method (of segmenting and monitoring suppliers) has the ability of being applied most anywhere in today’s industrial landscape. The ideas presented herein can be easily be adjusted to fit any manufacturers focused in assembly, so that they also can find applicatory benefits from the results in this thesis. So, since the recommendations (being some form of meta-result) are essentially a framework for solving a systemic problem throughout most supply chains, the authors argue that a case-study design has not inherently damaged or limited the results of this thesis.

That does not, however, in any way imply that practical details of the research process have not been affecting the results, which is undeniable. With regards to things like interview structure, selection of literary sources or practices of communication with ABBR etc., the authors consider all of these to have influenced the end result of this thesis in various ways. For instance, it is not difficult to see how any approach to academic reference gathering (no matter how structured) can miss vital information or return insufficient results, just by having it be too reliant on some human element. Although the sources gathered during this project were deemed sufficient to solve the given problem, it was the authors’ task to determine which areas were of highest interest to analyse during the initial literature study. The analysis itself was also indeed performed with a close connection to the interpretivist than to the positivistic paradigm, in that the statements were supported and validated through multiple sources and arguments. Despite all this, selection of said areas to study as well as selection of
an article as a source based on skimming, is not hard to find holes in. It is quite easily identified as an inferior solution to, say, a computer-generated algorithm to ensure maximum yield. Likewise, the academic process in itself can act as a hindrance in the way that information is passed forward through newer research. In most disciplines it is fair to assume it not having significant effect, but in cases where definitions can be vague and models are based on pure observation, it can be a risk. With regards to that, the authors acknowledge that the methods used in this thesis, most notably in terms of interview structure and literature review, have had influence over the work presented herein. However, in terms of what would be practically possible to have changed, only minor improvements can be suggested.

Lastly, on the topic of outside influences on the work, the authors feel a need to address the various inconsistencies found in the literature. On numerous occasions, different terms are used interchangeably in academic texts despite them being defined as completely separate in other bodies of work. The general question then becomes centred on how big of an issue this is. Depending on factors such as to what extent the effects of this are, and if the effects are mitigable, the real-life consequences will differ in severity. Thus, it is of importance to seek to answer whether the inconsistencies have had any significantly negative impact, specifically with regards to how information has been interpreted. In other words, has the general understanding of the sources, usages of practices in academia, or information found in academia had any important effect on the results of this thesis? Is the research conducted here legitimate in the sense that it serves to broaden research already present? With regards to the first question, when terms such as a SCF component or SCF dimension are used interchangeably it lowers the overall integrity of the academic area. Of course, this is not trying to suggest it has been done purposefully, but rather to imply a serious deficiency in terms of meta-studies or taxonomic studies. With issues such as these, difficulties can clearly arise when trying to analyse and address a problem. It might, for instance, be challenging to reach a shared understanding when two parties use different terms for identical phenomena. This can easily lower the level of applicability when translating academic research unto real world problems. Going back to this thesis, this will most likely not be the case, yet cannot be implied to not have any effect. The results presented herein use common English nomenclature and rely on intuitive understanding of the issue. They are furthermore constructed in such a way that no specific inside knowledge is needed for interaction. With regards to the second question, pertaining to the legitimacy of the research conducted herein as a result of this effect, equal care was taken. Despite the differences in taxonomy, the authors sought actively to compensate through rigorous cross-reference analysis and examinations. For instance, tables and figures are present throughout this thesis outlining the different views and contributions to give a better overview. Furthermore, the authors intended not to lean too heavily on any one overarching model, without a significant academic backing, leading to some models covering very specific areas. This has however meant that some own interpretations have sometimes been made. These are, if anything, the main causes for concern as incorrect understandings or assumptions can lead to larger snowball-effect problems later down the line. Still, the amount of care that has been taken to avoid this cannot be understated. All assumptions, interpretations etc. can also relatively easily be understood throughout the literature study, by means of references or the previously mentioned figures and tables, implying that any fallacies found in the results can likely be backtracked and corrected.
6.5 Contributions and research perspective

The research and recommendations presented in this thesis fits reasonably well with the ongoing progress of other academics. As has been explored, there seems to exist a limitation within the field with regards to certain definitions and uses of related terms. Through a consolidation of the research presented by various authors, this has been addressed in a minor way. More significantly, the work done herein goes well in hand with the works of researchers such as Gosling et al. (2010) and Duclos et al. (2003), who are respected academics and practitioners in the field. Their work in supply networks, as well as vendor and sourcing strategies, have been built upon in this thesis, with contributions centred on specifically the sourcing strategy aspects of the supply chain and SCF. The thesis also adds to the growing body of research examining how organizations of today work with these aspects, seeking to explore the intersection between academia and practical everyday problems.

Lastly, on a more concrete note, the findings herein serve another purpose. By having identified a significant absence of literature fixated on how SCF, supplier flexibility and information sharing affect buyers (or in essence, any end-user) by moving down the line instead of up (i.e. sales branch makes a forecast and sends it backwards in the SC), the authors intend to begin filling the gap via this thesis.

