Managing the bi-directional flow of materials to increase customer satisfaction and reduce cost

A case study at Sandvik Mining and Rock Technology

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Abstract

Purpose: This thesis explores the bi-directional flows of material perceived by manufacturing firms in the supply chain and accordingly derive suggestions to properly manage these flows to increase customer satisfaction and reduce cost.

Methods: A literature review was summarized in a conceptual framework. This framework was then illustrated in a case. In this case, 11 semi-structured interviews, 3 participant observations and 3 types of archival records were collected. Analysis and discussion of the preliminary conceptual framework compared to the case was the basis for the modified conceptual framework that was designed.

Main findings: In general material flows downstream the supply chain, but because of quality issues, recycling or returns material need to flow upstream the supply chain. This thesis provides a holistic view of how to manage these flows with a modified conceptual framework.

Academic contributions: Previously, almost no academic research has been conducted on decision variables when it comes to managing material flows upstream the supply chain. This thesis contributes to closing this gap by suggesting different actions to properly manage the bi-directional flow of material. Furthermore, previous research addressing how to manage material flows has been re-accessed and expanded.

Managerial implications: By using the framework, practitioners can determine helpful activities to increase customer satisfaction and reduce cost. This means management gets directions of where to allocate their resources.

Limitations: The perspective and evidence in this research are only collected from the manufacturer’s point of view, valuable insight from suppliers and customers may have been overlooked. The suggestions of how to manage the bi-directional flow of materials have not been tested and the outcome of these recommendations has not been compared to KPIs or other measurements.

Keywords: Material flows, customer satisfaction, reduce costs, supply chain management, logistics management
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1 Introduction

This chapter provides a background to this research, justification of the focus of the research and identifies purpose and research questions.

1.1 Background

As competitiveness has become critical for company’s survival (Christopher, 2016; Defee et al., 2010), managing a supply chain has become essential (Christopher, 2016; Prajogo and Sohal, 2013). To achieve competitive advantages, manufacturing companies are required to increase customer satisfaction and reduce cost (Singh et al., 2018a). Increasing customer satisfaction refers to increasing the degree in which the customer demand is fulfilled (Kotler et al., 2012) and reducing cost is referred to reducing the total cost in the supply chain (Harrison and New, 2002). Increasing customer satisfaction and reducing costs are the top two management priorities (Harrison and New, 2002) since profit is increased through reducing cost and increasing customer satisfaction (Kotler et al., 2012).

To increase customer satisfaction and reduce cost in the supply chain, the management of material flows are key (Huo et al., 2016a; Prajogo and Olhager, 2012). Since material flows are the primary business process to create value in manufacturing firms (Huo et al., 2016b) and the cost of managing material flows is extremely high (Tummala et al., 2006). Managing material flows refer to the management of a set of activities to transform material flowing downstream or upstream from input into output (Sangwan, 2017). Important factors of how to manage material flow need to be identified, especially valuable are more case studies in the field (Kaipia, 2009). Traditionally material was assumed to flow downstream the supply chain (Akcali, et al., 2009) however, in recent years the flow of materials upstream the supply chain has been recognized (Prajogo and Olhager, 2012).

Material flowing upstream the supply chain includes material being returned, recycled, remanufactured (He, 2015) or redistributed (Sangwan, 2017). Material flowing upstream the supply chain stands for on average 9.5 percent of all logistics costs (Daugherty et al., 2001) and to properly manage this flow is an opportunity to increase customer satisfaction (Russo et al., 2019). Also, companies are forced to become more sustainable and think of circular economy (Genovese et al., 2017). Hence the management of material flowing upstream the supply chain becomes more and more important (Hansen et al., 2018; Sangwan, 2017).

Unfortunately, there is almost no academic research on the decision variables when it comes to managing the flow of materials upstream of the supply chain (Sangwan, 2017). Future studies that explore the bi-directional flow of materials is suggested (Prajogo and Olhager, 2012), as the relationship between forward and reverse material flows are under-researched (Hansen et al., 2018). At the same time, increasing customer satisfaction and reducing cost is still essential (Singh et al., 2018a). No framework integrates the bi-directional flow of materials and management activities to increase customer satisfaction and reduce cost. This means that previous research addressing how to manage material flows in an excellent supply chain (Mehrjerdi, 2009) is too simple and must be re-accessed. Additionally, since manufacturing companies have a central role in the supply chain, manufacturing firms are of extra interest to investigate (Kaipia, 2009).
1.2 Purpose
This thesis explores the bi-directional flow of materials perceived by manufacturing firms in the supply chain and accordingly derive suggestions to manage this flow to increase customer satisfaction and reduce cost.

1.2.1 Research questions

1. How does the bi-directional flow of materials take place within a manufacturing company in the supply chain?

2. How could the bi-directional flow of materials be managed by manufacturing companies in the supply chain to increase customer satisfaction and reduce costs?

1.3 Scope of the thesis
The scope of this thesis is delimited to supply chains and manufacturing companies. The scope includes supplier - manufacturer - customers, but the perspective does not include suppliers nor customers, the manufacturers’ point of view is adopted. Furthermore, data is collected only from the manufacturer. The company to investigate is a large Swedish manufacturing company, Sandvik Mining and Rock Technology. Moreover, this research is delimited to Rotary in Sandviken (RT). Material flows to investigate are materials being produced, stored or transported along the supply chain.

1.4 Expected contribution
The expected contribution of this research is to integrate and provide a holistic view of important actions when managing the bi-directional flow of materials to increase customer satisfaction and reduce cost. Furthermore, it aims to give practical directions for helpful activities for managing the bi-directional materials flow.
1.5 Outline of the thesis

**Chapter 2:** Literature review – defines important terms and reviews what previous research has written about the topic. This chapter ends with a summary of the literature review that is presented in a conceptual framework.

**Chapter 3:** Methods – provides detailed information about the research process and motivates the choice of methods. This chapter ends by discussing the validity, reliability and ethical aspects of this research.

**Chapter 4:** Result – illustrates the conceptual framework with the case.

**Chapter 5:** Analysis and discussion – answers the research questions by analyzing and discussing why the established conceptual framework is modified. This chapter ends by presenting a modified conceptual framework.

**Chapter 6:** Conclusion – presents the main findings, the academic contribution, managerial implication and limitations of this research.
2 Literature review

This chapter starts by defining the terms; manage material flow, increase customer satisfaction and reduce costs. Next is a review of what previous researchers have written about the bi-directional flow of material and how to manage these flows within manufacturing firms in the supply chain to increase customer satisfaction and reduce costs. At the end of this chapter, the literature review is summarized in a conceptual framework.

2.1 Manage material flows

The essence of managing a supply chain is to manage material flows (Harsasi and Minrohayati, 2017), these flows are the primary business process to create value (Huo et al., 2016b). The cost of managing material flows is extremely high (Tummala et al., 2006). Transport alone costs 20 percent of the product price (Kotler et al., 2012), no wonder management put key priorities into managing material flows (Tummala et al., 2006). Managing material flows refer to the management of a set of activities to transform material flowing downstream or upstream from input into output (Sangwan, 2017). Material flow refers to the flow of raw materials, semi-finished products, components or end products (Van Wheele, 2012) transported, produced or stored along the supply chain (Kotler et al., 2012). In this research managing material flows refers to a set of activities to manage this material flow to increase customer satisfaction and reduce cost.

2.2 Increase customer satisfaction

Customer satisfaction is one of the top two performance measurements when managing a supply chain (Harrison and New, 2002). The underlying reason is that customer satisfaction is vital for any business survival (Harsasi and Minrohayati, 2017), as profit is created through customer satisfaction and since unsatisfied customers turn to competitors (Kotler et al., 2012). To satisfy customers, companies must, therefore, know the needs and wants of their customers (Harsasi and Minrohayati, 2017; Kotler et al., 2012). However, the goal is not to maximize customer satisfaction as this would be too costly and lower the company's profit (Kotler et al., 2012). The goal for companies is to be able to increase customer satisfaction while reducing the total costs in the supply chain (Harrison and New, 2002). In this research, increasing customer satisfaction refers to increasing the degree to which the customer requests/demands are fulfilled (Kotler et al., 2012).

2.3 Reduce cost

As mentioned earlier, customer satisfaction is one of the top two performance measurements when managing a supply chain, the other is to reduce the total cost in the supply chain (Harrison and New, 2002). The valid motive is that the total cost is directly related to the profit (Kotler et al., 2012). In this research reduced cost refers to reducing the total cost in the supply chain (Harrison and New, 2002).
2.4 How to manage material flows to increase customer satisfaction and reduce cost

In this section, seven perspectives on how to manage material flow to increase customer satisfaction and reduce costs are presented. One might ask, why these particular management perspectives were chosen. First, it was considered important to include vital management activities acknowledged for material flowing downstream the supply chain, as this flow stands for over 90 percent of the costs (Daugherty et al., 2001). These perspectives were adapted from Mehrjerdi (2009) and Otto and Kotzab (2003) which describes how material flows within an excellent supply chain should be managed. The four main perspectives in their papers are: integration, lead time, inventory levels and flexibility.

Secondly, it was considered important to include vital management activities to increase customer satisfaction. These perspectives were adopted from Chavez et al. (2017), Shin et al. (2016) and Ilic and Tesic (2016). According to Chavez et al. (2017), the main perspectives to increase customer satisfaction in a supply chain has been recognized decades ago and concern flexibility, delivery, quality, and cost. Consequently, delivery and quality were taken into consideration. Flexibility is already adopted from Mehrjerdi (2009) and Otto and Kotzab (2003) and reducing cost should be the outcome of this research, hence it should not be one of the management perspectives. Furthermore, delivery concerns; lead time and dependability Chavez et al. (2017). Lead time is already adopted from Otto and Kotzab (2003), but dependability was the fifth management perspective adopted in this research. As dependability also can refer to the ability to provide the promised quality (Shin et al., 2016), the perspective of quality was included in the fifth management perspective as well. Ilic and Tesic (2016) add responsiveness as a key perspective to increase customer satisfaction. Increased responsiveness is also essential to become more demand-driven (Christopher, 2016), the sixth management perspective is responsiveness.

Last, it was considered important to include vital management activities for material flowing upstream the supply chain. The last and seventh management perspective is adapted from Mahadevan (2019) and is reverse logistics procedures. These seven management perspectives were also found in the case. As it turned out that lead time reduction has a positive impact on several key management activities to increase customer satisfaction and reduce cost, lead time reduction has been given a larger place in the literature review.

