Analysing the Impacts of Using Direct Shipments in the Distribution Network for Spare Parts

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Abstract

Distribution is a part of the supply chain and refers to the steps taken to move and store a product from the supplier stage to the customer stage in the supply chain. Direct shipment is a concept within distribution and refers to shipping direct between a supplier and a retailer or customer. Distribution is considered a key driver for overall profitability of a company since it directly affects both supply chain costs and customer value. The design of the distribution network of a product is an important tool in the trade-off between responsiveness and cost-efficiency. Changing the distribution network design will affect the costs of three logistical drivers: Facilities, inventory and transportation.

This thesis is conducted in the aftermarket logistics for stone crushers at the company Sandvik and analyses the impacts of using direct shipments in the distribution network for spare parts. The distribution network comprises of European suppliers, a DC located in Europe and RDCs around the world. The purpose of this thesis is to investigate the economic consequences as well as the viability for direct shipments in the distribution network. The research is conducted using the case methodology where 12 of the suppliers are selected and analysed. The economic consequences are analysed by modelling the trade-off between the costs of the different logistical drivers in distribution. Since no suitable model for analysing the cost trade-off between the distribution costs could be found, this thesis has developed a model for the cost trade-off that closely follows the reality at Sandvik by using well-known theory. The viability for direct shipments has been analysed by assessing the supplier compliance for direct shipments mainly through a supplier survey.

The result shows that the number of exports and imports is a key factors when it comes to understanding the economic consequences. However, even for a solution where Sandvik is the exporter, which minimises the cost of exports, only a few suppliers are considered to be beneficial of direct shipments. These are the suppliers having the most number of dispatched order lines going to the RDCs at the DC. Although, direct shipments come with a lot of risks and it is therefore concluded that the savings must be very substantial in order to consider this solution. It is also concluded that other supply chain factors can have a huge impact on what distribution setup is the most beneficial, such as price breaks in purchase prices. A few suppliers, especially one, stand for most of the potential cost reductions from direct shipments and it is instead recommended that Sandvik should consider other options to save workload that don't require them to apply direct shipments. In general, the current setup of the distribution network seems very reasonable.

Key words: Supply chain management, distribution, direct shipments, spare parts, distribution modelling, supplier compliance

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List of Abbreviations

3PL	Third-Party Logistics
BA	Business Area
C&S	Crushing and Screening
COO	Country of Origin
DC	Distribution Center
ERP	Enterprise Resource Planning
FCL	Full Container Load
LCL	Less Than Container Load
LTL	Less Than Truck Load
MAD	Mean Absolute Deviation
MOQ	Minimum Order Quantity
RDC	Regional Distribution Center
ROP	Reorder Point
ROQ	Reorder Quantity
RQ	Research Question
SMCL	Sandvik Mining and Constructions Logistics
SMRT	Sandvik Mining and Rock Technology
SMS	Sandvik Machining Solutions
SMT	Sandvik Materials Technology
SS	Safety Stock
TL	Truck Load
VCI	Vapor Corrosion Inhibitor

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Chapter 1

Introduction

This chapter introduces the researched problem and the settings for the research.

1.1 Background

Supply chain management includes both the inbound and the outbound sides of a company's logistical system and typically stretches from the supplier's supplier to the customer's customer and concerns not only the flow of products but also the flow of services, information and financials (Coyle et al. 2016). Distribution is a part of the supply chain and refers to the steps taken to move and store a product from the supplier stage to the customer stage in the supply chain (Chopra and Meindl 2016). Many of the decisions in the supply chain come down to a trade-off of being either responsive or cost-efficient (Chopra and Meindl 2016). The design of the distribution network plays a key role in building an efficient and flexible logistics system (L. Lin et al. 2007). Distribution is further considered a key driver for overall profitability of a company since it directly affects both supply chain costs and customer value (Chopra and Meindl 2016). The most important decisions for distribution are facilities location decisions, inventory management decisions and distribution decisions (Shen and Qi 2007). Changing the distribution network design will affect the costs of three logistical drivers: Facilities, inventory and transportation (Chopra and Meindl 2016).

Direct shipment is a concept within distribution and refers to shipping direct between a supplier and a retailer or customer, in essence meaning without going through a distribution center (L. Lin et al. 2007). The advantage of using direct shipments is the possibility to reduce inventory and material handling at the consolidation terminal, whereas the advantage of non-direct shipment are more consolidated flows (Blumenfeld et al. 1985).

Freight documents controls the cargo from the origin point in the country of export to the final destination in the country of import. The most common freight documents are invoices, export documents, import documents and transportation documents. Missing or incorrect paperwork can cause long delays as well as additional costs. Special documents are also required for dangerous goods (Coyle et al. 2016).

Spare parts typically have special characteristics that impact the distribution. Among them there is typically a large amount of parts with very low and irregular demand (Huiskonen 2001). The variance of the demand can be large, leading to that relatively large quantities of safety stock must be held (Bartholdi III and Hackman 2019). The lead times to replenish parts to the warehouse can usually be quite long which further increases the need to hold safety stock (Huiskonen 2001). Spare parts typically have a different life cycle compared to other products (Bartholdi III and Hackman 2019).

1.2 Company Description

Sandvik AB is a global engineering group headquartered in Sweden that provides industrial products to customers world-wide. They have grown significantly since the founding in 1862 and currently have approximately 42,000 employees and sales in more than 160 countries. 2018 was a record breaking year with sales for the first time exceeding 100 billion SEK in combination with a record-high operating margin (Sandvik 2019).

The organisation is divided into three business areas (BA) called Sandvik Machining Solutions (SMS), Sandvik Mining and Rock Technology (SMRT) and Sandvik Materials Technology (SMT). An overview of the different business areas can be seen in table 1.1.

Table 1.1: Description of the business areas at Sandvik

Business Area	Description
SMS	Provide tools and tooling systems for advanced metal cutting.
SMRT	Provide equipment, tools, service and support to customers in the mining and construction industries.
SMT	Provide products made from advanced stainless steels and special alloys.

Each business area is further divided into divisions. Crushing and Screening (C&S) is one out of nine divisions within SMRT and provides customers in the mining and construction industries with equipment for stone crushing and screening as well as spare parts and wear parts for the aftermarket.

This thesis is carried out in the C&S division for aftermarket spare parts and wear parts and focuses on products within the item classes RP, SF and AU. For an overview of the organisational setting for this thesis, see figure 1.1. The name Sandvik will be referring to this part of the C&S division throughout this thesis.

1.3 Problem Formulation

The distribution of aftermarket products for the C&S division is carried out by Sandvik Mining and Constructions Logistics (SMCL) but inventory control and distribution decisions are in the control of C&S. An overview of the distribution network for aftermarket products can be seen in figure 1.2.

Currently the distribution network comprises of one distribution center (DC) in the Netherlands and five regional distribution centers (RDC) around the world. The DC receives shipments from the suppliers while the five RDCs receive shipments from the DC. Both the DC and the RDCs serve sales areas belonging to their specified region.

Sandvik has a business interest in providing aftermarket products to their customers with sufficient service and in the most efficient way. They have identified that shipping all products through the European DC might not be the most efficient solution due to the fact that every shipment going through a warehouse is causing processing time and driving the warehouse costs. The DC is currently also running out of space. Instead they want to investigate if direct shipments from the suppliers to the RDCs in some cases could be more efficient. By changing the distribution network towards direct shipments from suppliers to RDCs there is a possibility to be

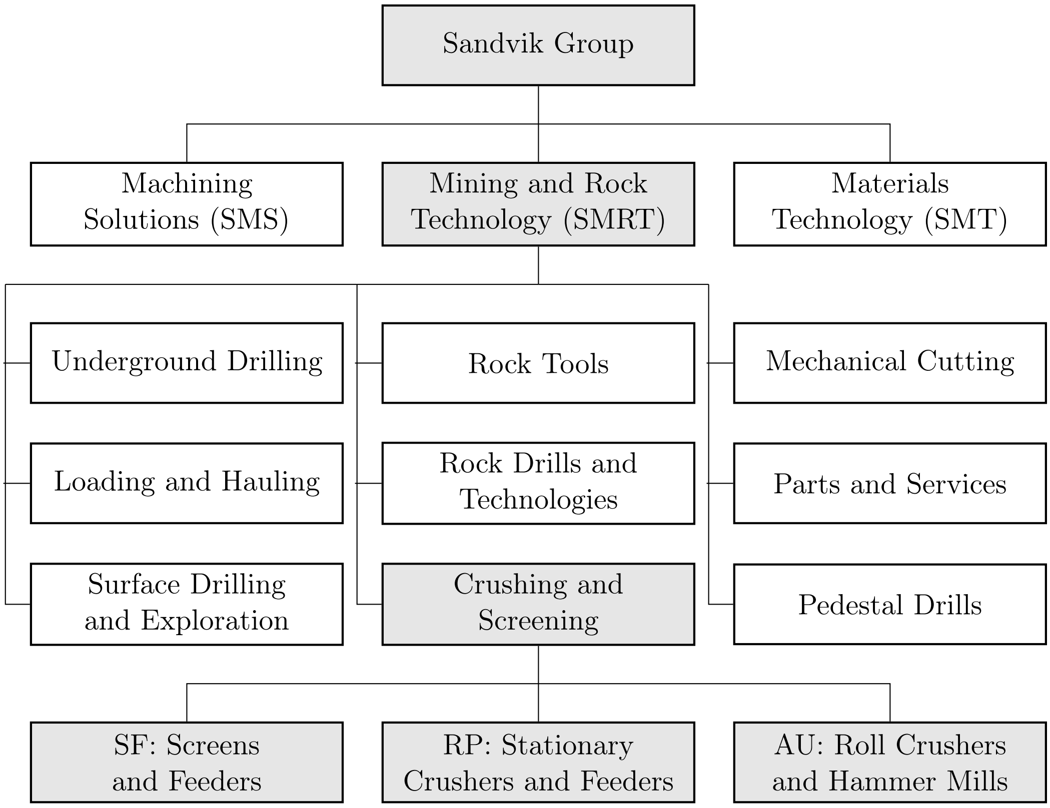

Figure 1.1: Organisational chart of Sandvik

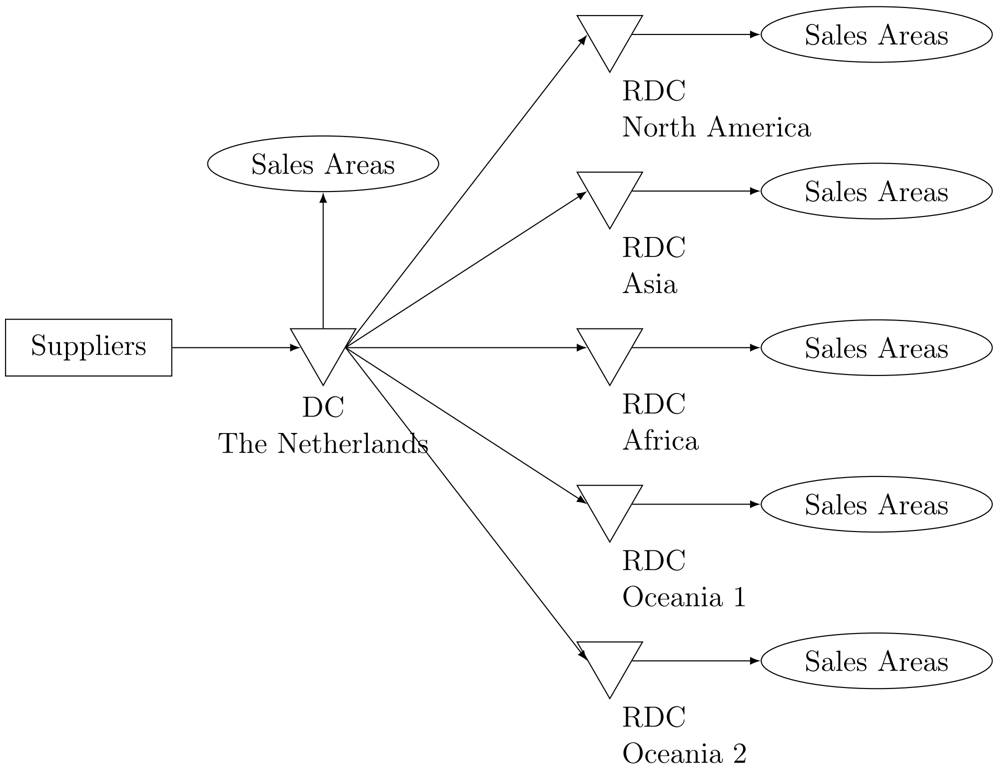

Figure 1.2: Overview of the distribution network

more efficient in terms of warehouse costs although this might affect other costs and factors in the distribution system. Especially the effect on warehousing, transportation and inventory have been identified by Sandvik to be of interest for investigation.

However, even if it cost-wise would be more reasonable to not ship through the DC, Sandvik has noticed other dimensions to this problem. Most of their suppliers are located in Europe and if they were to ship directly to the RDCs around the world this would require them to export the goods instead of shipping it on the European open market. Another dimension is also that the goods are being processed in various ways in the DC and it is unclear to the company if the suppliers can adapt to the needed changes. Sandvik therefore also want to investigate the supplier capabilities for direct shipments. Sandvik has also identified that an alternative to direct shipments from Europe could be to supply the RDCs from local entities of the suppliers since some of their suppliers should be operating globally.

1.4 Purpose

The purpose of this thesis is to investigate the economic consequences and the viability for direct shipments in the distribution network for spare parts at Sandvik.

1.5 Research Questions

The chosen research questions (RQ) in order to fulfill the purpose are:

RQ 1. What factors should be taken into account when deciding the optimal distribution setup for a company shipping spare parts?

This research question is aiming at understanding what factors should be looked in to further researched in order to make a decision about the distribution setup.

RQ 2. When is it more optimal to use direct shipments from suppliers to regional DCs and when is it more optimal to ship through a global DC for a company shipping spare parts?

This research question is aiming at providing a general insight about when it could be beneficial to use direct shipment and how the underlying factors are connected.

RQ 3. What distribution setup is most optimal in the case of Sandvik?

This research question is aiming at providing a recommendation about the certain distribution case at Sandvik in order to fulfill the purpose. The question also aims at providing understanding about what factors lead up the recommendation about the distribution at Sandvik, in order to provide understanding about how the recommendation might change if there is a change in the underlying factors.

1.6 Delimitation and Company Directives

This research project has some delimitations and company directives. The project will only investigate European suppliers that are currently shipping into the DC. In reality this means that the thesis will only consider spare parts since there are currently no European supplier for wear parts that ship into the DC. Sandvik also want to limit the project by focusing the research on a limited number of suppliers as well as not using more than one year of data.

Sandvik want the research project to be in the form of a pre-study, to see if they have a general business case in direct shipments. This project therefore has a reasonable high-level approach in analysing direct shipments and will not look into the trade-off between distribution costs and service levels for individual items in detail. Even though the project should analyse the impacts on inventory costs, the project should not look into changing the inventory stocking policies.

Chapter 2

Methodology

This chapter will present the methodology used when conducting the research project.

2.1 Research Process

The research process can be described as taking the current knowledge about a subject and combining it with collected new data in an analysis. The outcome of the analysis should answer the research questions as well as develop new theory about the subject. For an overview of the research process, see figure 2.1.

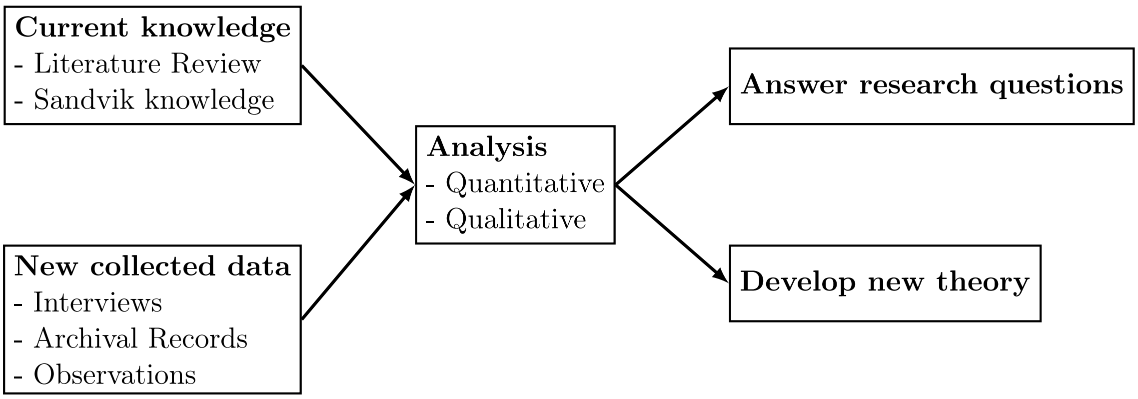

Figure 2.1: Overview of the research process

There exist several different strategies and methods on how to conduct a research project. The chosen one is further explained in section 2.2 Research Strategy. The current knowledge is mostly understood by conducting a literature review which is further explained in section 2.3 Literature Review. How data has been collected in this research project is further explained in section 2.4 Data Collection. The approach to analysing the data is explained in section 2.5 Data Analysis. Another important aspect when conducting a research project is making sure the research is credible. This is further explained in section 2.6 Research Trustworthiness. The final design of this research project is presented in section 2.7 Research Design.

2.2 Research Strategy

There exist several different methods on how to conduct a research project. A method is not in any way a detailed description of what to do or not to do, but rather a help on how to take suitable steps towards more knowledge in the researched question. What method to use depends on the goal and characteristics of the research (Höst et al. 2006). Yin (2014) has identified five major research methods and three conditions on how to select a proper method, see table 2.1.

Table 2.1: Relevant situations for different research methods (Yin 2014)

Method	Form of Research Question	Requires Control of Behavioral Events?	Focuses on Contemporary Events?
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival Analysis	who, what, where, how many, how much?	no	yes/no
History	how, why?	no	no
Case Study	how, why?	no	yes

The case study method is selected as the main research method in this thesis. The reasons for this are that the characteristics of the research questions and the research settings provide a valid ground for this method. Several of the other suggested research methods by Yin (2014) are clearly ruled out as not suitable. In this research project there is no control of behavioral events since the research project does not take place in a laboratory setting. The distribution of spare parts takes place in real life with many different interacting factors that are potentially constantly changing. Even though a mathematical model can be created in order to make analysis, there is no way to clearly control the outcome in real life. Furthermore, this research project focus on contemporary events where it is possible to do a broad collection of information from different sources. According to table 2.1 therefore the experiment and history methods are ruled out while survey, archival analysis and case study could be suitable methods.

The case study methodology aims at building theory from studying a selected case or selected cases. The case study method is chosen since it is a method for deep understanding of a problem and the factors affecting it since research questions typically address the reasons behind a result rather than the result itself, as can be seen in table 2.1. Even though the research questions in this thesis are not explicitly asking "how" or "why", there is an underlying "why" in all research questions since they are aiming to provide in-depth knowledge about what factors contribute to a certain result. Overall the case study method is therefore deemed the most reasonable research method in this case. However, it is important to remember that the research methods are not mutually exclusive and tools from another research methods than the chosen one could be used (Yin 2014).

It is however important to acknowledge that the case study method has several strengths and weaknesses according to Eisenhardt (1989). One important strength is the prominent likelihood that the researcher will develop a novel theory since important insights can arise even though the evidence is contradictory. Another strength is the strong likelihood of having developed a valid theory due to the close link to the evidences during the theory-building process. A clear weakness is that there might be a lack in generality when it comes to applying the theory to other cases.

How to define the case of the study is an important aspect and is also referred to as defining the unit of analysis. This study could on a high level potentially be viewed as a single case study with Sandvik as the unit of analysis or as a multi-case study with each supplier at Sandvik as the unit of analysis. According to Yin (2014) it is important to define the unit of analysis in relation to the research questions. In this research project the research questions are all about the situation at Sandvik, which clearly point towards having Sandvik as the unit of analysis. In detail, the chosen unit of analysis in this case study is the distribution system for spare parts at the C&S division at Sandvik. However, each supplier within this distribution system can also be analysed separately and the suppliers are therefore considered as the embedded unit of analysis.

2.3 Literature Review

Literature review is an important part of the research process and is performed by reviewing what other researchers have concluded about the subject. This is important in order to understand the current knowledge about the subject and make sure that the research is building upon it rather than just replicating it (Höst et al. 2006). It is as well important to consider the literature again after a research result has been reached in order to compare the reached result to results from other research (Eisenhardt 1989). The literature review is overall aiming to provide trustworthiness to the research through this comparison process. It is important to conduct literature review when necessary throughout the whole research process since the researched problem might evolve during the process.

When conducting literature review it is important to start off by doing a broad search in order to get a wide understanding about the subject as well as finding relevant search terms (Höst et al. 2006). After the broad search a more in-depth search should be conducted (Höst et al. 2006). Therefore the literature study in this research project has started with consulting text books that are considered credible in the subject area. By doing this it is possible to get a wider understanding about the domain that this research project is conducted within as well as finding relevant search terms. These search terms have then been used while searching for relevant peer-reviewed articles from different scientific journals. The search has been conducted through the Scopus and LUBSearch databases by searching for the selected search terms and combining them in different ways. For an overview of the used search terms, see table 2.2.

Table 2.2: Used search terms for literature review

chargeable weight	inventory cost
consolidation	inventory holding cost rate
DC	lead time
direct distribution	logistics
direct shipment	RDC
direct shipment from supplier	regional distribution center
distribution center	select products
distribution cost	spare parts
distribution model	transportation cost
distribution network	warehouse cost
distribution strategy	
freight consolidation	

2.4 Data Collection

Evidence in a case study can come from many different data sources (Yin 2014). Both Eisenhardt (1989) and Höst et al. (2006) conclude that the most common ones are interviews, observations, and archival sources. The collected data can typically be seen as either quantitative or qualitative (Eisenhardt 1989). Quantitative data refers to data that is measured in numbers and usually structured and statistical while qualitative data is non-numerical data that is usually non-structured and non-statistical.

Eisenhardt (1989) states that it is important to have a flexible approach to the data collection by overlapping it with the data analysis. This let the researcher start early on with the analysis but also to adapt the data collection to observations in the analysis which is beneficial since it might not be known exactly what data is relevant and needed at the beginning. Yin (2014) put big emphasis on using multiple data sources to be able to create triangulation of data in order to achieve a stronger hypothesis and overall higher research quality. According to Eisenhardt (1989), the combination of quantitative data and qualitative data can be highly synergistic. The strength of quantitative data is that it can provide evidence for an assumed hypothesis as well as provide indication for previously not known relationships in the data. The strength of qualitative data is the ability is provide explanation and understanding of the relationships in the quantitative data.

The data sources that have been used in this thesis are archival records, interviews and observations. Different data sources have been used in order to create as much triangulation as possible. An overview of how the different data sources have been used can be seen in table 2.3. The used data sources are further explained in the sections of this chapter.

Table 2.3: Used data sources

Data Source	Type of Data	Collected Data
Archival Records	Quantitative	ERP system data files, logistics system data, freight rate agreements, performance measurements
Interviews	Qualitative	Information about current operations, how to interpret data, potential problems with different setups etc.
Observations	Qualitative/ Quantitative	Product dimensions, packaging, stackability

In order to constrain the workload, a limited number of suppliers have been selected to be the basis for the research. In total, 12 suppliers have been selected out of over 100 suppliers, while considering the limitation of European suppliers delivering into the DC, as being the most important to analyse through several different measures. First, five suppliers (L) have been selected since they have the biggest numbers of dispatched order lines at the DC going to the RDCs during one year (December 2018 - November 2019). Second, five suppliers (W) have been selected since they have the biggest numbers of dispatched net weight at the DC going to the RDCs during the same time period. Suppliers J and K have been identified through both of these measures. Lastly four suppliers (S) have been selected by Sandvik as being of interest of them to analyse. The supplier E is specially selected since this suppliers is not an external supplier, instead this is an internal supplier being a part of Sandvik SRP in Svedala. Other similar internal suppliers have recently been setup for direct shipments in the distribution network. An overview of the suppliers and their values for the selection criteria can be seen in table 2.4.

In total the selected suppliers represent 50% of the dispatched order lines going to RDCs and 10% of the total number of dispatched order lines at the DC. When it comes to weight, they represent 35% of the dispatched net weight going to RDCs while only 2.9% of the total dispatched net weight at the DC. It is worth noting that several suppliers were disqualified in the selection process, either due to being non-European or that the supplier are no longer handled at the DC. One of these suppliers would have been qualified through dispatched order lines and weight, and the remaining three through dispatched weight.

Table 2.4: Selected suppliers and selection criteria

	SUPPLIER												
	A	B	C	D	E	F	G	H	I	J	K	L	Total
Dispatched order lines	581	168	139	1,010	501	409	324	925	158	1,792	630	274	6,911
Share RDC	4.2%	1.2%	1.0%	7.3%	3.6%	3.0%	2.3%	6.7%	1.1%	13.0%	4.6%	2.0%	50.1%
Share Total	0.9%	0.3%	0.2%	1.5%	0.7%	0.6%	0.5%	1.4%	0.2%	2.7%	0.9%	0.4%	10.3%
Dispatched net weight (tons)	1.95	15.9	46.4	2.56	12.9	46.0	13.9	6.83	9.75	36.5	80.8	11.5	285
Share RDC	0.2%	2.0%	5.7%	0.3%	1.6%	5.7%	1.7%	0.8%	1.2%	4.5%	10.0%	1.4%	35.1%
Share Total	0.0%	0.2%	0.5%	0.0%	0.1%	0.5%	0.1%	0.1%	0.1%	0.4%	0.8%	0.1%	2.9%
Selection Criteria	L	W	W	L	S	W	S	L	S	L/W	L/W	S	

2.4.1 Archival Records

Yin (2014) describes archival records as usually quantitative data and often in the form of computer files. Höst et al. (2006) states that analysis of archival records means going through documentation that has been created for another reason than the research project in question. It is therefore of importance to consider the provenance of the data and to question the accuracy.

In this thesis archival records has been used widely when analysing the current distribution setup. The collected data has been used in order to understand the characteristics of the distribution setup at Sandvik in general such as understanding the shipment flows and product characteristics. It has also been used when developing a model for trade-off analysis between different distribution costs. The records have mainly come from the ERP (Enterprise Resource Planning) system at Sandvik and consist of data files of product information, supplier information, inventory information, sales information and shipment transactions. Information about freight costs has come from a logistics system that Sandvik use as well as freight rate agreements and performance measurements from the carriers.

2.4.2 Interviews

Interviews are considered one of the most important sources of information in a case study (Yin 2014). According to Höst et al. (2006) interviews can be either structured, semi-structured or unstructured. Structured interviews refer to interviews with a well predefined list of questions to be asked, also described as an oral survey. Semi-structured interviews have predefined questions but is allowing for other questions or a change in direction. Unstructured interviews are more like a conversation where the interviewee has a lot of impact on what should be talked about.

In this thesis interviews have been held with employees of various positions as well as external parties in order to understand the research problem from a wide range of perspectives. The reasons for interviews have been to understand how Sandvik are currently operating, provide insights about the archival records as well as retrieve information for the development of a suitable model for cost analysis. Most interviews have been conducted using the semi-structured approach since this secures that the requested information will be collected while allowing for interesting perspectives that have previously not been considered. For a list of conducted interviews, see table 2.5. Throughout the project, follow-up questions and discussions with the listed interviewees have been conducted when questions have emerged.

