EVALUATING AND IMPROVING A SPARE PARTS WAREHOUSE IN THE MINING INDUSTRY

A CASE STUDY AT SANDVIK AB

LUND UNIVERSITY

Filip Linse & Jacob Sandefeldt

Supervisor: Joakim Kembro
Examiner: Jan Olhager

DEPARTMENT OF ENGINEERING LOGISTICS
Faculty of engineering, LTH, Lund University

Abstract

Title: Evaluating and improving a spare parts warehouse in the mining industry – a case study at Sandvik AB.

Authors: Filip Linse, Jacob Sandefeldt

Supervisor: Joakim Kembro, Department of Industrial Management and Logistics, Faculty of Engineering, Lund University

Problem description: The importance of having efficient warehouse operations is increasing as customer demand changes quickly in combination with an overall expectancy of shorter and shorter lead times. Warehouses are a major part of any large company when it comes to costs and supply chain performance which justifies making them subject to optimization. To enable items to move smoothly through the warehouse the different activities that are performed within must be aligned with each other as well as with the parts of the supply chain that extend beyond the warehouse walls. As opposed to many other warehouse optimization projects, this thesis does not focus on the picking operation. Instead, the focus is based on the hypothesis that improving the receiving operation can unlock the overall warehouse potential through synergies with the other operations.

Purpose: The purpose of this thesis is to identify improvement suggestions in the receiving operation of a warehouse in order explore how these can enhance the efficiency of the entire warehouse.

Research objectives: Characterize the warehouse based on operational and design aspects and identify the problems that can be found within. Suggest improvements focused on the receiving operation and determine how these suggestions impact the entire warehouse.

Methodology: The literature study was compiled into a support tool for characterizing a warehouse that lists the most important alternatives for each major operation that can be used when deciding on how a particular warehouse should be configured. Through a single case study, the tool is applied to a spare parts warehouse at Sandvik and used to identify problems and deliver improvement suggestions.

Conclusion: The hypothesis that the receiving operation can be the key to overall warehouse performance is justified. By changing different aspects of the receiving operation such as the placement of packing stations, number of warehouse operators, and how items are packed the ultimate measure of a warehouse, which is the ability to meet customer demand, is enhanced.

Keywords: Warehouse operations, warehouse design, warehousing, receiving operation, synergies, supplier collaboration.

Sammanfattning

Titel: Utvärdering och förbättring av ett reservdelslager inom gruvindustrin – en case-studie på Sandvik AB

Författare: Filip Linse, Jacob Sandefeldt

Handledare: Joakim Kembro, Institutionen för teknisk logistik och ekonomi, Lunds Tekniska Högskola vid Lunds Universitet.

Problembeskrivning: Betydelsen av att ha effektiva lagerfunktioner blir allt viktigare i takt med att kundefterfrågan allt snabbare varierar i kombination med en branschöverskridande förväntan på kortare ledtider. Lager är en viktig del av alla stora producerande bolag med avseende på kostnader och försörjningskedjans prestationsförmåga vilket berättigar viljan att optimera dem. För att möjliggöra att godset flyter genom lagret på ett smärtfritt sätt behöver de olika aktiviteterna däri vara utformade efter varandra och även efter den del av kedjan som sträcker sig utanför lagrets väggar. Till skillnad från många andra projekt inom lageroptimering så behandlar denna uppsats inte plockaktiviteten. Istället är fokus utformat efter hypotesen att förbättringar i godsmottagningen kan låsa upp lagrets allmänna potential genom synergier med andra aktiviteter.

Syfte: Syftet med denna uppsats är att identifiera förbättringsåtgärder i ett lagers godsmottagning för att utforska hur dessa kan förhöja effektiviteten för lagret som helhet

Forskningsmål: Karakterisera lagret baserat på process- och designmässiga aspekter och identifiera de problem som finns däri. Föreslå förbättringsåtgärder som är fokuserade på godsmottagningen och fastslå hur dessa åtgärder påverkar hela lagret.

Metod: Litteraturstudien sammanställdes till ett hjälpverktyg för karakterisering av ett lager som listar de viktigaste alternativen som kan användas för varje del av lagret när det bestäms hur det ska se ut. Genom en singulär case-studie tillämpas hjälpverktyget på ett reservdelslager hos Sandvik och används för att senare identifiera problem och leverera förbättringsåtgärder.

Slutsats: Hypotesen att godsmottagningen kan vara nyckeln till den övergripande prestationsförmågan för att lager är berättigad. Genom att ändra olika delar av godsmottagningen såsom placering av paketeringsstationer, antal arbetare, samt hur godset paketeras kan det slutgiltiga mätetalet för ett lager, förmågan att tillgodose kundefterfrågan, förbättras.

Nyckelord: Lageraktiviteter, lagerdesign, lagerhantering, godsmottagning, synergier, leverantörssamarbete.

Preface

This thesis was conducted in the spring of 2018 as a conclusion of our education in Mechanical Engineering and Industrial Management with master specialization in Supply Chain Management at Lund University, Faculty of Engineering. Through the process of researching and writing the thesis, we have gained insight of how major industrial companies are working in this field and a taste of which obstacles working professionals are faced with throughout their careers. The notorious relationship between theory and practice has been more present than ever and the challenges that come with it have deepened our understanding of academic research, supply chain management and general problem solving.