2.4.1 Increase responsiveness

As said by Christopher (2016), a responsive supply chain is characterized by the ability to read and respond fast to market demands. By increasing responsiveness in the supply chain, customer satisfaction can increase, and cost can be reduced (Singh et al., 2018a) since customer demands can be responded quickly (Singh et al., 2018a). If the supply chain fails to be responsive, market mediation costs will appear, these costs derive from lost sales when the demand cannot be met (Fischer, 1997). According to Pishvaee et al. (2010), responsiveness could be applied both for material flowing downstream as upstream. To enable a responsive supply chain, it is essential that the operational levels in the supply chain are responsive as well, this includes pulling the material to downstream operations (Roh et al., 2014), just-in-time (De Treville et al., 2004). Furthermore, responsiveness is increased when
lead time is reduced (De Treville et al., 2004) and is facilitated by the use of advanced manufacturing technologies (Roh et al., 2014).

2.4.2 Reduce lead time

Christopher (2016) clarifies that in a perfect supply chain, the supply matches exactly with demand. This is a major challenge in reality since most organizations cannot predict supply nor demand in an exact number (Christopher, 2016). In this context, lead time refers to delivery speed, that is the time from the customer order placing until the customer order is received (Singh et al., 2018a). Most organizations have a longer lead time than what customers are willing to wait for, this means that companies need to work with forecasts and ordering points, which further complicates the matching between supply and demand (Christopher, 2016). The ordering point can also be referred to as the decoupling point, where inventory is held upstream this point and customer orders are produced downstream this point (De Treville et al., 2004). Lead time reduction is the main mean to achieve market mediation (Kumar et al., 2017) and will, therefore, reduce market mediation costs (Fischer, 1997). For make-to-order firms, the lead time is a typical order winner and a competitive basis, additionally, price is typically not an order-winning criteria (Olhager and Prajogo, 2012). If the supply lead time is longer than the ordering point, the lead time should be reduced. Reducing lead time is not only important for material flowing downstream the supply chain, Cannella et al. (2016) demonstrate the importance of reducing lead time for material flowing upstream. Many researchers have pointed out the benefits by reducing the lead time, including increased customer satisfaction (De Treville and van Ackere, 2006) and reduced cost (Singh et al., 2018a). De Treville and van Ackere (2006) identified four major factors to be considered when reducing lead times; bottlenecks, utilization, lot sizes, and variability. Singh et al. (2018b) add set-up time, as it has a big impact on utilization and lot-sizes.

Identify and eliminate bottlenecks

As confirmed by De Treville and van Ackere (2006), bottlenecks have a huge influence on lead times, since the bottlenecks limit the production flow (Olhager, 2012). For this reason, bottlenecks must be identified (Myrelid and Olhager, 2015). There are different ways of identifying bottlenecks, Yuan and Zhang (2018) suggest using simulation techniques to determine the bottlenecks. An advantage with this method is the ability to simulate a large number of working days in a few minutes, a disadvantage with this method is the need for data collection. In the simulation, the bottleneck is determined by measuring which workstation has the most queuing products on average (Yuan and Zhang, 2018). Tang (2019) suggests a more comprehensive method of identifying bottlenecks in manufacturing systems by also considering the upstream and downstream systems. First, the overall equipment effectiveness (OEE) of the workstation is calculated:

\[
OEE = \frac{\text{actual production time}}{\text{planned production time}} \times \frac{\text{actual operation rate}}{\text{designed operation rate}} \times \frac{\text{good product produced}}{\text{All produced products}}
\]

Then it is determined how often (percentage) the workstation cannot produce because it is starved from the upstream workstation or it is blocked from the downstream workstation. Finally, the standalone OEE (or OEE-SA) is calculated:

\[
OEE_{SA} = OEE + Starved + Blocked
\]
According to Tang (2019), whichever workstation has the highest OEE\textsubscript{SA} is the real bottleneck. When the bottlenecks have been identified, the next step is to reduce the effect of the bottleneck by simply increasing its capacity (Myrelid and Olhager, 2015). One way of doing this is to add another machine to the bottleneck process (Yuan and Zhang, 2018). The problematic part with eliminating bottleneck is that new bottlenecks tend to appear, hence these must be identified and eliminated as well (Olhager, 2012). Conclusively, as the bottleneck determines the production rate, the bottlenecks can be eliminated by subordinating all other operations to the same production rate as the bottleneck (Myrelid and Olhager, 2015).

**Reduce set-up time**

Even though the benefits of reducing set-up times and how to do it has been discussed since the 1980s. Reducing set-up times are still possible in manufacturing companies and still relevant (Olhager, 2012). This might derive from the fact that the need for reducing set-up times revives when changes are implemented, for example when lot sizes decrease (Moacir, 2012) An effective and recognized approach of reducing set-up times, is SMED (Olhager, 2012). In this approach, the first step is to separate what can and cannot be done when the process is operating, next step is to perform as much as possible of the set-up when the process is operating, and finally, the set-up time for a non-operating process should be reduced (Olhager, 2012). The set-up time for a non-operating process can be reduced by adjusting jigs and fixtures to process different products (Samarghandi and Elmekkawy, 2014). Another effective way of reducing the total set-up time is to sequence production orders so that fewer set-ups are needed (Thurer et al., 2014).

**Maintain process utilization around 90 %**

As confirmed by De Treville and van Ackere (2006), utilization has a major influence on lead times. Unfortunately, production managers often wrongly try to increase the utilization to reduce the lead times (De Treville and van Ackere, 2006). Perhaps this can be derived from the fact that the cost per product decreases as the process utilization increase (Pachpor et al., 2017). From simulation research conducted by Hong et al. (2018) the causes of long queuing length and lead times were explored. The result of a million simulation tests showed that the queuing length and waiting time is significantly affected by the process utilization. Zhao et al. (2018) got the same result, when utilization increase, the waiting time and queueing length increases. They further suggest to maintaining the process utilization around 90 percent, as a higher utilization will create a too long waiting time.

**Find out the right lot sizes**

Basic rules when it comes to lot sizes are; as the lot size decreases the set-up frequency increases (Vaughan, 2006) and the production rate decrease (Monden, 2011). When it comes to determining the right lot size, queuing theory is of greater importance than models that determine order quantity based on costs (Vaughan, 2006), such as the EOQ, dynamic lot sizing, fixed order quantity and part-period balancing (Kumar et al., 2017). The reason is; set-up frequency has a minor influence on cost, but rather, spends available process time (Vaughan, 2006). Smaller lot sizes are generally a better option to reduce the lead time (De Treville and van Ackere, 2006) as the waiting time in queue decreases (Vaughan, 2006). Unfortunately, production managers mistakenly, often try to increase the lot size to
reduce the lead time, not knowing this is often an action to increase the lead time (De Treville and van Ackere, 2006). However, there is a point when reducing the lot size will increase the lead time (Moacir, 2012). This point occurs when set-up frequency drives the process utilization to escalate the waiting time in the queue and lead time (Vaughan, 2006). A basic prerequisite for reducing lot sizes is overcapacity in the machine, otherwise, the production rate will not be maintained (Filho and Uzsoy, 2011). If the set-up time is reduced, the lot size can also be reduced without affecting the production rate, hence reducing set up time should be done before reducing the lot size (Filho and Uzsoy, 2011). Furthermore, the distance between operations also affects how small the lot size can be, therefore the distance between operation should first be reduced to minimize lot sizes and lead time (De Treville and van Ackere, 2006). Selecting the right lot size is rather complex (Moacir, 2012). If data is collected such as arrival time between lots, processing time, set-up time, variability in set-up time, etc., then different model is available to calculate the right lot size to minimize the lead time (Filho and Uzsoy, 2011; Vaughan, 2006). If this data is not available, managers can gently reduce lot size over time and evaluate whether the desired production rate can be maintained with the shortened lead time (Filho and Uzsoy, 2011).

Reduce variability

As confirmed by De Treville and van Ackere (2006), variability has a major influence on lead times. Counterproductively, production managers often ignore variability, not knowing different processing and inter-arrival times increase the waiting time (De Treville and van Ackere, 2006). To decrease variability, the material flow should be pulled to downstream operations (Moacir, 2012) and the flow should be even (Chen et al, 2012). The importance of reducing arrival variability shrinks as the lot size reduces, hence this is a way to reduce the variability (Moacir, 2012). Furthermore, if fewer quality defects occur or if the time to solving quality problems reduced, the process variability decrease (Filho and Uzsoy, 2011).

2.4.3 Increase logistics integration

In this research, logistics integration refers to the extent material flows are seamless and coordinated (Prajogo et al., 2016). By increasing, logistic integration customer satisfaction can increase, and lead-time and costs can be reduced (Prajogo and Olhager, 2012). However, logistics integration is not of equal importance for all firms and all suppliers, Olhager and Prajogo (2012) argue that it is especially important in a make-to-order firm and with suppliers who provide key items. Logistics integration is relevant both for downstream and upstream supply chain (Mahadevan, 2019). Logistics integration can be improved by increasing; coordination of logistics activities (Chen and Paulraj, 2004; Prajogo and Olhager, 2012)

2.4.4 Reduce inventory without prolonging lead time

If the customers cannot receive the desired product in time, the customer gets dissatisfied and the risk to lose the customer to a competitor increase (Koos and Shaikh, 2019). When customer demand is difficult to forecast, inventory points need to be preserved not to prolong the lead time (Singh et al., 2018a). Due to this
fact, inventory is in many cases a vital piece to balance the supply and demand (Christopher, 2016; Kotler et al., 2012). Nonetheless, inventory is one of the biggest costs in the supply chain (Ilic and Tesic, 2016) and if inventory can be reduced, the supply chain costs will decline (Singh et al., 2018a). Inventory can be replaced with earlier demand information (Christopher, 2016). Interestingly, Wang and Disney (2017) concluded that the lead time determines the inventory levels, hence an effective way of reducing inventory is to reduce the lead time (De Treville et al., 2004). To balance inventory levels, inventory can be redistributed where the demand is, this activity reduces the overall inventory and lead time (Turan et al., 2017). If the order variability (Wang and Disney, 2016) is reduced, inventory will also be reduced (Christopher, 2016). Inventory can also be reduced by increasing logistics integrations (Prajogo and Olhager, 2012). Logistics integration can be demonstrated by allowing the supplier to manage the inventory, this is referred to as operating a vendor-managed-inventory (Olah et al., 2017). As inventory is not equally important for all material, the focus of reducing inventory should be on less strategically valuable material (Christopher, 2016). Certain raw materials should never be out of stock (Olah et al., 2017) and a higher inventory level should be kept on more profitable products (Christopher, 2016).