Table 2.5: List of interviews

Date	Interviewee	Purpose	Structured
2019-10-29	Logistics Specialist A	Warehouse operations	Semi
2019-10-31	Logistics Specialist B	Transportation network and operations	Semi
2019-11-05	Inventory Analyst	Inventory management	Semi
2019-11-27	Inventory Analyst	Inventory modelling	No
2019-11-27	Carrier A	Transport operation and pricing between suppliers and the DC	Semi
2019-11-29	Inventory Manager Supply Chain Specialist	Options for modelling inventory	No
2019-12-13	Purchaser Order Coordinator	Purchasing operations and current direct shipment operations	Semi
2019-12-18	Production Leader	Packaging requirements and shipping procedures	Semi
2020-01-14	Carrier B	Transport operations, document requirements and dangerous goods requirements between the DC and the RDCs	Semi
2020-01-14	Sourcing Engineer A Sourcing Engineer B Sourcing Engineer C	Supplier compliance and pricing structures for products	Semi
2020-01-22	Carrier A	Pricing options for direct distribution	No

Interviews in the form of written surveys have been held with the suppliers in order to understand their capabilities for direct shipments. The survey has been developed after understanding the supplier compliance requirements throughout the literature review and empirical findings and can be found in appendix B. The survey has then been sent out to the 12 suppliers in scope and in case any of the answers has be unclear, follow-up questions have been sent through email. Therefore this survey can be seen as similar to written structured interviews.

2.4.3 Observations

The fact that a case study typically focus on contemporary events opens up a possibility for direct observations which is to directly observe the studied phenomenon by your own senses (Höst et al. 2006). Observations can take place with different levels of interaction where the special situation when the observer is actively interacting can be called participant-observation

(Yin 2014). When performing observations it is important to understand if and how the level of interaction is affecting the observed result. All observations in this thesis have been conducted openly with some level of interaction and there could be a risk that this would have affected the results. However, since mostly physical items have been observed it is hard to believe that the results of these observations would have been affected by the fact that the observations have been done openly. For a list of the conducted observations, see table 2.6.

Table 2.6: List of observations

Date	Observation	Purpose
2019-10-08	Production tour at Sandvik SRP in Svedala	Understanding of the products and production process of the C&S division.
2019-11-28	Product observation at a warehouse at Sandvik SRP in Svedala	Understanding of product characteristics and characteristics of the inbound shipments from suppliers such as packaging and stackability.
2020-01-24	Outbound process at Sandvik SRP in Svedala	Understanding of packaging requirements and characteristics of outbound shipments to the RDCs such as packaging and stackability.

2.5 Data Analysis

In case studies, it is essential to have a clear strategy for the analysis in order to avoid the risk of getting lost in the collected data (Yin 2014). Eisenhardt (1989) states that a key step is the within-case analysis. The idea is to get familiar with each case and finding its unique patterns. The other key step is the cross-case search for patterns, where the patterns of all cases are brought together in order to create generalisations across the cases. By combining the within-case analysis and cross-case search for patterns with an overall impression, it is possible to create concepts and relationships between variables (Eisenhardt 1989). In order to prove these hypothesises, a systematic and iterative approach is needed where the evolving theory is compared to the case data. The idea is to continue this iteration until saturation is reached and the incremental improvement to theory of another iteration is minimal (Eisenhardt 1989).

A big part of the data analysis in this thesis has been to model the cost-trade offs between different distribution costs. First an extensive search for a suitable model in the literature was conducted. Since no suitable model was found, a model was instead developed by using theory from the literature in combination with found characteristics from reality. The model was developed to resemble the situation at Sandvik as close as possible. For a description of the model, see chapter 7. A couple of suitable scenarios were developed and evaluated through the model and the most promising ones were further investigated by sensitivity analysis, see chapters 8-9. A supplier survey was conducted in order to understand the suppliers capabilities for direct shipments. The result from the survey was analysed as part of determine how easy it would be for Sandvik to implement direct shipments, see chapter 10. Also a risk analysis have been conducted in order to understand the risks, see chapter 11.

2.6 Research Trustworthiness

In order for research to achieve credibility and trustworthiness the researcher needs to demonstrate how the used methods follow best-practice of good research (Denscombe 2010). There exist several different criteria for measuring if research follows these practices. Conventional quality criteria typically talks about correspondence and uses four different measurements called internal validity, external validity (also referred to as generalizability), reliability and objectivity. However, these criteria were developed for quantitative research and it is therefore not easy to judge qualitative research by these criteria (Denscombe 2010).

Halldórsson and Aastrup (2003) argue that there has been a general shift in logistic research from a mainly quantitative approach towards more qualitative aspects and therefore it could be beneficial to look into other quality criteria. This is very much along the lines of this thesis, which uses both quantitative and qualitative approaches. Halldórsson and Aastrup (2003) instead suggest the use of trustworthiness as the quality criteria. Trustworthiness uses four measurements called credibility, transferability, dependability and confirmability which all have an equivalent in the conventional quality criteria. Short explanations of these measurements as well as an overview of how these have been used in this thesis can be seen in table 2.7. For more extensive explanations, see the sections of this chapter.

Table 2.7: Components of trustworthiness

Criteria	Description	Approach in This Thesis
Credibility	Data describes reality well	Create triangulation by using different data sources. Interview wide range of stakeholders. Analytic model verified by stakeholders. Analytic model output verified by system data.
Transferability	Possible to apply the research on other cases	Thorough description of the context. Examine the factors driving the result.
Dependability	Consistency in data over time	Openness about model construction. Openness about assumptions. Use transaction data of a full year. Use representational selection for observations.
Confirmability	Absence of bias in research	Ask open questions during interviews. Avoid making assumptions. Clarify uncertainties in the data.

2.6.1 Credibility

Credibility has its conventional equivalent in internal validity which refers to the accuracy and precision of the data (Denscombe 2010). Halldórsson and Aastrup (2003) describe internal validity as the degree of correspondence between study findings and the reality investigated. Credibility is instead established on the notion that there is no single objective reality and defines credibility as matching the different versions of reality with the version of the researcher (Halldórsson and

Aastrup 2003). There is therefore of big importance to get a wide and deep understanding of the studied subject.

In order to increase the credibility in this project, several different types of data sources have been used in order to create triangulation. Especially when it comes to the interviews, a wide range of different stakeholders in this project have been interviewed in order to create a wide understanding of the different aspects of the problem. Furthermore, the built analytic model has been verified by different stakeholders in order to make sure that it gives a reasonable representation of the reality. The output of the analytic model has also been verified towards the system data. Also the fact that the work has been performed at the studied organisation which has allowed for the possibility to ask follow-up questions in order to make clarifications has increased the credibility.

2.6.2 Transferability

Transferability has its conventional equivalent in external validity which refers to that the findings from research should be possible to apply to other examples of the phenomenon (Denscombe 2010). This means that the research should not only explain this certain case but also be applicable and valuable for similar cases in general. External validity usually talks about that the contexts have to be random samples from the same population to be externally valid. Transferability instead assumes that it is never possible to fully generalise and instead puts emphasis on the degree of similarity in the contexts (Halldórsson and Aastrup 2003). It is therefore of big importance to thoroughly describe the context of which the research is conducted under in order for it to be useful in other contexts, which has been done in this thesis. Also the fact that this thesis is examining the factors driving the result instead of just focusing on the result it-self increases the transferability.

2.6.3 Dependability

Dependability has its conventional equivalent in reliability which refers to whether a research instrument is neutral in its effects and consistent across multiple occasions of its use (Denscombe 2010). By this means that there should be stability in the data over time (Halldórsson and Aastrup 2003). Conventional reliability is very sensitive to alterations in methodology, while the concept of dependability allows for changes in methodology in order to adjust for the reality as long as they are possible to track (Halldórsson and Aastrup 2003). It is therefore important to be open with how the methodology has been selected and how it has been changed.

In order to achieve dependability this thesis is open with how the models have been constructed and how they have changed. It is as well open with what assumptions have been made in order to receive the result and what disadvantages this causes. In order to create stability in the data over time, transactions of one full year (December 2018 - November 2019) have been selected and used in the analysis. When selecting products for observation, these have been selected depending on there physical characteristics in order to create a representational picture.

2.6.4 Confirmability

Confirmability has its conventional equivalent in objectivity which refers to absence of bias in the research (Denscombe 2010). This means that the research should not be affected by prejudices of the researcher. The concept of confirmability put emphasis on that the result should be confirmed through the data and that conclusions and recommendations should be possible to be traced back to the data (Halldórsson and Aastrup 2003).

This thesis tries to base the analysis on data as much as possible and tries to avoid making assumptions. As well it always presents the origin of the data used in the analysis. Open questions have been asked during interviews in order to really capture the view of the interviewee and to reduce the bias. Also, whenever anything in either quantitative or qualitative data has been unclear, questions about it have been asked in order to avoid making prejudiced conclusions.

2.7 Research Design

The research project has been designed while considering the stated case methodology. For an overview of the selected research design, see figure 2.2. First of all an initial data collection is performed in order to understand the problem. The next step is to develop a mathematical cost model. The development of the cost model is an iterative process performed together with data collection, data analysis and literature review. The data analysis is performed in order to discover factors that have impact on the costs in order to be able to include those factors in the cost model. When the cost model is fully developed, the research takes two different paths. The first path is to define and select scenarios to be analysed. The scenarios are analysed in an iterative process by using the developed cost model together with sensitivity analysis and risk analysis. The other path is the supplier survey which are constructed and sent out to the suppliers. These two different paths then leads to the result where recommendations and conclusions of the researched problem is reached.

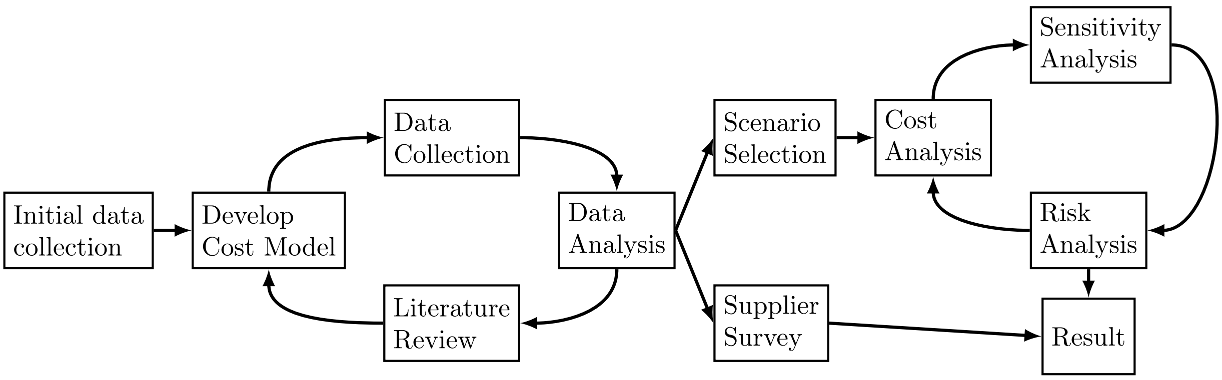

Figure 2.2: Research design

Chapter 3

Frame of References

There are several different areas of knowledge that are researched in order to understand what is currently known about the direct distribution. First it is of essence to understand the general concept of distribution as well as the special distribution act of direct shipments. Since the act of distribution takes places as a part of a supply chain it is also of importance to understand essential supply chain management theories. By doing this it is possible to make connections between how the distribution is operating and the supply chain as a whole.

It is also of importance to understand the considered functions of the distribution network, which are transportation, warehousing and inventory management. For all three of these functions it is important to understand how they contribute to the cost of distribution. Some specific subjects relevant for this thesis are also investigated such as freight documentation, warehousing operations and inventory control.

At last, some very specific knowledge areas need to be investigated for this thesis. Since the thesis takes place in a spare parts setting, this setting is investigated. A purpose of the thesis is also to model trade-offs between different distribution costs with regard to direct shipment, therefore previously developed models for this purpose are searched for.

An overview of the different researched topics can be seen in figure 3.1.

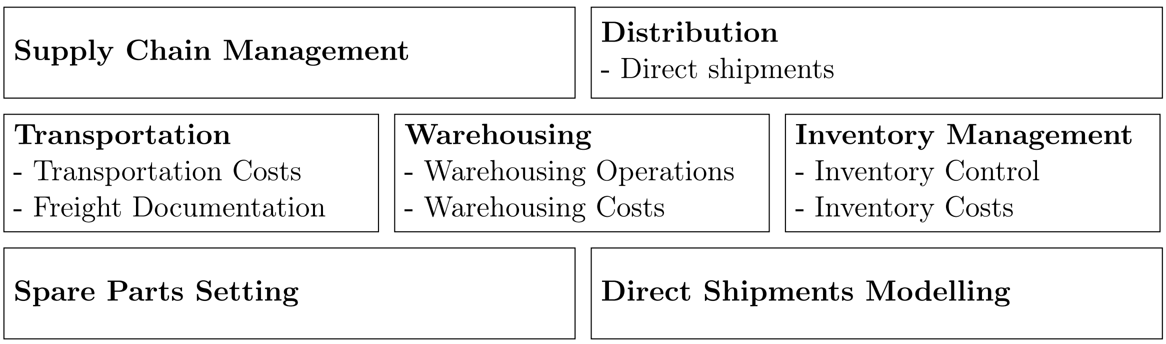

Figure 3.1: Researched topics

3.1 Supply Chain Management

The supply chain management concept has been around since the 1990s and was according to Coyle et al. (2016) developed from the previous known concept of physical distribution management which focused on the outbound side of a company's logistical system. The typical focus of physical distribution management was on system costs and trade-offs with regards to transportation, inventory levels, warehousing, protective packaging, materials handling and customer service. Supply chain management includes also the inbound side of a company's logistical system and typically stretches from the supplier's supplier to the customer's customer and concerns not only the flow of products but also the flow of services, information and financials (Coyle et al. 2016). Bozarth and Handfield (2013) describe the supply chain as the linkages between a company and its suppliers, distributors and customers. The linkages can consist of physical flows, information flows and monetary flows. According to Chopra and Meindl (2016), a supply chain consist of all parties involved in fulfilling a customer request, all the way from the manufacturer to the end customer.

How the fulfilling of a customer request is performed in a supply chain is very much dependant on how the supply chain is designed and the strategies behind it. Chopra and Meindl (2016) talk about the importance of achieving strategic fit. The meaning of this is to first understand the customers and their needs as well as understanding the capabilities of a certain supply chain design. The strategic fit is then achieved by developing a competitive strategy that matches the insights and making sure that the supply chain is designed to match the strategy. In a similar way Bozarth and Handfield (2013) state that the ultimate goal for any company is to develop a supply chain strategy that supports the business strategy.

In order to understand the capabilities of a certain supply chain design it is of importance to consider performance measurements. Bozarth and Handfield (2013) talk about four important performance dimensions for measurement: Quality, time, flexibility and cost. For explanations of these dimensions and examples of performance indicators, see table 3.1. The same performance dimensions are as well considered by Jonsson and Mattsson (2011) even though they consider capital cost as separate from other costs and also mention environmental sustainability as a performance dimension.

Table 3.1: Performance dimensions and performance indicators (Bozarth and Handfield 2013)

Performance Dimension	Description	Performance Indicators
Quality	Does the quality of the product satisfy the customer needs?	Performance quality Conformance quality Reliability quality
Time	Does the product arrive when it is needed?	Delivery speed Delivery reliability
Flexibility	Can the supply chain respond to the unique needs of different customers?	Mix flexibility Changeover flexibility Volume flexibility
Cost	Can the customer get the product at the desired cost?	Product cost Delivery cost

When it comes to supply chain strategy, Chopra and Meindl (2016) describe it mainly as a trade-off between responsiveness and cost efficiency. Responsiveness could in this case be seen as the combination of the performance dimensions quality, time and flexibility. This trade-off can be plotted in a cost-responsiveness diagram such as figure 3.2 together with the efficient frontier which shows the lowest possible cost for a given level of responsiveness. According to Chopra and Meindl (2016), only companies that perform at the cost-responsive efficient frontier achieve strategic fit and will be successful in the long run. It is however important to note that the efficient frontier shifts whenever companies are outperforming it.

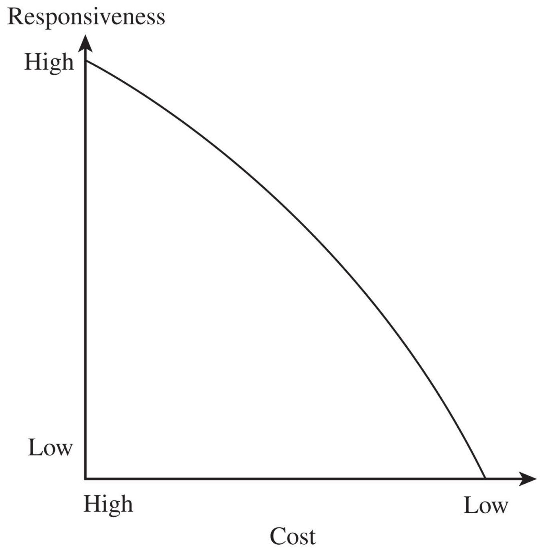

Figure 3.2: The cost-responsive efficient frontier (Chopra and Meindl 2016)

In order to develop a suitable supply chain strategy it is important to understand the trade-offs between the different performance dimensions, especially since their importance can vary for different products and different markets. Both Bozarth and Handfield (2013) and Jonsson and Mattsson (2011) suggest considering order winners and order qualifiers as a good way to understand this trade-off. This concept is basically a way to differentiate the importance of the performance dimensions and understanding what the customers think are most important. Order qualifiers are minimum requirements that must be fulfilled in order to get a customer order while order winners are the competitive dimensions considered after the minimum requirements are fulfilled. For example an order qualifier might be "very good quality", then all companies that qualify will compete through the rest of the dimensions (Bozarth and Handfield 2013).

According to Chopra and Meindl (2016), the supply chain performance in terms of responsiveness and efficiency depends on the interaction between three logistical drivers and three cross-functional drivers which can be seen in figure 3.3. The structure and decisions regarding one of the factors will affect all the other drivers as well as the supply chain performance.

The three logistical driver are facilities, inventory and transportation. These are the ones that actually make a product move through the supply chain. Facilities refer to physical sites where products are typically manufactured or stored. Inventory refers to policies about how inventory are built, while transportation refers to the shipments of products. The responsiveness is typically increased by an increased number of facilities, increased inventory or by faster mode of transportation. The cross-functional drivers are information, sourcing and pricing. Information refers to the information needed in the supply chain to be able to perform more responsively as well as more efficiently, while sourcing refers to the choice of who to perform a certain supply chain activity. Sourcing can take place in the procurement of products as well as in logistics, where a typical sourcing decision in logistics is weather to perform the operations in-house or outsource it to a third-party logistics provider (3PL) (Chopra and Meindl 2016). Pricing refers to what products and services are offered to the customers and for what price.

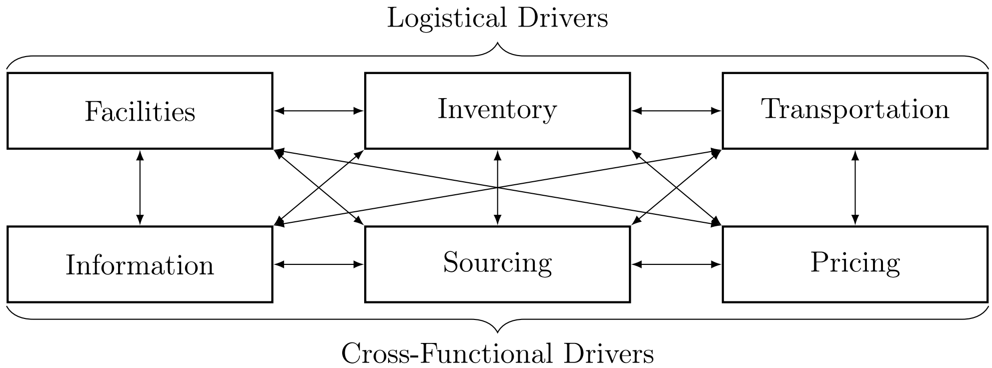

Figure 3.3: Supply chain drivers (Chopra and Meindl 2016)

3.2 Distribution

Distribution refers to the steps taken to move and store a product from the supplier stage to the customer stage in the supply chain (Chopra and Meindl 2016). According to Moretti (2019) distribution refers to how products or services flow through distribution channels in order to reach the end-users. A distribution channel is here defined as the path which products or services take on the way from the manufacturer to the consumers and is composed by the set of involved interdependent organisations. An example of a distribution network can be seen in figure 3.4.

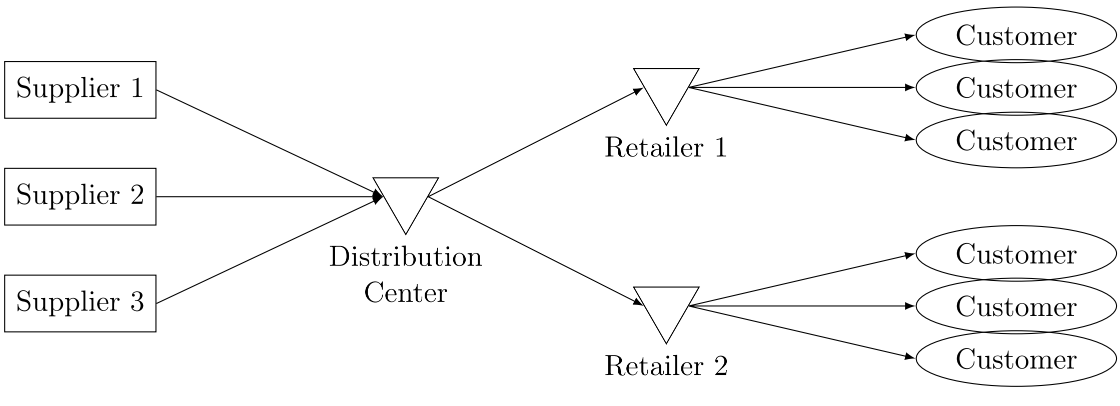

Figure 3.4: Example of a distribution network

Changing the distribution network design will affect the performance and costs of the supply chain. Distribution is considered a key driver for overall profitability of a company since it directly affects both supply chain costs and customer value (Chopra and Meindl 2016). L. Lin et al. (2007) state that the logistics network design plays a key role in building an efficient and flexible logistics system. According to Chopra and Meindl (2016), the performance of the distribution network should be evaluated along the two dimensions of value provided to the customer and the cost of meeting customer needs. It is further suggested that the customer value should be measured by the following factors that are influenced by the structure of the distribution network: Response time, products variety, product availability, customer experience, time to market, order visibility and returnability. Changing the distribution network design will affect the costs of four out of the six supply chain drivers (Chopra and Meindl 2016) and these should therefore be considered. The affected drivers are all three of the logistical drivers: Facilities, inventory and transportation. Also one of the cross-functional drivers is affected: Information. Shen and Qi (2007) state that the most important decisions for distribution are facilities location decisions, inventory management decisions and distribution decisions. When designing the distribution network there are typically two kind of risks that have to be considered. The first is the risk of bad coordination of supply and demand. The second is the risk of events such as natural disasters, economic disruption, political situation, labor disputes or terrorist attacks (Ouhimmou et al. 2019).

3.2.1 Direct Shipments

In order to understand the subject of direct shipments it is important to understand the definition of the concept. Blumenfeld et al. (1985) see direct shipment as a shipment from an origin to a destination that is not shipped through a consolidation terminal such as a warehouse or cross-dock facility. A graphical overview of this interpretation can be seen in figure 3.5.

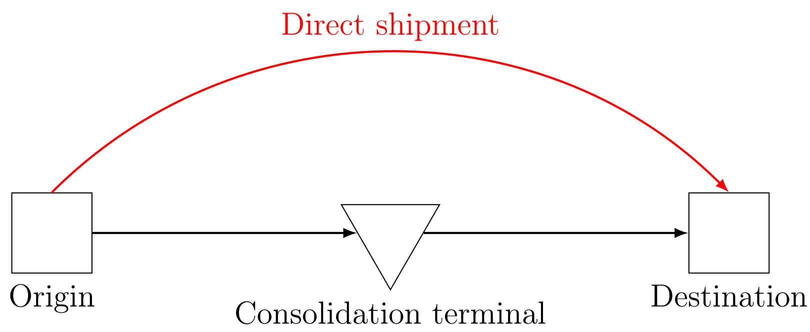

Figure 3.5: Definition of direct shipment according to Blumenfeld et al. (1985)

Bozarth and Handfield (2013) talk about direct truck shipment as a shipment with no stops, no changing of trucks and loading of additional cargo. L. Lin et al. (2007) differentiate between the terms direct shipment and direct delivery. Direct shipment refers to shipping direct between a supplier and a retailer or customer, in essence meaning without going through a distribution center. Direct delivery on the other hand refers to shipping directly from a distribution center to the customer, bypassing the retailer.

The advantage of using direct shipments is the possibility to reduce inventory and material handling at the consolidation terminal, whereas the advantage of non-direct shipment are more consolidated flows (Blumenfeld et al. 1985). L. Lin et al. (2007) states that direct shipments can increase the flexibility in a distribution network since the distance between the supplier and the customer can be reduced, leading to shorter delivery times. Blumenfeld et al. (1985) state that the most cost-efficient solution is always to either ship all demand of a product direct or all demand via a consolidation point. It is never the most cost-efficient to ship some demand direct and some via consolidation. Products that are shipped directly from suppliers are typically fast turning, high velocity and high-demand items (Zhi and Keskin 2018).

3.3 Transportation

Transportation refers to the movement of goods from one location to another (Chopra and Meindl 2016) and is one of the two major parts that represent the physical flow of goods through a logistics system (Bozarth and Handfield 2013). Transportation can be seen as the links that connect the nodes in a distribution network, where the nodes can be suppliers, customers or different types of intermediate gateways such as warehouses. Goods are normally brought together to larger consignments during transportation, a process called consolidation (Lumsden 2007). The size of the consignment can vary and decides how the goods can be transported. The load carrier for consolidation can vary and for example be a box, a pallet, a container or a truck. The consolidation process can be performed either by the goods owner or by a transportation company such as a carrier or a freight agent.

There exist five widely recognized modes of transport which are road, rail, water, air and pipeline (Bozarth and Handfield 2013; Coyle et al. 2016). The use of more than one mode of transport in order to move a shipment to its destination is referred to as intermodal transportation (Chopra and Meindl 2016; Coyle et al. 2016). The use of intermodal transportation has grown considerably after the development of shipping containers since the containers provide a solution for easy transfer between different transportation modes without having to reload the actual goods (Chopra and Meindl 2016). Direct deliveries strive for reducing the handling of goods, hence container transportation can be seen as a comparable option to direct deliveries when using intermodal transportation (Lumsden 2007).

3.3.1 Transportation Costs

The prices for transportation are set by the carrier and are typically quoted as prices per kg between different destinations(Coyle et al. 2016). The prices typically vary depending on the distances between the origins and the destinations (Coyle et al. 2016) as well as on how balanced the inbound and outbound goods flows are (Chopra and Meindl 2016). Despite this standard procedure in setting rates there exists a myriad of different rate forms. Carriers generally have certain fixed costs for each shipment and many of the rate forms have been developed by taking into account that shipping additional units or weight will not lead to additional fixed costs (Coyle et al. 2016).

One common rate form is the differentiation between less-than-truckload (LTL) and truckload (TL) rates. A full truckload being shipped requires less handling by the carrier and therefore the price per kg is lower (Bozarth and Handfield 2013; Chopra and Meindl 2016). For container transportation at sea the equivalent rate forms are less-than-container-load (LCL) and full-container-load (FCL) (Lumsden 2007). Another common rate form is called incentive rates which is inducing the shipper to load the existing load carrier more fully (Coyle et al. 2016). In practice this rate form means that the price per kg will be reduced by an increased shipment load.