The collaborating partner for this project has been Sandvik AB where we would like to thank Miguel Rocha for initiating this case and getting us on board. We would also like to thank Jamie Heath and Gustav Karlström for their useful advice and competent supervision throughout the semester as well as being great company on our trips to the warehouse in Venlo, Netherlands. Having Sandvik as case company has enabled a particularly exciting learning experience for us since the company is a representative for many others in neighboring fields. Lastly, we would like to thank our supervisor at Lund University, Joakim Kembro, for challenging us to continuously improve the quality of our thesis.

Svedala, June 2018

Filip Linse

Jacob Sandefeldt

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1. Introduction

1.1 Introduction to subject

One of the most important components that exist within modern society is the accessibility to minerals (Stewart, 2010). The total revenue of the top mining companies worldwide in 2016 was 496 bn USD which is more than five times the value in 2002 (Statista, 2018). Within the EU, alone mining supports construction, chemicals, automotive, aerospace and more (European Commission EDG, 2004). This thesis will focus on how to efficiently handle the spare part components that are used to build mining equipment when they are stored in a warehouse.

A common denominator for components used in drilling machines, blast tools and crushing tools is that they tend to be large and expensive. Nevertheless, there is also a need for plenty of small-standardized parts that hold everything together. These components often come from multiple sources, both external suppliers and internal manufacturers, which creates a need for consolidation in a warehouse. The need for consolidation particularly applies to spare parts, since they often are used together for maintenance and service (Moharana & Sarmah, 2017).

Manzini (2012) states that warehousing and material handling has become one of the most critical components within a global supply chain, importance being equally divided between the function as a point of storage and the function as a point of information. Additionally, a spare parts warehouse is one of the most challenging warehouse types to operate since the warehouse functionality usually is essential for the entire business to run (Bartholdi & Hackman, 2017, p. 8).

Kembro et al (2017) states that the capital and operating expenses that come with a warehouse often induce it to be considered a burden for the supply chain which ties into increased overall emphasis on improving lead times. To cope with this, companies such as Sandvik put constant pressure on the warehouses to improve. However, changing anything in a warehouse operation needs careful planning because warehouses are normally operated on a daily basis and alterations can require shutdown time (Gu et al., 2010). Typically, a warehouse has two flows, an inbound- and an outbound flow, which are divided into different operations; receiving, put-away, picking, packing and shipping (e.g. Kembro et al., 2017).

Dotolo et al. (2015) reasons that in many research fields and especially in warehousing the law of the vital few, or the 80-20 rule, applies. This means that roughly 20% of the causes accounts for 80% of the effects. This rule is a basis for this thesis that operates on the hypothesis that through relatively few improvements in the receiving area a greater potential in the overall warehouse and extended supply chain can be unlocked.

In many ways, the receiving operation decides how the entire warehouse is performing and issues in the receiving operation can obstruct downstream operations from performing well. In other words, the thesis' intent is to connect the receiving operation to the other operations in the warehouse as opposed to working with isolated, well-defined sub problems which Rouwenhorst et al. (2000) states that most literature on warehousing systems is doing. Koster et al. (2007) as well as Baker & Canessa (2009) agree that literature that is linking the different areas in a warehouse to each other is not as easy to find as literature that focuses on individual operations. The thesis includes a case study at a spare and service parts warehouse located in Venlo, Netherlands that belongs to Sandvik AB (see chapter 3.2.1 for thorough company information).

The research is based on a literature study that will converge into a decision support framework in which the case warehouse will be fitted based on its function, purpose and operation. The warehouse will be analyzed based on different forms of data such as purchase and sales orders, inventory data, through physical observation, and interviews. Supervisors at the company will constantly validate the findings from the data collection.

1.2 Purpose and research objectives

Rouwenhorst et al. (2000) emphasize the complexity of redesigning a warehouse. The reasoning is that a large number of alternative solutions are possible as well as the presence of trade-off decisions between objectives. The research process consists of analyzing the different alternative solutions a warehouse can have, profiling the case warehouse, identifying problems, and generating improvements suggestions.

The purpose of this thesis is to identify improvement suggestions in the receiving operation of a warehouse in order to explore how these can enhance the efficiency of the entire warehouse.

To engage the purpose, eventual problems that arise within all of the operations will be connected to the receiving operation and vice versa. The reason for this is to generate all-covering improvement suggestions through focusing on a single operation, both in terms of operation and design. The following research objectives are pursued through the thesis:

RO 1. Characterize the warehouse based on operational and design aspects and identify the problems that can be found within.
This research objective is approached by developing a support tool based on warehousing theory that lists all major alternative solutions for the different operations in a warehouse. The support tool will then be applied to the case warehouse and problems will be identified through analyzing the gaps between theory and practice in combination with interviews and observations. A *problem* is defined as an activity that contributes to creating customer backorders.