2.4.5 Determine and align flexibility level

Flexibility is an important capability and is considered to be an order winner and to increase customer satisfaction (Chavez et al., 2017). Aligning the flexibility level is considered to be an effective way of managing uncertainty (Bai and Sarkis, 2013). Unfortunately, there is a well-known trade-off, when increasing flexibility, the cost also increases (Wurzer and Reiner, 2018). The challenge is to develop the right flexibility level (Mabel et al., 2008). As flexibility plays a central role in the make-to-order firm flexibility is needed, furthermore excess capacity is common and not as important as it is for the make-to-stock firm (Olah and Prajogo, 2012). Flexibility is desired in both operations and the supply chain (Christopher, 2016), furthermore, the operations need to be capable to adapt to volatility in supply and demand (Christopher, 2016). Choosing the right flexibility level have a significant effect both for material flowing downstream as upstream (Bai and Sarkis, 2013).

Volume flexibility and product mix flexibility is affected by manufacturing design and multi-trained employees (Hallgren and Olhager, 2009). Another aspect with great influence on flexibility, but harder to achieve is a corporate culture that is open and comfortable with frequent changes. In general, a higher level of collaboration across organizational boundaries also increases flexibility (Christopher, 2016). To increase flexibility in manufacturing design the company should strive for frequent interactions between R&D and manufacturing and R&D should involve the production early on in new product development (Hallgren and Olhager, 2009). To increase flexibility through multi-trained employees, the employees fundamentally need training of multiple tasks (Hallgren and Olhager, 2009). As increased knowledge and talent in the organization increase flexibility (Christopher, 2016). Furthermore, visibility and information sharing in the operations and supply chain also increase flexibility (Christopher, 2016). Yang et al. (2007) state capacity flexibility can be increased by utilizing extra personal only when needed. This can be done by giving the employees the choice to work overtime when needed and compensate the employees with time off when resources are not needed (Yang et al., 2007).
2.4.6 Determine reverse logistics procedures

Material flowing upstream is often referred to in the literature as reverse logistics (Huscroft et al., 2013) Reverse logistics has gotten more attention the last years (Mahadevan, 2019) and is an opportunity to increase customer satisfaction and reduce cost (Richey et al., 2004). Reverse logistics refers to raw material or components, semi-finished products or end products that need to flow upstream to recapture or create value (Huscroft et al., 2013). If material should flow upstream should be a decision taken from a cost perspective, followed by environmental impact and market demand (Sangwan, 2017). Consequently, if materials should flow upstream to recapture value (Huscroft et al., 2013), procedures need to be developed (Mahadevan, 2019) to ensure that cost is reduced and customer satisfaction is increased (Richey et al., 2004). The reverse logistics procedures should determine the trends and cause for claims (Christopher, 2016). As 10-20 percent of the cost in Swedish industrial companies derive from quality issues, one of the most important procedures is to find out the trend and cause for quality issues and perform improvements to reduce the quality issues (Bergman and Klefsjö, 2012). Furthermore, it should be determined how quickly claims should be dealt with and how to compensate the customers (Christopher, 2016).

2.4.7 Increase dependability

Customer satisfaction should be reflected in the delivery dependability (Ilic and Tesic, 2016). Since increased dependability increases customer satisfaction and profit, as the customer becomes more loyal (Chavez et al., 2017). To increase dependability certain orders can be given priority (Olhager, 2012). If the dilemma would arise that all orders cannot be delivered on time, customers which are more profitable should be given priority, as less profitable customers can migrate to other service packages with longer lead times (Jüttner et al., 2007). Christopher (2016) strengthen this argument by applying the Pareto-Law, 4 percent of the order stand for 64 percent of all profit, as 20 percent of the customers purchase 80 percent of the products and 20 percent of the product generate 80 percent of all products profit. Hence key priority should be given to the most profitable customers buying the most profitable product (Christopher, 2016), as customer satisfaction from the most profitable customer is more important (Lau et al., 2016). Olhager (2012) stresses the importance of being careful when prioritizing orders as it is difficult to predict the operational consequences. However, if and when orders are prioritized, new and initial orders need to be re-scheduled (Ivanov and Sokolov, 2015), as successful scheduling reduces cost (Huang et al., 2013). Furthermore, products should be produced of quality to meet customer demands, and quality defects should be reduced (Chavez et al., 2017). A well-known tactic to improve quality is implementing Total Quality Management (Wurzer and Reiner, 2018). However, some researcher argues that increased quality comes with an increased cost (Wurzer and Reiner, 2018).

2.5 Conceptual framework

Figure 1 demonstrates the main conceptual framework in this research. The framework can be applied to large manufacturing companies within a supply chain, which aims to become more demand-driven. The framework gives a holistic view
of how to manage the bi-directional flow of materials to increase customer satisfaction and reduce cost. The framework displays; when managing material flows to increase customer satisfaction and reduce cost, these management actions could be taken; increase responsiveness (Christopher, 2016; Fischer, 1997; Singh et al., 2018a), reduce lead time (De Treville and van Ackere, 2006; Olhager and Prajogo, 2012; Singh et al., 2018a), increase logistic integration (Prajogo and Olhager, 2012), reduce inventory without prolonging lead time (Illic and Tesic, 2016; Koos and Shaikh, 2019; Singh et al., 2018a), determine and align flexibility level (Chavez et al., 2017) and determine reverse logistics procedures (Richey et al., 2004). When managing material flow, customer satisfaction and profit could also be increased by increasing dependability (Chavez et al., 2017).

Increased responsiveness could be applied both for material flowing downstream as upstream (Pishvae et al., 2010). To increase responsiveness managers could; reduce the lead time (De Treville et al., 2004), use advanced manufacturing technologies (Roh et al., 2014), apply just-in-time (De Treville et al., 2004) and pull material to downstream operations (Roh et al., 2014). Reducing lead time could be applied both for the flow of material downstream (Singh et al., 2018a) and upstream (Cannella et al., 2016). To reduce lead time, managers could; reduce variability (De Treville and van Ackere, 2006), find out the right lot size (De Treville and van Ackere, 2006), reduce set-up time (Singh et al., 2018b), maintain process utilization around 90 percent (Hong et al., 2018; Zhao et al., 2018), identify and eliminate bottlenecks (De Treville and van Ackere, 2006; Myrelid and Olhager, 2015) and increase logistic integration (Prajogo and Olhager, 2012).

Increasing logistics integration is relevant both for the material flow downstream and upstream the supply chain (Mahadevan, 2019). To increase logistics integration management could increase coordination of logistics activities, (Chen and Paulraj, 2004; Prajogo and Olhager, 2012). Reducing inventory without prolonging lead time is relevant both for materials flowing downstream (De Treville et al., 2004) as upstream (Turan et al., 2017). To reduce inventory without prolonging lead time managers could; reduce lead time (De Treville et al., 2004; Wang and Disney, 2017), increase logistic integration (Prajogo and Olhager, 2012), provide earlier demand information, (Christopher, 2016), redistribute excess inventory where the demand is (Turan et al., 2017), reduce variability and reduce inventory on less strategically valuable material (Christopher, 2016).

Determining and aligning the flexibility level (Chavez et al., 2017) have implications both for material flowing downstream as upstream (Bai and Sarkis, 2013). To reduce flexibility management could; remove excess capacity (Olhager and Prajogo, 2012). To increase flexibility management could; increase information sharing and visibility, develop a facilitating corporate culture (Christopher, 2016) increase collaboration (Christopher, 2016; Hallgren and Olhager, 2009), train employees for multiple tasks (Hallgren and Olhager, 2009) and utilize extra personnel when needed (Yang et al., 2007). Reverse logistics procedure is applicable only for material flowing upstream the supply chain (Mahadevan, 2019). To determine reverse logistics procedure managers could; determine when material should flow upstream (Sangwan, 2017), identify trends and cause of quality issues and perform improvements (Bergman and Klefsjö, 2012), determine how to compensate customers and determine how quickly claims should be dealt with (Christopher, 2016). To increase dependability managers could; reduce quality issues (Chavez et al., 2017) and carefully decide if and when orders should be prioritized (Olhager, 2012). To reduce variability managers could; pull material to
downstream operations (Moacir, 2012), reduce bullwhip effect (De Treville et al., 2004), reduce quality issues (Filho and Uzsoy, 2011) and find out the right lot-size (Moacir, 2012). To find out the right lot size managers could; first reduce set-up time to make a smaller lot-size possible (Filho and Uzsoy, 2011) and then identify the right lot size by using existing models or gently reduce lot size over time and evaluate the effect (Filho and Uzsoy, 2011; Vaughan, 2006). To reduce set-up time managers could; first separate the set-up time, what can and cannot be done while process in operating, secondly convert as much set-up as possible to when the process is operating, third reduce time for the non-operating set-up (Olhager, 2012) and last, sequence production orders so that fewer set-ups are needed (Thurer et al., 2014). To identify and eliminate bottlenecks managers could first identify the bottleneck with existing models (Tang, 2019; Yuan and Zhang, 2018), secondly increase capacity in bottleneck (Myrelid and Olhager, 2015) and then repeat step 1-2 (Myrelid and Olhager, 2015) or subordinate all operations to the same production rate as the bottleneck (Olhager, 2012).
Figure 1: Conceptual framework
3 Methods

This chapter provides detailed information about the research process and motivates the choice of methods. The quality of this research (validity and reliability) is discussed and evaluated. Furthermore, ethical, societal and sustainability aspect is discussed.

3.1 Overview of research process

An overview of the research process is shown in figure 2.

![Figure 2: Overview of research process](image)

The research gap was the starting point, followed by the purpose. Based on the purpose, the method (case study) was selected. The selected case (Sandvik Mining and Rock Technology) was based on the purpose and the desired study phenomena. After performing the literature review a conceptual framework was created. This framework was illustrated with a case. Within the collected evidence from the case, themes were identified and categorized. The categorization of evidence derived an analysis of why the conceptual framework was modified. The research process ended with a conclusion. Though this is described as a linear process, case studies are an iterative process where the different parts are revisited during the research (Voss et al., 2002) still, this was the general process of this research.

3.2 Method selection

The method is the plan in which scientists/students try to complete the study (Biggam, 2015), hence this determines the process of the research, how the evidence is collected and analyzed (Remenyi et al., 1998). Biggam (2015) advises selecting the research method that is best suitable for the research. The strongest argument for selecting a case study is that this research aimed to answer research questions of how in a current event and there was no need to control behaviors (Yin, 2009).