3.3.2 Freight Documentation

Freight documents controls the cargo from the origin point in the country of export to the final destination in the country of import and since the documentation requirements are governed by the importing and exporting countries and may vary widely depending on the origin and destination of the shipment. Missing or incorrect paperwork can cause long delays as well as additional costs (Coyle et al. 2016). Coyle et al. (2016) further talks about four main types of documents for international cargo: invoices, export documents, import documents and transportation documents.

The most common type of invoice is called commercial invoice and is often used by governments when assessing customs duties. According to Coyle et al. (2016) the commercial invoice must contain descriptions, quantities, value and country of origin of the products. Furthermore it should also contain Incoterms, payment terms, and currency as well as details of involved parties in the shipment such as buyer, seller, shipment origin and shipment destination. Export documents can be required by the exporting country in order to collect statistics and to control the outflow of strategic products such as military items telecommunication equipment as well as national treasury (Coyle et al. 2016). Importing documents can be required by the importing country in order to limit products that the importing country finds inappropriate. An import document often required by customs is the Certificate of Origin (COO) which is an international trade document attesting the origin of the of the goods.

The disruption-free flow of goods depends upon the availability of key transportation documents. Typically a carrier will not accept goods unaccompanied by accurate documents since it is otherwise hard for them to create an accurate freight manifest (Coyle et al. 2016). A key transportation document is the packing list, which is a detailed inventory of the contents of a shipment. According to Coyle et al. (2016) it should contain, seller, buyer, shipper, invoice number, date of shipment, mode of transport, carrier, item quantities and descriptions, package types and quantities, net and gross weight, package marks and dimensions. Special documents are also required for dangerous goods (Coyle et al. 2016).

3.4 Warehousing

Warehousing is the second of the two major parts that represent the physical flow of goods through a logistics system. It represents any operation that stores, repackages, stages, sorts or centralises goods (Bozarth and Handfield 2013). Typically it plays a critical role in companies' logistics success (de Koster et al. 2007). Warehousing is an expensive function requiring labor, capital and information systems (Bartholdi III and Hackman 2019). Bozarth and Handfield (2013) have identified four reasons how warehousing can create value in a distribution network despite these expenses. An overview of these reasons can be found in table 3.2.

Table 3.2: Reasons for warehousing

Warehouse Reason	Description
Reduce transportation costs	Larger and fewer shipments by reducing the number of transportation links.
Improve operational flexibility	Postpone final assembly or packaging by combining the warehouse with light manufacturing.
Shorten customer lead times	Hold stock closer to the customer in order to shorten the lead time.
Lower inventory-related costs	Reduce overall stock by using inventory-pooling in a common warehouse.

A warehouse has the ability to reduce transportation costs by reducing the amount of needed links in a distribution network, generating larger shipments and therefore exploiting economies of scale in transportation through consolidation (Bozarth and Handfield 2013). The idea is that instead of having X senders shipping directly to Y recipients which needs $X * Y$ transportation links, the goods can be shipped via a warehouse leading to a total need of $X + Y$ transportation links (Bartholdi III and Hackman 2019). An illustrated example with 5 senders and 3 recipients can be seen in figure 3.6.

A warehouse can improve the operational flexibility by combining the warehouse with light manufacturing (Bozarth and Handfield 2013). By doing this the warehouse can store one generic

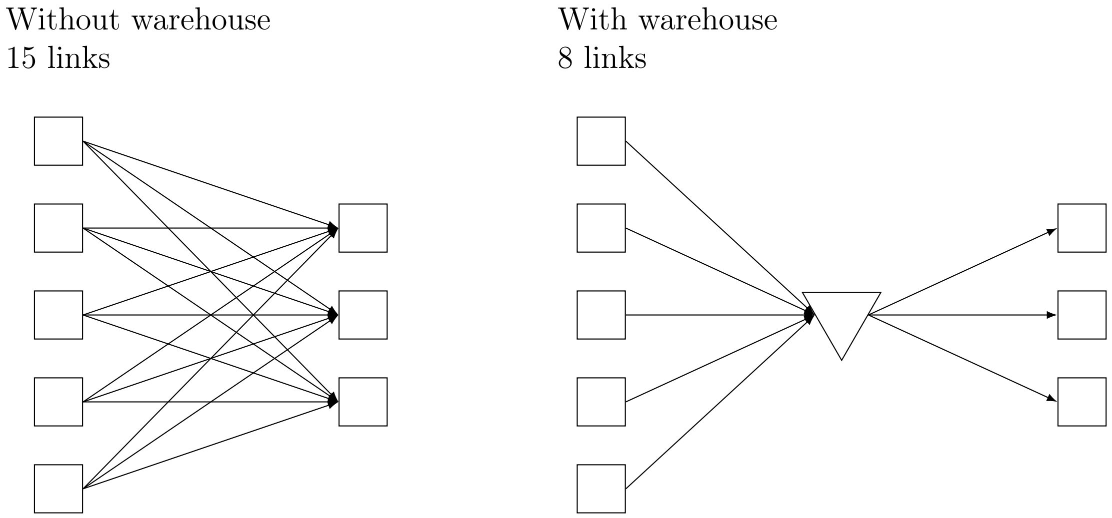

Figure 3.6: How a warehouse reduces the number of needed transportation links

version of the product instead of several customised versions. The product will be customised by for example branding and packaging it according to the customer needs whenever shipped out or further down the distribution chain.

A warehouse can also shorten the customer lead time by stocking a product beforehand of a customer order (Bozarth and Handfield 2013). By doing this the customer only has to wait during the lead time from the warehouse to the customer and not during the supplier lead time. The closer the warehouse is located to the customer, the shorter the customer will have to wait. The use of a warehouse to shorten the customer lead times is most attractive when the distances and lead times between the originating source and the customers are long and when the customers emphasize high availability or quick delivery (Bozarth and Handfield 2013).

Adding a central warehouse can also have the ability to lower the inventory-related costs. By having a common safety stock for several warehouses, the total stock level can be reduced due to a concept called inventory pooling (Bozarth and Handfield 2013). Since safety stock is held to hedge against uncertainty in supply and demand, which is affected by a stochastic process, this concept can reduce the total amount of needed safety stock. Inventory pooling is further discussed in section 3.5 Inventory Management.

3.4.1 Warehousing Operations

The operations at a warehouse can be seen as a flow of products going through different common processes (Bartholdi III and Hackman 2019). An overview of these processes can be seen in figure 3.7.

Figure 3.7: Operation processes in a warehouse

The warehouse operations start with the inbound processes where the goods first of all are received. During the receiving process the goods are inspected and controlled for damage, incorrect counts and wrong descriptions etc. The goods are then put-away to an appropriate location for storage (Bartholdi III and Hackman 2019).

After the warehouse has received an order of a product, the outbound processes start. The order lines of the order is transferred into one or several pick lists, potentially combined with order lines from other orders. These pick lists are then used by the warehouse workers to collect the products from the storage locations and bring them to the pack and ship area. During the packing process the products are usually consolidated as much as possible, by for example packing them in the same box and on the same pallet in order to save on transportation charges. After the packing is done the goods are shipped out (Bartholdi III and Hackman 2019).

A warehouse might also handle returns and perform value-added processing which could be labeling, monogramming, repackaging and kitting (Bartholdi III and Hackman 2019). A special form of warehousing is cross-docking, where the received products are transferred directly to the shipping docks and no storage takes place (de Koster et al. 2007).

3.4.2 Warehousing Costs

According to Bartholdi III and Hackman (2019) the management of an existing warehouse is all about managing the expensive resources of space and labor. They further state that most of the expense in a typical warehouse is in labor. According to Frazelle (1996) the warehouse process that is the most labor intensive is the order picking. The cost of order picking is estimated to be as much as 55% of the total warehouse operating expense (de Koster et al. 2007).

3.5 Inventory Management

The existence of inventory in a supply chain can basically be explained as a mismatch in supply and demand (Chopra and Meindl 2016). The reason for holding inventory can be as a result of trying to bridge the mismatch in supply and demand of external factors but it can also be in order to exploit economies of scale for the own organisation such as that ordering in bigger quantities could lower both the purchase price as well as the transportation cost per item. Even though inventory is intentionally created in order to increase the revenue or reduce the costs, inventory in itself also drives cost. The reason for this is that inventory ties up space and capital (Bozarth and Handfield 2013). Inventory needs to be physically stored somewhere which generates a cost for warehouse storage. The tied up capital could instead have been invested and therefore generates an opportunity cost of capital. Holding inventory also bears a risk for the company since inventory is typically built on forecasts which could potentially be wrong and lead to holding inventory for a longer period than anticipated. A stored product could also potentially become obsolete and depreciate in value (Bozarth and Handfield 2013). In the end, the different inventory decisions come down to the supply chain trade-off between responsiveness and efficiency (Chopra and Meindl 2016).

Inventory can be classified into six different types according to Bozarth and Handfield (2013). These are further explained in table 3.3. Bozarth and Handfield (2013) have also identified four different inventory drivers. For descriptions of the inventory drivers and how they are connected to the inventory types, see table 3.4.

There are several ways for a business to reduce their need for holding inventory. A business can for example reduce their need to hold anticipation inventory by reducing the lead times or by persuading customers to wait longer (Bozarth and Handfield 2013). If the lead time decreases

Table 3.3: Inventory types

Inventory Type	Description
Cycle stock	Products received in bulk, gradually used up and then replenished in bulk.
Safety stock	Protection against uncertainties in demand or replenishment lead time.
Anticipation inventory	Held in anticipation of customer demand.
Hedge inventory	Hedge against potential future events such as labor strikes, price increments etc. Special form of safety stock.
Transportation inventory	Moving from one link to another in the supply chain.
Smoothing inventory	Smooth out differences between upstream production levels and downstream demand.

Table 3.4: Inventory drivers and the impact on inventory types (Bozarth and Handfield 2013)

Inventory Driver	Inventory Type Impact
Uncertainty in supply or demand.	Safety stock, Hedge inventory
Mismatch between a downstream partner's demand and the most efficient production or shipment volumes for an upstream partner.	Cycle stock
Mismatch between downstream demand levels and upstream production capacities.	Smoothing inventory
Mismatch between timing of customer demand and supply chain lead times.	Anticipation inventory, Transportation inventory

by a factor k, the required safety inventory decreases by a factor of $\sqrt{k}$ (Chopra and Meindl 2016). By reducing the transportation lead time, the transportation inventory can be reduced as well. When it comes to safety stock there are large potential benefits of reducing the lead time variability (Chopra and Meindl 2016). Bozarth and Handfield (2013) state that a longer average lead time exposes the company to the lead time variability during a longer period.

Another important factor for inventory reduction when it comes to safety stock is inventory pooling, also called inventory aggregation. Aggregating demand for a product at fewer spots in the supply chain cause more accurate forecasts which leads to lower coefficients of variation and the result is a reduced need for safety inventory (Chopra and Meindl 2016). How big the effect of inventory aggregation can be on the inventory costs depends on several factors. The safety inventory savings of aggregation increase with the desired cycle service level (CSL), the replenishment lead time, the holding cost and the coefficient of variation. The coefficient of variation is typically high for slow-moving product while typically low for fast-moving products (Chopra and Meindl 2016). The coefficient of variation further depends on the demand correlations at the different sites, meaning that products with uncorrelated demand cause greater savings (Chopra and

Meindl 2016). The reduction of inventory from aggregation is most significant for low-demand items with high uncertainty (Chopra and Meindl 2016). A classic strategy to reduce the risk of increased inventories is therefore to centralise the inventory of unpredictable high-value product while predictable low-value products can be stored closer to the customers in order to provide good service (Chopra and Sodhi 2004).

3.5.1 Inventory Control

Inventories are controlled by setting up rules for when to order and how much to order, where the most common rule is called the (R,Q)-policy (Axsäter 2006). The R can also be denoted ROP and means reorder point, while the Q can also be denoted ROQ and means reorder quantity. The (R,Q)-policy works such as when the inventory position falls to or below the reorder point R, a batch quantity of Q is ordered (or several batches of Q if needed to get the inventory position above R) (Axsäter 2006). Directly after the ordering of an item, the inventory position increases above R. However, the inventory level is not directly increased since it usually takes a certain amount of time, called replenishment lead time L, before the item arrives in stock. It is important to keep the definitions of inventory position and inventory level apart. The definitions according to Axsäter (2006) are the following:

$$inventory\ position = stock\ on\ hand + outstanding\ orders - backorders$$

$$inventory\ level = stock\ on\ hand - backorders$$

The values of Q and R can be determined in many ways. The most well known way to determine the Q value is by using the economic order quantity formula which determines an optimal Q^* value with regard to holding cost (h, per unit and time unit), fixed ordering cost (A, per order) and demand (d, per time unit).

$$Q^* = \sqrt{2Ad/h}$$

(Axsäter 2006; Bozarth and Handfield 2013)

For an item that always should be in stock, the R value should in an ideal world equal the demand during lead time dL (Bozarth and Handfield 2013). This will lead to a situation where orders are always received instantly whenever the inventory level becomes zero. Most often this ideal world does not exist and the demand during lead time will vary depending on both the demand and the lead time. In order to manage this situation the demand during lead time is calculated by using average values of demand and lead time, and then a certain level of safety stock (SS) is held in order to increase the customer service for the situations when the demand or lead time is above average. A graphic overview of an inventory modelling system with (R,Q)-policy and safety stock can be seen in figure 3.8. The average inventory level in this system can be calculated according to the following expression, under the condition of non-negative safety stock.

$$average\ inventory\ level = SS + Q/2 \ , \quad SS \geq 0$$

(Axsäter 2006)

The decision of how much safety stock to hold depends on five factors according to Bozarth and Handfield (2013): The average demand and the average lead time, the variability of demand and the variability of lead time, and the desired service level. In order to statistically calculate

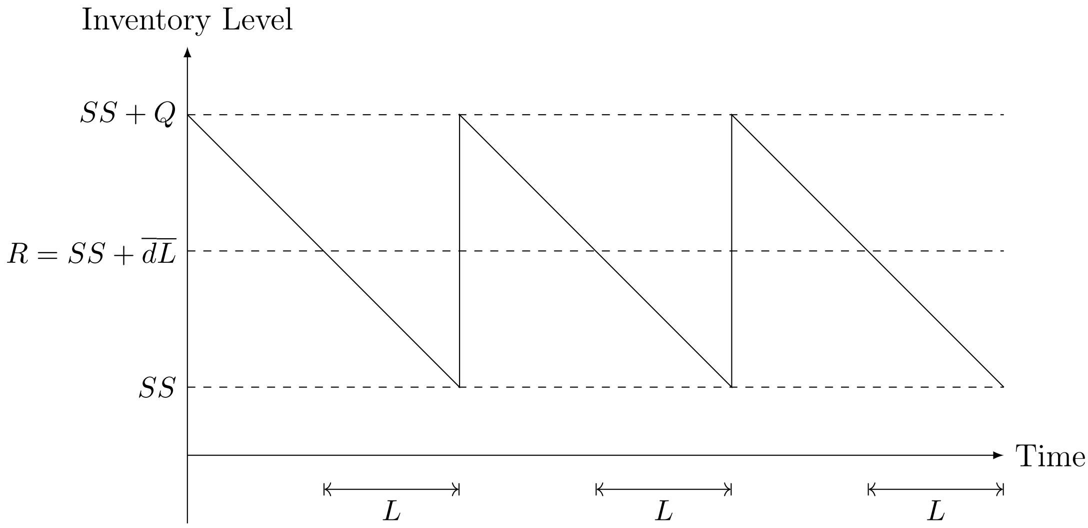

Figure 3.8: Inventory modelling system with (R,Q)-policy and safety stock

the desired level of safety stock, an assumption must be made about the statistical distribution of demand during lead time. Most common is to assume that the demand during lead time is normally distributed. The reasons for this are that this distribution is usually a good estimation of the reality and also that it does not require any extensive calculations. However the assumption of normal distribution only works well when the demand during lead time is quite high, otherwise the likelihood of having negative demand will typically be way to high compared to the reality and this issue can cause too much impact on the model (Axsäter 2006). The factors for safety stock and how they are typically measured can be seen in table 3.5.

Table 3.5: Factors for safety stock decision

Factor	Denotation	Description
Average demand	$\overline{d}$	Average demand per time period
Variability of demand	σ_d	Variance of demand per time period
Average lead time	$\overline{L}$	Average lead time
Variability of lead time	σ_L	Variance of lead time
Desired service level	z	Number of standard deviations above the average demand during lead time

The safety stock and the value of R can be calculated from these factors by using the following expressions.

$$SS = z\sqrt{\overline{L}\sigma_d^2 + \overline{d}^2\sigma_L^2}$$

$$R = \overline{dL} + z\sqrt{\overline{L}\sigma_d^2 + \overline{d}^2\sigma_L^2}$$

(Bozarth and Handfield 2013)

When implementing an inventory control systems in a real life setting, the average demand per time period for the future is typically estimated by using a forecasting model that takes the historical demand into account such as moving average or exponential smoothing (Axsäter 2006). The demand variation for the future is typically estimated by calculating how much the historical forecasts has typically deviated from the demand by measuring the standard deviation or the Mean Absolute Deviation (MAD) (Axsäter 2006). MAD can be converted to variance by using the following expression.

$$\sigma_d = \sqrt{\pi/2} * MAD$$

(Axsäter 2006)

Average lead times for the future are usually manually set and are in practice often assumed to be fixed (Bozarth and Handfield 2013), causing the σ_L to have a value of 0. The service level is a management decision of how much stock outs that could be tolerated (Bozarth and Handfield 2013).

A special version of the system in figure 3.8 is the situation of "negative safety stock". This system would in real life correspond to a situation where the lead time demand on average is larger than the reorder point and where back orders are issued whenever demand occur and there is no inventory. When the replenishment order is received, the back orders are fulfilled and the remaining replenishment order quantity are put in inventory. The fraction of demand that is back ordered can be denoted x. In analogy this also means that the fraction of the replenishment order quantity that serves back orders is x and the ratio of time with no inventory on hand is x. A graphic overview of an inventory modelling system with (R,Q)-policy, no safety stock and with back ordering can be seen in figure 3.9. The average inventory level of this system can be calculated according to the following expression.

$$average\ inventory\ level = Q(1-x)^2/2 \quad , \quad 0 \leq x \leq 1$$

(Axsäter 2006)

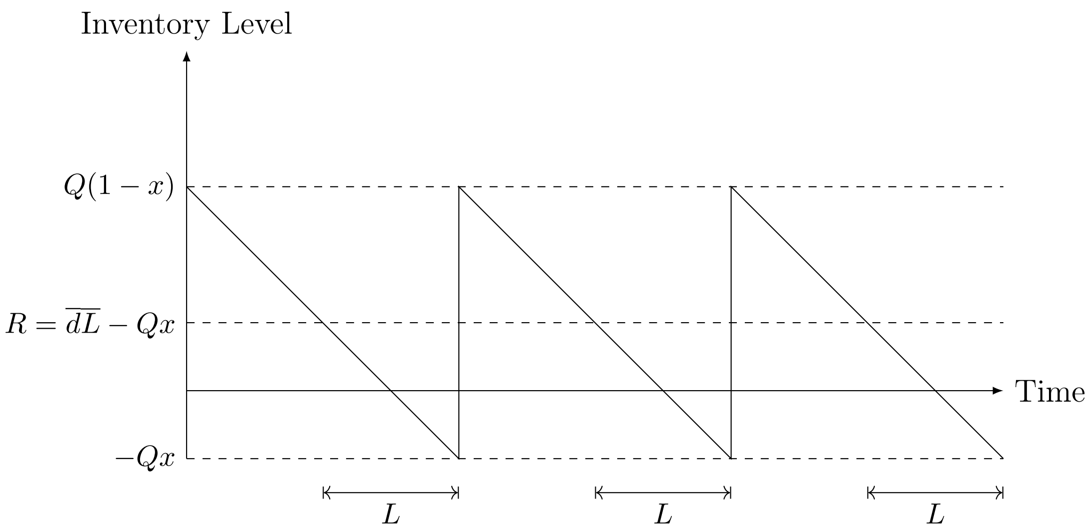

Figure 3.9: Inventory modelling system with (R,Q)-policy and back ordering

3.5.2 Inventory Costs

For the purpose of inventory modelling, the cost for holding inventory is typically set as a percentage rate for carrying some value of inventory per year (Chopra and Meindl 2016). The holding cost per product and year is achieved by multiplying this holding cost rate with the product price. The reasoning behind this cost calculation is that the capital cost is usually regarded to be the dominating part of the holding cost (Axsäter 2006; Silver et al. 1998). Axsäter (2006) further states that other parts included in the holding cost can be material handling, storage, damage and obsolescence, insurance, and taxes. Lambert (1975) has defined four major categories of costs that should be considered: Capital costs such as the costs for inventory investments and asset investments, inventory service costs such as taxes and insurance, storage space cost and inventory risk costs such as the costs for obsolescence, damage and relocation.

It can be hard to determine a reasonable level of the inventory holding cost rate. All costs that are variable with the inventory level should be included according to Axsäter (2006). In general, the percentage should be considerably higher than the interest rate charged by the bank (Axsäter 2006). Lambert (1975) has calculated the inventory holding cost for six companies arriving at holding cost rates stretching from 14% to 35% with an average of 28%. Berling (2019) states that the value of 25% has been promoted by several researchers.

3.6 Spare Part Setting

A major special characteristics of spare parts is that among them there is typically a large amount of parts with very low and irregular demand (Huiskonen 2001). Bartholdi III and Hackman (2019) state that the demand for any particular part is relatively small and therefore hard to predict. This also means that the variance of the demand can be large, leading to that relatively large quantities of safety stock must be held. Sometimes there is as much safety stock as cycle stock so these items require much warehouse space in aggregate (Bartholdi III and Hackman 2019). The lead times to replenish parts to the warehouse can usually be quite long which further increases the need to hold safety stock. The act of postponing the movement of stock to downstream locations makes it possible to consolidate the demand and reduce the demand variability (Huiskonen 2001). According to Huiskonen (2001) the current spare part logistics research is mostly related to inventory management research. Typically, spare part inventory management is often considered as a special case of general inventory management with some special characteristics, such as very low demand volumes.

The life cycle of spare parts can be quite unusual compared to other items, which is reflected in figure 3.10. The demand is typically the highest in the beginning and in the end of the life cycle. This makes it hard to have good availability of new products at the start of the life cycle and easy for the warehouse to be stuck with obsolete parts at the end of the life cycle (Bartholdi III and Hackman 2019).

3.7 Direct Shipments Modelling

The purpose of modelling the supply chain is to provide answers for decisions needed to be taken. These supply chain decisions are typically taken in different decision phases. Chopra and Meindl (2016) talk about three different decision phases where the differences are mainly the considered time frames and how easy a decision could be changed. Miranda and Garrido (2006) instead talk about strategic, tactical and operational decisions. For an overview of these decision types, see

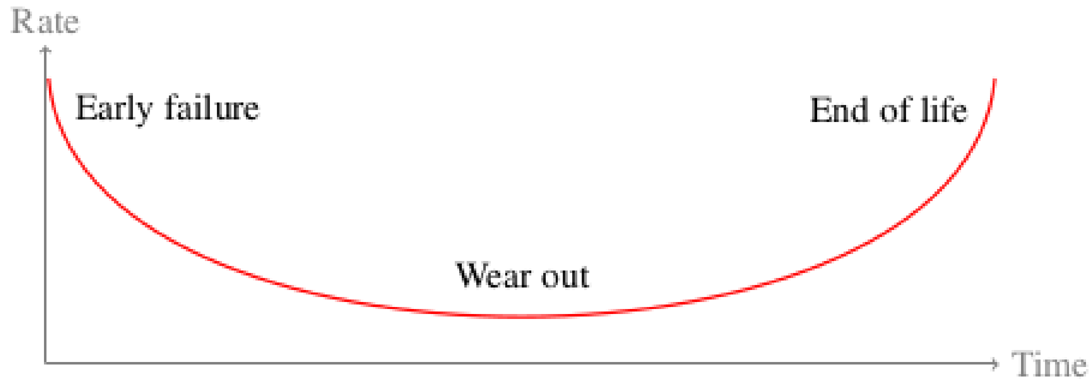

Figure 3.10: Typical life cycle of a spare part (Bartholdi III and Hackman 2019)

table 3.6.

Table 3.6: Decision types in supply chain management

Decision Type	Time Frame	Examples
Strategic	Several years	Perform logistics in-house or outsource? Where to locate facilities?
Tactical	Up to one year	What suppliers should be used? What warehouse should supply which market?
Operational	Weekly/Daily	When to place next order? How should orders be allocated to customers?

When it comes to distribution decisions, the network design, the flow of goods and the location of facilities are typically considered as decisions on the strategic level while inventory management and transportation are typically considered decisions on the tactical level (Jha et al. 2012). According to Kaviani (2009) the location of distribution centers can be seen as strategic decisions whereas other distribution decisions can be seen as tactical decisions and inventory service level as a tactical or operational decision. The supply chain decision levels are typically considered separately in supply chain modelling, so one model might deal with strategic decisions while another model deals with tactical decisions. This makes perfectly sense in one way but it may also lead to non-optimal decisions, since there is interaction between the different levels in reality (Miranda and Garrido 2006). Tiwari et al. (2010) conclude that decisions on the strategic and tactical levels should be considered in an integrated manner in order to avoid non-optimal decisions.

A classic model for modelling the distribution network design is the capacitated plant location model described by Chopra and Meindl (2016). This model aims at determining where to locate plants and which markets each plant should serve while minimising facility and transportation costs by using the Simplex algorithm. This model can be extended by adding another layer of potential distribution centers between the plants and the markets. The capacitated plant location model has been used as a base for developing several models with regard to direct distribution. Cheshmehgaz et al. (2013) have developed a model for a three-level logistics network with suppliers, distribution centers and customers that considers direct shipments between suppliers and customers. This model mainly aims at deciding what customer should be supplied by which supplier and which distribution centers that should be opened or closed, while minimising facility costs, transportation costs and response times. The optimisation is done by using the evolutionary algorithm. Jha et al. (2012) have developed a similar model that also uses the evolutionary algorithm for a three-level logistics network with suppliers, distribution centers and retailers. This model considers direct shipments by converting retailers into distribution centers. The model focuses on optimizing the number of DCs and assumes full truck load shipments. Zhi and Keskin (2018) have developed another three-level distribution model that together with direct shipments also considers lateral trans-shipments between the distribution centers. It is important to note that the models by Jha et al. (2012) and Zhi and Keskin (2018) do not take the inventory holding cost into consideration at all. The inventory holding cost is considered in the model by Cheshmehgaz et al. (2013) but just by differentiating the average holding cost per product between the different distribution centers. The model does not take the issue of safety stock and inventory pooling into consideration.

Other models are based on the assumption of customer demand as a Poisson process and one-for-one replenishment. One-for-one replenishment means that as soon as an item is demanded, an order is immediately placed of its replacement. By having this assumption the inventory costs associated with safety stock can be approximated as a linear function of the number of DCs (J.-R. Lin et al. 2006) and can therefore be considered by the models in an easy way. J.-R. Lin et al. (2006) have developed a versions of the capacitated plant location model with plants, distribution centers and retailers, that uses these assumptions. The model considers direct shipment as well as economies of scale in transportation and potential consolidation centers. Basten and van Houtum (2014) have developed a model especially made for spare parts that assumes fixed facility locations and works under the stated assumptions of Poisson demand and one-for-one replenishment. It does however only consider inventory holding cost and also only assumes direct shipments for emergency needs.