RO 2. Suggest improvements focused on the receiving operation and determine how these suggestions affect the entire warehouse.
The approach here is to use the information gathered through interviews, data mining and observation to understand the root causes of the problems in order to create improvement suggestions. After suggestions have been identified, a risk analysis will be conducted to identify possible errors and risks when implementing them. The last step is to rank the solutions according to how large the impact will be on the warehouse and how quickly they can be implemented.

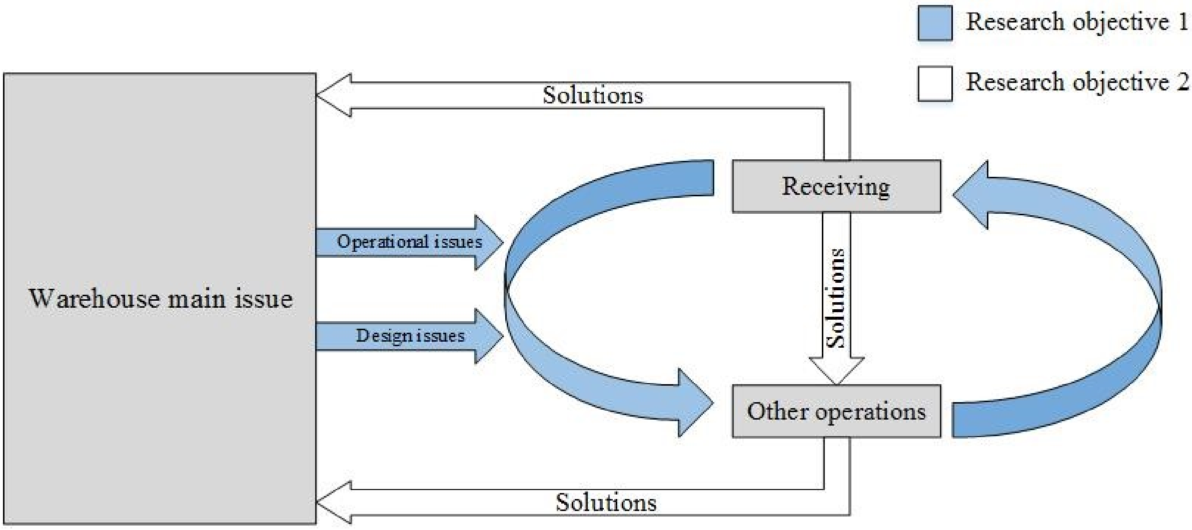

Figure 1.1. Visual representation of the research objectives

1.3 Delimitations

This thesis is intended to address the issues found in an existing up and running warehouse and explore which of these can be solved second-handedly through improving the receiving operation. The agreement to focus on receiving was determined through discussions with the case company as well as from initial observations of the warehouse. The overall layout of the building such as outside walls or any operations outside of the perimeter of the warehouse will not be analyzed. All strategic aspects of Sandvik and their supply chain will be considered as constant. The quantitative historical data that is used for graphs and calculations is partly taken from the new warehouse and partly from the previous one. This is because the new warehouse only has been running for a short time. Since the change in logistics set-up (see chapter 3.2.1) does not affect sales, using data from the previous warehouse is not considered to have any impact on the result.

This study will focus on improvements which will cover a short-term aspect (<10 years) and will therefore not take into account further changes within the company structure and other changes that might happen concerning aspects such as the products. The study is conducted during about 20 weeks, which creates a limitation concerning the depth of the project. The project will therefore base many conclusions on a single case study whereas more studies would have provided results that are more generalizable. Since the case warehouse is newly taken into operation, some data will need to be gathered from a similar warehouse in which the products of the case warehouse were previously stored.

2. Frame of reference

In the frame of reference, literature and theory that is relevant to the subject of warehousing is presented. To the greatest extent possible, warehousing theories are attributed to which chronological operation within the warehouse they belong, be it receiving, put-away, storing, picking, packing or shipping.

Rouwenhorst et al. (2002) provide three perspectives a warehouse can be viewed from when characterizing it: processes, resources and organization. The activities in a warehouse can be divided into operations, an operation is for example receiving or picking. The frame of reference is divided into several parts that all play a key role when characterizing and finding improvements for a warehouse. Figure 2.1 visualizes the frame of reference and shows how it is connected to the analysis of this thesis.