The case study is flexible in its nature and fits both positivistic and phenomenological studies (Remenyi et al., 1998). A case study is defined as; (1) an empirical study where current phenomenon is investigated in depth, particularly when boundaries of the context is indistinct and (2) the investigation manage technical unclear situations, sources need to be triangulated and the research benefits by collecting theory to guide the collection and analysis of evidence (Yin, 2009). Consistent with Voss et al. (2002) benefits with the case study include that it is very suitable in the fast-changing field of business and management and the depth of the study is significantly greater than in surveys, experiments or archival analysis. Complementary Remenyi et al. (1998) reveals critiques to case studies, stressing the risk of bias, the tendency to use incomplete evidence and that it is not
able to generalize a case study. He defends this critique by explaining that bias is a risk in any other research method, evidence can be completed by triangulating different sources and that generalization in a case study would not be possible, is just a misunderstanding. Besides Yin (2009) clarifies that in contradiction to surveys, case studies cannot be generalized in a statistical way, instead, case studies are dependent on analytical generalization. Moreover, he explains that case studies are one of the hardest types of research to do. Nevertheless, a case study was the chosen research method as it is the best fitting for this research and as there is a need for more case studies in operations management (Voss et al., 2002) and within the selected topic (Kaipia, 2009).

The nature of the case study is phenomenological, the motive for this choice is that this is the only approach appealing to a holistic view of a phenomenon that can cope with the complexity in the field of business and management (Remenyi et al., 1998). This was considered vital as a holistic view of how to manage complex material flows was the intent of this research. Furthermore, a theory elaboration approach is used to develop an understanding of how to manage the bi-directional flow of materials to increase customer satisfaction and reduce cost. The theory elaboration approach is used to build on to existing theory (Ketokivi and Choi, 2014) and as a general conceptual idea exists of how to manage material, theory elaboration is possible (Ketokivi and Choi, 2014). This choice was made as the existing theory is considered to be underdeveloped.

3.3 Building a theoretical foundation

The theoretical foundation was built before collecting case study evidence, the general approach to building the theoretical foundation is shown in figure 3.

![Figure 3: General approach to building the theoretical foundation](image)

To find this literature, Scopus was the primary database used. The basic criteria’s are listed in table 1.

**Table 1: Basic criteria for all selected literature.**

<table>
<thead>
<tr>
<th>Books, conference paper or academic journal</th>
<th>Language: English</th>
<th>Full text available for free for students of University of Gävle</th>
<th>1999 or newer articles</th>
</tr>
</thead>
</table>

Additionally, three specific search criteria’s where used to find the main literature. The words used, are presented in table 2.

**Table 2: Advanced criteria to find literature**

<table>
<thead>
<tr>
<th>Search criteria</th>
<th>Term 1</th>
<th>Term 2</th>
<th>Term 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material flow</td>
<td>Customer satisfaction</td>
<td>Cost</td>
</tr>
<tr>
<td>2</td>
<td>Material flow</td>
<td>Customer satisfaction</td>
<td>Cost</td>
</tr>
</tbody>
</table>
When selecting literature, it is a good idea to evaluate it towards the 3 Rs (*relevant, reliable* and *recent*) (Biggam, 2015), hence the literature in this research has systematically been evaluated towards the 3 Rs table 3.

**Table 3: How literature was evaluated towards the 3 Rs**

<table>
<thead>
<tr>
<th>R</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant</td>
<td>Acceptable: The literature contributes to the researched topic</td>
</tr>
<tr>
<td></td>
<td>Great: The literature highly contributes to the researched topic</td>
</tr>
<tr>
<td>Reliable</td>
<td>Acceptable: Books from well-known authors</td>
</tr>
<tr>
<td></td>
<td>Great: Peer-reviewed scientific article that have been cited</td>
</tr>
<tr>
<td>Recent</td>
<td>Acceptable: Has been published within the last 25 years</td>
</tr>
<tr>
<td></td>
<td>Great: Has been published within the last 5 years</td>
</tr>
</tbody>
</table>

Only acceptable literature was used and when literature was considered having great relevance and reliability, the citing articles were reviewed to find more literature. Furthermore, when it was found that managing a specific activity, for example reducing lead time, contributed to increasing customer satisfaction and reducing cost, further literature where searched based on this activity.

### 3.4 Case selection

When choosing a case company, it was essential to choose a company that had a bi-directional flow of materials. It was also desirable that the company was best and had more bi-directional flows of materials than other companies, a company that recycles most. According to Huscroft et al. (2013), if the material flows are complex, the result is allowed to be more generalized. Consequently, it was regarded as important to find a large, global company to increase the complexity, hence facilitate a deeper understanding of how to manage the bi-directional flow of material and to facilitate generalizability. Since there is a trending shift in supply chains to become more demand-driven rather than forecast driven (Christopher, 2016), this phenomenon was desired in the case company as well. The case company found to meet the criteria’s was Sandvik Mining and Rock Technology. The manufacturing company operates a worldwide supply chain with global, complex, bi-directional material flows. It is the only mining company that recycles both steel and cemented carbides, this means that they have more material flows upstream the supply chain. Sandvik Mining and Rock Technology is leading in its industry, employs 15 000 people worldwide and aims to decrease its lead time to become more demand driven.

### 3.5 Collected evidence

Consistent with Yin (2009) when the time comes to collect evidence, it is very important that this phase is well prepared. He clarifies that the preparation can be difficult and complex, however, if this phase is not done well, the whole research can be at risk. Consequently, in this research, before collecting evidence, preparations were made. A folder for meeting notes and ideas was created to structure the work and the design of evidence collection was done before the research started. Yin (2009) further explain; the six most frequently collected
evidence in case studies are: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts. He states that all sources have strengths and weaknesses and no source should be solely used. Furthermore, Remenyi et al. (1998) and Yin (2009) agree that it is preferable to use as many sources of evidence as possible. As Remenyi et al. (1998) clarified that the most essential source of evidence in a case study is interviews, the primary source of evidence in this research was interviews followed by archival records and participant observations. Below it is further discussed why these sources of evidence were selected and also how the evidence collection was done.

3.5.1 Semi-structured interviews

Interviews are an essential source of evidence in case studies in operations management (Voss et al., 2002), it is considered to be both targeted and insightful (Remenyi et al., 1998). However, Yin (2009) emphasizes risks with interviews, this includes bias and poor recall of the interview. Furthermore, Voss et al. (2002) explain; interviews can be unstructured, semi-structured or highly structured. As interviews are argued to be an essential source of evidence in case studies (Remenyi et al., 1998), interviews were a source of evidence collected in this research. In the context of characteristics, the performed interviews were regarded as semi-structured. This allowed the researcher to have pre-arranged questions (Appendix A) as a guide during the interviews. A major aspect of preparing for interviews is to screen for participants (Yin, 2009). Since there was a desire to correctly perceive how to manage material flows in a production environment to increase customer satisfaction and reduce cost, it was considered essential to take different views into account. Hence the aim was to interview various roles in the organization. Due to the limited period of this research, not all different roles in the organization could be considered. Therefore, eleven participants with eleven different roles connected to the production department Rotary (RT) in Sandviken were interviewed between April 8th and 16th, see table 4.

**Table 4: Respondents**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Main task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Demand Planner</td>
<td>To plan the demand in North America</td>
</tr>
<tr>
<td>2. Global Sales and Operations Manager</td>
<td>Responsible for sales and operations process globally for Rotary. This include balancing sales, manufacturing and warehousing for the two production units (Sandviken and India)</td>
</tr>
<tr>
<td>3. Material Handler</td>
<td>Materials and warehousing for RT, this includes transport and loading/unloading of materials</td>
</tr>
<tr>
<td>4. Operative Support</td>
<td>Support Operators and plan machines at RT</td>
</tr>
<tr>
<td>5. Process Expert</td>
<td>Improvement for production, purchasing, planning, logistics and customer service</td>
</tr>
<tr>
<td>6. Production Manager</td>
<td>Responsible for safety, quality, employees and to delivered what is promised to Rotary customers as efficient as possibly.</td>
</tr>
<tr>
<td>7. Production Planner, hard material flow</td>
<td>Production planning for hard material flow RT</td>
</tr>
<tr>
<td>8. Production Planner, soft material flow</td>
<td>Production planning for soft material flow RT and purchaser of carbides</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>9. Purchaser</td>
<td>Ensure material supply RT</td>
</tr>
<tr>
<td>10. Quality Engineer</td>
<td>Quality</td>
</tr>
<tr>
<td>11. Supply Planner</td>
<td>Receives Rotary customer orders, monitor related work orders and store customer orders in IT systems</td>
</tr>
</tbody>
</table>

All interviews aimed to increase the understanding of how to manage the bi-directional flow of material to increase customer satisfaction and reduce cost. Interview questions were prepared and sent out in advance (Appendix A), as this correctly prepare the respondents (Voss et al., 2002). The duration per interview was on average 40 minutes. A naive approach to the subject was taken during the interview, as this inspire the respondent to give their full view of the subject (Yin, 2009). The nature of the questions was broad and open-ended at first, then specific and detailed follow-up questions were asked depending on the respondent's answer. All interviews except one were recorded. This was done to be more present in what the respondent had to say and to ask better follow-up questions. Furthermore, recording interviews is according to Yin (2009) a recognized tactic to ensure that the interviews are remembered correctly. One disadvantage of recording interviews is the time needed after the interviews (Yin, 2009), after each interview, the recordings were transcribed.

3.5.2 Archival records

According to Yin (2009), archival records include files available for the public, service records, organizational records maps, charts, and survey data. He states that one advantage with archival records is that is can be reviewed many times and that it is impartial and precise, but it is important to judge the accuracy and take in consideration when the archival record was produced. Besides Yin (2009) alerts that these records can be hard to access, and it is hard to evaluate bias. As it is suggested to collect as many sources of evidence as possible and since it was judged to enrich the research, archival records were collected. Archival records collected in this research was; information on the corporate website, an annual report and a rotary drilling brochure.

3.5.3 Participant observation

According to Yin (2009), participant observations mean not being passive during observation, being allowed to interact with people and participate in the event. He expresses that participant observation is valuable as it can be targeted, insightful and is a precise demonstration of an event. Furthermore, Remenyi et al. (1998) is convinced this source of evidence is particularly useful in the field of business and management. Nonetheless, participant observations are time-consuming, there is a high risk of bias (Yin, 2009) and it can be difficult to be granted access within the studied organization (Remenyi et al., 1998). As participant observation can help to confirm what has been said during interviews, and as this source of evidence is considered to be insightful, participant observation was a source of evidence in this research. To minimize bias during participant observation, the researcher was open
to contractionary findings, as suggested by Yin (2009). Three observations (table 5) were conducted between April 8th and 16th. During observations, it was observed how the bi-directional flow of material is managed and how it could be managed.