Amrani and Khmelnitsky (2017) have developed another model especially made for spare parts that uses an arbitrary demand distribution and allocates a given total inventory between a central depot and several warehouses in order to optimise inventory and transportation costs. Blumenfeld et al. (1985) have developed a model that does not stem from the capacitated plant location model but rather just considers direct shipments or shipments via a consolidation terminal. The model takes transportation costs into account as well as the costs for several types of inventory such as transportation inventory and cycle inventory due to batch sizes of Q. However, it does not consider the cost for safety stock and the issue of inventory pooling.

3.8 Theoretical Framework

The result of the literature review is a theoretical framework that is used further on in the thesis for data collection of the empirical findings. The resulting framework can be seen as three main categories of information that needs to be assessed in order to deliver an answer to the research questions. The theoretical framework can be seen in figure 3.11.

The first category is general information about the supply chain in which the distribution network is operating. What does the structure of the distribution network look like? What are the characteristics of the products? How do the products enter and exit the distribution network? How is the supply chain controlled and what strategic decisions have been taken? General supply chain information is important in order to understand the environment in which the distribution network operates and to be able to make connections between the distribution network and the supply chain.

The second category is detailed information about the logistical drivers in the distribution net-

Supply Chain Perspective	**Distribution Network** - Structure - Cost drivers	**Products** - Characteristics	**Customers** - Demand structure
	Suppliers - Relationship - Purchase routine - Lead times	**Control Tools** - Data - Differentiation	**Strategic Decisions** - Rules
Logistical Drivers in Distribution Network	**Transportation** - Operations - Price structure - Costs	**Warehousing** - Operations - Costs	**Inventory** - Control systems - Policies - Costs
Suppliers Compliance Requirements	**Freight Documentation** - Requirements	**Dangerous Goods** - Requirements	**Other aspects relevant to Sandvik**

Figure 3.11: Developed theoretical framework

work: Transportation, warehousing and inventory. How are the functions operating? This is mainly important in order to select and develop a suitable cost model of the distribution network that reflects reality.

The last category regards supplier compliance requirements that need to be fulfilled in order for direct shipments to work in the real life setting. This is important in order to understand what supplier compliance requirements that exist.

Chapter 4

Empirical Findings

This chapter presents the empirical data found from the data collection process at Sandvik. The data are presented according to the developed framework in the literature review.

4.1 Supply Chain

This section goes through different aspects of the supply chain in order to provide understanding of the settings of the problem.

4.1.1 Distribution Network

The distribution network in the scope of this thesis is the network that the spare parts flow through on the way from the suppliers to the RDCs. A detailed overview of the network can be seen in figure 4.1.

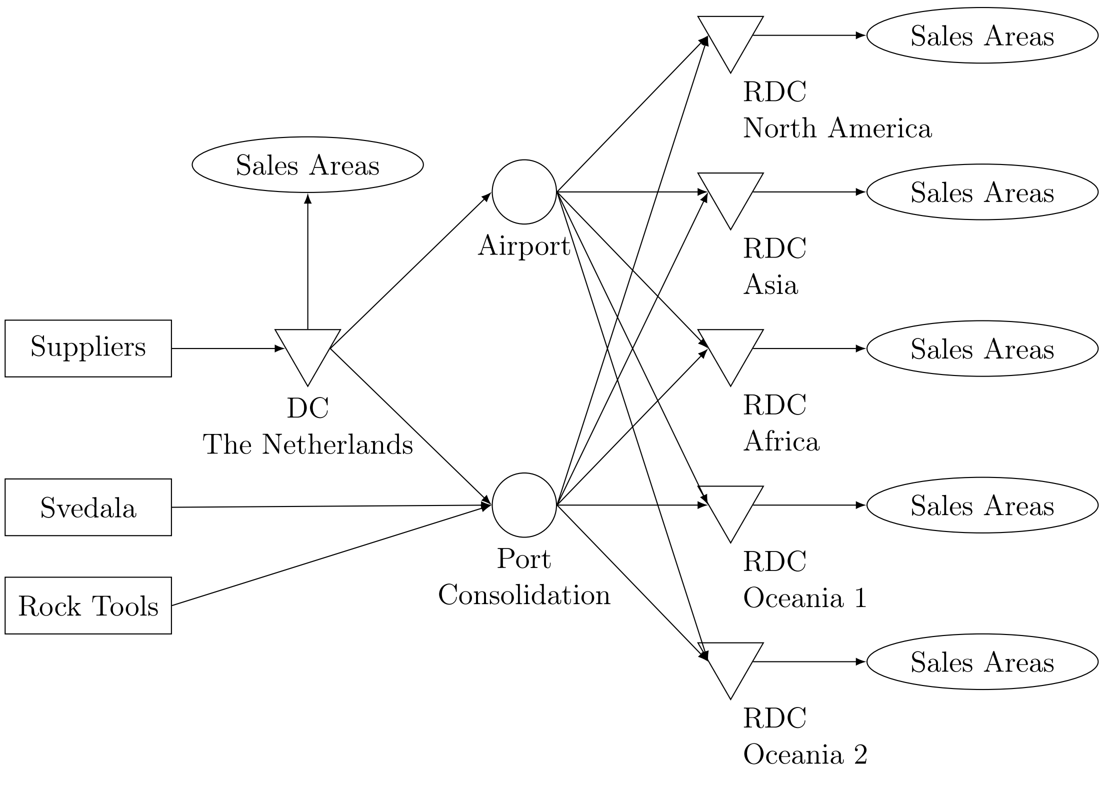

Figure 4.1: Detailed overview of the distribution network

The distribution network comprises of a DC in the Netherlands and five RDCs around the world. The DC receives shipments from the suppliers while the five RDCs receive shipments from the DC. Both the DC and the RDCs serve sales areas belonging to their specified region.

The transportation from the European suppliers to the DC is conducted by truck. When products are shipped from the DC to the RDCs the standard procedure for replenishment orders is to ship them by sea. First the products are shipped by truck to a consolidation point next to a major European port. At the consolidation point, the products are consolidated with other products from other entities within Sandvik, such as Sandvik SRP and Rock Tools, and loaded into containers going to the different RDCs. Products can also be shipped to the RDCs by air if needed and in those cases they are shipped out from the DC to a major European airport. Air shipments are shipped as Air Economy or Air Express depending on the need.

Products can be so called stock standard or non-stock standard in a stockroom, such as a DC or an RDC, in the Sandvik distribution network. If a product is stock standard, the product will be stocked at the distribution center waiting for an order. If a non-stock standard product is ordered, a so called back-to-back order will be created, and the product will flow through the shown distribution network towards the end customer.

4.1.2 Products

The C&S division produces heavy machinery and the main products are stone crushers, where a typical product is the cone crusher which can be seen in figure 4.2. This is a machine that takes larger rocks and crushes them into smaller rocks or gravel. The C&S division also produces screens and feeders which are products that are used together with the stone crushers and perform sorting and transportation of the rocks.

Figure 4.2: A cone crusher by Sandvik

Every product is built up by many different components which as well are sold in the aftermarket as either wear parts or spare parts. Wear parts are parts of the machines that are meant to be worn out after a certain amount of usage. For the stone crushers these are the cones of manganese that have direct connection with the stones during the crushing process. Spare parts are parts that do not have a certain replacement cycle but might brake anyway due to several reasons. As stated in the limitations, in practice only spare parts are in the scope of this thesis.

A stone crusher typically has around 400 spare parts and wear parts that can be ordered in the aftermarket. Sandvik has quite limited product range of active models and the models typically share many of the components. However, in the aftermarket Sandvik can as well receive orders of spare parts for products that are no longer in production. In fact they continuously receive orders for products that have not been sold for many years, examples exist of spare parts still being ordered as long as 70 years after the crusher was bought. This makes it hard to know which products that are "active" and potentially will be sold again. Sandvik considers themselves to have 10,000-12,000 different spare parts and wear parts in their product portfolio of which 5,000 are "actively rolling". The considered 12 suppliers in this thesis shows 1,517 different products sold in the aftermarket during one year.

The physical appearances of the spare parts can vary widely. The size and shape of the products can vary from small nuts and bolts to large rings, with item weights ranging from 10 g up to 1,200 kg. The forms can vary from cubic boxes to weird shapes. The materials can be rough metal, painted metal, rubber, plastic or electronic components. Some of the items are considered dangerous goods which impose restrictions on how they can be shipped.

4.1.3 Customers

The end customers of the C&S products are companies in the mining and construction industries. They place orders to the sales areas which in turn place orders to the RDCs. However, the actual customers to the considered distribution network is the last considered distribution point which in this case are the RDCs.

Due to the fact that the considered products are spare parts the demand at the end customer site are very stochastic and usually ordered in quite small volume. However, when considering the RDCs as the customers, the demand patterns vary depending on if an item is stock standard or not. If an item is non-stock standard the demand pattern at the RDC is basically the same as at the end customer or sales area site while if an item is stock standard the demand is aggregated before an order is placed towards the DC (as long as the reorder quantity is larger than 1).

4.1.4 Suppliers/Purchase

Whenever a stock standard item needs to be replenished at the DC or whenever the DC receives an order of a non-stock standard item, an order is placed towards the supplier. Every product has a supplier lead time, which is the time it takes for a supplier to have the product ready to be shipped out plus the times of the transportation and the receiving process at the warehouse. These lead times vary a lot and can be between 1.5 weeks and up to 5 months, with an average of 5.5 weeks. Typical standard components usually have shorter lead times since they are also ordered by other companies apart from Sandvik, while items produced in small batches just for Sandvik usually have longer lead times.

Several of the suppliers use price breaks. By this means that Sandvik pays different prices depending on the quantity of the purchase order. The reason behind this is that the concerned items are only manufactured when an order is received. The costs for setting up the manufacturing tools such as the cost for human labour as well as the cost for machine down time can be quite large compared to the production costs of material and direct labor for small quantities of an item. The suppliers use price breaks in order to capture this issue and to give incentives to the customers to buy larger quantities. The discounts for buying larger quantities can be very large indeed and in the same way the punishment costs for buying smaller quantities can be very large. Table 4.1 shows examples of price breaks for two example products at two different suppliers in order to give a view of the problem. The table shows the total discount as well as the price discount and price increment of changing to a certain price category from an adjacent price category.

Table 4.1: Example of price breaks in purchasing

	Quantity	Price (€)	Total Discount	Price Break Discount	Price Break Increment
Supplier L	1	649	0%	0%	56%
	2-4	417	36%	36%	50%
	5-9	278	57%	33%	22%
	10-19	227	65%	18%	9%
	20-34	208	68%	8%	7%
	35-49	194	70%	7%	2%
	>=50	190	71%	2%	0%
Supplier F	1-2	4784	0%	0%	33%
	3-4	3600	25%	25%	10%
	>=5	3283	31%	9%	0%

Some suppliers store buffer stock on behalf of Sandvik. This means that the supplier produces items made for Sandvik ahead of orders. In practice this means that Sandvik buys stock for 2-4 months ahead of orders. This procedure is currently not common and has only been done for products with very long lead times as a way to improve customer service. This has not been applied more widely due to several downsides such as increased administrate work of contracts and demand prognosis as well as the increased risk for Sandvik since they have agreed to buy all products in buffer stock. However the suppliers currently take the economic cost of tying up capital in products ahead of orders.

Some suppliers also use minimum order quantities (MOQs) and order multiples. Minimum order quantity means that Sandvik must at least order a certain amount of an item when an order is placed, whereas order multiple means that only order quantities that are evenly dividable by the order multiple are acceptable. The reason for order multiples can be that the products come packed in these multiples and that the supplier will only ship whole packages. In essence both MOQs and multiples are very related to price breaks since many suppliers would be willing to break the rules when the price per item is increased sufficiently. When Sandvik uses the term MOQ they use it in a similar analogy for items with price breaks where they have taken a decision that it would not make economical sense to buy a smaller quantity at a higher price.

During the purchase process an order proposal is shown by the ERP system and the purchaser takes the final decision on what products to buy and in what quantities. In general they order as according to the system but sometimes they adjust the quantities upwards due to the price breaks if they consider it reasonable. Supplier J does not follow the system purchase decisions and are instead bought through a KANBAN system. This means that the supplier keeps track of the stock levels on the shelf physically and replenish whenever needed.

The spare part items for models that are currently being produced are of course as well ordered by the production. However, there is generally no coordination between the flows of the production and the aftermarket. Demand is ordered separately and items for production are going to Svedala while items for the aftermarket are going to the DC in the Netherlands. The purchase department are however looking into the possibility of coordinating these flows in order to retrieve lower purchase prices due to the price breaks. In these cases they are looking into shipping the products to the DC in the Netherlands and let Svedala retrieve their supply from there.

4.1.5 Control Tools

The governance of a distribution network is typically based on some kind of data and since it is hard to control every different product separately usually some kind of diversification is used in order to group products together. This section describes the most prominent data and diversification used for controlling the distribution network at Sandvik.

Main Data

The most prominent data for controlling the supply chain at Sandvik are the measurements of Order Intake and Hits during the last 12 months. These are registered per item at every stocking point such as the DC or the RDCs. Order intake means the total quantity that has been requested by customers during the last 12 months while number of hits means how many different occasions an item has been requested.

Every time a customer order is received these numbers are updated for every stocking point that the product should pass on its way to the customer according to the supply path in the ERP system. For example if a product should take the path Supplier → DC in the Netherlands → RDC in Asia → Sales Area, the numbers at both the DC and the RDC will be updated straight away when a customer order is received.

This means that this demand data at any stocking point will be fully updated with the most recent sales number. However, it is important to notice some important consequences. For items that are stock standard at an RDC and replenished in ROQs it could be easy to think that the number of hits at the DC is connected to how often an item is replenished by the RDC, but this is not the case. The number of hits is just connected to how often the item is demanded by the final customer. Another important aspect to notice is that if an item for some reason is not shipped according to the supply path in the system, the data of order intake and hits will not be correct. However, the numbers are updated in case of a cancelled order.

Differentiation

Sandvik uses several different ways to differentiate the products but the most important one when it comes to controlling the distribution network is the SIC code. The reason why this code is considered the most important is because it is behind so many of the control decisions in the supply chain, such as the decisions of stock standard and service level. The SIC codes are set per stockroom and depend on the number of hits. An overview of the SIC codes can be seen in table 4.2.

Other differentiation classifications that are used when controlling the supply chain are a classic ABC-classification and product groups.

4.1.6 Strategic Decisions

Sandvik have taken some important strategic decisions on how they are controlling their distribution network. These decisions can be seen as independent of the physical distribution setup and can quite easily be changed if needed. These decisions are however considered very important since they have big impact on customer service and costs in the supply chain.

Table 4.2: SIC codes used by Sandvik

SIC Code	Number of Hits	Stock Standard
0	0	No
Z	1-2	No
L	3-4	Yes
K	5-6	Yes
Y	7-10	Yes
X	11-30	Yes
W	>30	Yes

Stock Standard

One important strategic decision is regarding however a product should be stock standard, meaning that is should be stocked and automatically replenished in advance of a customer order. Sandvik has a policy saying that products that have more than 2 hits during the last 12 months (any SIC code except 0 and Z) at a DC or RDC should be stock standard. The connection between stock standard and SIC codes can as well be seen in table 4.2. The stock standard decisions are recalculated on monthly basis.

Order Criticality

Another important strategic decision is the rules for order criticality. Order criticality is set for every order placed by RDCs and determines what shipment mode will be pre-selected. An overview of the different order criticalities can be seen in table 4.3. It is importent to note that if a customer order is received and there is no stock of the demanded item at the RDC, a back-to-back order will be created and the order criticality will in general be set to 2 leading to that the item will be shipped by air unless it is extremely heavy.

Table 4.3: Order criticalities used by Sandvik

Order Criticality	Shipment Mode	Rule
1	Air Express	Customer orders with machine break-down
2	Air Economy	Customer orders
3	Sea	Replenishment orders

4.2 Logistical Drivers

This section will go through the logistical drivers of the distribution network. The considered logistical drivers are transportation, warehousing and inventory.

4.2.1 Transportation

There exist several different transportation links in this distribution network. These are the link from the suppliers to the DC in the Netherlands, from the DC to the port consolidation point or the airport and then further on to the RDCs. These links are explained further down in this section. First of all, different weight concepts and especially the important concept of chargeable weight are introduced.

Weight Concepts

There exists several different type of weight concepts. Descriptions of these can be found in table 4.4.

Table 4.4: Weight concepts

Weight Concept	Description
Net weight	The weight of actual products.
Gross weight	The actual weight of a shipment including products and packaging such as boxes and pallets.
Dimensional weight	The volume of a shipment converted to weight. The conversion depends on the transportation mode and carrier.
Chargeable weight	The largest of the gross weight and the dimensional weight.

Many carriers use the concept of chargeable weight when charging for transportation costs. Chargeable weight is a way to incorporate the cost of physical volume for the carrier since otherwise it might be unprofitable for them to ship light weight shipments with large shipment volumes. The chargeable weight is the largest of the gross weight and the dimensional weight. The dimensional weight is calculated from the volume of a shipment and factor used when converting the volume to weight differs depending on the shipment mode and carrier. The carriers in the case of Sandvik use the most common conversion factors which can be seen in table 4.5.

Table 4.5: Conversion factors for dimensional weight

Transportation Mode	Weight of 1 m^3
Truck	333 kg
Sea	1,000 kg
Air	167 kg

In the analysis of this thesis, three different weight factor concepts have been developed and are subsequently used. These are gross weight factor, chargeable weight factor and total weight factor. The definitions are as follow:

$$gross\ weight\ factor = \frac{gross\ weight}{net\ weight}$$

$$chargeable\ weight\ factor = \frac{chargeable\ weight}{gross\ weight}$$

$$total\ weight\ factor = \frac{chargeable\ weight}{net\ weight}$$

Supplier to DC

The transportation from the suppliers to the DC can be arranged in various ways. The preferred alternative is that the goods are shipped by a trucking carrier chosen by Sandvik: Carrier A. The strategy is to ship as much goods as possible from the European suppliers through this carrier in order to consolidate volumes and lower the transportation prices. Since many of the suppliers are located in Sweden, Sandvik has established a shipping schedule where they ship each supplier once a week to be able to perform milk runs and push down the transportation prices even further. Shipments by Carrier A are performed under the FCA Incoterm which means that Sandvik pays for the shipment cost. About 80% of the suppliers are shipped by this method and most of them have also integrated the IT system of Carrier A into their work routine. In the system they can confirm when goods are ready and arrange for pick-up which gives Sandvik visibility.

Carrier A charges different prices per kg chargeable weight depending on the shipment origin and they use incentive prices which means that the price per kg vary depending on the amount of goods shipped. Example of these incentives prices can be seen in table 4.6, which is a condensed version of the full price list available in appendix table A.1. There is also a minimum level of the freight cost which is equivalent to about 50-70 kg of goods depending on the route. As seen in the table the price discount can be substantial if the shipment volume is increased. In case a shipped pallet is non-stackable, meaning that it is not possible to stack other pallets on it, the dimensional weight of that pallet position all the way up the ceiling of the truck is used when calculating the chargeable weight.

Table 4.6: Example of price breaks in transportation

Chargeable Weight (kg)	Price per kg (€)	Total Discount	Price Break Discount	Price Break Increment
0-299	0.86	0%	0%	26%
300-499	0.68	21%	21%	26%
500-999	0.54	37%	21%	13%
1000-2499	0.48	44%	11%	50%
2500-4999	0.32	63%	33%	45%
5000-6999	0.22	74%	31%	10%
7000-7999	0.20	77%	9%	25%
8000-9999	0.16	81%	20%	33%
>= 10000	0.12	86%	25%	0%

It is important to note two things. First of all, freight costs are charged and invoiced strictly per freight document. If a supplier makes two different bookings that are picked-up at the same time and even go on the same truck to the DC, these will be charged as separate shipments and the freight rate categories will be chosen independently for each shipment. Second of all, the price breaks are hard. With regard to the shown example of price breaks, this means that it is in fact much more expensive to ship 2499 kg than to ship 3000 kg.

The remaining 20% of the suppliers do not ship with Carrier A due to several reasons, but often the supplier just does not accept the solution. Instead the supplier choose the carrier and Sandvik may or may not pay for the shipment cost depending on the Incoterm used.

DC to RDCs

The transportation from the DC to the RDCs is performed by carrier B and is either mainly by sea transportation or air transportation. For sea transportation, goods are first trucked to the consolidation point where the goods are loaded into containers. The truck transportation is charged by gross weight and not chargeable weight. For air transportation, goods are first trucked to the airport. There are departures heading to the RDCs once per week for both sea transportation and air transportation.

The cost for sea shipment and air shipment is charged by chargeable weight according to the rules of each mode of transport. Sandvik is usually charged for weight and not volume since the items are typically quite heavy. In practice, this is always the case when it comes to sea shipments, which can be seen in table 4.7 since the chargeable weight factor is 1.0. It is most often the case when it comes to air shipments which can be seen in table 4.8. The cost per kg for air shipment is about 5 to 8 times higher than the cost for sea shipment, which can be seen in table 4.8.

Table 4.7: Cost and lead times for sea shipments to the RDCs

RDC	Lead Time (days)	Cost per Charge. Weight (€)	Cost per Gross Weight (€)	Chargeable Weight Factor
North America	44	0.96	0.96	1.00
Asia	52	0.94	0.94	1.00
Africa	63	0.82	0.82	1.00
Oceania 1	64	1.26	1.26	1.00
Oceania 2	73	1.06	1.06	1.00

Table 4.8: Cost for air shipments to the RDCs

RDC	Cost per Charge. Weight (€)	Cost per Gross Weight (€)	Chargeable Weight Factor	Sea to Air Cost Factor
North America	4.82	4.86	1.01	5.06
Asia	5.32	5.78	1.09	6.15
Africa	5.40	5.46	1.01	6.66
Oceania 1	7.88	8.14	1.03	6.46
Oceania 2	8.42	8.62	1.02	8.13

4.2.2 Warehousing

The main warehousing driver in this distribution network is the DC in the Netherlands. However in order to understand the problem it is also needed to understand the operations of the port consolidation point as well as the RDCs.

The DC

The warehouse in the Netherlands performs all phases of standard warehouse duties such as receiving, put-away, picking and shipping. An overview of the performed tasks with each phase can be seen in table 4.9. Apart from the standard phases, the warehouse also performs duties on demand such as inventory checking, detailed quality control and return handling. Declaration of dangerous goods are not performed by the warehouse, instead a third-party performs the declarations.

Table 4.9: Overview of performed warehouse tasks in the DC

Phase	Description
Receiving	Counting of received items and quality checking. Items are scanned and confirmed delivered so that the stock records are updated. Items with faulty packaging faulty are being repacked.
Put-away	Items are put away to the current location according to the system. If there is no current place, a new place is found.
Picking	Orders are received and then released to the workers. Small items are picked from mezzanine while larger items are picked by truck. Smaller items that are stored together are repacked in smaller packages according to the ordered quantity.
Shipping	Dangerous goods are being declared by external partner. Goods are being shipped out according to the shipment schedule where different destinations have different cut-off times.

What can be noted is that the warehouse performs a lot of repackaging, an estimate is that about 75% of all inbound products are being repacked. The reasons for repacking varies and can be seen in table 4.10. More detailed explanations about packaging requirements can be found in section 4.3.3 Packaging.

Table 4.10: Overview of repackaging reasons

Reason	Description
Wrong branding	No Sandvik branded or neutral packaging.
Missing protection	Box is not good enough, shock protection (foam rubber) is missing, rust protection is missing or packaging is not matching the requirements of a certain shipment mode.
Mismatch in quantities	Goods have to be repacked to smaller boxes since quantities in the outbound flow is not corresponding to the quantities per box in the inbound flow.

The warehouse is run by another entity of Sandvik and the C&S division pays a fixed fee every month depending on previously used space, workers etc of last year. Out of the total cost for the warehouse per year the actual warehouse workers account for 58% of the cost, the storage space for 25% of the cost and the remaining 17% of the costs can be classified as overhead costs.

Port Consolidation Point

The consolidation point next to a major European port receives products from DC and other entities within Sandvik, such as Svedala SRP and a division called Rock Tools. The products from the different origins are combined into containers to different destinations. Whenever the consolidation point receives a shipment, they check if all packages have been received according to a list provided by the sender with all package numbers in that shipment. No checks on item level, such as item counting, is performed. Whenever a certain destination should be shipped, all packages going to that destination are collected and the packages are stuffed into containers. There are usually enough goods to ship full container loads (FCL) to all the RDC destinations but in case not a full container is needed, goods can as well be sent as less-than-container-load (LCL). Whenever the goods has been loaded, a commercial invoice and packing list are issued for all items going to a certain destination.

There are several reasons for having this consolidation point. First of all since the goods from different sources are combined, the likelihood of achieving a reasonable fill rate for FCL shipments increases. This is important since shipping FCL means better freight rates than shipping LCL. Also this also leads to better negotiation power for Sandvik when it comes to freight rates. Another reason for the consolidation is that it is possible to put all items of the C&S division on a combined commercial invoice and packing list for every destination. By doing this, it is possible to reduce the number of imports and exports for every shipped destination to once per week. The costs for exports and imports are typically paid per freight document, so having the goods on a combined documents can save huge amount of money. On average the fixed costs for import and export can be approximated as $250 for sea transport and $200 for air transport.

RDCs

The RDCs work in a different way compared to the DC. Since the DC warehouse assures that all items shipped into the SMCL network are packaged as needed, very little repackaging takes place at the RDCs. Another difference is that the RDCs are run by 3PL companies and not by a Sandvik entity. The costs for the RDCs are purely depending on the number of handled inbound and outbound order lines. However if the used storage space would increase, Sandvik may be asked to remove goods or might be offered a higher price next time.

4.2.3 Inventory

The strategic decision made by Sandvik about stock standard leads to that only those items will be stocked and build inventory. In order to control the inventory of these items Sandvik uses the (R,Q)-policy. The forecasts as well as the MAD values of the products that should be stock standard are based on the order intake data and are recalculated on a monthly basis by using exponential smoothing with varying smoothing factors depending on the SIC codes. In order to calculate the reorder points, Sandvik uses three different methods called Average Hits, ROP Weeks and Automatic ROP. The method that achieves the highest R value will be used. An overview of how the reorder point is calculated by these methods can be seen in table 4.11. Since both lead time and ROP Weeks are in weeks while forecast and MAD are calculated per month, these values are converted by the factor 52/12 before being applied in the formulas.

The Average Hits method calculate the ROP by taking the total order intake over a year divided by the number of hits. The intention by this method is to capture items with very irregular flows and where large shares of the demand are requested in just a few orders. This method also secures that the ROP is always at least 1 for all stock standard items.

Table 4.11: Methods to calculate ROP used at Sandvik

Method	Calculation
Average Hits	ROP = Order Intake / Hits
ROP Weeks	ROP = Forecast * ROP Weeks
Automatic ROP	ROP = Basic Stock + Safety Stock Basic Stock = [Forecast * Lead Time] Safety Stock = Safety Factor * MAD * [.1 + .07 * Lead Time]

The ROP Weeks method works by setting the ROP to a predetermined number of weeks of forcasted demand. The intention by this method is to set some sort of general fixed lowest acceptable level of stock, which especially comes in hand for items with short supplier lead time.

The Auto ROP method sets the ROP in a similar way as the classic method assuming normal distributed demand described in theory. However, the method used by Sandvik does not completely follow the theoretical calculations. The reason for this is unknown to Sandvik, but a reasonable guess would be that the changes have been done in order to make the calculations linear. The underlying IT system at Sandvik is quite old and it might be the case that it did not support non-linear calculations when the inventory control was implemented or that non-linear calculations could not be calculated with acceptable efficiency. The fact that the method deviates from the theory makes it hard to understand the performance of it. It is important to notice that only the Auto ROP method takes the lead times into account. If the lead times get longer, this method is more likely to be used.