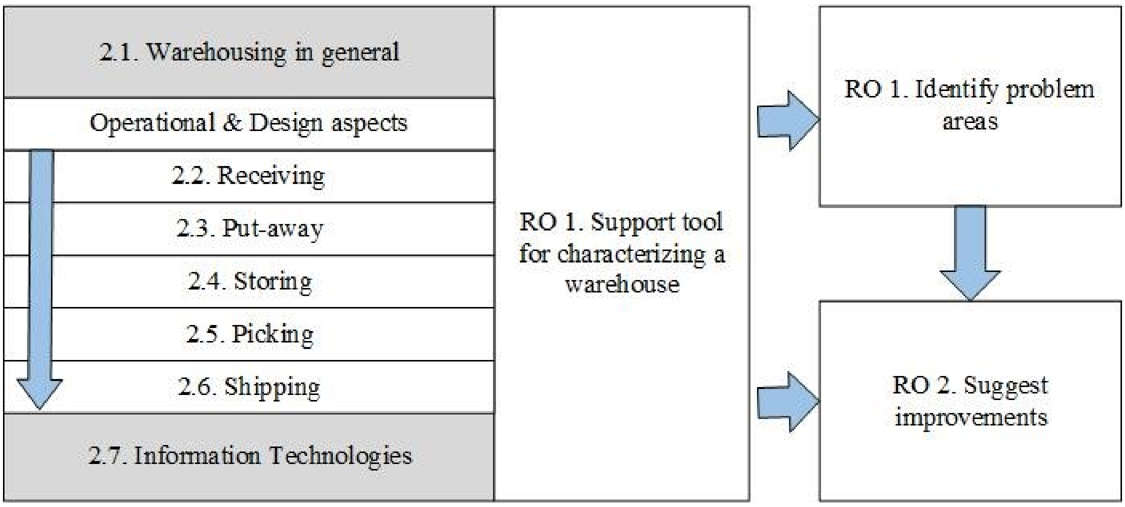

Figure 2.1. Visual representation of the frame of reference and connection to research objectives

2.1 Warehousing in general

Evaluating and improving aspects within the complex field of warehousing requires an understanding of how the different operations are connected to each other both within and outside of the warehouse. Choices regarding layout, equipment selection, batch sizes and work routine policies are all examples of factors that affect the efficiency of the different processes within a warehouse (Aminoff et al., 2002, Gu et al., 2007). Each process is interrelated with the rest meaning that making decisions in one area commonly require trade-offs with others, which results in a complicated problem (Rouwenhorst et al., 2000). Additionally, van den Berg & Zijm (1999) state that the information flow between different parts is of utmost importance and can be improved with information technology.

Literature divides warehouses into categories depending on their different functions and purposes. See table 2.1 for a compilation of how the various types of warehouses can be separated.

Literature	**Warehouse types**
Bartholdi & Hackman (2017)	Retail distribution center, service parts distribution center, catalogue fulfilment center, 3PL warehouse, perishables warehouse
Frazelle (2002)	Raw material and component warehouse, work-in-process warehouse, distribution center, fulfilment warehouse, local warehouse, value-added service center
Berg and Zijm (1999)	Contracted warehouse, distribution warehouse, production warehouse
Rouwenhorst et al. (1999)	Distribution warehouse, production warehouse

Table 2.1. Different divisions of warehouse types according to major literature

In this thesis, the first division by Bartholdi & Hackman (2017) is chosen. The reason for this is mainly that it provides a clear distinction between a service part distribution center and the other types. Table 2.2 shows a short explanation of the different types according to this literature.

Warehouse type	Description
Retail distribution center	Supplies products on a regular basis to retail stores which are its immediate customer. Typically, very large orders and the warehouse is possibly serving hundreds of stores.
Service parts distribution center	Handles spare and service parts which is challenging to manage due to an unstable demand and high number of SKUs. This type of warehouse consequently typically has a much inventory on hand. Manages both larger stock orders and smaller emergency orders. The large number of parts means that the labor requirements usually are stable over time.
Catalogue fulfilment center	Small but many orders both in and out of the warehouse. Outgoing orders need to be handled and shipped immediately after receipt. Pressure on the warehouse can somewhat be regulated through pricing.
3PL warehouse	Outsourced warehouse operation and possibly serves many customers from on facility gaining economics of scale.
Perishables warehouse	Handles items which a limited shelf life such as food and medicine. Typically requires a cold (with regards to temperature) supply chain which makes space more expensive. Must take consideration to special requirements such as FIFO.

Table 2.2. Description of different warehouse types according to Bartholdi & Hackman (2017).

When conducting research within warehousing, the studied aspects can be divided into operational and design based (Gu et al., 2007). Operational problems concern aspects within the operations that the workflow in a warehouse generally is divided into. Problems related to the design aspects of a warehouse focus on structure and layout. Gu et al. (2007) explain this separation by dividing the problems in a way that is compiled into table 2.3, see Appendix A for the complete table.

Warehouse aspect	Problems	Examples of decisions
Warehouse design	Overall structure Sizing and dimensioning, Department layout Equipment selection Operation strategy	Location of departments Size of the warehouse Aisle orientation Width of aisles Random or dedicated storage
Warehouse operation	Receiving and shipping Storage (SKU assignment, zoning, storage location) Order picking (batching, routing, sorting	Truck dispatch schedule Space allocation Assignment of pickers Batch sizes Routing and sequencing

Table 2.3. Problems and decisions in the warehouse based on operational and design aspects based on Gu et al. (2007).

Rouwenhorst et al. (2000) elaborate on the different types of warehouse design problems that can be encountered. On the strategic level the decisions are centered on the process flow, i.e. how operations are connected to each other and to the extended supply chain. Apart from the basic processes, there are several optional ones such as sorting in order to batch orders, inclusion of forward pick areas, and reserve replenishment from bulk storage. On the tactical level, decisions are made regarding dimensions of resources and organizational issues. The last level is the operational one, here the decisions concern how to assign staff to specific activities and how to schedule arriving and departing trucks.