Table 5: Participant observations

<table>
<thead>
<tr>
<th>Observed event</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily meeting (pulse)</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Sales and operations planning meeting</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Production area</td>
<td>160 minutes</td>
</tr>
</tbody>
</table>

3.6 Analysis of evidence

According to Yin (2009) analysis of evidence means recombining evidence to be able to draw conclusions by examining, categorizing, tabulating or testing the evidence. He explains that analysis of evidence is the most challenging part of a case study and to simplify this process, it is beneficial to have a general strategy and to use analytic techniques when analyzing evidence. The general strategy in this research is to recombine and analyze within RQ1 and RQ2. This can help the researcher to shape the plan for collecting evidence and help the researcher to focus on certain evidence and ignore others (Yin, 2009). Consequently, evidence which did not concern RQ1 and RQ2 was ignored. One technique to analyze the evidence is to identify themes (Biggam, 2015), patterns. This is one of the best techniques when doing case studies, if the pattern match or overlap, the internal validity is increased (Yin, 2009). To identify themes, the collected evidence needs to be read and re-read several times (Remenyi et al., 1998). After the themes have been identified and the evidence has been categorized within these themes, the themes should be evaluated regarding the existing theory (Remenyi et al., 1998). Consistently, in this research different themes within the two RQs were created. These themes derived from the collected evidence by thoroughly study the evidence. After the themes were identified, the collected evidence was categorized within these themes. Finally, the categorized evidence was evaluated towards the conceptual framework to see similarities, differences, and extension of current theory.

3.7 Quality of the study

The quality of case studies is most commonly evaluated in terms of; construct validity, internal validity, external validity and reliability (Remenyi et al., 1998; Yin, 2009). Thus, the discussion and evaluation of the quality of this research have been categorized accordingly.

3.7.1 Construct validity

Construct validity refers to how well/true the measurements of the concepts studied are reflected (Voss et al., 2002; Yin, 2009). Yin (2009) proposes different techniques to increase the construct validity, this includes triangulating different sources of evidence and to let key informants review the draft (Yin, 2009). Suggestions from Yin (2009) were followed and since similar results were shown
from interviews, observations and archival records, the construct validity increased (Voss et al., 2002). Furthermore, key informants have reviewed drafts of the thesis.

### 3.7.2 Internal validity

Internal validity is applicable in explanatory case studies, there the research seeks to explain how the relationship between two phenomena, how event X lead to event Y (Yin, 2009). As the purpose of this research is to establish how event X (bi-directional flow of materials) can lead to event Y (increased customer satisfaction and reduced costs), internal validity is applicable in this research. As patterns from the literature review and the result from the case study overlapped, the internal validity in this research increased (Yin, 2009). Furthermore, internal validity should be confirmed by convincing arguments when researching in the field of business and management (Remenyi et al., 1998), thus, the internal validity is built in the analysis (Voss et al., 2002). To increase the internal validity in this research, recommendations from Yin (2009) were followed, hence patterns and themes were created, furthermore, logic and evaluation were devoted to the analysis.

### 3.7.3 External validity

External validity refers to the ability to generalize the result of the research to other populations (Yin, 2009). The external validity increases in multiple case studies (Voss et al., 2002) and the single case study have poorer conditions of being generalized (Yin, 2009). Though, an advantage with single case studies is greater depth (Voss et al., 2002). Researchers within business and management would not argue that the result from a case study can be as generalized as in the field of physical science, life science or social science (Remenyi et al., 1998). Case studies cannot be generalized in a statistical way, instead they can be generalized analytically (Yin, 2009). As suggested by Yin (2009) this research was analytically generalized and consistent with Remenyi et al. (1998) dedicated on being authentic and to correctly represent the case, the case of Rotary Sandviken. Furthermore, a case company with complex material flows was chosen, which according to Huscroft et al. (2013) allows the result to be more generalized.

### 3.7.4 Reliability

Reliability refers to the extent the result of the research had been the same if another researcher had conducted the same case study (Yin, 2009), that is, the extent the research can be trusted (Biggam, 2015). To increase reliability, it is essential to minimize errors and bias in the research and to present in detail how the research was conducted (Yin, 2009). The use of recognized and relevant research strategies and techniques will increase the reliability of the research (Biggam, 2015). To increase the reliability in this research, recognized and relevant strategies and techniques were used (case study, archival records, semi-structured interviews, participant observations, creating and analyzing evidence in themes). Because some questions were asked to all respondents, bias and errors were minimized, hence the reliability increased (Voss et al., 2002). Furthermore, as a detailed description of how the research was conducted is given, the reliability of this research increased.
3.8 Ethical, societal and sustainability aspects of the research

The ethical aspect of research refers to moral (Biggam, 2015), what is right and wrong (Remenyi et al., 1998) when it comes to human participant in empirical research. When doing empirical research, such as a case study, there are five core aspects to consider from an ethical point of view (Biggam, 2015), see table 6.

Table 6: Ethical aspect to consider in a case study, Biggam (2015)

<table>
<thead>
<tr>
<th>Ethical aspect</th>
<th>Practical implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voluntary</td>
<td>Do not force participant to be a part of the research</td>
</tr>
<tr>
<td>Confidentiality</td>
<td>Allow participant to be anonymous</td>
</tr>
<tr>
<td>Transparency</td>
<td>Before participating in the research, explain the purpose of the research how they will be involved and how the findings will be used</td>
</tr>
<tr>
<td>Do not harm</td>
<td>Do not put yourself or the participant in risk</td>
</tr>
<tr>
<td>Impartiality</td>
<td>Declare the ability of bias by for example explain the researcher relationship with participant and the organization</td>
</tr>
</tbody>
</table>

Accordingly, these five ethical aspects were considered in this research. Only those who agreed to participate were a part of the case study. The purpose of this research was shown in screens at Sandvik Mining and Rock Technology facilities. Additionally, before each interview and observation, participants were given the purpose of this research, how they were to be involved and how the findings were going to be used. Each participant had the option to be anonymous and to decline being recorded. One participant wanted to be anonymous and all participants agreed upon the use of their titles. To not put any participant at risk, the participant’s names have not been stated in this thesis, all recordings were only listened by the author of this thesis and the recordings were deleted in May 2019. Furthermore, interviews were done away from the production floor, since this was considered a place of risk when not paying attention.

For participants protection, interviews were conducted privately, behind closed doors where curious people could not eavesdrop. As for the societal aspect of this research. A contribution of this research is providing knowledge of how material flows can be managed to increase customer satisfaction and reduce costs, which according to Christopher (2016) means increased profit. Increased corporate profit affects the society according to Drooge et al. (2010), hence this research might have societal relevance. This research may also increase sustainability. As this research provides knowledge of how to manage the bi-directional flow of material flows. The result might lead to, increased corporate profit, better utilization of recourses and better working conditions, this research affects the economic, social, environmental and time dimension, which according to Elkington (1998) refers to increased sustainability.
4 Results

This chapter illustrates the conceptual framework with a case study. First, the case company and the boundaries of the study are properly introduced. Then it is presented how the bi-directional flow of materials takes place at Rotary Sandviken (RT) and how it is managed.

4.1 Case company

General information and context of the case, Rotary Sandviken (RT) is presented in figure 4.

![Diagram of Sandvik Group, Sandvik Mining and Rock Technology, Sandvik mining and Rock Tools, Rotary, and Rotary Sandviken, with information such as offering high tech engineering solutions, focus on being no 1 or 2 in chosen markets and segments, employs 42 000 people, annual revenue of 100 billion SEK, offers high tech engineering solutions for Mining and Rock excavation, is no 1 in its industry, employs 15 000 people, and annual revenue of 4.3 billion SEK, producing consumable rock tools, producing consumable rotary bits, and customers mainly located in South America, Australia, and South Africa (interviews).]

Figure 4: General information and context of the case, Rotary Sandviken

The scope of the case is the supply chain, but the perspective and evidence are collected from Rotary (figure 5).

![Diagram of the supply chain from Supplier to Customer, with perspectives and scope highlighted in the middle.]

Figure 5: Scope and perspective of the result
4.1.1 The product and what customers value

The rotary bit is considered to be a premium product according to the Global Sales and Operations Manager. Customers attach the rotary bit to a drill rig (Sandvik, 2019c), this is illustrated in figure 6.

Figure 6: Rotary bit and drill rig

Through interviews with the Demand Planner and the Global Sales and Operations Manager, it was determined that RT’s customers value; lead time, quality, dependability and customer service. The Global Sales and Operations Manager and Demand Planner disagree on the importance of price. The Global Sales and Operations Manager state that price is not so important for Rotary’s customer since Sandvik is a premium brand. Furthermore, Sandvik cannot compete with many competitors on the price. The Demand Planner stated price is one of the most driving factors in the market and it is very important that quality and price go hand in hand. Both the Global Sales and Operations Manager and the Demand Planner agree that Rotary’s customers want a shorter lead time. The Demand Planner informs that if Sandvik does not have the rotary bit in stock when the customer needs it, the customer will turn to Rotary’s competitors. The Demand Planner also clarified that it is very important that Rotary Sandviken (RT) increases its lead time flexibility. Both the Demand Planner and the Global Sales and Operations Manager describe that many of the rotary bits have only one customer using a typical size and type of bit; hence customization is huge in the Rotary business.
4.2 The bi-directional flow of material in RTs Supply chain

From interviews and archival records it became clear that material flows downstream to the customer as long as quality problems, reclaims, returns or redistributions do not arise. If anything of this happens, material flows upstream the supply chain (figure 7).

![Figure 7: The bi-directional flow of material in RTs supply chain](image)

Interviews show two scenarios when materials flow upstream from customers to Rotary, the scenarios are; recycling of end products and reclaims of end products. Sandvik Mining and Rock Technology (SMRT) is recycling cemented carbide and steel (Sandvik, 2019c), respondents clarify that Rotary India regains the cemented carbides. Respondents explain that rotary bits are reclaimed due to quality issues and can either be fixed on site or returned to RT. The Demand Planner described a scenario when end products flow upstream from the customer to the global warehouse. RT has a return policy that allows customers to return purchased end-products to the regional warehouse within a certain time regardless of the reason. As the rotary bits can exclusively be used by one customer, the rotary bits can get stuck in the regional warehouse.