It may be interesting to ask how the various stakeholders have affected research practices and the research perspective of the thesis. As is apparent, there exists a total of two major stakeholders: ABBR (the benefactors of this study) and KTH (the supervisors). Quite reasonably, these have their own interests in need of catering and it is not illogical to assume them having influence over this study. The question then becomes to what extent, and which types of influence. With regards to KTH, the answer is simpler, solely based on their lower level of direct involvement. Pressures such as on legitimacy of research, validity of methods, high levels of academic consistency and so forth have been communicated from KTH. While these certainly have led to a more coherent thesis, they have in some terms also inhibited the deliverance of some practical result to ABBR. Likewise, of course, the opposite can be said. By having the authors focus their attention on two things at once, the outcome is not reasonably expected to be as perfectly tailored to any stakeholders needs as can be. At the same time, the emphasis placed on the thesis holding certain academic standards have also served to limit and manage scope more easily. Regarding ABBR and their influence, naturally, the answer is a bit less straightforward. Since this thesis’ inception, many meetings have been held and changes made with regards to expectations and to the projected results. This is not to imply any unfair exchange, but instead a natural part of any thesis project. Still, the effects of this must be examined, so as to better understand the report. For instance, much talk was initially had on buffer stocks, and how knowledge of these would serve an important part of the purpose of the thesis. This later turned out to be a sort of red herring, where including buffer stocks was instead incorporated in another part of the suggested solution. Although still relevant, it led to some side-tracking on the behest of the stakeholder and ultimately turned out to not be as important as initially understood. Despite instances such as this, the overwhelming majority of interactions are considered to have been value-adding to the project. Just as with KTH, the stakeholder of ABBR offered something highly valuable through its interests in the thesis: a level of grounding for the results. Via their own activity, they supplied information vital to reaching the suggestions and conclusions herein, allowing for much needed substance to balance the formalities of a structured approach.
7. Future research

A few suggestions for future research can be made, in order to keep the ball rolling. Firstly, some form of medium to long term monitoring research is suitable, so that results and implications can be recorded over longer periods of time. Any type of cohort study would do, regardless of its inquisitiveness into whatever is being monitored. Secondly, and likewise, statistical data on factors such as demand or flexibility needs (specifically with regards to the relationship between buyer and supplier) should be gathered to as large an extent possible. This would allow for greater clarity in an environment otherwise barraged with contextual information, as well as give the ability to better identify causal relationships or trends. It would also, to a lesser extent, serve other purposes such as allowing academics (or economists for that matter) to understand the involved industries and markets better. Finally, the authors suggest future research look upon a larger portion of the supply chain. In this thesis, focus was on flexibility between actors, but it should be entirely possible to zoom out and examine how the entire chain is affected by information travelling downstream, from supplier to buyer (from start to finish).

In terms of what ABBR can do to improve upon the model, most has already been discussed. This paragraph will thus serve as a congregation of all previous comments and suggestions. Firstly, ABBR need to adjust the segmentation model to fit them optimally. This should be done mainly within the department of sourcing and be done through collection and use of historical demand data and historical flexibility demand data. Furthermore, the data provided by suppliers should also be collected, averaged and analysed in some regular interval, preferably by some employee (such as a strategic or operative purchaser) with knowledge or responsibility of similar ongoing projects. This person could also look into how to incorporate ABBR’s internal buffer stocks into the model. Together with this, some employee or team should look into the percentages of the current segments to adjust and improve them, for instance through the previously mentioned historical data. Lastly, the international information coordinator, tasked with improving information flow and cooperation between plants, should be put into practice and work in tandem with the flexibility measures proposed herein.
8. Conclusion

In conclusion, global trends of fluctuating demand the industrial robot market leads to robot manufacturers having to ensure robust flexibility in their supply chain in order to meet the demand. The flexibility is in turn affected by internal as well as external actors, with this thesis focusing explicitly on the interface between the manufacturer and its suppliers. It was found that increased information sharing and supplier segmentation can increase flexibility and the knowledge thereof in the supply chain. Segmenting suppliers based on criteria related to required flexibility gives a relatively simple and easy to use solution to supplier management with regards to what flexibility requirements a buyer should have on their different suppliers. Combining the supplier segmentation with sharing of upside flexibility data and evaluation of upside flexibility over time gives an overview of the current and past state of upside flexibility from suppliers along with guidelines for moving forward.

With regards to future research, the main suggestions involve a broader database of information. Whether through ABBR’s use of internal improvements or for research purposes, a large set of data for statistical use would be the next step. Beyond that, improvements need to be made to the model in order to guarantee a better fit, and incorporate internal buffer stocks to better calculate flexibility requirements. These can most aptly be made by ABBR themselves, as they are well-equipped to handle such work. Lastly, further work should be done in the area of studying operational flexibility as an extension of information sharing, segmentation or information flowing downstream.
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