Rouwenhorst et al. (2000) and Gu et al. (2010) describe different types of warehouse objectives. The objectives can be to fulfill external customer orders such as distribution warehouses, to handle raw material for production or to replenish other warehouses. The part of the product cycle that is stored in the warehouse can vary from raw material, work in progress, spare parts and finished goods. Concerning the capacity per staff member, Little's law (equation 2.1) (Bartholdi & Hackman, 2017).

$$L = \lambda W$$

Equation 2.1. Little's law, L = average length of queue, λ = average arrival rate and W = average waiting time

The following sections of this chapter will go through each individual operation as well as the warehouse management system (WMS) that is an information technology that spans across the entire warehouse. Major literature is shown in table 2.4.

Warehouse operation	**Literature**	**Short description**
2.2 Receiving	Bartholdi & Hackman (2017) Tompkins et al. (2003; 2007) Gu et al. (2007) Frazelle (2002)	Items are received through the warehouse docks, unloaded and amount and quality is confirmed. Items are registered and possibly repacked.
2.3 Put-away	Bartholdi & Hackman (2017) Frazelle (2002) Koster et al. (2007)	It is decided where in the warehouse the item is to be stored, and then it is transported there.
2.4 Storing	Tompkins et al. (2010) Gu et al. (2007) Bartholdi & Hackman (2017) Phillips (2010)	The items are stored in different areas of the warehouse depending on how they are categorized.
2.5 Picking	Frazelle (2002) Gu et al. (2007) Berg & Zijm (1999) Chiang et al. (2011) Bartholdi & Hackman (2017)	The items are picked from the storage to be shipped according to customer orders.
2.6 Shipping	Frazelle (2002) Gu et al. (2007)	Items are consolidated, loaded onto carrier and shipped out through the docks.
Information technology	**Literature**	**Short description**
2.7 WMS	Kembro et al. (2017) Mentzer (2002) Faber et al. (2002) Van den Berg (2012)	Software package that helps manage inventory.
Frameworks	**Literature**	**Short description**
2.8 Warehouse characterization support tool	Baker & Canessa (2007) Rouwenhorst et al. (2000) Mohsen (2002)	Support tool for characterizing a warehouse based on theory, the references are used to get inspiration of which parts to include.

Table 2.4. Major references for each section.

2.2 Receiving

As seen in figure 2.2, receiving is a hub that connects to the majority of the other areas making it a key factor for the entire warehouse operation. These connections are important when pursuing the purpose of the thesis, which is to solve problems throughout the warehouse via improvements in the receiving operation.

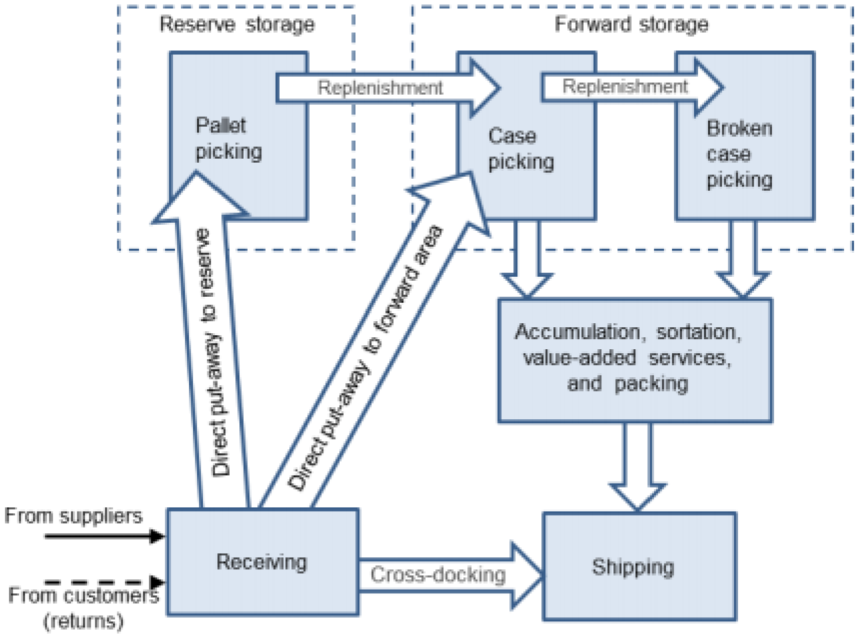

Figure 2.2. Tompkins et al. (2010) shows the connection between processes in the warehouse. The squares visualize activities that require space in the warehouse.

Before describing the processes within the warehouse there is an important relationship that needs to be addressed, the relationship between the warehouse and the suppliers. Typical problems that concern both the warehouse and the suppliers are for instance a lack of well-defined specifications from the buying company and insufficient integration of purchasing in logistics management (Van Wheele, 2014). The latter means that the way that items are purchased or the way they are packed might not be in line with the logistics processes of the buying company. This creates a need for extra labor and delays at the warehouse. A way of benchmarking the performance of suppliers is to develop a scorecard that put different suppliers against each other. Galankashi et al. (2016) suggest many attributes that can be included in a supplier scorecard. for instance quality, defect rate, order handling, flexibility and satisfaction.