To solve this issue, rotary bits are redistributed to other regions where there is demand. During interviews it is explained; end products in the regional warehouses that are to be redistributed may need to flow upstream, back to the production unit in Sandviken before it can be redistributed to another country. This applies when shipping between the USA and Russia. Through interviews and participant observations in the production area, it turned out that semi-finished products flow upstream the internal operations at RT to be remanufactured due to quality issues. This may include help from an outside company to perform parts of the remanufacturing. Furthermore, respondents explain that raw material or components flow upstream from RT to the supplier to be reclaimed as a consequence of poor quality received from the supplier.
4.3 Managing the bi-directional flow of material

The most frequent themes discussed during interviews in terms of managing the bi-directional flow of material to increase customer satisfaction and reduce cost was; increase responsiveness, reduce lead time, increase logistics integration, reduce inventory without prolonging lead time, determine and align flexibility level, determine reverse logistics procedures and increase dependability. Consequently, these themes are presented in this section. The different themes are given different ranges in this section based on how much the themes were discussed during interviews.

4.3.1 Increase responsiveness

When conducting observations in the production area, an Operator working in the welding exemplified how responsiveness is applied for material flowing upstream. If semi-finished products arrive from downstream operations which are to be remanufactured, these are dealt with before manufacturing new products. In table 7, management activities at RT to increase responsiveness is presented.

<table>
<thead>
<tr>
<th>Management activities at RT to increase responsiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pull material to downstream operations</td>
</tr>
<tr>
<td>During interviews, the need for semi-finished products and components to arrive just-in-time is discussed. Respondents say that it is not smart to start a production order if raw material or components are missing, as this would lead to half-produced orders in the factory. Respondents emphasize the need for raw material, components, and semi-finished products to arrive just-in-time to the assembly line. To enable this, the Production Planner waits to start production orders until purchasing has confirmed arrival date for raw material and components.</td>
</tr>
<tr>
<td>Apply just-in-time</td>
</tr>
<tr>
<td>Two respondents suggested increasing the use of advanced manufacturing technologies, more specifically to automate processes. Respondents claim that this would reduce costs and increase the production rate.</td>
</tr>
<tr>
<td>Use advanced manufacturing technologies</td>
</tr>
<tr>
<td>Respondents explained, when the lead time is reduced, RT can respond faster to customers.</td>
</tr>
<tr>
<td>Reduce lead time</td>
</tr>
</tbody>
</table>

4.3.2 Reduce lead time

The Global Sales and Operations Manager clarified that if the lead time can be reduced, the amount of material and information will also decrease. Several respondents emphasize the importance of reducing the lead time for material flow,
including materials being remanufactured, it is often the same Operator performing the remanufacturing as manufacturing new products. Through observations, it is displayed that some remanufacturing procedures have a separate flow, which does not affect the manufacturing of new products. Furthermore, the Demand Planner exemplified how the customer might react if the lead time is prolonged. For some reason, Sandvik was late to deliver a rotary bit to a customer in Mexico. This ruined the relationship with the customer and Sandvik lost the business. Previously Sandvik had delivered rotary bits regularly for at least a year. In table 8, management activities at RT to reduce lead time is presented.

Table 8: Management activities at RT to reduce lead time

<table>
<thead>
<tr>
<th>Reducing variability</th>
<th>Finding out lot size based on supplier capacity and reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different types of variability are discussed during interviews, including processing variability and arrival variability.</td>
<td></td>
</tr>
<tr>
<td>• During interviews and observations, it becomes clear that processing and arrival variability increase when quality issues occur. The reason is, that it might be the same Operator who deals with quality issues (remanufacturing) as well as manufactures new products.</td>
<td></td>
</tr>
<tr>
<td>• The respondents are convinced that variability can be reduced if the material is pulled to downstream operations.</td>
<td></td>
</tr>
<tr>
<td>Through observation in the production, it became clear that the lead time could significantly be reduced by reducing lot sizes. The Process Expert clarifies, when lot sizes are reduced, the production rate decreases as the time for administrative task emerge.</td>
<td></td>
</tr>
<tr>
<td>• The Production Planner for the soft material flow informs that lot sizes in the soft material flow are controlled by the maximum lot size at the external heat treatment company. Furthermore, this choice is based to reduce cost per heat treated product. The maximum lot size in the soft material flow is 67 pieces.</td>
<td></td>
</tr>
<tr>
<td>• The Production Planner for the hard material flow informs that the lot sizes in the hard material flow depend on the size of the customer’s order. If the customer’s order is large, then the customer’s order is divided into smaller lot sizes. Currently the maximum lot size in the hard material flow is 25-30 bits per order. The Production Planner for the hard material flow explains that this lot size has been reasoned, not calculated.</td>
<td></td>
</tr>
</tbody>
</table>
Reducing set-up time by sequence production orders so that fewer set-ups are needed

During observations in the production area, it became apparent that set-up time also exists when semi-finished products are remanufactured. An Operator working in the welding explains, when the thread needs rewelding, the first welding takes around 3.5 hours for one bit due to set-up time and the rest of the bits take around 2.5 hours per piece.

- Respondents claim, if a better production plan is created, the sequence of production orders will generate fewer set-ups, hence reduce the total set-up time. A Production Planner explains; to create a better production plan, enough time must be available. This requests faster information sharing and to reduce the number of prioritized orders, as prioritization usually requires the production plan to be rescheduled.

- Through interviews and observations, it is revealed that a manual board gives a visual picture of the on-going production orders. This manual board also shows the current operation for each production order. A Production Planner informs that the manual board can be used to identify bottlenecks. During observations in the production area, a Flow Manager emphasizes a problem with the manual board, it does not give a representative picture of the reality. The Flow Manager points out that it is not displayed when the manual board was last updated, and on-going production orders are not always moved to visualize the current operation. During interviews, respondents present the biggest downside, the manual board is it not live updated. Several respondents propose a digital board. An Operational Support informs that welding was identified as a bottleneck in the past.

- Respondents argue that the capacity in bottlenecks needs to increase, to reduce the lead time. To increase capacity in bottlenecks, respondents state that machine downtime should be reduced and one way of doing so would be to invest in new machines and this was recently done for welding.

- The Operational Support state that the current bottleneck is threading and greasing.

- Several respondents are convinced that if the coordination of logistics activities increase, the lead time will be reduced. The importance of collaboration with suppliers to reduce lead time is emphasized by the purchaser.
Several respondents inform, if the frequency of order releases from the Global Sales and Operations Manager can increase, this will reduce the lead time as the average waiting time before production starts will be reduced. Furthermore, Rotary is looking to transform from monthly to weekly order releases. Respondents are sure this will reduce the lead time with two weeks. During an observation of a Sales & Operation Planning meeting, the head of operational purchasing and planning expresses that the lead time will decrease by two weeks when weekly order releases are implemented.

4.3.3 Increase logistics integration

Through interviews, it becomes clear that increased logistics integration is relevant both for downstream and upstream material flows. In table 9 management activities at RT to increase logistics integration are presented.

Table 9: Management activities at RT to increase logistics integration

<table>
<thead>
<tr>
<th>Increasing coordination of logistics activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Several respondents discussed increasing logistics integration by increasing coordination. The respondents clarify that coordination to the assembly line is extra important. The coordination of material flows upstream is discussed by the purchaser. The Purchaser exemplifies; if RT reclaims raw material or components, it is important that the supplier sends new raw material or components before investigating the stated flaws on the reclaimed material.</td>
</tr>
</tbody>
</table>

4.3.4 Reduce inventory without prolonging lead time

During interviews, reducing inventory without prolonging the lead time is emphasized. It is confirmed that reducing inventory without prolonging lead time is applicable for downstream and upstream materials flow. In table 10 management activities at RT to reduce inventory without prolonging lead time are presented.

Table 10: Management activities at RT to reduce inventory without prolonging lead time

<table>
<thead>
<tr>
<th>Reduce lead time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Several respondents described that if the lead time is reduced, then the inventory will automatically be reduced. The Global Sales and Operations Manager exemplifies, if the lead time can be reduced, the inventory in the regional warehouses can also be reduced.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Provide earlier demand information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Several respondents discuss the benefits of earlier demand information. One of the benefits is the ability to reduce inventory. Through interviews, it becomes clear that Rotary aims to provide earlier demand information by increasing the frequency of order releases from monthly to weekly releases.</td>
</tr>
</tbody>
</table>
Redistribute excess inventory

The Demand Planner and Supply Planner describe an occasion when inventory and lead time can be reduced simultaneously. The occasion is when excess inventory is redistributed where the demand is.

Reduce variability

The Global Sales and Operations Manager and the Demand Planner discuss the effect of order variability (bullwhip effect). During a period, the lead time from RT was extended by 2-3 months. When the backlog was released, it created an enormous inventory in the regional warehouse, because the Demand Planner expected to receive delivery of rotary bits 2-3 months later. As a consequence, the Demand Planner stopped ordering from RT which created problems for the production unit at RT.

Reduce inventory on less strategically valuable material

Different respondents explain that inventory is very costly and should be reduced and the focus should be on reducing inventory for less strategically valuable material. Respondents explain that RT has a higher stock availability on certain raw materials, components, semi-finished products, and end products which should never be out of stock.

4.3.5 Determine flexibility level

Several respondents have determined that flexibility needs to increase. The Demand Planner state that it is little room to improve lead time at RT and that the flexibility level needs to increase when the Demand Planner places an urgent order. During interviews, it became clear that the flexibility level influenced both materials flowing downstream as upstream. In table 11 management activities at RT to increase the flexibility level are presented.

Table 11: Management activities at RT to increase the flexibility level

| Increase information sharing and visibility | Several respondents discussed that the flexibility level can increase if information sharing and visibility are increased. The respondents emphasize that flexibility will increase among the employees if they are informed of why it is needed. |
| Increase collaboration | Increased collaboration is demonstrated to increase flexibility during an observation of a daily pulse meeting. During this meeting, the Production Manager and Flow Managers discussed collaboration across boundaries in the production. If a certain Flow Manager temporarily needs resources, the other flow managers offer help. |
| Training employees to perform multiple tasks | Training employees to perform multiple tasks will increase flexibility according to the Production Manager. The Production Manager state that it is beneficial to create an education plan where different aspects are considered, including employees, similar machines/processes and where more experience is needed. |
To increase the flexibility, respondents emphasize the value of having a facilitating corporate culture. Respondents clarify that this culture should make employees open to fast changes.

Respondents clarify that flexibility can increase by utilizing extra Operators when needed. The Production Manager informs that hiring consultants who work only when needed will increase the volume flexibility and reduce costs. When products are to be remanufactured, a respondent suggests paying overtime to Operators to avoid stopping the manufacturing of new products.