The value of Q is not derived through the formula for economic order quantity but instead set by using a method called ROQ Weeks. This method works in a similar way as the ROP Weeks method, meaning that Sandvik will buy the demand of a certain number of weeks every time an order is placed.

The service variables, which are the service level for the Auto ROP method and the number of weeks of demand for the ROP Weeks method and the ROQ Weeks method, are set in the system on stockroom level and are differentiated depending on SIC code, ABC-class and item group.

The (R,Q)-policy used at Sandvik has several general inconsistencies compared to the theory. The system at Sandvik issues orders when the inventory position falls below R, not when it falls to or below R as in the theory. This leads to that orders will be placed too late in order to live up to the set service levels. Another issue when setting the ROP is that the system rounds the number to the nearest integer and in the cases of rounding down this will also contribute to the fact that the system will not live up to the set service criteria. The numbers for ROQ is also rounded to the nearest integer, leading to the issue that some items are achieving an ROQ of 0. These items are treated as having an ROQ of 1 in the system.

4.3 Supplier Compliance Requirements

In the theory it was found that different types of freight documentation are needed in order to ship goods and perform export and import. The theory also states that special documents can be needed for dangerous goods. This section will discuss those issues as well as other supplier compliance requirements found at Sandvik such as the issue of packaging requirements and the

ISPM 15 standard.

4.3.1 Freight Documentation

In the theory it was found that commercial invoice and packing list are typically the most important freight documentations. This is confirmed by Carrier B, who is responsible for exports and imports at Sandvik. Sometimes the importing country uses both the commercial invoice and the packing list when declaring the import which require them to match completely since otherwise it will cause problems. Some countries on the other hand typically only use the commercial invoice for this duty. This leads to slacker requirements meaning that the commercial invoice and the packing list do not have to match completely. According to Carrier B, shipments to the concerned countries typically only require the commercial invoice for imports and do not require any special documents such as certificate of origin.

4.3.2 Dangerous Goods

The rules for shipping dangerous goods vary between truck, sea and air shipments. The reason for this is due to that the regulations for the different transportation modes are set by different organisations. The regulations for sea and air transportation are more rigorous compared to the ones for truck transportation. In general there is also a shift in responsibility between the transportation modes, where the carrier has more responsibility when it comes to truck shipments whereas sea and air shipment put more responsibility on the shipper. The party certifying dangerous goods and providing dangerous goods documentation must be certified and have gone through extensive training. Sandvik SRP in Svedala always uses an external agent to handle dangerous good sent by air since the regulations for packaging are so complex. The DC uses an external agent for both sea and air shipments.

4.3.3 Packaging

Sandvik has requirements and rules on how products should be packed when being shipped through the SMCL network for spare parts. The reasons behind the rules vary and can be both due to branding as well as protecting the products with proper packaging. The most common pre-packaging requirements are shown in table 4.12. The general rule is that the products should be singled packed, meaning one piece per box, bag or crate. However, small parts typically with value of less than 5 € or weight of less than 0,01 kg are excepted from this rule. Items also need to have correct protection, use neutral or Sandvik branded packaging material and be correctly labelled.

Currently the DC is the distribution point where goods are entering the SMCL network and it therefore works as a packaging gateway. They have the main responsibility of making sure that the packing used by the supplier is approved according to the rules and if the packaging is not approved they will repack the items into proper packaging. By serving as a gateway they make sure that all products arriving at the RDCs and to the customers are in good condition and will not need any extensive repacking further down the distribution network.

Many of the suppliers do not currently ship as according to the packaging rules for the SMCL distribution network and therefore require repackaging at the DC. However, there are discussions with some of the suppliers to change the packaging so that they will ship according to the rules.

Table 4.12: Packaging requirements

Requirement	Item Types
Sandvik branded outer packaging material. Neutral packaging material can sometimes be accepted.	All items
Protection against corrosion by using anti-corrosive plastic bag, anti-corrosive paper or sprayed with an anti-corrosive agent. The recommendation is to use Vapor Corrosion Inhibitor (VCI).	Unpainted metal items
Protection against deterioration by using UV bags.	Rubber items
Items should be single packed in order to be ready for customer shipment. The general rule is that there shall be one piece per box, bag or crate.	Items with value $>$ 5 € and weight $>$ 0,01 kg
Each box, bag or crate needs to be labeled with the Sandvik spare part item number in order for easy identification at the RDCs and further down the supply chain. Preferably the label should show other information as well, such as the item name, pieces in the packaging, weight, COO, packing date, barcode and the Sandvik logo.	All items

4.3.4 ISPM 15 Standard

The main outer packaging material used by Sandvik are either cartons or plywood boxes. When shipping goods in wood packaging such as plywood boxes, the packaging need to be approved according to the ISPM 15 standard. This means that the material must be heat treated in order to prevent the wood from being infested by insects. The plywood boxes currently used are bought already heat treated and have the correct stamp to prove it. However, when shipping in plywood boxes there is also a need for securing the goods inside and this is currently done by loose wood pieces. Since the wood is usually cut in the process there is no guarantee the the stamp will be visible on every piece of wood which is needed in order to comply with the standard. A company can apply for being certified according to the ISPM 15 standard in order to gain a permit to stamp the wood packaging by themselves, but this application however costs money. In Sweden the responsible authority is Jordsbruksverket. Sandvik currently has these permits both at the DC and in Svedala. The ISPM 15 standard is of course also applicable when it comes to standard wood pallets that are used by many suppliers.

This standard is needed to be met for shipments to all countries of the RDCs. However the countries of the RDCs in Oceania are especially strict about that all packaging must follow the standard scrupulously. If not everything is correctly marked upon receipt in Oceania, goods will be held in custody and hefty fines will apply. The countries also have special requirements such as that the containers shipped from continental Europe must be fumigated, although this is not needed for goods being shipped out from Sweden. The container fumigation bears a cost of several hundred dollars per container.

Chapter 5

Setup for Direct Shipments

There exist several potential interpretations of the meaning of direct shipments in the context of shipments between the suppliers and the RDCs at Sandvik. Therefore also several potential distribution setups can be considered to be direct shipments. The reason for this is that the same mode of transportation can not be used for shipping the goods all the way from the suppliers to the RDCs. The goods therefore need to be transferred and reloaded between the different transport modes and there is a question of where and how this action should take place. According to theory, direct shipment is considered to be shipments that bypass consolidation terminal in order to reduce inventory and material handling at the consolidation terminal. The shipment solution for direct shipment that reduces the goods handling the most is to use intermodal container transportation. This means that the supplier would pack the goods into a container at their site, which then are shipped on a trailer to the closest port by a truck and loaded on a ship. The same trailer procedure would occur at the destination as well. In this way goods will never be handled individually during the distribution process. However, this solution is not seen as a reasonable option. Under the assumption that it should be possible to ship goods from every supplier to the RDCs every week as in the current system, the volume of goods per shipment is deemed to be far too little in order to fill up a container and be economical viable. The goods therefore need to be shipped to a terminal where it could be consolidated into containers.

One option could be that the suppliers ship out the goods as LCL shipments through the closest port. For most of the suppliers that are located in Sweden this would probably mean Gothenburg, which is the biggest port in southern Sweden. At the port, the LCL goods would be consolidated and loaded into containers by a freight agent. Another option would however be for the suppliers to ship out the goods via the current port consolidation point for sea shipments in continental Europe. The question is if shipping via Gothenburg can be considered as a more efficient way of distributing the goods and if this option should be further investigated. It could however be reasoned that shipping via Gothenburg should not be further investigated. First of all, the decisions to use a consolidation point is a quite strategic decision taken by Sandvik. The fact that Sandvik are consolidating the goods in the SMCL network with goods from Sandvik SRP and Rock Tools means that they have better chances to ship goods as FCL instead of LCL, resulting in lower freight costs. Further more, the consolidation of goods give Sandvik bargaining power in the negotiation of shipment prices. It could therefore be considered as out of scope to consider an option that goes against this strategic decision. As well from an operational perspective it is hard to see the benefits of using the port of Gothenburg. Of course there is a chance that the cost for transportation to the port could be lower since Gothenburg is closer to the Swedish suppliers compared the port in continental Europe. However Gothenburg only has direct liner services to the Asian RDC out of the different RDC locations (Port of Gothenburg 2019). Shipments to the other RDC destinations have to be transshipped via the big ports in continental Europe. It is assumed that shipping via Gothenburg will cause longer transportation times and higher prices compared to the solution where the goods are shipped into the port consolidation point. A solution where the suppliers are shipping out the goods via Gothenburg port is assumed to require them to be the exporters which will drive cost for exports and imports, whereas shipping via the consolidation point could offer a solution where either the supplier or Sandvik is the exporter. A solution where Sandvik is the exporter would however require them to set up a virtual stockroom. A virtual stockroom is an option provided by the ERP system at Sandvik that makes it possible to "deliver" goods into the system without delivering it into an actual warehouse. This makes it possible to produce a combined commercial invoice in order to reduce the number of exports and imports.

There could be a question regarding if shipping into the consolidation point can be considered to be direct shipments according to theory. However, according to Blumenfeld et al. (1985) this can be considered to be a direct shipment with the origin as the supplier and destination as the consolidation point. Sandvik are mainly interested in direct shipments since they are concerned with the amount of handling and used space at the DC and from this perspective shipping into the consolidation point is a valid solution. Shipping into the consolidation point is also how direct shipments have been setup for other parts of Sandvik SRP in Svedala. This solution is overall considered to be the most reasonable option to investigate.

By choosing this setup the current costs for sea shipment and air shipment can be used. There is an underlying assumptions that this change in the distribution setup will not affect the costs for sea and air shipment to the RDCs. As concluded in the empirical findings the cost for sea shipment will likely not increase due to direct shipments and there is a small risk of cost increments for air transportation but this will not be modelled and is instead considered a risk.

There is still a question regarding how air shipments should be handled. Since it is not possible to fully determine which products that will be shipped by air and as well in order to simplify the model, these products are assumed to also be shipped to the port consolidation point if being shipped directly. A consolidation center for both sea and air shipments does not have to be located where the current port consolidation point is located, but for modelling reasons it is assumed that the current facility is used. In reality this assumption would equal an assumption of that air shipments would still be shipped out via the current airport and that the cost for transportation between the port and the airport is about the same size as the cost between the DC and the airport. This assumption is somewhat reasonable since the distances are quite similar in reality.

What will be modelled in this setup can be seen in figure 5.1. When applying direct shipments, the purchase orders from the RDCs are sent directly to the suppliers which deliver the products to the port consolidation point. Both the option where the suppliers are the exporter of the goods and the option where Sandvik set up a virtual stockroom and is the exporter of the goods will be modelled.

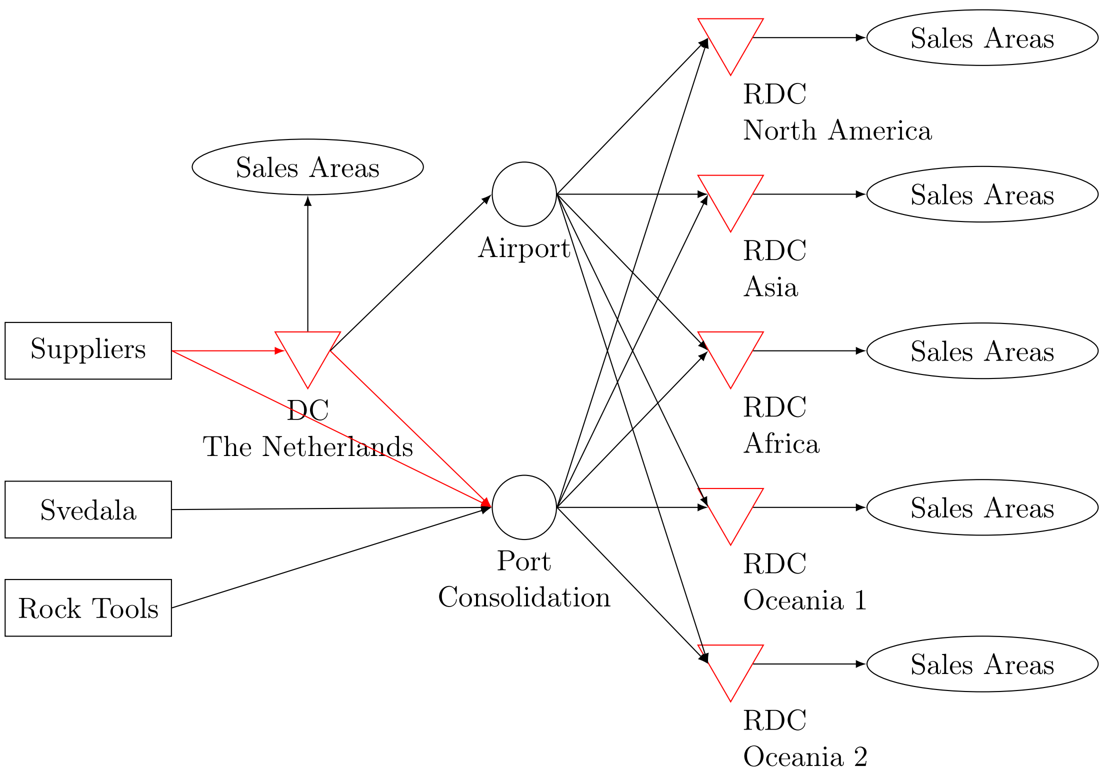

Figure 5.1: Modelled setup

Chapter 6

Problem Definition

The purpose of this thesis is, as previously stated, to investigate the economic consequences as well as the viability for direct shipments in the distribution network. What has been discovered in the empirical findings is that the issue of determining the economic consequences of direct shipments is closely related to two other issues, namely the issue of pre-packaging and the issue of price breaks, minimum order quantities and order multiples at the suppliers. Since these other issues are related to direct shipment when it comes to economic consequences, it is important to take them into account but it is equally important to separate the different problems in order to give answers about direct shipments. All these issues can be seen as cost trade-offs of different underlying factors and sometimes the factors are working contradictory for different problems. This chapter will go through the different problems in order to determine the factors behind them and how they are connected as well as not connected.

6.1 The Problem of Price Breaks, MOQ & Order Multiples

Even if price breaks, MOQs and order multiples are different things, they are all different outcomes of the same problem. Namely that the supplier has a higher cost per item when producing and handling a lower quantity of a product compared to a larger quantity, a phenomenon called economies of scale. Although there might be differences in these concepts regarding how willing the supplier is to ship a different amount for a higher cost. When it comes to price breaks, it is usually built into the concept that the supplier is willing to ship a lower quantity at a higher price, whereas it might not be accepted when it comes to MOQ and order multiples.

The main cost trade-offs for this problem and the underlying factors driving them can be seen in table 6.1. The main purpose of buying a larger quantity is to reduce the product price and generate a better margin. At the same time, the purchase frequency will be reduced leading to less workload. However this will also impact the costs for the distribution of the products. The number of inbound handled order lines at the warehouses will be reduced, saving labour cost. The volume per shipment will increase, leading to more efficient shipments and lower cost for transportation. Although it is important to remember that the transportation cost also depends on the transportation flow of other products from the same supplier. The lower product price will also help reducing the inventory holding cost. However the inventory cost is also driven up by the increase in inventory due to the increased cycle stock. Apart from a higher inventory holding cost, buying larger quantities also means that the buyer takes on a bigger risk. Buying ahead of customer demand always imposes a risk on the buyer since the buyer is just acting on a prognosis and can not know when or even if a product will be demanded in real life. When buying larger quantities, the buyer is relying on the prognosis even further into the future and the risk of this decision is increasing. The problem of price breaks, MOQs and order multiples is well connected to the problem of economic order quantities, since the trade-offs are basically the same. However, all of the mentioned cost affections are typically not considered when calculating economic order quantities.

Table 6.1: Cost affections of increased quantities

Cost Driver	Driver Change	Cost Change
Purchase Costs		
- Purchase price	−	−
- Purchase frequency	−	−
Transportation Costs		
- Size per shipment	+	−
Warehouse Costs		
- Inbound order lines	−	−
- Stored volume	+	+
Inventory Costs		
- Cycle stock	+	+
- Product value	−	−

It can be noted that in some inventory control systems, the ROP is adjusted downwards when the ROQ is forced higher in order to compensate for the increased service by reducing the safety stock. However, this is not the case when it comes to the inventory control system at Sandvik, which leads to that applying price breaks, MOQs and order multiples are increasing the customer service.

6.2 The Problem of Pre-Packaging

The main cost trade-offs for this problem and the underlying factors driving them can be seen in table 6.2. The problem of pre-packaging mainly aims at reducing the amount of workload spent on packaging goods at the DC with the aim of reducing the warehouse handling costs. If this packaging process is no longer performed in the DC, this however means that it has to be done at the supplier which will lead to potential economic consequences. The suppliers supposedly already pack the products in the most efficient and easy way for them. If the suppliers should do the packaging in any other way, there is a risk that they will demand a higher product price. In general it could be argued that the products are already packed at the suppliers so changing the process at the suppliers should be more efficient than having to repack the goods at the DC despite the risk of a higher price due to that goods no longer have to be packed twice. The DC however does this repackaging extensively and therefore should do this with higher efficiency compared to how well a supplier might be able to do this.

If the supplier packages the products according to the packaging instructions by Sandvik, this will most likely lead to increased gross weight on the outbound transportation from the supplier. The reason for this is that many of the items should be packed in singular which will inevitably lead to a higher ratio of the packaging material compared to the total gross weight and therefore increase the gross weight factor. Also the chargeable weight factor will be affected although it is more unclear how. Products that previously have been stacked on each other, and now should be packed in singular, will probably cause a higher shipped volume. The consequence of this is however very dependant on the product characteristics, since items with high weight per volume

Table 6.2: Cost affections of applying pre-packaging

Cost Driver	Driver Change	Cost Change
Purchase Costs		
- Purchase price	+	+
Transportation Costs		
- Gross weight factor	+	+
- Chargeable weight factor	−/+	−/+
Warehouse Costs		
- Time spent on repackaging	−	−
- Stored volume	+	+
Inventory Costs		
- Product value	+	+

could increase in volume without increasing the chargeable weight, while items with lower weight per volume can not. On the other hand there is also a potential for reducing the chargeable weight factor. This potential exist for products that are put on pallets that are currently not stackable. If these products would be put singularly in boxes that are stackable, there is a chance that the chargeable weight factor could decrease despite in the increased volume. How the chargeable weight factor will change is concluded to depend on current and future stackability as well as on product characteristics where the most prominent factor is weight per volume. Another issue caused by the repackaging is increased administrative work if Sandvik has to be involved in supplying the supplier with packing material.

6.3 The Problem of Direct Shipments

The main cost trade-offs for this problem and the underlying factors driving them can be seen in table 6.3. The problem of direct shipments can be seen as the problem of changing the distribution flow through the distribution system in order to reduce the warehouse handling. However changing the distribution flow will as well, in the case of Sandvik, also change where and how the system will build inventory. Direct shipments will clearly reduce the demand flowing through the DC and the number of outbound order lines towards the RDCs. It should as well reduce the number of inbound order lines at the DC even though it is a bit more uncertain by how much since direct shipments could as well lead to more frequent purchasing. This is due to that the purchase frequency is dependant on the ROQs, which in turn is dependant on the demand. The number of inbound order lines at the RDCs should remain the same. Direct shipments will also clearly lead to an increment in the number of outbound shipments from the suppliers. Even if all demand at the RDCs is shipped direct, many products will still have demand in the sales areas served by the DC. This will inevitably lead to a split transportation flow where some amount of the products are shipped direct to the RDCs while some amount are shipped to the DC. This will increase the total number of shipments in the distribution system and lead to a clear reduction in size per shipment, causing less efficient and more expensive shipments. The chargeable weight factor might increase due to that the smaller shipments are less consolidated. It is important to understand that direct shipments to the RDCs will not only affect the flow of products to the RDCs but also the flow of products ordered by sales areas belonging to the DC. This increment in transportation cost is however somewhat counteracted by an average reduction in transportation distance since goods being shipped direct do not have to take the detour via the DC.

Table 6.3: Cost affections of applying direct shipments to the RDCs

Cost Driver	Driver Change	Cost Change
Purchase Costs		
- Purchase frequency	+	+
Transportation Costs		
- Number of shipments	+	+
- Size per shipment	−	+
- Chargeable weight factor	+	+
- Transportation distance	−	−
Warehouse Costs		
- Inbound order lines DC	−	−
- Outbound order lines DC	−	−
- Stored volume DC	−	−
- Stored volume RDC	+	+
Inventory Costs		
- Cycle stock DC	−	−
- Safety stock DC	−	−
- Safety stock RDCs	+	+
- Transportation inventory	−	−

Table 6.4: Impact of direct shipments depending on stock standard

		DC	
		Stock standard	Non-stock standard
RDC	Stock standard	• Reduced cycle stock at the DC • Reduced safety stock at the DC • Might lead to items no longer being stocked at the DC • Longer lead time at the RDCs • Increased safety stock at the RDCs	
	Non-stock standard	• Reduced cycle stock at the DC • Reduced safety stock at the DC • Might lead to items no longer being stocked at the DC • Longer lead time at the RDCs	• No stock changes at the DC • Shorter lead time at the RDCs • No stock changes at the RDCs

Several of the found inventory types in the theory are affected when applying direct shipments. At the RDCs, the safety stock will increase due to the increased lead times in order to achieve the same customer service. At the DC, the inventory is affected due to several reasons. First of all, the safety stock will change due to changed forecasts and MAD values. Also the cycle stock at the DC might change, since the ROQs might change due to changed forecasts. Both the safety stock and cycle stock at the DC might be reduced since the reduced demand through the DC can cause products to become non-stock standard. The inventory part can be seen as similar to the classic problem of aggregating or dis-aggregating the inventory but with a twist, since warehouse in the Netherlands works as a DC and an RDC at the same time. Applying direct shipments will dis-aggregate the inventory and push the inventory towards the RDCs. The transportation inventory will also be reduced since direct shipments will reduce the transportation time from the suppliers to the RDCs.

It is important to remember that the consequences are very dependant on what ROP rule is currently used by a product and how this will change when applying direct shipments. There could for example be an increased use of the auto ROP rule at the RDCs due to the longer lead times. How direct shipments is affecting the lead times and the inventory for a certain product are also very dependant on if the product is stock standard or not. An overview of these affections can be seen in table 6.4.

6.4 Combination

The issue of combining the three problems is that different factors affect the total cost in different ways for different problems and the total effect becomes very hard to model. When it comes to the problem of pre-packaging, this is something that the supplier has to perform in order to apply direct shipments. From a cost-analysis perspective, it could be argued that this problem should be considered completely separate from the problem of direct distribution. If it is more efficient to let the supplier do the pre-packaging, then the supplier should do it, no matter if direct shipments are applied or not. As a consequence, it could be considered that the time spent on repackaging at the DC should be disregarded in the analysis. Otherwise the answer for direct shipment could be yes even though that the most cost-beneficial solution might be to just let the supplier do the pre-packaging, but continue with shipments via the DC.

There are however also arguments of why the cost for pre-packaging should be included in the analysis. Due to the space limitation at the DC, it is not sure if a solution where the supplier also prepackages the demand going to the DC is desirable. The reason for this is that items packed singularly will take up more space at the warehouse, which currently is limited. On the other hand, there might also exist other solutions to the problem such as local direct shipments from a supplier that is much closer to an RDC. These cases might not be possible to catch if not the cost for repackaging at the DC is taken into account. The aim for this thesis is to answer the problem about direct shipment, so this is where the most focus will be. Although, the cost for repackaging are taken into account. The problem of price breaks, MOQs and order multiples are considered in the risk analysis.

Chapter 7

Cost Model Development

In the literature review Chopra and Meindl (2016) stated that the most important costs to consider when deciding the distribution setup are the costs for facilities, inventory, transportation and information. In the empirical findings it was also concluded that buying in different quantities can have a big impact on product prices due to price breaks. This means that the cost for the supply chain driver of sourcing is also of big importance. However, since the scope of this thesis is to analyse the logistic costs, the purchase cost as well as the cost for information are not included in the cost model. Although there are still comments and reasoning around these issues in the analysis.

Two different alternatives for deciding a cost model were considered. One of the considered options was to use an already developed model by other researchers for the cost trade-off analysis. Therefore an extensive search for models dealing with distribution cost trade-off was conducted in the literature review. The found models however had several issues that made it hard to apply them on the concerned problem in this thesis. Some of the models did not consider the inventory costs at all or did not take into consideration the issue of safety stock or inventory pooling. The models that did take safety stock into consideration were all based on Poisson distributed demand with one-for-one replenishment. Since one-for-one replenishment can not be assumed for all items, it is unclear how well those model would suit the reality. Many of the models were based on the capacitated plant model, which did not really seem relevant in the context of this thesis. It is not an option to close the DC and it is therefore not of interest to model it. Overall the found models seem to have been developed for a high level decision phase with focus on where to locate a distribution facility.

The other considered option was to develop the model by hand using current knowledge found in the literature. This approach was used in the thesis and the developed model is described in the remaining parts of this chapter. The considered costs were warehouse cost, transportation cost and inventory cost. The goal has been to develop a cost model that reflects the reality at Sandvik as closely as possible.

7.1 Data Source

Different costs are mainly affected by different underlying factors. For transportation costs, it is most important how much weight is being shipped, while warehouse costs is mostly affected by how much volume is being stored as well as the amount of material handling at the warehouse. Inventory cost on the other hand is primarily based on how much value is being stocked. One way to analyse the change in costs is to look at historical data and to basically calculate what would have happened if a certain amount of the products would have been shipped in another way. It is a quite easy calculation when it comes to calculating how the flows through the DC and the different transportation flows would change. However it is not as simple when it comes to understanding how the inventory holding costs would change. There is also another problem with this approach and that is that the data would have been based on different data sources and it would be hard to understand how the changes in costs are connected. In order to build a model where it is possible to see the trade-offs between the different distribution costs they have to be connected, meaning that the different costs have to be based on the same main data source.

The chosen main data source for the developed model is the data of order intake and hits. There are several reasons for this. First of all, it is chosen as it clearly reflects the demand for products during one year. Second of all, it is chosen since this data is what the inventory control is based on and it is therefore possible to build an inventory model using this data. One year of data has been used in the model, from December 2018 to November 2019. Data was withdrawn from the ERP system during first week of December. There is a major assumption for the model behind this data selection. That is that the withdrawn data represent how the system will operate in the future. In reality this is of course not true, instead there is another underlying assumption of that the model would give a good answer anyway since changes against reality will occur in all directions. The inventory model is further based on the current values of forecast and MAD values (which generate certain ROP and ROQ) and assumes that these will be constant over the upcoming year unless some demand is directly shipped.

7.2 Transportation Cost

Due to the considered model setup the transportation costs that needs to be modeled are the truck transportation from the suppliers to the DC and to the consolidation point. In the empirical findings it became clear that the weight per shipment is highly affecting the cost for LTL transportation due to the incentive prices with price breaks. According to theory as well confirmed by Carrier A the cost per kg is also dependant on the distance as well as the goods traffic flow. The modelling of the transportation cost will try to capture both of these factors.