Receiving is the first operation that occurs within a warehouse and accounts for 10% of the operational cost (Bartholdi & Hackman, 2017). This percentage can possibly be reduced through implementation of information technology, which will be further described in chapter 2.7. Receiving can be divided into several activities and different authors have different views on how these are divided. Table 2.5 shows some of the options available from two different authors. By combining these two sub-categories, a general pattern can be seen. According to Tompkins et al. (2007, pp. 392-393) in order for the warehouse to perform these activities, sufficient docking area and equipment is needed.

Activity Order	Tompkins et al (2007)	Bartholdi & Hackman (2017)
1	Inbound truck receives delivery information and provides the warehouse with information about the content	Inbound truck arrives at the receiving terminal
2	Warehouse staff confirms the information	Warehouse receives order receipt
3	Truck arrives to the assigned dock	Merchandise is unloaded
4	Vehicle is secured at dock	Verifying amounts and quality
5	Load is inspected	Pallets are broken apart
6	Merchandise is unloaded	SKUs are labeled
7	Possible repacking	SKUs are assigned a storage location
8	Load is stored	SKUs are stored

Table 2.5. Comparison of activities within receiving.

The first step in receiving is that the inbound shipment and shipment information arrives at the receiving dock. The decision process for how and when to assign arriving trucks is based on time and content of the shipment combined with labor and equipment needs in each shipping dock (Gu et al., 2007). These decisions are based on the available information about both the carrier and the warehouse. Table 2.6 shows three different knowledge tiers and what information is available in each of them. Out of these three scenarios, the most common in a company-owned warehouse is the second one. To elevate the knowledge to tier three more sophisticated technologies such as RFID and GPS is required to track goods.

Knowledge tier	Description
1	No knowledge except for warehouse layout
2	Partial knowledge of arriving carriers
3	Perfect knowledge regarding each arriving carrier

Table 2.6. Levels of knowledge according to Gu et al (2007).

The second step is to unload and then inspect the merchandise through quality control. Basic quality control concerns checking the most essential order requirements, such as correct amount and occurrence of damages. This can be done with or without technical assistance, such as scales. Advanced quality control is about applying a quality management system over a longer period to provide continuous improvements (Bouhouche, 2017). The third step is additional activities such as break apart pallets, repacking and relabeling. The fourth and last step is that the goods move on to put-away. Gu et al. (2007) state that when measuring the entire receiving operations the following metrics should be included; amount of resources required to complete receiving operations, service level such as unload time and cycle time for the whole warehouse, dock layout, management policies, and throughput requirements for the docks.

Regarding the design of the receiving operations, Manzini (2012) state that items should be scanned in order to keep track of their locations at all times as well as their specifications such as weight and dimensions. The actual scanning can be done in several different ways using different technologies and connecting them to different systems. Several different ways of setting up the receiving docks are shown in figure 2.3.

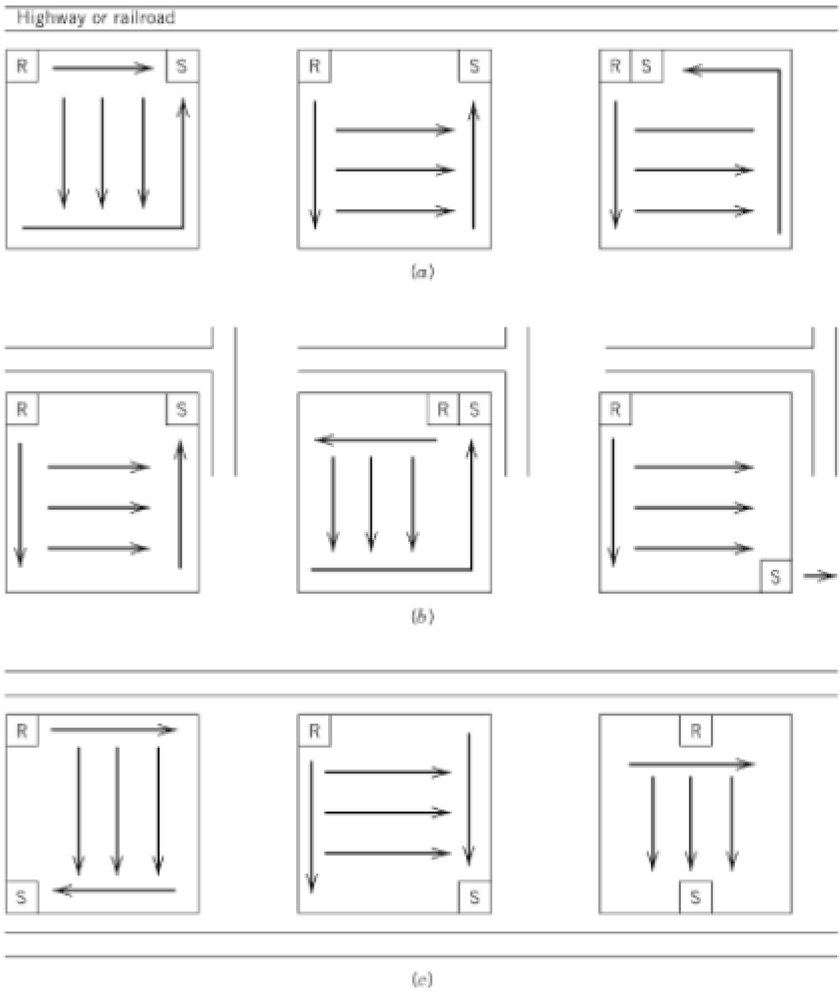

Figure 2.3. Possible ways of arranging the receiving (R) and shipping docks (S) (Tompkins et al 2007, p. 393).