4.3.6 Determine reverse logistics procedures

When it comes to managing material flowing upstream the supply chain, the most frequently discussed activity among respondents is to determine reverse logistics procedures. Through observation in the production area, it is displayed that reverse logistics procedures exist. Respondents clarify that standardized procedures are relevant for all material upstream being remanufactured, redistributed, reclaimed or returned. In table 12, reverse logistics procedures at RT is presented.

Table 12: Management activities at RT to create reverse logistics procedures

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine when material should flow upstream</td>
<td>The Process Expert and a Production Planner discuss deciding if semi-finished products should be remanufactured. The Process Expert is convinced; when quality issues are detected at RT, it is assumed that it is cheaper to remanufacture the semi-finished rotary bit. The Process Expert continues by stating that this decision has not been calculated and it should be compared if it is more cost effective to remanufacture or to manufacture a new rotary bit. The Production Planner for the hard material flow is convinced that it is less costly to remanufacture and believe the lead time would increase if a new bit where to be manufactured from the start.</td>
</tr>
<tr>
<td>Identify trends and cause of quality issues and perform improvements</td>
<td>Respondents mention the importance of identifying trends and causes of quality issues, both when it comes to semi-finished products and end products. Through observations in the production area, it is displayed that RT documents cause of quality issues. A respondent informs that RT has laboratory resources and conduct research to find out the cause of reclaimed end products. Several respondents highlight the value of learning from mistakes to increase quality.</td>
</tr>
<tr>
<td>Determine how to compensate customers</td>
<td>How to compensate customers when reclams happen is discussed during interviews. Respondents highlight the importance of offering customers replacement products when reclams occur.</td>
</tr>
</tbody>
</table>
During an observation in the production area, a Flow Manager informs that it is important that quality issues are dealt with correctly. The Flow Manager explains; otherwise, these issues might pile up and create a messy production. During this observation, an Operator informed, if a quality issue is detected the Operator usually take action right away. The Operator explains that if the issue is not solved when the next shift arrives, a note is written. During an interview with the purchaser the importance of receiving new material from the supplier right away when reclaims occurs is stressed.

4.3.7 Increase dependability

Several respondents emphasized the importance of being dependable, to keep promises to customers. In table 13 management activities at RT to increase dependability are presented.

Table 13: Management activities at RT to increase dependability

Through interviews, the most frequent suggestion to increase customer satisfaction and reduce cost was to reduce quality issues. Respondents inform, if quality issues are reduced, the dependability and customer satisfaction is increased. Additionally, the Demand Planner explains that poor quality hurts the reputation of Sandvik. It became clear during interviews, if quality issues can be reduced, the cost can be reduced as scrapping and remanufacturing can be avoided. The Production Planner for the soft material flow explains that sometimes extra units are produced in the soft material flow to adapt to possible quality issues in the hard material flow.

Through interviews, it becomes evident that to increase dependability, certain orders are given priority. Respondents inform that these priorities derive from the product owner, late delivery, out of stock or the loudest screaming regional warehouse. A Production Planner explains if the frequency of prioritized order increases, the frequency of re-scheduling increases as well. A Production Planner underlines the importance of carefully deciding if orders should be prioritized, as the quality of the production plan decrease as more frequent re-scheduling is needed. During an interview, a respondent stated the consequences of frequent re-scheduling. This includes more set-ups in the production and less time for the Production Planner to do improvements.
5 Analysis and discussion

This chapter starts by discussing how the bi-directional flow of material takes place within a manufacturing company in the supply chain. Then it is analyzed why the conceptual framework presented in figure 1 is modified.

5.1 Answering RQ1

How does the bi-directional flow of material take place within a manufacturing company in the supply chain?

The case shows that the general material flow is downstream towards the customer. This is in line with Daugherty et al. (2001) declaring that most of the logistics costs are allocated in the general material flow. The case shows that material also needs to flow upstream the supply chain to be remanufactured, reclaimed, redistributed, returned or recycled. End products (rotary bits) flow from the customer to Rotary if the end-products are to be recycled. This is a competitive advantage as SMRT is the only mining company that recycles both steel and cemented carbides (Sandvik, 2019c). However, end products also flow from the customer to Rotary if the customer wants to return the rotary bit within the time frame of the return policy or because of quality issues.

Needless to say, it would be beneficial for SMRT if customers did not want to return rotary bits, as this creates problems for regional warehouses. To solve this situation redistribution of end products is needed as rotary bits otherwise can get stuck in the regional warehouse. It would also be beneficial if quality issues did not occur as these cause end products to be reclaimed from the customer, semi-finished products to be remanufactured and raw material or components to be reclaimed to the supplier. All in the supply chain would benefit if quality issues did not occur since customer satisfaction and profit then would increase (Chavez et al., 2017). Furthermore, it is evident, recycling would be the only upstream material flow needed if quality problems would not exist and customers would not regret purchases. However, as the reality is different in most supply chains (Christopher, 2016), this is not the situation. The bi-directional flow of material within Rotary is displayed in figure 7.

5.2 Answering RQ2

How could the bi-directional flow of material be managed by manufacturing companies in the supply chain to increase customer satisfaction and reduce cost?

How the bi-directional flow of material could be managed by manufacturing companies in the supply chain to increase customer satisfaction and reduce costs, is presented in a conceptual framework (figure 1). The conceptual framework in figure 1 is modified through new insights from the case. These modifications are justified in this section and the discussion concerns what remains, is changed or new in the modified conceptual framework.
5.2.1 Remain in the modified conceptual framework

In the conceptual framework (figure 1), the main activities of managing material flows are; increase responsiveness, reduce lead time, increase logistics integration, reduce inventory without prolonging lead time, determine and align flexibility level, determine reverse logistics procedures and increase dependability. The same activities were the most frequently discussed themes during interviews when asking respondents how to manage the bi-directional flow of material to increase customer satisfaction and reduce cost. As the case confirmed the main activities described in the conceptual framework (figure 1), these remain unchanged in the modified conceptual framework (figure 8). Some management activities are conflictingly described (table 14) in the case compared to the conceptual framework. Why these management activities remain unchanged in the modified conceptual framework is justified in this section.

Table 14: Management activities which are conflictingly described in the case compared to the framework

<table>
<thead>
<tr>
<th>Management activity described at RT</th>
<th>Management activity described in the framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding out the right lot size by basing it on supplier capacity and reason</td>
<td>Finding out the right lot size by using existing models or gently reduce lot size over time and evaluate the effect</td>
</tr>
<tr>
<td>Identifying bottlenecks by using a manual board</td>
<td>Identifying bottlenecks by using existing models</td>
</tr>
</tbody>
</table>

When describing how to choose the right lot size, respondents did not mention that this should be done to reduce lead time. The Production Planner for the hard material flow informed that the current maximum lot size of 25-30 pieces has not been calculated, only reasoned. Intriguingly, through observations in the production, it became clear that the lead time could significantly be reduced by reducing lot sizes, which is in line with the understanding of De Treville and van Ackere (2006). The Process Expert correctly emphasized when reducing lot sizes, the production rate decrease, as described by Monden (2011). Hence a reason why the Production Planner for the hard material flow has not reduced the lot size more could depend on non-existing overcapacity in machines. Overcapacity in machines is described by Filho and Uzsoy (2011) as a precondition when reducing lot sizes.

Another inconsistency with the framework is that the lot sizes in the soft material flow are based on maximum capacity at the supplier. Hence the lot sizes are not chosen to reduce the lead time, but to be cost effective. However, as lead time reduction is also a way of reducing costs and is the main means to achieve market mediation (Kumar et al., 2017) and will, therefore, reduce market mediation costs (Fischer, 1997). The correctness of the choices of lot sizes at RT may be questioned. It might be a good idea for RT to use existing models to find out the right lot size and hence reduce lead time, as described in the conceptual framework.

In the conceptual framework (figure 1) it is suggested to use existing models to identify bottlenecks. This includes performing measurements and simulation models described by Tang (2019) and Yuan and Zhang (2018). In the case, a manual board is used to identify bottlenecks, which does not give a representative picture of reality. A representative reality should be essential when identifying bottlenecks. How would management otherwise ensure it is a bottleneck which has been
identified? RT could benefit by using existing models as these appear to be more reliable. Hence, to identify bottlenecks by using existing models remains unchanged in the modified framework. In table 15, management activities missing in the case are presented.

Table 15: Management activities missing at RT and their expected outcome in the framework

<table>
<thead>
<tr>
<th>Management activity missing at RT</th>
<th>Expected outcome in the framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain process utilization around 90%</td>
<td>Reduced lead time</td>
</tr>
<tr>
<td>Remove excess capacity</td>
<td>Reduced flexibility</td>
</tr>
<tr>
<td>1. Separate the set-up time, what can and cannot be done while the process is operating</td>
<td>Reduced set-up time</td>
</tr>
<tr>
<td>2. Convert as much set-up as possible to when the process is operating</td>
<td></td>
</tr>
<tr>
<td>3. Reduce time for the non-operating set-up</td>
<td></td>
</tr>
</tbody>
</table>

Although these management activities were not expressed during interviews, the activities could still exist at RT. The expected outcome if these activities existed will shortly be discussed. Maintaining process utilization around 90 percent was not discussed by any respondents. Unfortunately, Production Managers often have a poor understanding of how utilization affect lead time (De Treville and van Ackere, 2006). Nonetheless, utilization has a huge effect on lead time (De Treville and van Ackere, 2006) and should be kept around 90 percent (Hong et al., 2018; Zhao et al., 2018). Concludingly this management activity is needed in the framework and remains unchanged.

Another activity that was not illustrated in the case was how to reduce flexibility. Still, this has a natural explanation, the respondents determined that the flexibility level at RT needs to increase. Since this might not be the reality for every firm (Mabel et al., 2008), this management activity remains unchanged in the modified conceptual framework. The case only illustrates the fourth management activity to reduce set-ups (sequencing production order in a better way), if RT has not already done so, RT should consider management activity 1-3 to reduce set-ups (table 16). As this is an effective way of reducing set-up time (Olhager, 2012) and reducing set-up time is a precondition for reducing the lead time (Singh et al., 2018b) and lot sizes (Filho and Uzsoy, 2011).

5.2.2 Changes in the modified conceptual framework

**Determine how quickly claims and quality issues should be dealt with**

One of the management activities described in the framework when determining reverse logistics procedures is to determine how quickly claims should be dealt with. This appeared somewhat different in the case. It was established by the purchaser that suppliers should have a quick response to reclaims. This confirms the established management activity in the framework. However, during an observation, the value of dealing with quality issues quickly was also stressed. The management of these quality issues might delay if it is not determined how quickly to do so. Hence, it can be concluded that it is important to determine how quickly
to deal with claims and quality issues. Accordingly, this will be adopted in the improved conceptual framework.