Since it is not possible to know exactly how big every shipment will be and what price break it will end up in, it was investigated if the average weight per shipment could be a good indicator of what the price would be by looking up the corresponding price in the price list of Carrier A. A methodology that seems to work well was to take the average of the matching price break and the closest upper price break (that has potentially a lower price per kg). The reason for this is quite reasonable due to the varying shipment sizes and since the larger shipments ending up in an upper price break will have a bigger influence on the average price per kg than the smaller shipments ending up in a lower price break. The acquired price per kg was compared to the real price per kg for last year in order prove the method. Table 7.1 shows the results of this comparison and it can be concluded that this method shows to be quite accurate. Results for suppliers A and I differs quite a lot, when investigated this seems to be due to a faulty data underlying the real average cost. The suppliers H and J are not shipped via Carrier A using the FCA Incoterm and the change in transportation cost for these suppliers are not considered in the model.

In order to calculate how much the cost will change due to distance, the change in road distance between the supplier to the DC versus supplier to the consolidation point is calculated. The cost per kg will not decrease with the same ratio as the change in distance due to that the carrier also has fixed costs that have to be covered. According to Carrier A, as an example the cost will be reduced by approximate 12% if the distance is reduced by 20%. The reason for this is changed goods traffic flow and fixed charges for ferry crossings. These numbers are used when calculating how much the price per kg is changing when shipping to the consolidation point instead of the

Table 7.1: Analysis of average transportation prices, model versus reality

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Model Average Cost per kg (€)	0.39	0.20	0.16	0.42	0.08	0.19	0.24	-	0.50	-	0.14	0.27
Real Average Cost per kg (€)	0.45	0.17	0.15	0.41	0.09	0.20	0.25	-	0.37	-	0.14	0.27

DC.

It is assumed that the maximum number of shipments per year between a supplier and the DC or the consolidation point is 50, basically once per week minus holidays. The number of shipments that will be used can be somewhere between 0 and 50 and is depending on the number of order lines. If the order lines are assumed to be independently distributed over the year, the probability of having a certain number of shipments in a week will be binomial distributed. This means that the probability of having k number of shipments in a week can be calculated as the following expression where n is the number of order lines and p is the probability of selecting a week, in this case 1/50.

$$p(k) = \binom{n}{k} p^k (1-p)^{n-k} \quad , \quad k = 0, 1, 2, ..., n$$

(Blom et al. 2005)

The number of shipments used per year will in average be $p(0) * 50$.

The methodology when calculating new transportation prices for a supplier is the following:

1. Calculate the number of shipments of when shipping everything to the DC and determine the average weight per shipment.
2. Determine price per kg for shipping everything to the DC by using the price list.
3. Determine price per kg for shipping everything to the consolidation point due to changed distance and transport flow.
4. Calculate the weight split between the DC and the consolidation point when direct shipment is implemented.
5. Calculate the number of shipments of a split flow going to both the DC and the consolidation point and determine the average weight per shipment for each destination.
6. Determine how much the kg price will go up due to split flows by using the price list.
7. Apply the price increments on the determined price per kg for transportation to the DC and to the consolidation point.

The prices derived by this method are prices per chargeable weight. The weights in the ERP system by Sandvik are net weights. In order to transform the prices to costs per net weight, these are multiplied by the corresponding gross weight factor and chargeable weight factors as seen in

Table 7.2: Analysis of weight factors, between the suppliers and the DC

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Total Weight Factor	2.26	3.08	1.33	2.59	1.36	1.13	1.24	-	1.99	-	1.23	3.43
Chargeable Weight Factor	2.13	2.32	1.24	1.77	1.10	1.03	1.08	-	1.58	-	1.07	1.51
Package Weight Factor	1.06	1.33	1.07	1.46	1.23	1.10	1.15	-	1.26	-	1.15	2.27

figure 7.2. The price per kg for shipping the RDC flow to the consolidation point via the DC is as well calculated.

For the situation where the supplier is the exporter, the costs for an increased number of exports and imports are calculated as the following. First the number of order lines going between the supplier and a single RDC are taken and split between air shipment and sea shipment according to the shares of last year. Then the number of used shipments between a supplier and an RDC for a certain shipping mode is calculated in a similar methodology as for calculating the number of shipments going to the DC or to the consolidation point. The cost for an increased number of exports and imports is calculated as the number of used shipments times €227 (≈\$250) for sea shipment and €182 (≈\$200) for air shipment.

7.3 Warehouse Cost

The warehouse handling cost will be affected when applying direct shipments since goods being directly shipped will no longer be handled at the DC which will save time for workers. The used warehouse space will as well be affected but this cost is modeled in the inventory cost which is recommended by theory. According to theory the labor cost is typically the biggest warehouse cost and the order-picking is the most labor intensive process at the warehouse. The number of outbound order lines is a good estimation of the number of picks and therefore a good driver of the warehouse handling cost. However, the developed model also considers the number of inbound order lines as an important cost driver that is needed to be taken into account. There are two main reasons for this. First of all, it is due to the reason that some suppliers are bought in much bigger quantities due to the problem of price breaks, MOQs and order multiples. Second of all, it is due to the repackaging process conducted at the DC. In the empirical findings it was found out that this process is quite extensive and conducted during both the inbound and at the outbound processes and in order to be able to differentiate this, the number of inbound order lines is needed as a cost driver.

The number of inbound order lines at the DC are calculated by using the values of Hits, Order Intake and ROQ at the DC. The number is calculated as being the minimum value of the number of hits and the order intake divided by the ROQ. In general the order intake divided by the ROQ should reflect the number of inbound handlings, however in case of large customer orders these are supposed to be delivered as one shipment and the number of hits is considered to be a reasonable upper constrains of the number of inbound order lines. The number of outbound order lines at the DC are calculated in a similar matter by using the values of hits, order intake and ROQ for the RDCs. It is important to note that the number of inbound order lines reflect the total demand at the DC, not only the demand for the RDCs. The outbound order lines on the other hand only reflects the demand at the RDCs.

The cost per order line have been calculated and differentiated per suppliers depending on how much time it takes to handle one order line at the DC, which can be seen in table 7.3. The warehouse manager in the DC has estimated the factors used in the calculation, where for example a supplier with a factor of 3 means that this supplier takes about 3 times the workload per order row compared to a supplier with a factor of 1. The calculations have been based on the costs for warehouse workers (excluding warehouse space and overhead costs), the assumption that the total share of workload of the selected 12 suppliers is equivalent to the share of order lines these suppliers stand for, and the assumption that the sum of the factors multiplied by the number of order lines should equal the cost of the workload for these suppliers.

Table 7.3: Differentiated handling costs per supplier

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Factor inbound	3	3	1	5	1	5	2	4	3	1	15	1
Cost per inbound row (€)	28.8	28.8	9.6	48.2	9.6	48.2	19.2	38.6	28.8	9.6	144.4	9.6
Factor outbound	1	1	3	1	1	1	1	1	1	5	1	1
Cost per outbound row (€)	12.2	12.2	36.3	12.2	12.2	12.2	12.2	12.2	12.2	61.2	12.2	12.2

7.4 Inventory Cost

In order to build a model for inventory costs, several options were considered. One option was to use the way to set ROP and ROQ as is currently used by Sandvik in their system. Another option was to bring in an external model from theory and either make an assumption of the distribution (for example normal distributed demand) or analyse the demand distribution in detail to find a fitted distribution. Pros and cons of the different approaches can be seen in table 7.4.

Looking into demand distributions in detail will be very complex and take a lot of time and is outside of the scope of this thesis. The best approach is considered to be to use the way of setting ROQ and ROP that the system uses since this will give a clear answer about the situation at Sandvik. The problem of understanding how customer service will be affected could somewhat be solved by calculating the service level backwards. A model was built to replicate how the system sets the ROP and ROQ with high accuracy. The model calculates the exact same values as in the system in more than 99.5% of the cases.

It is needed to analyse how much the demand forecast and MAD should change due to direct shipments since these factors drive how much inventory is held. If the demand is reduced by 20% over a year it could be argued that the forecast in general should be reduced by 20% but it is definitely not certain that the MAD factor should be reduced by 20% due to the effect of inventory pooling.

The forecast and MAD values of the RDCs will not be affected when applying direct shipments and the system values are therefore used. In order to recalculate the values for the DC, the following procedure is performed: First the forecast and MAD at the DC are calculated from the

Table 7.4: Pros and cons of different approaches to model the inventory

	System	External
Pros	• Will give answers on a practical level what would happen if implemented now. • Easier to compare to current situation. • Requires few assumptions since Sandvik is already working like this .	• Gives answers on a theoretical level about how inventory level would change given same service level. • Could be done by looking into demand distributions (accurate) or without looking into demand distributions (less accurate).
Cons	• Based on three different ways of setting ROP which makes it a bit complex to understand how all is connected. • Will be replaced in somewhat near future. • Not really clearly based on academic theory. • Hard to make conclusions about cost for customer service with regards to direct shipments, since they way of setting ROP might change with direct shipments.	• Requires a detailed look into demand distributions in order to make sure it is accurate, due to very low demand on many products. • Requires assumption on how to set ROP and ROQ. • Requires assumptions on service levels. • Do to many assumptions is needed it will be hard to prove the accuracy. • The future way of setting ROP and ROQ is a bit unclear, but does not seem to be connected to the external models.

demand patterns of the last 12 months by assuming a smoothing factor of 0.2. The initial values are set to be the order intake of the first month for the forecast calculation and to be zero for the MAD calculation. Whenever a certain flow to an RDC is directed to be shipped directly in the model, the forecast and MAD at the DC are recalculated in the same way for this new demand pattern of the last 12 months. The percentage difference between the different calculated values are then applied on the original system forecast and MAD values for the DC. This method is considered to achieve good estimation of what the values would have been if a certain RDC would have been shipped directly over during the last 12 months.

The average inventory is calculated according to the theory in section 3.5.1 Inventory Control. First the safety stock is calculated as $SS = ROP - dL$ and then the average inventory is calculated to be $SS + Q/2$. In case the calculated safety stock is negative, back ordering is assumed and the average inventory is calculated as $Q(1-x)^2/2$. The reduction in transportation inventory over a year is calculated as the total value flow of items to the RDCs over a year multiplied by 5/365.

The inventory holding cost rate was suggested by the inventory team to be set to 25%. This number seems to be well linked to theory and is applied to the average inventory at the DC and the RDCs. There is also a considered saving of 5 days in transportation inventory for items being shipped direct. For the transportation inventory savings, an inventory holding cost rate of 10% is used since it is mainly the locked-up capital costing money.

It could be questioned if it is reasonable to have the same interest holding rate of 25% for both the DC and the RDCs. One could argue that since the DC is tight on space capacity it would be most fare to price space as the marginal cost for extra space (for example what space would cost an external warehouse) and therefore the interest holding cost rate should be higher at the DC. Another argument for differentiating the inventory holding cost rate in this way is that Sandvik currently does not pay for the space used at the RDCs, just for the number of handled order lines. However, it must be remembered that Sandvik of course pays for the space and just that it is included in the cost per handling. It is unlikely that the RDCs would accept a big sudden increase in used space and Sandvik has confirmed that they might ask for removal of goods or negotiation of prices. According to theory the cost for space is a minor part of the total inventory holding cost. This have been confirmed by analysing the numbers at Sandvik as well which can be seen in table 7.5. The analysis is based on stock values from beginning of December 2019 and these are assumed to represent average values. The cost for space is calculated to be about 2.2% for spare parts which is considered small compared to an assumed inventory holding cost rate of 25%.

Table 7.5: Analysis of the cost for warehouse space at the DC

	Stock Value (€)	Inventory Cost - 25% (€)	Space Cost (€)	Space Cost Share of Inventory Cost	Space Cost Share of Inventory Value
Spare Parts	18,282,000	4,570,000	400,000	8.8%	2.2%
Spare Parts + Wear Parts	26,162,000	6,540,000	1,000,000	15%	3.8%

On the other hand the inventory at RDCs in general bears higher risk due to that demand is not aggregated. The risk is certainly high for items that have very little demand and therefore might never be requested again. If those items become obsolete and have to be scrapped, the cost for doing this should also be higher at the RDCs compared to DC due to that the cost for scrapping should also cover the cost for transportation to the RDCs. These items could however potentially be sourced from the RDC having stock instead of the DC if demanded somewhere else in the distribution system.This will however cause significant relocation costs which should be captured by the inventory holding cost rate according to theory. One idea could however be to differentiate the inventory holding cost rate depending on the demand in order to capture the risk of stocking products with very low demand. However, it is not totally clear what items that actually bears the biggest risk. Items with very little demand can clearly be seen as having a risk of not being requested again. Items with high demand however have the risk of ending up with huge excess inventory if the demand suddenly drops, which is suggested as a typical life cycle for spare parts by Bartholdi III and Hackman (2019).

7.5 Total Cost

The transportation cost, the warehouse cost and the inventory cost are all combined in the model in order to get the total cost. The total cost is calculated both including and excluding the costs for an increased number of exports and imports in order to model both options.

The model is developed on item level, where a certain item in a certain RDC can be set to be shipped direct. However, since the transportation cost is dependant on knowing how much goods are transported on different routes it is not possible to model the costs on pure item level. Instead different scenarios are modelled, where direct shipments are applied on a certain category of products.

7.6 Model Validation

The built model is just a model of reality in order to be able to perform a cost trade-off analysis. Especially since the model is built on only one main data source the model does not necessary truly reflect reality. As stated earlier the main data source in this model is the number of order intakes and hits over one year (December 2018 - November 2019). It is therefore important to validate the model by comparing it to reality. The dimensions that where considered the most important to compare are the ones driving the costs in the model, which can be found in table 7.6. The comparison of these drivers are available in table 7.7. The table contains the value of the model driver (M), the value of the real driver (R) and the performance (P) of the model compared to reality.

Table 7.6: Compared drivers in model validation

Model Driver (M)	Real Driver (R)
Number of inbound order lines at the DC	Actually number of received order lines during December 2018 - November 2019
Number of outbound order lines at the DC	Actually number of dispatched order lines during December 2018 - November 2019
Shipped net weight between supplier and the DC	Actual shipped net weight during December 2018 - November 2019
Shipped net weight between the DC and the RDCs	Actual shipped net weight during December 2018 - November 2019
Average inventory in the DC	Actual inventory in the DC at beginning of December 2019
Average inventory in the RDCs	Actual inventory in the RDCs at beginning of December 2019

There will naturally be a difference in the numbers due to the different sources of information. The values of the model is based on the orders while the numbers from reality are based on what have been shipped. Since there might be a quite big time gap between the ordering and the shipment of an items, the numbers will probably never fully match. However, it could be argued that the numbers should be quite similar since this time shift occur in both the beginning and the end of the time period.

Table 7.7: Model validation

		SUPPLIER												
		A	B	C	D	E	F	G	H	I	J	K	L	Total
Inbound order lines	M	858	319	285	1,485	605	592	461	732	91	1,981	1,004	298	8,712
	R	498	207	124	795	432	295	327	291	33	1,132	348	124	4,606
	P	72%	54%	130%	87%	40%	101%	41%	152%	177%	75%	188%	140%	89%
Outbound order lines	M	829	152	140	1,362	621	537	376	1,192	237	2,220	850	429	8,945
	R	581	168	139	1,010	501	409	324	925	158	1,792	630	274	6,911
	P	43%	-9%	1%	35%	24%	31%	16%	29%	50%	24%	35%	57%	29%
Shipped net weight S→ DC (tons)	M	5.91	38.8	162	6.95	48.3	125	52.3	18.0	32.3	109	258	35.1	892
	R	4.71	36.1	178	4.50	39.0	125	46.0	10.0	16.0	81.4	231	28.0	799
	P	25%	7%	-9%	54%	24%	0%	14%	79%	102%	34%	12%	25%	12%
Shipped net weight DC→ RDCs (tons)	M	2.36	15.7	50.1	2.70	14.4	46.3	16.0	7.37	11.1	48.4	96.4	13.7	325
	R	1.95	15.9	46.4	2.56	12.9	46.0	13.9	6.83	9.75	36.5	80.8	11.5	285
	P	21%	-2%	8%	5%	12%	1%	16%	8%	14%	33%	19%	20%	14%
Inventory DC (K€)	M	48.0	15.3	155	12.6	111	29.2	20.0	13.9	29.2	73.9	199	81.6	790
	R	109	74.8	561	39.2	263	141	66.0	37.4	34.9	159	912	179	2,576
	P	-56%	-80%	-72%	-68%	-58%	-79%	-70%	-63%	-16%	-54%	-78%	-54%	-69%
Inventory RDCs (K€)	M	17.7	2.60	10.9	3.62	34.6	10.2	3.49	5.37	13.3	34.8	46.7	23.8	207
	R	99.5	36.3	136	23.5	192	54.0	27.6	19.0	26.5	80.0	289	90.6	1,073
	P	-82%	-93%	-92%	-85%	-82%	-81%	-87%	-72%	-50%	-56%	-84%	-74%	-81%

When looking into the outbound order lines and the different values of shipped net weight there is a quite big percentage difference between the numbers of the model and the reality of previous year, where the model seems to overestimate the numbers. When looking deeper into the data in order to find reasons behind this, the data showed that there were quite big differences in the inbound and outbound values of both the DC and several of the RDCs for the considered time period. The inbound numbers showed to be substantially less than the numbers of the outbound. The reasons behind this seems to be that warehouses in the system have been holding more inventory compared to what the inventory policies state. The inventory team stated that the sales during the year previous to the last year were quite good which could have helped build inventory which are now being used. Exactly how much of the difference that can be explained by this is however somewhat unclear. If looking into the number of inbound order lines, the model seems to overestimate this quite a lot more than the outbound order lines. A clear reason for this is that the model is not taking into account the issue of price breakes, MOQs and order multiples, which reduce the number of inbound order lines.

On the other hand the model seems to clearly underestimate the inventory levels both at the DC and at the RDCs. It is important to remember that the values of reality is just a snap shot and not average numbers over the year. Despite this the number difference is so significant that it can be concluded that this can not be the only explanation. Even though some of this might be connected to the general change in sales as discussed above, this is also very expected due to the model settings. The rules in the inventory system states that items with more than 2 hits over the last 12 years should be stocked. This is a very low demand which clearly imposes the system to the risk of stocking items that might not be demanded again for a very long time.

Chapter 8

Future Scenario Analysis

Several scenarios have been developed in order to understand the impacts of direct shipments on the distribution system. The scenarios have been developed based on information from interviews as well as theory for inventory control. Five of the scenarios were selected in cooperation with Sandvik to be the most interesting to analyse. An overview of the selected scenarios can be seen in table 8.1. The scenarios are further explained in the sections of this chapter. Each scenario are analysed both with and without the cost for an increased number of exports and imports.

Table 8.1: Overview of the scenarios

Scenario	Description	Purpose
1	Ship all demand of all RDCs direct	Reduce the warehouse handling and warehouse costs as much as possible at the DC.
2	Ship all demand of the North American RDC direct	Analyse if the cost savings could off-set the costs for an increased number of exports and imports when shipping only the largest RDC.
3	Ship all products that only have demand at RDCs direct	Exploit clear benefits of shipping those items direct.
4	Ship all products that are not stocked at the DC direct	Exploit clear benefits of shipping those items direct.
5	Ship products with SIC codes X and W direct	Appeal to classic inventory risk reduction strategy found in theory.

8.1 Base Scenario

The base scenario has the intention to model the current situation. All products are shipped through the DC and the demand for RDCs are then shipped from the DC to the port consolidation point. The issue of price breaks, MOQs and order multiples are disregarded in this model, and it is assumed that the products can be ordered in the quantities that the system suggests to the price that is currently in the system (that might be a result of another order quantity). The purpose of the base scenario is to use it as a comparison when evaluating the other scenarios. The costs for the base scenario can be seen in table 8.2. It can be noted the total costs for all 12 suppliers are in about the same sizes for inventory, warehouse and transportation cost. However, when looking into each supplier it can be noted that the shares of each of these costs vary deeply among the suppliers.

Table 8.2: Costs of the Base Scenario

	SUPPLIER												
Cost (K€)	A	B	C	D	E	F	G	H	I	J	K	L	Total
Inventory Cost	16,4	4,5	41,6	4,1	36,4	9,9	5,9	4,8	10,6	27,2	61,5	26,4	249
- DC	12,0	3,8	38,8	3,2	27,7	7,3	5,0	3,5	7,3	18,5	49,9	20,4	197
- RDCs	4,4	0,6	2,7	0,9	8,6	2,6	0,9	1,3	3,3	8,7	11,7	6,0	52
Transportation Inventory Savings	-	-	-	-	-	-	-	-	-	-	-	-	-
Warehouse Cost	17,5	5,5	3,9	44,1	6,7	17,5	6,7	21,4	2,8	77,4	77,7	4,1	285
- Inbound	12,4	4,6	1,4	35,7	2,9	14,3	4,4	14,1	1,3	9,5	72,5	1,4	175
- Outbound	5,1	0,9	2,6	8,3	3,8	3,3	2,3	7,3	1,4	67,8	5,2	2,6	111
Transportation Cost	5,4	26,2	35,0	6,5	7,2	32,4	17,6	-	29,8	-	55,2	34,7	250
- S→V Non-RDC	3,1	14,2	20,1	3,7	3,7	16,8	10,8	-	18,5	-	26,9	19,1	137
- S→B RDC	2,3	11,9	14,9	2,8	3,5	15,6	6,8	-	11,3	-	28,3	15,7	113
Total Costs	39	36	80	55	50	60	30	26	43	105	194	65	784

8.2 Scenario 1: *Direct shipments of all products*

The first scenario examines the situation where all demand at the RDCs are shipped directly to the port consolidation point. A big advantage of this scenario is that the product flow to the RDCs will be removed from the flow going through the DC. This will reduce the amount of resources taken up at the DC maximally when it comes to both space and warehouse handling. A drawback of this scenario is that the removal of all RDC demand from the DC might lead to items becoming non-stock standard at the DC, which might lead to worse customer service for both the sales areas belonging to the DC and for other RDCs due to the longer lead times.

The cost changes of this scenario is shown in table 8.3 and shows that direct shipments seems to be beneficial for 10 out of 12 supplier, with total potential savings of €156,000 per year if the cost for an increased number of exports and imports is excluded. When it comes to inventory the result shows that the inventories will be pushed towards the RDCs. Inventory at the DC is reduced for all suppliers due to the reduced demand. The model shows reduction between 9% and 44% depending on the supplier, with an average reduction of 35%. Inventories at the RDCs are increased due to the increased lead times. The changes here varies widely between 2% and 400% with an average of 82%. The suppliers that show the biggest percentage increments are the ones having the longest supplier lead times. The model further shows that total inventory is reduced for all suppliers. The model shows a reduction in transportation costs for two of the suppliers, while transportation costs for the rest of the suppliers are increased. It can be noted that Supplier E that shows the biggest decrease in transportation cost is a bit of an exception, since the supplier does not really have incentive prices with regards to transportation. If the costs for an increased number of exports and imports are included, direct shipments shows to be non-beneficial for all suppliers. The total costs for this solutions shows to be much higher.

Table 8.3: Cost changes for Scenario 1

Cost Change (K€, %)	SUPPLIER A	B	C	D	E	F	G	H	I	J	K	L	Total
DC Inventory	-5.1	-0.35	-12.0	-1.4	-11.0	-2.4	-1.2	-1.3	-2.3	-7.0	-19.1	-6.2	-69.2
	-42%	-9%	-31%	-44%	-40%	-32%	-23%	-37%	-31%	-38%	-38%	-30%	-35%
RDC Inventory	1.6	0.01	10.9	0.24	2.5	1.1	0.13	0.47	1.5	3.6	14.0	6.3	42.4
	37%	2%	402%	27%	29%	43%	15%	35%	45%	41%	120%	106%	82%
Total Inventory	-3.4	-0.34	-1.0	-1.1	-8.5	-1.3	-1.0	-0.81	-0.76	-3.5	-5.1	0.12	-26.8
	-21%	-8%	-3%	-28%	-23%	-13%	-18%	-17%	-7%	-13%	-8%	0%	-11%
Warehouse	-7.4	-2.9	-3.0	-16.7	-4.3	-6.8	-3.2	-8.5	-1.6	-69.1	-21.5	-2.8	-148
	-43%	-52%	-75%	-38%	-64%	-39%	-47%	-40%	-57%	-89%	-28%	-69%	-52%
Transportation	0.06	1.1	2.9	1.0	-2.0	5.7	-0.14	-	4.3	-	8.9	7.4	29.3
	1%	4%	8%	16%	-27%	18%	-1%		14%		16%	21%	12%
Transportation Inventory	-0.54	-0.14	-0.46	-0.07	-0.77	-0.33	-0.08	-0.05	-0.15	-0.36	-1.6	-0.65	-5.3
Total	-11.4	-2.1	-1.6	-16.9	-15.5	-2.6	-4.6	-9.4	1.8	-72.9	-19.4	4.0	-150
	-29%	-6%	-2%	-31%	-31%	-4%	-15%	-36%	4%	-70%	-10%	6%	-19%
Export/Import	67.7	19.7	21.4	83.6	63.5	58.3	49.8	85.1	37.5	93.5	62.9	51.0	694
Total Incl. Export/Import	56.3	17.6	19.8	66.7	48.0	55.6	45.3	75.6	39.3	20.5	43.5	55.0	543
	143%	49%	25%	122%	95%	93%	150%	289%	91%	20%	22%	84%	69%

8.3 Scenario 2: *Direct shipments of all products at the largest RDC*

The second scenario stems from the result of Scenario 1 where it could be shown that the solution of having the supplier as the exporter was not beneficial for any of the suppliers. Some of the RDCs have much less demand than others, which can be seen in table 8.4. For those warehouses, the costs of an increased number of exports and imports would be high compared to the sizes of the shipments. It is therefore of interest to analyse the validity of the result in Scenario 1. This has been done in Scenario 2 where only the biggest RDC is shipped directly, which in this case is the RDC in North America, in order to see if a solution where the supplier is the exporter is still non-beneficial for the suppliers. The other RDCs are still shipped via the DC.

Table 8.4: Demanded products of one year, divided per SIC code

Warehouse	Total	SIC CODE W	X	Y	K	L	Z	0
DC	1,517	264	293	130	156	218	456	0
		17%	19%	9%	10%	14%	30%	
RDC - North America	889	49	160	90	70	134	386	661
		6%	18%	10%	8%	15%	43%	
RDC - Asia	532	32	72	40	38	76	274	1,018
		6%	14%	8%	7%	14%	52%	
RDC - Africa	343	3	17	28	28	52	215	1,207
		1%	5%	8%	8%	15%	63%	
RDC - Oceania 1	367	2	22	25	27	54	237	1,183
		1%	6%	7%	7%	15%	65%	
RDC - Oceania 2	282	1	12	26	22	46	175	1,268
		0%	4%	9%	8%	16%	62%	

The results of Scenario 2 can be seen in table 8.5 and shows that fewer of the suppliers seem to be cost-beneficial for direct shipments and the total savings is shown to be less compared to scenario 1. The aim of Scenario 2 was however to see if direct shipments could be beneficial for any of the suppliers when the supplier would be the exporter, if shipping only the flow of the biggest RDC. The result shows that this scenario is cost beneficial for supplier J which is the supplier that showed the biggest cost savings in Scenario 1. However, the cost for an increased number of exports and imports show to outweigh any savings from direct shipment also in this scenario for all the other suppliers.