In general, there are two main ways of configuring the receiving and shipping docks; flow-through and u-flow (Bartholdi & Hackman, 2017). A flow-through configuration is for example the bottom right one in figure 2.3 and a u-flow is the top right one. Chapter 2.4 will elaborate on this further.

Frazelle (2002) emphasizes the benefits of direct shipment. This means that if certain items could be shipped immediately after having been received (cross-docking), they should. This is connected to the fact that picking accounts for about 55% of the operating cost of the warehouse (Bartholdi & Hackman, 2017) which direct shipment removes the need for. Another option that sometimes is available is drop shipment. This means that the item is delivered directly to the customer, skipping the warehouse entirely thus eliminating all labor and opportunities for mishandling the goods (Frazelle 2002).

2.3 Put-away

The put-away accounts for 15% of the operational cost and it is important since it acts as a basis for the coming order picking. To perform a smooth put-away, information regarding available locations, how much weight they can hold, and which item sizes fit needs to be relayed. This information must be known at all times and after the item has been put away, the location should be tracked in order to be able to conduct pick lists later on (Bartholdi & Hackman, 2017).

Frazelle (2002) states that it is common that put-away induces double-handling of the goods since it often is put on hold after being unloaded, this is called indirect put-away. The opposite of doing this is called direct put-away which is preferable. The design of the storage area and of the entire warehouse greatly affects the put-away operation. Koster et al. (2007) describes the facility layout problem as the decisions of where to locate the departments (receiving, picking, storing, sorting and shipping) in which the operations take place. In order to minimize the handling cost of put-away and throughout the warehouse, it must be considered how the activities in various places of the warehouse affect each other.

The choice of location for the items should be based on good product rotation, picking productivity and take into consideration how products will be batched when leaving the warehouse (warehouse zoning). It is in the put-away that the largest storage unit is handled, i.e. pallets (Bartholdi & Hackman, 2017). An efficient way of doing put-away is to do it in conjunction with the picking, so called dual commands. This means that the same warehouse operator picks and puts away items in the same run. Dual commands are most important when using heavy material handling equipment such as counterbalance trucks because it reduces deadheading (travelling empty) (Frazelle, 2002).

When putting away carton cases there are different ways of packing as many as possible into a limited shelf space, called detailed slotting. Bartholdi & Hackman (2017) describes two heuristics called next fit and first fit. The difference is that the next fit tries to put an item into the shelf and if it is unsuccessful, that shelf is considered closed. First fit does not consider the entire shelf closed if an item does not fit, instead it always keep the partly full shelves available.

2.4 Storing

The actual storing of products in the warehouse is a major function. According to Gu et al (2007) there are four decisions that are the basis of this function: amount of each SKU, replenishment frequency, how the SKUs move, and where should SKUs be stored within the warehouse. As seen in figure 2.3, Tompkins et al. (2010) show the different types of areas that can be used to store items; the reserve, broken case pick area and case pick area. Figure 2.4 shows the different tiers of packaging that a warehouse can handle. If the same packaging tier is used throughout an entire warehouse, it is called a unit load warehouse. The opposite is called a break-up warehouse. The break-up warehouse breaks apart pallets and consolidates lower levels of packaging tiers into orders. This is commonly the case for a distribution warehouse while cross-docking warehouses commonly are unit load (Bartholdi & Hackman, 2017). The reserve holds the largest handling unit and the case pick holds the smallest handling units. A forward pick area usually contains frequently picked items in cases and can be either the lowest floor of a pallet rack or a separate area.

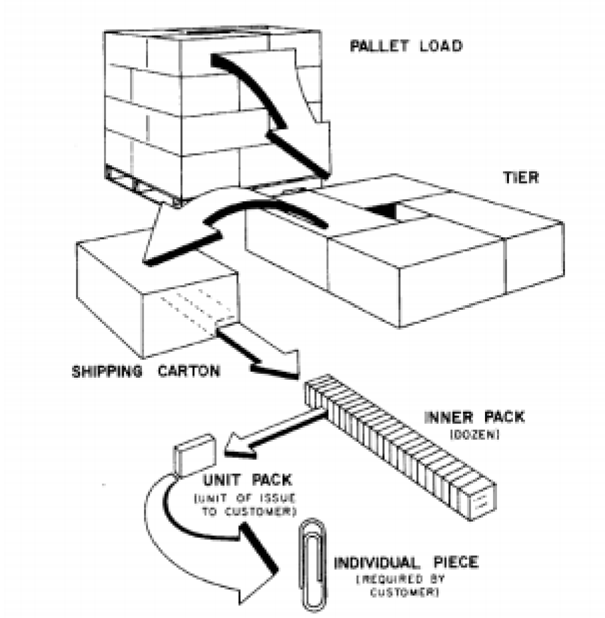

Figure 2.4. Packaging tiers in a warehouse (Bartholdi & Hackman, 2017).