**Increased dependability is applicable in the downstream and upstream material flow**

To increase customer satisfaction through increase dependability (Ilic and Tesic, 2016), quality defects can be reduced (Chavez et al., 2017) and certain orders should be prioritized (Christopher, 2016; Jüttner et al., 2007 Lau et al., 2016). This must be applied both for the flow of material downstream as well as upstream. For example, if a product is to be remanufactured and quality defects persist after the remanufacturing and these could be avoided, then this is an equal waste or perhaps even bigger than producing quality defects in the flow downstream. Consequently, the most profitable customers/products should be prioritized. Thus, increasing dependability is applicable both for material flowing upstream as downstream. To sum up, all seven main management activities in the framework is relevant in the bi-directional flow of material, except creating reverse logistics procedures, which is obviously only applicable for upstream material flows.

**Increased dependability increases customer satisfaction and reduces cost**

One of the activities described in the conceptual framework of managing material flow is to increase dependability. In the framework, this activity is described to increase customer satisfaction but not to reduce cost. However, Chavez et al. (2017) established that increased dependability leads to increased customer satisfaction and increased profit. The overall result demonstrates that this activity is beneficial also from a cost perspective, as the profit from increased income is higher than the possible loss of increased costs. Besides, the case shows that a consequence of poor dependability is increased costs. For example, quality issues do not only make the customers less satisfied, but it also generates increased costs for RT. Therefore, increased dependability should be described in the modified conceptual framework to both increase customer satisfaction and to reduce cost. Concludingly this means that all main activities described in the modified conceptual framework of managing material flows could increase customer satisfaction and reduce cost.

It may not be obvious why all activities described in the framework increase customer satisfaction and reduce cost. As established earlier, all seven main activities (increase responsiveness, reduce lead time, increase logistics integration, reduce inventory without prolonging lead time, determine and align flexibility level, determine reverse logistics procedures and increase dependability) increase customer satisfaction and reduce cost. It will now be justified that all activities leading up to these main activities also increase customer satisfaction and reduce cost. To do so, increasing flexibility and reducing lead time will be used as examples. As it has been established that reduced lead time increases customer satisfaction (De Treville and van Ackere, 2006) and reduces cost (Singh et al., 2018a), the actions to reduce lead time should be recognized to indirectly increase customer satisfaction and reduce cost as well. For example, reducing set-up time reduces the lead time (Singh et al., 2018b), which increases customer satisfaction (De Treville and van Ackere, 2006) and reduce cost (Singh et al., 2018a). The same applies to increase flexibility. If it has been established that flexibility needs to increase (Olhager and Prajogo, 2012), then increased flexibility is needed in the...
operation to adapt to volatility in supply and demand (Christopher, 2016). Although increasing flexibility is often described to increase the cost (Wurzer and Reiner, 2018). As Fischer (1997) describe market mediation cost as lost sales when the supply cannot meet the demand. Then does not the absence of required flexibility create market mediation cost? This was moderately demonstrated in the case; the Demand Planner clarifies that RT has low flexibility to improve lead time when an urgent order is placed. The same Demand Planner provided an example when Sandvik lost its business as RT were unable to meet the required lead time. Hence if it has been determined that flexibility needs to increase, and the flexibility level is not aligned, this certainly results in market mediation costs. Moreover, increasing flexibility increases customer satisfaction (Chavez et al., 2017). Hence all activities described in the modified conceptual framework (figure 8) could increase customer satisfaction and reduce cost.

5.2.3 New in the modified conceptual framework

New management activities and links found in the case are presented in table 16.

<table>
<thead>
<tr>
<th>New management activity found at RT</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide earlier demand information</td>
<td>Reduced lead time</td>
</tr>
</tbody>
</table>

A new management activity found at RT was to provide earlier demand information to reduce lead time. Providing earlier demand information appeared in the case as providing more frequent order releases, which could reduce the lead time with several weeks. Hence providing earlier demand information seems to have a significant impact on lead time and this connection needs to be added in the modified framework.

5.2.4 Summary of modifications of the conceptual framework

The modifications to the conceptual framework in figure 1 are presented in table 17 and the modified conceptual framework is displayed in figure 8.

<table>
<thead>
<tr>
<th>Conceptual framework</th>
<th>Modified conceptual framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine how quickly claims should be dealt with</td>
<td>Determine how quickly claims and quality issues should be dealt with</td>
</tr>
<tr>
<td>Increased dependability is applicable in the downstream material flow</td>
<td>Increased dependability is applicable in the downstream and upstream material flow</td>
</tr>
<tr>
<td>Increased dependability increase customer satisfaction</td>
<td>Increased dependability increases customer satisfaction and reduces cost</td>
</tr>
<tr>
<td>-</td>
<td>Providing earlier demand information reduces lead time</td>
</tr>
</tbody>
</table>
Figure 8: Modified conceptual framework
6 Conclusion

This chapter answers the purpose of this research, provides the academic contributions, managerial implications, discusses the limitations of this research and gives recommendations for further research.

6.1 Main findings

The purpose of this thesis was to explore the bi-directional flow of materials perceived by manufacturing firms in the supply chain and accordingly derive suggestions to manage this flow to increase customer satisfaction and reduce cost. This thesis has fulfilled its purpose. A conceptual framework of how to properly manage the bi-directional material flows to increase customer satisfaction and reduce cost was created and illustrated through the case of Rotary Sandviken. The bi-directional flow of materials perceived by this manufacturing firm is presented in figure 7. This research shows that, in general, materials flow downstream the supply chain, towards the customer. However, materials need to flow upstream the supply chain because of quality issues, recycling or returns. This is displayed through reclaims, remanufacturing, redistribution, returns or recycling. The conceptual framework was modified through new insight from the case. The modified conceptual framework (figure 8) contains suggestions to properly manage the bi-directional flow of materials to increase customer satisfaction and reduce cost. The framework acknowledges that the main actions in managing the bi-directional flow of materials to increase customer satisfaction and reduce cost is; increasing responsiveness, reducing lead time, increasing logistics integration, reducing inventory without prolonging lead time, determining and aligning flexibility level, determining reverse logistics procedures and increasing dependability. Furthermore, the framework presented in figure 8, acknowledges how these actions can be achieved.

Other insights from the case include the importance of determining how quickly to deal with quality issues and that increased dependability is also applicable for material flowing upstream the supply chain. By providing earlier demand information upstream, the lead time can be reduced. Furthermore, it seems that practitioners still have a poor understanding of how utilization affects the lead time. It may also be that practitioners use too simple procedures to identify bottlenecks, procedures that might fail to identify real bottlenecks.

6.2 Academic contributions

Previously, almost no academic research has been conducted on decision variables when it comes to managing material flows upstream of the supply chain (Sangwan, 2017). Also, no framework existed that integrated the bi-directional flow of materials and management activities to increase customer satisfaction and reduce cost. This research contributes to closing this gap as the modified conceptual framework (figure 8) recognizes the main actions to properly managing the bi-directional flow of material to increase customer satisfaction and reduce cost. Also, previous research addressing how to manage material flows have been expanded and integrated. Integrating the bi-directional flow of materials and management activities is important as they influence each other. Hence, the holistic view
provided in this thesis enables the two top management priorities of increasing customer satisfaction and reducing costs to be better fulfilled.

6.3 Managerial implications

When doing case studies in the field of business and management, putting the result of the research into practical use is of most importance (Remenyi et al., 1998). Companies are forced to become more sustainable and think of circular economy (Genovese et al., 2017). The case can be used as an example to show other companies how to manage bi-directional flows of materials. Also, for practitioners, the management activities presented in figure 8 compose a framework of managing the bi-directional flow of materials. Using the framework, practitioners can determine the most helpful activities to increase customer satisfaction and reduce cost, hence management knows where to allocate their resources.

6.4 Limitations and future research

A limitation of this research is that the perspective and evidence is only collected from the manufacturer point of view. Consequently, valuable insights from suppliers and customers may have been lost. This decreased the construct validity of this research (Yin, 2009). Some of the insight from the case has not been tested, hence the internal validity of this research decreases (Yin, 2009). Furthermore, the author of this thesis previously worked for and is still employed by the company on which the case study is made, therefore access within the studied organization might have been granted more freely. To be granted access within an organization can be difficult (Remenyi et al., 1998), hence another researcher might have gotten another result. This reduced the reliability of this research (Yin, 2009).

Another limitation is the generalizability of the result. The case is not generalizable as the chosen company stands out. However, the aim when choosing the case was to choose a company that is best and has more bi-directional flows of material. However, as the case, Rotary Sandviken has complex material flows, the outcome of this study might according to Huscroft et al. (2013) be allowed to be more generalized. Despite that suggestions have been derived to manage the bi-directional flow of materials; these recommendations have not been tested and the outcome of these recommendations has not been compared to KPIs or other measurements. This can be rectified in future research, preferably through a survey as this could generalize and validate this research.


Appendix A

**General questions**
1. Do you want to be anonymous?
2. Is it okay to record this interview?
   (the recording will if so, only be listened by me, Catharina Cannava, and deleted in late May 2019)
3. What is your title and main task?

**Questions about customers**
1. How does the perfect order look like for the in-market warehouse or Rotary’s end customers?
2. How important is price, delivery time, quality and the ability to get customized solutions for Rotary’s customers?
3. What other aspects are essential?
   1. How well do Rotary meet these demands?
4. What is behind the decision of prioritizing certain orders?

**Questions about information flows**
1. When is it needed to share information downstream (Downstream: Supplier -> Sandvik -> Customer)?
2. What information needs to be shared downstream and why?
3. Who need this information and why?
4. What would the consequence be if information could not be shared downstream?
5. How should information downstream be management to reduce cost?
6. How should information downstream be management to increase customer satisfaction?
7. Do you have anting else to add, of how information flows should be managed to increase customer satisfaction?
8. Do you have anting else to add, of how information flows should be managed to reduce cost?

**Questions about material flows**
1. When does material need to flow upstream (Upstream: Customer -> Sandvik -> Supplier)?
2. What would the consequence be if material could not flow downstream?
3. How should material flowing upstream be managed to increase customer satisfaction?

4. How should material flowing upstream be managed to reduce cost?

5. How should material which is stored be managed? Why? Consequences?

6. How should material which is produced be managed? Why? Consequences?

7. How should material which is transported be managed? Why? Consequences?

8. Do you have anything else to add, of how material flows should be managed to increase customer satisfaction?

9. Do you have anything else to add, of how material flows should be managed to reduce cost?