Table 8.5: Cost changes for Scenario 2

Cost Change (K€, %)	SUPPLIER A	B	C	D	E	F	G	H	I	J	K	L	Total
DC Inventory	-4.3	-0.18	-6.8	-0.86	-6.7	-1.1	-0.43	-0.64	-1.1	-3.7	-11.8	-2.9	-40.5
	-36%	-5%	-18%	-27%	-24%	-15%	-9%	-18%	-16%	-20%	-24%	-14%	-21%
RDC Inventory	1.4	0.01	6.0	0.21	0.58	0.38	0.12	0.24	0.60	1.9	6.9	2.7	21.1
	31%	2%	221%	23%	7%	15%	13%	18%	18%	21%	59%	46%	41%
Total Inventory	-2.9	-0.17	-0.83	-0.64	-6.1	-0.73	-0.32	-0.40	-0.54	-1.8	-4.9	-0.12	-19.4
	-18%	-4%	-2%	-16%	-17%	-7%	-5%	-8%	-5%	-7%	-8%	0%	-8%
Warehouse	-4.3	-2.3	-1.6	-7.7	-2.0	-3.1	-1.0	-3.2	-0.56	-31.1	-11.2	-1.2	-69.4
	-25%	-41%	-42%	-17%	-30%	-18%	-15%	-15%	-20%	-40%	-14%	-30%	-24%
Transportation	0.24	3.3	4.5	1.2	-0.55	4.9	0.25	-	2.3	-	3.1	4.2	23.5
	5%	13%	13%	18%	-8%	15%	1%		8%		6%	12%	9%
Transportation Inventory	-0.35	-0.10	-0.25	-0.04	-0.37	-0.18	-0.03	-0.02	-0.07	-0.19	-0.89	-0.30	-2.8
Total	-7.3	0.77	1.8	-7.2	-9.0	0.85	-1.1	-3.6	1.2	-33.1	-13.9	2.6	-68.1
	-19%	2%	2%	-13%	-18%	1%	-4%	-14%	3%	-32%	-7%	4%	-9%
Export/Import	20.2	13.8	9.2	20.4	18.9	15.7	15.2	20.2	10.8	20.4	17.9	15.2	197.8
Total Incl. Export/Import	12.9	14.5	10.9	13.2	9.8	16.6	14.1	16.6	12.0	-12.7	4.0	17.8	130
	33%	40%	14%	24%	20%	28%	46%	63%	28%	-12%	2%	27%	17%

8.4 Scenario 3: *Direct shipments of products with demand only at the RDCs*

In this scenario only products that do not have any demand at the sales areas belonging to the DC are shipped directly. The reason for this scenario is that these products have been identified from interviews and analysis of having a clear benefit for direct shipments. Since none of these products have any demand from sales areas supplied by the DC, these products could be removed from the flow through the DC without affecting the service for those sales areas. There might potentially be products that have big demand only at an RDC and which therefore could be more efficient to ship directly. As showed in the demand analysis in table 8.6 there is a quite substantial part of the products matching this scenario. The analysis shows that on average 11% of the items are only demanded by RDCs, but for some suppliers the numbers are as high as over 20%. Supplier C and L do not have any items matching this scenario.

This scenario is however most beneficial for products demanded only by a single RDC, since otherwise the service for other RDCs might be decreased due to that items are no longer stocked at the DC or since items might get higher safety stock inventory due to no inventory pooling. Out

Table 8.6: Demanded items of one year, split per demand source

	SUPPLIER												
	A	B	C	D	E	F	G	H	I	J	K	L	Total
Demanded items	126	55	28	355	96	93	100	128	13	437	70	16	1,517
Items demanded	23	13	0	41	21	15	10	6	2	38	4	0	173
only at RDCs	18%	24%	0%	12%	22%	16%	10%	5%	15%	9%	6%	0%	11%
Items demanded	30	12	12	103	17	31	34	20	1	131	9	0	400
only at DC	24%	22%	43%	29%	18%	33%	34%	16%	8%	30%	13%	0%	26%
Items demanded	73	30	16	211	58	47	56	102	10	268	57	16	944
at RDC and DC	58%	55%	57%	59%	60%	51%	56%	80%	70%	61%	81%	100%	62%

Table 8.7: Cost changes for Scenario 3

	SUPPLIER												
Cost Change (K€, %)	A	B	C	D	E	F	G	H	I	J	K	L	Total
DC Inventory	-0.22	-0.02	0.00	-0.02	0.00	-0.07	0.00	0.00	-0.09	-0.07	-0.04	0.00	-0.52
	-2%	-1%	0%	-1%	0%	-1%	0%	0%	-1%	0%	0%	0%	0%
RDC Inventory	-0.09	-0.01	0.00	0.01	0.00	-0.06	0.00	0.00	0.00	0.00	-0.10	0.00	-0.25
	-2%	-2%	0%	1%	0%	-2%	0%	0%	0%	0%	-1%	0%	0%
Total Inventory	-0.30	-0.04	0.00	-0.02	0.00	-0.13	0.00	0.00	-0.09	-0.07	-0.13	0.00	-0.77
	-2%	-1%	0%	0%	0%	-1%	0%	0%	-1%	0%	0%	0%	0%
Warehouse	-1.1	-0.51	0.00	-2.3	-0.32	-1.0	-0.28	-0.25	-0.08	-2.2	-0.47	0.00	-8.4
	-6%	-9%	0%	-5%	-5%	-6%	-4%	-1%	-3%	-3%	-1%	0%	-3%
Transportation	0.73	0.40	0.00	0.83	0.34	0.59	0.07	-	0.08	-	0.29	0.00	3.3
	14%	2%	0%	13%	5%	2%	0%		0%		1%	0%	1%
Transportation Inventory	-0.01	-0.01	0.00	0.00	-0.03	-0.02	-0.01	0.00	0.00	0.00	-0.02	0.00	-0.11
Total	-0.64	-0.16	0.00	-1.5	-0.01	-0.53	-0.22	-0.25	-0.09	-2.2	-0.33	0.00	-5.9
	-2%	0%	0%	-3%	0%	-1%	-1%	-1%	0%	-2%	0%	0%	-1%
Export/Import	9.7	4.9	0.00	13.6	5.7	5.8	3.5	2.0	0.86	11.4	1.3	0.00	58.8
Total Incl.	9.0	4.7	0.00	12.1	5.7	5.3	3.3	1.7	0.77	9.2	1.0	0.00	52.9
Export/Import	23%	13%	0%	22%	11%	9%	11%	7%	2%	9%	1%	0%	7%

of the 173 items demanded by only RDCs, 157 of those items were actually demanded only by a single RDC which show potential for this scenario. This scenario will save warehouse handling for all the concerned items but only warehouse space at the DC for the items that are currently stock standard. Only 32 out the 173 items are actually stock standard at the DC, of which 23 items have demand only by one RDC. These 23 items have a clear benefit of direct shipments since it is possible to avoid building stock at two warehouses. A big potential problem with this scenario is however if it even would be possible to distinguish these products demanded by only RDCs in real life. A problem related to this is how the supplier of an RDC is set in the ERP system of Sandvik. The supplier is set on item/stockroom level which leads to that if demand suddenly occurs in the sales areas belonging to the DC, an item might become stock standard at the DC but the RDC will still order directly from the supplier. In order to avoid this situation, someone must manually keep track of item demand in the system and manually change the supply path.

Even if there is a quite big share of items qualifying for this scenario, the result does not show any substantial cost savings. The result in table 8.7 shows that this scenario shows most reduction in warehouse handling cost, but the reduction is not close to be of the same size as the share of items qualifying for this scenario. This means that those items are in general less cost driving than average items. In total this scenario shows a total cost reduction of €5,900 per year. The scenario is not beneficial for any supplier if the supplier is the exporter.

8.5 Scenario 4: *Direct shipments of products not stocked at the DC*

In this scenario only products that are non-stock standard at the DC will be shipped directly. The reason for this scenario is that these products have been identified from interviews and analysis of having a clear benefit for direct shipments. Every time those products are demanded by an RDC, the order is just passed on to the supplier and the product is then shipped via the DC on its way from the supplier to the RDCs. This generate unnecessary warehouse handling at the DC without adding the value of holding inventory. Since those products are not stocked at the DC anyway, direct shipment of these products would not affect the customer service. On the opposite, these products would rather generate shorter lead times for RDCs (calculated 5 days) which would increase customer service and as well as lower both safety stock and transportation inventory.

The products that qualify for this scenario are the products with SIC code Z at the DC. The analysis of the SIC codes at the DC, which can be seen in table 8.8, shows that this is a large group representing 30% of the demanded products at the DC. Another group of items that would benefit from direct shipments in the same way are products that have an order from an RDC but where the product is currently out of stock at the DC. These products are however not possible to capture in this scenario.

Table 8.8: Demanded items at the DC, split per supplier and SIC code

	SUPPLIER												
	A	B	C	D	E	F	G	H	I	J	K	L	Total
Total	126	55	28	355	96	93	100	128	13	437	70	16	1,517
W	23	1	4	35	17	11	8	47	7	75	24	12	264
	18%	2%	14%	10%	18%	12%	8%	37%	54%	17%	34%	75%	17%
X	27	7	6	61	18	12	18	34	1	86	21	2	293
	21%	13%	21%	17%	19%	13%	18%	27%	8%	20%	30%	13%	19%
Y	10	6	2	27	6	5	12	15	3	38	5	1	130
	8%	11%	7%	8%	6%	5%	12%	12%	23%	9%	7%	6%	9%
K	14	9	2	50	5	9	21	3	0	41	2	0	156
	11%	16%	7%	14%	5%	10%	21%	2%	0%	9%	3%	0%	10%
L	16	8	4	63	15	21	12	11	1	59	7	1	218
	13%	15%	14%	18%	16%	23%	12%	9%	8%	14%	10%	6%	14%
Z	36	24	10	119	35	35	29	18	1	138	11	0	456
	29%	44%	36%	34%	36%	38%	29%	14%	8%	32%	16%	0%	30%

A big problem with this scenario is that the SIC codes are not stable. This leads to the same ERP system problem as in scenario 3, where the SIC codes have to be controlled and the supply path manually updated. If an item is non-stock standard at the RDC and suddenly sees increased demand, it might become stock standard with the risk of building high inventory due to the longer lead times. Another problem is that this scenario will not help reducing the inventory in the DC since the concerned products are not stocked there. Even though the concerned 456 products are a big share of the total number of products, the potential savings in warehouse handling are rather limited since a maximum of 4 handlings (2 inbound and 2 outbound) can be saved from shipping products with SIC code Z directly. A deeper analysis shows that out of the 456 products demanded at the DC, only 147 have demand at the RDCs. This is clearly reflected in the result, which is shown in table 8.9, since this scenario shows very marginal cost savings. In total, this scenario shows a cost reduction of €3,700 per year. The scenario is not beneficial for any supplier if the supplier is the exporter.

Table 8.9: Cost changes for Scenario 4

	SUPPLIER												
Cost Change (K€, %)	A	B	C	D	E	F	G	H	I	J	K	L	Total
DC Inventory	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RDC Inventory	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total Inventory	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Warehouse	-0.53	-0.45	-0.02	-1.5	-0.34	-0.54	-0.36	-0.23	-0.02	-1.7	-0.39	0.00	-6.1
	-3%	-8%	-1%	-3%	-5%	-3%	-5%	-1%	-1%	-2%	-1%	0%	-2%
Transportation	0.49	0.41	0.03	0.69	0.33	0.28	0.07	-	0.04	-	0.19	0.00	2.5
	9%	2%	0%	11%	5%	1%	0%		0%		0%	0%	1%
Transportation Inventory	-0.01	-0.01	0.00	0.00	-0.04	-0.02	-0.01	0.00	0.00	0.00	-0.01	0.00	-0.10
Total	-0.05	-0.06	0.00	-0.82	-0.04	-0.28	-0.30	-0.23	0.02	-1.7	-0.21	0.00	-3.7
	0%	0%	0%	-2%	0%	0%	-1%	-1%	0%	-2%	0%	0%	0%
Export/Import	5.3	4.4	0.23	9.3	6.1	3.7	4.6	1.9	0.23	9.1	1.1	0.00	45.9
Total Incl. Export/Import	5.2	4.3	0.23	8.5	6.1	3.4	4.3	1.6	0.25	7.4	0.91	0.00	42.2
	13%	12%	0%	16%	12%	6%	14%	6%	1%	7%	0%	0%	5%

8.6 Scenario 5: *Direct shipments of products with high demand at the RDCs*

In this scenario, only products having a SIC Code of W or X at an RDC will be shipped directly. The reason behind this scenario is that theory states that a typical inventory strategy is to centralise the demand for slow-moving products while fast-moving items can be decentralized. The reason why the specific SIC codes have been chosen is since these represent quite fast-moving products, that on average are ordered at least once per month. A deeper analysis also shows that these SIC codes tend to be quite stable over time. The result of Scenario 1 showed that the inventory at the RDCs would be increased quite significantly if applying direct shipments. A big benefit of Scenario 5 is therefore that it reduces the risk of increasing the inventory at the RDCs of items with very low demand. The risk of increasing the stock of those items is much higher since the demand is much more uncertain.

The analysis of the SIC codes at the RDCs, which can be seen in table 8.10, shows that on average 16% of the demanded products at the RDCs have a SIC code of either X or W. It is however important to note that items demanded by several of the RDCs are also represented several times in the table. 16% is not a big share of the products, but these items might generate a greater effect since they are demanded more frequently.

Table 8.10: Demanded items at the RDCs, split by supplier and SIC code

	SUPPLIER												
	A	B	C	D	E	F	G	H	I	J	K	L	Total
Total	212	61	36	496	160	111	137	307	37	646	159	51	2413
W	4	0	0	13	2	3	0	21	12	24	3	5	87
	2%	0%	0%	3%	1%	3%	0%	7%	32%	4%	2%	10%	4%
X	28	1	3	37	21	12	11	50	4	76	27	13	283
	13%	2%	8%	7%	13%	11%	8%	16%	11%	12%	17%	25%	12%
Y	11	6	4	30	20	11	4	32	5	61	19	6	209
	5%	10%	11%	6%	13%	10%	3%	10%	14%	9%	12%	12%	9%
K	21	1	5	31	9	4	7	28	5	56	13	5	185
	10%	2%	14%	6%	6%	4%	5%	9%	14%	9%	8%	10%	8%
L	29	5	7	72	21	18	25	48	2	94	33	8	362
	14%	8%	19%	15%	13%	16%	18%	16%	5%	15%	21%	16%	15%
Z	119	48	17	313	87	63	90	128	9	335	64	14	1,287
	56%	79%	47%	63%	54%	57%	66%	42%	24%	52%	40%	27%	53%

Table 8.11: Cost changes for Scenario 5

	SUPPLIER												
Cost Change (K€, %)	A	B	C	D	E	F	G	H	I	J	K	L	Total
DC Inventory	-3.7	-0.05	-2.4	-0.65	-1.7	-1.4	-0.38	-0.65	-2.1	-4.9	-7.9	-3.2	-29.0
	-31%	-1%	-6%	-21%	-6%	-20%	-8%	-19%	-28%	-26%	-16%	-16%	-15%
RDC Inventory	1.5	0.04	3.4	0.28	0.98	0.93	0.19	0.28	1.4	2.8	6.2	3.9	21.9
	34%	5%	124%	31%	11%	36%	22%	21%	43%	32%	53%	65%	42%
Total Inventory	-2.2	-0.02	0.98	-0.37	-0.76	-0.51	-0.19	-0.37	-0.62	-2.1	-1.7	0.67	-7.2
	-13%	0%	2%	-9%	-2%	-5%	-3%	-8%	-6%	-8%	-3%	3%	-3%
Warehouse	-2.8	-0.07	-0.72	-2.2	-1.5	-2.0	-0.79	-2.9	-0.97	-23.7	-4.5	-1.9	-44.3
	-16%	-1%	-18%	-5%	-23%	-11%	-12%	-14%	-35%	-31%	-6%	-47%	-16%
Transportation	0.36	0.20	0.21	0.37	0.65	3.5	0.27	-	4.2	-	3.7	6.4	19.8
	7%	1%	1%	6%	9%	11%	2%		14%		7%	18%	8%
Transportation Inventory	-0.33	0.00	-0.10	-0.03	-0.19	-0.21	-0.03	-0.03	-0.15	-0.25	-0.61	-0.49	-2.4
Total	-5.0	0.10	0.37	-2.3	-1.8	0.78	-0.74	-3.3	2.4	-26.1	-3.2	4.6	-34.1
	-13%	0%	0%	-4%	-4%	1%	-2%	-13%	6%	-25%	-2%	7%	-4%
Export/Import	32.4	2.2	5.8	37.7	30.3	41.9	17.3	42.3	27.3	54.8	31.7	39.8	363
Total Incl. Export/Import	27.5	2.3	6.2	35.4	28.4	42.7	16.6	39.0	29.7	28.7	28.6	44.4	329
	70%	6%	8%	65%	56%	71%	55%	149%	69%	27%	15%	68%	42%

There are however some problems with this scenario as well. Even though the SIC codes of X and W at the RDCs tend to be quite stable, there will still be a problem of items changing SIC codes. The same problem as in the Scenario 3 and Scenario 4 therefore applies, although the risk of this problem is reduced since these items are fast-moving and the SIC codes are quite stable. There is however another risk, in connection to the spare part life cycle. The demand of fast-moving items can suddenly drop if the products are in the end of the life cycle. The risk is of course most significant for items with long supplier lead times. The result of this scenario can be seen in table 8.11. It shows that this scenario seems to be cost-beneficial for 7 out of 12 suppliers with total potential savings of €42,000 per year.

8.7 Scenario Summary

An overview of the different scenarios can be seen in table 8.12. The table shows the main concluded characteristics of the scenarios as well as the potential savings.

Table 8.12: Summary of the Scenarios

	SCENARIOS				
	1	2	3	4	5
	All products	All products at the largest RDC	Products with demand only at the RDCs	Products not stocked at the DC	Products with highest demand at the RDCs
Reduction of workload at the DC	Big	Medium	Small	Small	Medium
Reduction of used space at the DC	Big	Medium	Small	None	Medium
Risk of reducing service at the DC	High	Medium	Low	None	Low
Risk of pushing inventory towards the RDCs	High	Medium	Low	None	Medium
Potential savings (K€) (Sandvik is exporter)	156	–	5.9	3.7	42
Potential savings (K€) (Supplier is exporter)	0	12.7	0	0	0

Chapter 9

Sensitivity Analysis

Sensitivity analysis is important in order to understand how valid the results are. Scenario 3 and Scenario 4 show too little potential cost-benefits and are therefore not further analysed. Scenario 2 is just a spin-off of Scenario 1 and just shows to be cost-beneficial for one supplier and are therefore not further analysed. Sensitivity analysis are performed on Scenario 1 and Scenario 5 and only for the option with no further costs for exports and imports.

In the model validation it was shown that the model clearly underestimates the values of inventory with highest underestimation of the inventory at RDCs. Since the results of the scenarios show a push of the inventory toward the RDCs, there is clearly a risk that the model underestimates the cost impact for the inventory cost. At the same time the number of handled order lines in and out of the DC are clearly overestimated which leads to the risk of overestimating the cost savings at the DC. In order to analyse the impact of this, a reality check is performed. Behind this analysis is an assumption of that the percentage changes should be quite valid, even though the exact values of the model clearly deviate from reality. The reality check is done by using the actual values of those cost drivers identified in the model validation and then applying the percentage changes estimated by the model. The results can be seen in table 9.1 and table 9.2. The tables show the total costs before and after applying direct shipments (D) as well as the changes.

Table 9.1: Reality check - Scenario 1

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Total Cost (K€)	69.7	57.9	212	49.7	127	91.6	46.5	27.0	47.1	133	386	105
Total Cost D (K€)	60.4	55.2	305	35.1	108	86.4	40.5	17.4	50.0	57.2	381	120
Change (K€)	-9.2	-2.7	93.0	-14.6	-19.1	-5.2	-6.0	-9.6	3.0	-75.9	-4.4	14.4
Change (%)	-13%	-5%	44%	-29%	-15%	-6%	-13%	-36%	6%	-57%	-1%	14%
Beneficial	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No

Table 9.2: Reality check - Scenario 5

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Total Costs (K€)	69.7	57.9	212	49.7	127	91.6	46.5	27.0	47.1	133	386	105
Total Costs D (K€)	67.3	58.2	245	47.6	127	91.0	46.2	23.2	50.6	105	388	117
Change (K€)	-2.3	0.4	33.0	-2.1	0.3	-0.7	-0.3	-3.8	3.5	-28.1	1.8	11.7
Change (%)	-3%	1%	16%	-4%	0%	-1%	-1%	-14%	7%	-21%	0%	11%
Beneficial	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	No	No

In chapter 7 Cost Model Development, it was argued that the inventory holding cost should reasonably be higher at the RDCs compared to the DC in order to capture the increased risks. As a part of the sensitivity analysis, an analysis of how high the inventory holding cost rate can be at the RDCs before direct shipments become non-beneficial is performed. This number is compared to the current used number of 25% and if the number is considered to substantially bigger then the supplier is considered to be beneficial to ship directly. Regarding transportation prices the model takes into consideration how they will change due to the split flow and the incentive prices. However, it does not take into consideration how the transportation prices will change due to a potential increment in either gross weight factor or chargeable weight factor due to smaller and less consolidated shipments. As a part of the sensitivity analysis, this will therefore be considered by analysing by what factor the transportation prices can increase before direct shipments become non-beneficial. This number is compared to the current number of the total factor found in table 7.2, since if the total factor is small, the supplier is assumed to be more resistant to an increase of the factor due to less consolidated flows. These two analysed factors are considered to be the most important uncertain factors and the analysis are done for both the original result as well as for the reality check. The result can be seen in tables 9.3 to 9.6.

Table 9.3: Factor analysis - Scenario 1

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
RDC Holding Cost Rate	199%	3000%	28%	1800%	180%	80%	890%	520%	-5%	530%	60%	10%
Transportation Factor	3.10	1.08	1.04	3.20	4.00	1.07	1.25	-	0.95	-	1.30	0.90
Beneficial	Yes	No	No	Yes	Yes	Maybe	Maybe	Yes	No	Yes	Maybe	No

Table 9.4: Factor analysis - Scenario 1 Reality check

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
RDC Holding Cost Rate	50%	500%	8%	250%	60%	45%	170%	170%	2%	260%	26%	10%
Transportation Factor	2.70	1.09	-1.45	2.90	4.70	1.13	1.35	-	0.91	-	1.07	0.65
Beneficial	Yes	No	No	Yes	Yes	Maybe	Maybe	Yes	No	Yes	No	No

Table 9.5: Factor analysis - Scenario 5

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
RDC Holding Cost Rate	105%	25%	25%	220%	70%	5%	120%	320%	-20%	250%	38%	-5%
Transportation Factor	1.85	1.00	1.00	1.35	1.25	0.98	1.04	-	0.93	-	1.05	0.89
Beneficial	Yes	No	No	Yes	Maybe	No	No	Yes	No	Yes	Maybe	No

Table 9.6: Factor analysis - Scenario 5 Reality check

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
RDC Holding Cost Rate	32%	5%	5%	50%	24%	28%	29%	120%	-5%	135%	24%	5%
Transportation Factor	1.40	0.98	0.06	1.30	0.96	1.02	1.02	-	0.90	-	0.97	0.71
Beneficial	Maybe	No	No	Maybe	No	No	No	Yes	No	Yes	No	No

9.1 Result

In order for a supplier to be considered as cost-beneficial with regard to direct shipments, with some level of confidence, it is thought that it should pass the first scenario analysis as well as all the sensitivity analyses. The result is shown in table 9.7. In Scenario 1, the suppliers A, D, E, H and J are considered to be beneficial for direct shipment, while the suppliers F and G might be beneficial. It is interesting to note that the beneficial suppliers are the ones that have savings of about >30% in the scenario analysis. It can also be noted that suppliers A, D, H and J were selected for analysis due to that they have the most number of dispatched order lines. Supplier E on the other hand has a quite substantial saving in transportation costs due to not really having incentive prices. According to the scenario analysis, shipping these five suppliers directly can save about € 126,000 in distribution costs. The saved inventory in the DC will be about 0.3% in total and the saved workload in the DC will be about 3.5%. If the result from the selected suppliers could be applied on all the suppliers, the total saved inventory at the DC could be about 1%, and the saved workload about 7% which equals a bit more than one warehouse worker. However, it is uncertain if the results from these suppliers could be applied on the rest of the suppliers since the ones being cost-beneficial with regards to direct shipment are the ones with the higher number of dispatched order lines. The top ones are already part of this analysis.

In Scenario 5, the suppliers H and J are considered to be beneficial for direct shipment, while the suppliers A and D might be beneficial. The suppliers H and J are the suppliers having the most number of products with SIC codes X and W, followed by the suppliers A and D. According to the scenario analysis, shipping the beneficial suppliers directly can save about € 29,000 in distribution costs. The saved inventory in the DC will be about 0.07% in total and the saved workload in the DC will be about 1%. If the result from the selected suppliers could be applied on all the suppliers, the total saved inventory at the DC could be about 0.2%, and the saved workload about 2%. However, as in Scenario 1, it is very uncertain if the results from these suppliers could be applied on the rest of the suppliers.

Table 9.7: Result after the sensitivity analysis

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Scenario 1	Yes	No	No	Yes	Yes	Maybe	Maybe	Yes	No	Yes	No	No
Scenario 5	Maybe	No	No	Maybe	No	No	No	Yes	No	Yes	No	No

Chapter 10

Supplier Compliance Analysis

The supplier compliance analysis is conducted in order to understand how easy it would be for Sandvik to apply direct shipments due to the capabilities of the suppliers. The analysis is mostly based on the answers received from the supplier compliance survey, found in appendix B, but also on information from the sourcing team at Sandvik. It can be noted that all suppliers have answered the survey, although the work positions of the respondents have varied. The survey questions regard different areas such as ordering, shipments etc, that are typically handled by different functions at a company. It is therefore hard to understand the validity of the received answers. The result of the survey can be seen in table 10.1. The answers of each section of the survey have been classified as being of no problem (🟢), potential problem (🟡) or clear problem (🔴).

Table 10.1: Supplier compliance result

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Previous Experience	🟡	🔴	🟢	🟡	🟢	🟡	🔴	🟢	🟢	🟢	🟡	🟢
Shipping Documents	🟢	🟢	🟢	🟢	🟢	🟡	🟡	🟢	🟡	🟢	🟢	🟢
Dangerous Goods	🟢	🟢	🟢	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Quantities	🟢	🟡	🟢	🟢	🟢	🔴	🟢	🟡	🔴	🔴	🔴	🔴
Quantities (sourcing)	🟢	🔴	🔴	🔴	🟢	🔴	🟢	🔴	🔴	🔴	🔴	🔴
Packaging	🟢	🟢	🟡	🟢	🟡	🟢	🟢	🟢	🟡	🟡	🟡	🟢
ISPM 15	🔴	🔴	🟡	🟡	🟡	🔴	🔴	🟡	🟡	🟡	🟡	🟡
Local Direct Shipments	🔴	🔴	🔴	🔴	🟡	🔴	🔴	🟢	🟢	🟢	🔴	🟡

Most of the suppliers, 10 out of 12, have previous experience from exporting goods outside of the EU internal market. However, not all of them have experience from shipping goods by sea or air transportation. Only 6 out of 12 have experience from sea transportation and 8 out of 12 from air transportation. This mean that the other suppliers might not be aware of special regulations for these transportation modes. There is in general no problem regarding compliance when it comes to shipment documentation. However, it can be noted that a couple of suppliers are not completely sure if they can issue a commercial invoice. There is as well no problem when it comes to dangerous goods since almost all of the selected suppliers are certain that they don't ship such goods to Sandvik. However, it can be noted that the general knowledge about dangerous goods requirements is low.

Among the investigated suppliers, 9 out of 12 have either price breaks, MOQs or order multiples. This issue can cause clear problems for direct shipments. An interesting thing to note is that there are discrepancies in the answers of the suppliers versus the sourcing department. The reason behind these discrepancies are unclear.

The suppliers are in general willing to modify their packaging process according to instructions from Sandvik. They can provide item labels as well as either single pack or pack small items in multiples of 10. However, some suppliers are not completely certain about what they can do. Regarding the ISPM 15 standard, there is indeed very low knowledge among the suppliers and none of them seem to be certified. If this would cause problems or not depends a lot on the item characteristics and on how these products should be shipped. Three of the analysed suppliers have a clear potential for local direct shipments since they have local entities nearby the RDCs. The RDCs could be supplied by these local warehouses instead of being supplied from Europe.

Chapter 11

Risk Analysis

There are several risks associated with the decision of direct shipments. One risk is that the assumptions that the model is based on can be wrong. Another risk is that the used prices and costs in the model might change and therefore favor another solution. An example is that the transportation prices between the DC and the port consolidation point or the airport might increase if a substantial part of the flow is distributed directly instead. Another example is that transportation cost changes for supplier H and J have not been considered at all. Since these suppliers have an increased distance to the consolidation point compare to the DC, together with the split flow, there is a clear risk that the transportation costs should increase which might affect Sandvik regardless if Sandvik or the suppliers are responsible for paying the freight according to the Incoterms. Some of the model risks are briefly considered in the sensitivity analysis but not to a full extent. Even if some risks have been considered, it is not possible to fully understand them without further investigation, such as the issue of less consolidation.

Several other risks have not been accounted for in the cost-trade off model. The greatest risks that have been found are the following, which are further explained in sections of this chapter:

- Increased purchase prices
- Changed customer service
- Increased supplier dependency
- Practical issues

11.1 Increased Purchase Prices

Direct shipments will as earlier stated lead to an increment in the number of order lines to the suppliers, while the item quantity of each order line is reduced, for items that previously have been stock standard at the DC. This has potential to interfere with the price breaks, MOQs and order multiples at the suppliers and can either lead to increased prices or unnecessary amount of stock being kept at the RDCs. Both options have the potential to cause substantial cost increments to Sandvik. Table 11.1 compares the potential savings of Scenario 1, for the solution where Sandvik is the exporter, with the total value of goods being shipped direct to the RDCs. It also shows how much the purchase prices can change before the potential savings are erased. In general only the suppliers D, H an J seem to have some resilience for increased purchase prices. Although, it must be remember that also the flow of goods to the DC can be affected by higher purchase prices if the flow to the RDCs are removed. As seen in the empirical findings, the price break increments can be very large and the increment in purchase prices can be much higher than any potential savings of direct shipments.

Table 11.1: Analysis of changed purchase price in Scenario 1

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Cost Change (K€)	-11.4	-2.1	-1.6	-16.9	-15.5	-2.6	-4.6	-9.4	1.8	-72.9	-19.4	4.0
Value Flow (K€)	397	106	338	48.3	560	238	60.9	38.9	113	262	1,198	478
Price Change	3%	2%	0%	35%	3%	1%	8%	24%	-2%	28%	2%	-1%

11.2 Changed Customer Service

There is a risk of a change in customer service when applying direct shipments. One reason for reduced customer service is that items might no longer be stock standard at the DC according to the rules. This will lead to longer lead times for sales areas belonging to the DC, which will reduce the customer service and potentially lead to increased requests of express shipments. It is hard to determine a cost for this since the removal of these items from the DC also helps saving inventory costs. The number of stock standard items at the DC for different scenarios can be seen in table 11.2. Several interesting things can be noted. As expected, Scenario 1 reduces the number of stock standard items the most, whereas Scenario 5 practically keeps the same items as in the base scenario as stock standard. This means that this risk is much lower for Scenario 5. It is as well interesting to see Scenario 3 as a comparison for Scenario 1 in order to see how many of the items that are no longer stock standard that will have an impact of the sales areas belonging to the DC, and which will only affect the RDCs.

Table 11.2: Number of stock standard products at the DC in different scenarios

	SUPPLIER											
	A	B	C	D	E	F	G	H	I	J	K	L
Base Scenario	90	31	18	236	61	58	71	110	12	299	59	16
Scenario 1	76	23	16	180	46	42	59	103	11	260	53	15
	-16%	-26%	-11%	-24%	-25%	-28%	-17%	-6%	-8%	-13%	-10%	-6%
Scenario 2	80	27	18	212	52	50	67	107	11	281	58	16
	-11%	-13%	–	-10%	-15%	-14%	-6%	-3%	-8%	-6%	-2%	–
Scenario 3	84	29	18	226	61	54	71	109	11	292	58	16
	-7%	-6%	–	-4%	–	-7%	–	-1%	-8%	-2%	-2%	–
Scenario 4	90	31	18	236	61	58	71	110	12	299	59	16
	–	–	–	–	–	–	–	–	–	–	–	–
Scenario 5	88	31	18	236	61	58	71	110	12	299	59	16
	-2%	–	–	–	–	–	–	–	–	–	–	–

There is also a risk for service reduction at the RDCs. Even though the service for stock standard items at the RDCs should be the same, the longer lead time can in fact reduce the service a lot when looking at single customer orders. The reason for this is due to the that the demand is stochastic and it is therefore not possible to determine when it will happen. Out of accident, demand might occur while an RDC is out of stock and the longer the lead time the longer it will take for the customer to receive the item. This will make the distribution system less responsive. The question is how items like this should be handled. Currently at Sandvik, a customer order will be created in those cases with order criticality of 2 which in general will lead to air shipment.

But if the lead time is really long, the time to receive the item might still be really long. One option for those cases could be to source the item from another stockroom instead such as the DC. Though, a problem with this is that the item might no longer be stocked at the the DC. Another problem is that the demand for those items (order intake and hits) will not be recorded at the DC since the demand is currently only recorded in the system according to the supply path. Therefore the RDC will use demand that was aimed for the sales areas belonging to the DC which will reduce the service for those customers. To supply from another stockroom will also require manual administrative work. This leads to an increased risk of air shipment for the RDCs although it is hard to determine how big the risk is. But as stated in the empirical findings the cost for air shipment is several times higher compared to the cost for sea shipments, so the increase could be significant.

There is as well a risk of increasing the customer service at the RDCs too much. While this is not a risk from the customer perspective there is a clear risk of increased cost from the perspective of Sandvik. Due to the longer lead time for the RDCs, the decision of replenish an item will have to be made earlier. This increased the risk of ending up with excess inventory if the demand suddenly drops. It can clearly be stated that longer lead times put more pressure on having correct forecasts.

Even though the analysis in general shows increased amount of inventory at the RDCs due to longer lead times, a deeper analysis shows that for some items the inventory is actually reduced. The reason behind this is that if the ROP is calculated as the same after applying direct shipments, the larger lead time demand will help reduce the safety stock. Although, this should in theory only happen for items that overperform with regard to service. However, since the inventory system at Sandvik is not working as according to theory, it is hard to make a conclusions about this.

11.3 Supplier Dependency

A big risk that has been identified is that direct shipments would lead to increased dependence on the suppliers. Direct shipments would mean a change from a multi-echelon inventory system to a single-echelon inventory system. This means that if the supplier can not deliver according to the set lead time, the problems will be pushed directly towards the RDCs. The fact that the inventory is pushed towards the RDCs and that the total inventory is reduced for most suppliers in most scenarios confirms this dependency. The inventory system at Sandvik does not take supplier lead time variances into consideration, therefore this factor has not been taken into consideration in the inventory calculations.

It has also been identified that shipments that do not have correct freight documentation or correct ISPM 15 stamps can cause severe delays in customs and potential fees. Packages without correct markings or faulty packaging lists might get stuck somewhere in the distribution chain. As stated before, direct shipments will lead to increments in the number of packages which will further increase this risk. Direct shipments push this responsibility of having correct markings and documentations towards the supplier.

In a scenario with direct shipments, products will not be inspected on product level until they have reached the RDCs. In case there are any product problems such as wrong items, incorrect counts, faulty packaging or bad item quality, these problems will not be identified until quite late in the supply chain when the possibility to get new products within short time might be limited. It is as well unclear how well the RDCs can identify some of the problems, such as problems of quality. The RDCs are 3PL warehouses that do not have the same experience and competence when it comes to product knowledge as the DC which is managed by Sandvik. A similar problem occurs if a quality check is demanded by for example the supplier. In those cases the supplier has to coordinate several RDCs instead of just the DC. This postponement of quality check clearly increases the reliance on the suppliers as well as the external 3PLs.

From a supplier perspective, direct shipments increase the administrative work since the number of connection points the supplier have towards the customer increases. There might be a risk that they are not willing to accept the increase or take this as an excuse to raise prices. Not only will the administrative work increase at the supplier side but also from the perspective of Sandvik. Due to the increased dependence on the suppliers, Sanvik will need to have more extensive supplier management.

11.4 Practical Issues

There are several practical issues that have been identified as unclear how they should be solved and they are therefore considered risks. When applying direct shipments, each replenishment order from the RDC will lead to purchases of new items from a supplier instead of just relocation of goods within the SMCL network. Therefore these orders will probably need more manual checking compared to today in order to make sure that Sandvik don't buy items of which there might be excess inventory somewhere else in the distribution network. It remains unclear who will be responsible for this within the organisation of Sandvik.

For a situation where the suppliers are the exporter, a big issue is the order visibility. Currently data from the ERP system of Sandvik is exported into a logistics system used for sea and air shipments between the DC and the RDCs. This system is used for tracking orders for sales areas and without the data in the system the order visibility will be very low. This will require either some sort of data integration between the suppliers and the logistics system or a lot of manual work. There is a also an identified problem with the Incoterms, where the suppliers currently use FCA while the DC use the DAP when shipping to the RDCs. In order to be able to consolidate the goods in the same container, the same Incoterm has to be used for all goods. It is doubtful that there will be possible to find a common Incoterm that suits both of these flows. This issue can however be solved by manual work at the freight agent side, although they will charge money for it.

For a situation where Sandvik is the exporter, a virtual stockroom has to be created within the ERP system of Sandvik. In practice this means a virtual stockroom in the consolidation point in this case. Virtual stockrooms have been created in other distribution networks at Sandvik, in for example China. This solution means that the goods will be delivered into the stockroom and then it will be possible for Sandvik to create a commercial invoice and export the goods. As stated above, there will not be any checks on item level and the goods must therefore be delivered into the system at Sandvik upon the trusts of the suppliers. This will further increase the reliance on the suppliers and require either a data integration or manual work.

Chapter 12

Discussion of Alternative Solutions

The use of buffer stock and local direct shipments have been identified during the thesis project as possible alternative solutions in order to implement direct shipments. These solutions would have influences on the result of whether or not direct shipment is more suitable. The effects on the distribution system are discussed in this chapter.

12.1 Buffer Stock

As found in the empirical analysis, a solution to the problem of price breaks, MOQs and order multiples could be to have buffer stocks at the suppliers. This would make sure that the RDCs can order in their preferred order quantity without risking increased price or increased cycle stock. If buffer stocks are implemented, this would reduce the lead time and as stated in theory also help to reduce the safety stock. However, in the case of Sandvik, this will only happen as long as the auto ROP method is used, since this method is the only one dependent on the supplier lead time. Buffer stock might mean stock of work in process or finished goods, depending on where in the production process the supplier can benefit from economies of scale. How much the lead time can be reduced depends on what kind of buffer stock that are being stored and in essence how quick the supplier can ship it out. If finished goods are assumed, where the supplier lead time can be cut the most, something very interesting happens in the distribution system. What happens is that the lead time for replenishment from the supplier towards the RDC will be about the same as replenishment from the DC. This would lead to a reduction of safety stock at the DC without increasing the safety stock at the RDCs. In order to see the cost consequences of this, it is possible to just look at the already develop cost analysis but neglecting the increased inventory at the RDCs. As long as the suppliers are willing to pay for the capital cost of having the products in stock there could potentially be substantial savings as well as a reduced need of space at the DC. Even though the suppliers that currently have buffer stock have agreed to the responsibility of the capital costs, it is important to remember that Sandvik still bears the risk of those products and therefore bears the cost for that. It is also unclear if other suppliers would agree to bear the cost for capital.

There are however several identified problems with the buffer stock approach apart from the ones already concluded for direct shipments. A very important problem is the increased supplier management and the extensive manual work with administrating contracts. Buffer stock levels need to be set and constantly monitored. Especially with regards to direct distribution, the different forecasts of the RDCs needs to be coordinated. For the suppliers currently having buffer stock, only the forecast of the DC is needed to be taken into consideration. If this is done manually, it should as well lead to a less efficient stock management compared to the automated calculated inventory management that Sandvik have today. In practice, buffer stocks should therefore only be reasonable for fast-moving products.

Another important issue with this strategy that have been raised by the sourcing team is that it comes with legal issues of responsibility that needs to be sorted out. Sandvik has agreed to purchase these products, but who is economically responsible if there for example is a warehouse fire? If these issues are not sorted out, they can cause severe complications.

12.2 Local Direct Shipments

Local direct shipments have been identified as an alternative to supplying the RDCs from Europe. There are several benefits of this solution. A clear benefit is that the supplier lead times at the RDCs should be reduced compared to direct shipments from the European entities. This leads to a lower need for safety stock at the RDCs as well as a reduced need for express shipments. Another benefit is that the total transportation distance is reduced which should lead to a reduction in distribution costs. A problem with this solution is that the issue of price breaks, MOQs and order multiples will still persist. Although, this solution has not been further investigated and it therefore remains unclear how beneficial this solution is.

Chapter 13

Recommendations

As a general solution, direct shipments of the European suppliers is not considered a good option. On the contrary, the current setup of the distribution network seems to suit Sandvik quite well. The analysis shows that direct shipments can be cost-beneficial for some of the suppliers, but only the ones that have the most number of dispatched order rows at the DC seem to be beneficial. These suppliers can however only be beneficial if Sandvik is the exporter, which require Sandvik to implement a virtual stockroom. Apart from the cost perspective, the analysis shows that direct shipments also come with a lot of risks and that it is very hard to calculate the cost of those risks. All the work of setting up a divided distribution network where some of the products are being shipped directly, along with the discovered risks, makes it doubtful that direct shipments will provide any substantial savings.

Furthermore, the analysis shows that the issue of congestion at the the DC can not be solved. This is partially due to that the beneficial suppliers are not the suppliers with large products and partially due to that the flow of goods to the RDCs represent quite a small part of the goods being shipped through the DC. The flow going to the RDCs represent in total only 21% of the dispatched order lines at the DC and only 8.3% of the dispatched net weight. It is instead advised that Sandvik look into the management of inventory and potentially an extended use of buffer stocks as a way to reduce the inventory at the DC.

Most of the potential cost reductions are in saved warehouse handling at the DC. It must however be remembered that most of the potential cost savings in warehouse handling actually belongs to one specific supplier, namely supplier J, due to that this supplier has such extensive warehouse handling costs and ships the most number of order rows. It is therefore recommended to try to reduce this cost, but it does not necessarily have to be done by using direct shipments. Instead, other options are recommended to be considered. One of these options is to let the supplier prepackage the products without applying direct shipments. In general, this supplier ships small items and it can therefore be an idea to make the supplier prepackage the products in certain batch quantities according to instructions from Sandvik. Another option is to further investigate local direct shipments. Even though many of the problems of direct shipments from Europe would remain, this solution can potentially reduce both the lead times and the transportation costs due to reduced distance. Supplier H and J show to be cost-beneficial in both Scenario 1 and Scenario 5, and both of these suppliers have options for local direct shipments. It is therefore recommended to consider and further investigate this option.

To let the supplier prepackage the products without applying direct shipments is also recommended to be considered as a way to reduce the freight costs, since this can reduce the total factor if goods are currently shipped on unstackable pallets. Especially supplier B has been identified as a beneficial case for this. This supplier has the highest chargeable weight factor, despite shipping very heavy items which seems to be due to the fact that the supplier ships the goods on unstackable pallets. If Sandvik would like to apply direct shipments, even though it is generally not recommended, it is recommended to start by shipping supplier E directly, since this supplier is beneficial in scenario 1 and can be shipped directly without the need of setting up a virtual stockroom.

In general, Sandvik is recommended to apply a supply chain perspective by really analysing the need of the customers and set a distribution network matching a distribution strategy. The fact that the customer service has not been considered more deeply in this thesis is the main drawback. The supply chain perspective is important since it is very hard to just look at the distribution network and conclude that direct shipments are favorable or not. As can be seen, the issue of price breaks, MOQs and order multiples can be a very important factor when it comes to profitability of the whole supply chain. The project that the purchase department is looking into of combining the purchase for the production and the aftermarket and storing it in a combined DC could reasonably be a good strategy. If the current DC is too small for this, then maybe it is better to look into a long-term solution for this issue, such as expanding the warehouse space or renting another warehouse nearby. In fact the decision of direct shipments can be concluded to be a very strategic one.

Chapter 14

Conclusions

This chapter provides answers to the researched questions, contribution to practice, contribution to theory as well as suggestions for further research.

14.1 Answers to Research Questions

RQ 1. What factors should be taken into account when deciding the optimal distribution setup for a company shipping spare parts?

There are many factors that should be taken into account when deciding the optimal distribution setup. When it comes to cost, the logistical drivers need to be taken into consideration: Transportation, warehousing and inventory. For transportation, it is important to understand how the split transportation flow will affect the size per shipment and the consolidation. It is also important to take the price structures into account, as well as how the number of exports and imports will change. Regarding warehousing it is important to understand how a warehouse is providing benefit to the distribution network but also understanding what factors are driving the costs at the warehouse. Inventory is an important part of the distribution decision. In order to understand how it is affected, it is important to understand how the inventory is controlled as well as understanding how the inventory control will change due to increased lead times. It is also of importance to consider the distribution of the demand as well as the life cycle of spare parts. Also the cross-functional driver of information should be taken into account apart from the logistical drivers.

The results have also shown that it is of big importance to take the impacts on the whole supply chain into consideration. Especially the sourcing driver needs to be taken into consideration, since the order quantities of customer made spare parts can clearly have a huge impact on the total supply chain costs. From the same perspective of taking the whole supply chain into account, the strategy of being either responsive or cost-efficient is an important factor. With regard to direct shipments, it is especially important to understand how the customer service will change due to increased lead times.

It has also been shown that the risks of applying direct shipments can be huge. This factor needs to be taken into consideration and be evaluated. Also what capabilities the suppliers have for direct shipments should be considered.

RQ 2. When is it more optimal to use direct shipments from suppliers to regional DCs and when is it more optimal to ship through a global DC for a company shipping spare parts?

Direct shipments are beneficial if the savings in warehouse handling, especially the number of order picks, are big enough to off-set the increased transportation costs of splitting the transportation flow and increasing the number of transportation links, as well as off-setting the risk of higher transportation prices due to less consolidated transportation flow and the risk of costly excess inventory further down the supply chain.

Typically direct shipment can be suitable for fast-moving and high-demand items. However, spare parts typically have low and irregular demand and are therefore typically not suitable for direct shipments from the inventory perspective. From the transportation perspective, the flow of goods when it comes to spare parts is typically not big enough.

Further more, the cost savings of direct shipments must also off-set the increased risks and the increased supplier management. The decision to ship directly or not is a very strategic decision and the potential cost-savings must also off-set any reduction in responsiveness.

RQ 3. What distribution setup is most optimal in the case of Sandvik?

The solution of direct shipments are a bit special in the case of Sandvik, since the DC also works as an RDC. This means that only parts of the goods flow to the DC can be removed, which will lead to a split distribution flow. Direct shipments are not considered a good solution is general. Direct shipments can in practice only be beneficial if a virtual stockroom is implemented. In this case, direct shipments can be beneficial for some of the suppliers at Sandvik, but only the ones having the most number of dispatched order lines going to the RDCs at the DC. It is also concluded that direct shipments come with a lot of risks as well as increased management. Therefore the cost-savings must be large enough to off-set these risks. It is very hard to estimate the cost of those risks but the cost can potentially be very big.

Direct shipments can maximally reduce 1% of the warehouse space for the beneficial suppliers. It was also concluded that the cost for space at the DC is a small cost compared to other costs in the distribution network. Direct shipments can maximally reduce the number of warehouse by 1 employee. The current distribution setup seems very suitable. A major reason behind this is that Sandvik has quite many suppliers, of which most ship a quite small flow of products.

14.2 Contribution to Practice

This thesis has fulfilled the purpose and provided Sandvik with a recommendation for direct shipments. It has also provided Sandvik with knowledge about the problem and insights into what important factors to consider.

14.3 Contribution to Theory

Chopra and Meindl (2016) state that changing the distribution network will affect cost of inventory, transportation, facilities and information. However in the case of Sandvik it can be concluded that also the cost of sourcing will be highly affected depending on the distribution network due to the concept of price breaks, minimum order quantities and order multiples. These factors become very important to Sandvik since many of the products are spare parts that are made-to-order and have very low demand which generates high changes in product costs if the order quantities is reduced.

The research also shows that the fixed cost for exports and imports can be very large compared to other distribution costs when considering direct shipments, especially in the cases of shipping small volumes. This knowledge has not been found stated in the researched literature. Furthermore, the theory also stated that distribution decisions on different decision levels are typically modelled in separate models. This thesis confirms that this is quite reasonable, since it is hard to understand how different factors drive the end result if too many factors are considered.

14.4 Future Research

It has been concluded that it is hard to model the change of service and the costs in this system due to several reasons. One reason is that the demand of many items is very small making it hard to predict a certain demand in the future. Another reason is that the distribution system at Sandvik operates under quite complex rules. Examples of this are that the DC operates as both a DC and RDC at the same time, the rules of stock standard and the fact that the inventory control system at Sandvik is not clearly connected to theory. Therefore a suggestion for further research is to analyse the system by using simulation. This would provide a tool that can correctly analyse a system with quite complex rules like the one at Sandvik. This would also make it possible to take the concept of multi-echelon inventory system into consideration.

The distribution system at Sandvik also opens up for some specific research subjects. It could be interesting to especially analyse how the stock standard rule (>2 hits) are affecting the service level and the optimal distribution setup. Another interesting research area could be to further analyse the efficiency of manually agreed buffer stock compared to system where inventory is held at a DC but with automated replenishment.

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Appendix A

Extended example of price breaks in transportation

Table A.1: Extended example of price breaks in transportation

Chargeable Weight (kg)	Price per kg (€)	Total Discount	Price Break Discount	Price Break Increment
0-44	0.86	0%	0%	0%
45-99	0.86	0%	0%	0%
100-199	0.86	0%	0%	0%
200-299	0.86	0%	0%	26%
300-399	0.68	21%	21%	0%
400-499	0.68	21%	0%	26%
500-599	0.54	37%	21%	0%
600-799	0.54	37%	0%	0%
800-999	0.54	37%	0%	13%
1000-1499	0.48	44%	11%	0%
1500-1999	0.48	44%	0%	0%
2000-2499	0.48	44%	0%	50%
2500-2999	0.32	63%	33%	0%
3000-3499	0.32	63%	0%	0%
3500-3999	0.32	63%	0%	0%
4000-4999	0.32	63%	0%	45%
5000-5999	0.22	74%	31%	0%
6000-6999	0.22	74%	0%	10%
7000-7999	0.20	77%	9%	25%
8000-8999	0.16	81%	20%	0%
9000-9999	0.16	81%	0%	33%
>= 10000	0.12	86%	25%	0%

Appendix B

Survey: Supplier Capability for Direct Shipments

Previous Experience

1. Do you have experience in exporting goods (outside of EU internal market)?
   (a) Yes
   (b) No
   (c) Don't Know
2. Do you have experience in shipping goods by sea transport?
   (a) Yes
   (b) No
   (c) Don't Know
3. Do you have experience in shipping goods by air transport?
   (a) Yes
   (b) No
   (c) Don't Know

Shipping Documents

4. Are you able to provide a commercial invoice for export with the following information: Consignee and shipper including addresses, invoice date, customer order number, total weight, total value, currency, incoterm, VAT number and description of items including quantity, value, tariff code and country of origin.
   (a) Yes
   (b) No
   (c) Don't Know
5. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
   - Text Field
6. Are you able to provide a packing list with the following information: Consignee and shipper including addresses, weight per package, dimensions per package, total volume, total weight and total number of packages.

   (a) Yes
   (b) No
   (c) Don't Know

7. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
   - Text Field
8. Are you able to provide a label on every shipped out package with at least package number and consignee?
   (a) Yes
   (b) No
   (c) Don't Know
9. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
   - Text Field
10. Are you able to provide a list of all shipped out package numbers in a certain shipment? Either on a separate list or included in the packing list or commercial invoice.
    (a) Yes
    (b) No
    (c) Don't Know
11. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field

Dangerous Goods

12. Are you shipping any products to Sandvik that classify as dangerous goods?
    (a) Yes
    (b) No
    (c) Don't Know
13. Do you have knowledge about rules for dangerous goods for sea and air shipments?
    (a) Yes, only for sea shipments
    (b) Yes, only for air shipments
    (c) Yes, for both shipment modes
    (d) No
    (e) Don't Know
    (f) Not Applicable
14. Are you certified to pack dangerous goods and create dangerous goods declarations for sea and air shipments?

(a) Yes, only for sea shipments
(b) Yes, only for air shipments
(c) Yes, for both shipment modes
(d) No
(e) Don't Know
(f) Not Applicable

15. If not certified, are you able to provide dangerous goods declarations for dangerous goods by an external party?
    (a) Yes, only for sea shipments
    (b) Yes, only for air shipments
    (c) Yes, for both shipment modes
    (d) No
    (e) Don't Know
    (f) Not Applicable

16. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field

Quantities

17. Do you have price breaks on products ordered by Sandvik? (meaning that Sandvik gets different purchase prices depending on the quantity of the purchase order)
    (a) Yes
    (b) No
    (c) Don't Know

18. If you answered yes to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field

19. Do you have minimum order quantities on products ordered by Sandvik? (meaning that Sandvik has to order at least a certain amount when placing a purchase order)
    (a) Yes
    (b) No
    (c) Don't Know

20. If you answered yes to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field

21. Do you have order multiples on products ordered by Sandvik? (meaning that Sandvik has to order in special quantity multiples when placing an order)

(a) Yes
(b) No
(c) Don't Know

22. If you answered yes to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field

Packaging

23. Do you have a packing process that is flexible and could potentially be modified upon request by Sandvik?
    (a) Yes
    (b) No
    (c) Don't Know
24. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field
25. Are you able to single pack all items?
    (a) Yes
    (b) No
    (c) Don't Know
26. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field
27. Are you able to pack small items in multiples of maximum 10 pcs? Small items can approximately be considered to be items with weight below 0,01 kg or value below €5.
    (a) Yes
    (b) No
    (c) Don't Know
    (d) Not Applicable
28. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field
29. Are you able to provide a label with Sandvik item number on every item package?
    (a) Yes
    (b) No
    (c) Don't Know
30. If not, would you be willing to change your outbound process to include this?

(a) Yes
(b) No
(c) Don't Know
(d) Not Applicable

31. If you answered no to the previous question, why? Or if you want to clarify the answer in any way.
    - Text Field

ISPM 15

32. Are the packaging you are currently using approved according to the ISPM 15 standard?
    (a) Yes
    (b) No
    (c) Don't Know
    (d) Not Applicable
33. Do you have a license to stamp already treated wood packaging according to the ISPM 15 standard?
    (a) Yes
    (b) No
    (c) Don't Know
    (d) Not Applicable

Direct Shipments Locally

34. Do you have an entity which Sandvik can buy from locally? (In or close to: North America, Asia, Africa, Oceania)
    (a) Yes
    (b) No
    (c) Don't Know
35. If yes, where are those located?
    - Text Field