The design of the storage area determines how far the operator will travel both in put-away and picking which makes decisions related to the layout important (Koster et al. 2007). Bartholdi & Hackman (2017) describes two main types of configurations that determine the design of the storage area; flow-through and u-flow as seen in figure 2.5. In the flow-through warehouse, many locations are equally convenient for the picker concerning travelling time. In a u-flow configuration there is potential for locating items according to an ABC classification, where the A-items account for a higher percentage of activity. An advantage of the flow-through layout is that the docks can be specialized to a higher degree based on the activity. A u-flow is however preferable when the workload for the receiving and shipping docks varies since all docks can be used for only receiving or only shipping at times. A warehouse that delivers raw material to production is an example of when a flow-through configuration is appropriate (Ackerman, 1997).

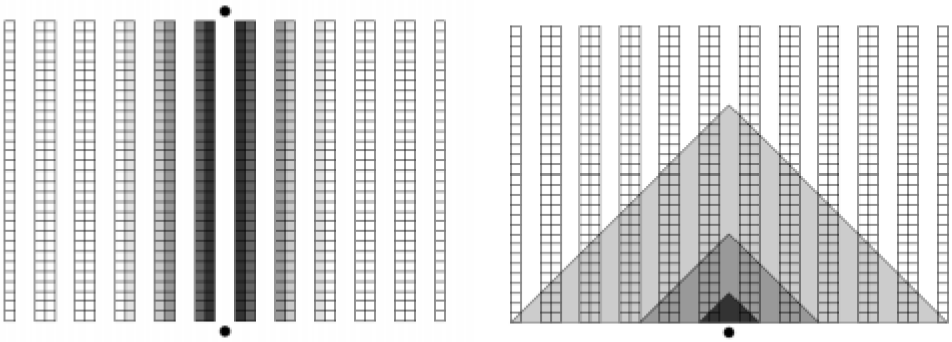

Figure 2.5. Placement of fast moving (darker) SKUs based on flow-through (left) and u-flow (right) (Bartholdi & Hackman, 2017).

The aisles between shelves are recommended to run parallel with the item flow in order to minimize travel time, but when the picker is moving through the warehouse, it can be a good idea to enable travelling between shelves. One way of doing this is by having cross-aisles, as shown if figure 2.6. The breaks in the shelves make for shorter travel when moving through locations but it naturally decreases the amounts of storage locations in that same area. Another option for shelf orientation is to have angled aisles, also known as a fishbone layout. This is recommended if the picking generally consists of movement to and from a central point of the warehouse. However if the picking consists of much movement between storage locations without stopping at a central point in between, this layout may worsen the performance (Bartholdi & Hackman 2017, p. 68-69).

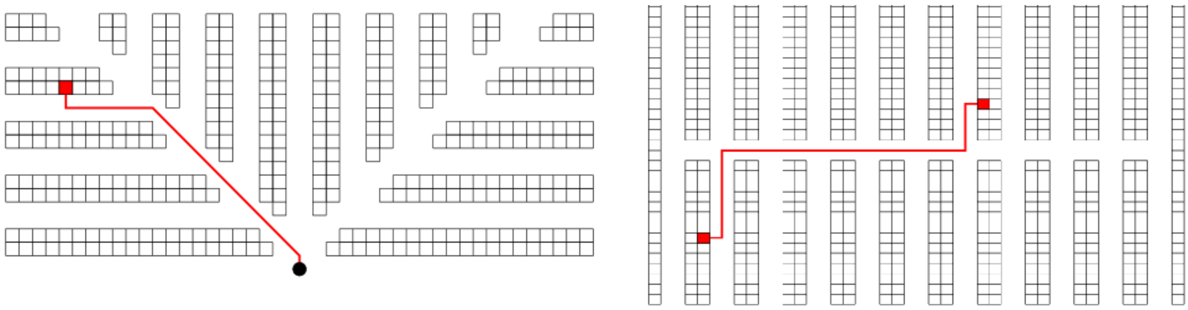

Figure 2.6. Angled aisles (left) and Cross-aisles (right).

Koster et al. (2007) describes the different item allocation methods that can be used in a warehouse. A forward pick area holds items in the lowest packaging tier and the reserve area holds items in the highest. When designing the forward pick area the major decision is which and how many items that should be stored there. A smaller area will fit fewer items but will also reduce the travel time needed. Another concept related to this that Koster et al (2007) mention is dynamic storage. Dynamic storage means that by using different technologies and automated solutions such as automated cranes and carousels the pick area can become very small which removes the internal travel times for the items altogether. This brings us to the decision of level of automation, this is closely related to the picking activity. Figure 2.7 shows an overview of storage and handling variations based on different requirements.

		Storage requirements	
		High	Low
Picking requirements	High	High density storage Automated handling	Dedicated locations Low density storage Automated handling
	Low	Random location Dense storage Manual handling	Dedicated pick locations Dual storage Low density storage Manual handling

Figure 2.7. Storage and handling variations based on storage and picking requirements, Blomqvist (2010).

Naish & Baker (2004) also present the level of automation that is appropriate for a warehouse based on the number of different items and the throughput in a graph, this is shown in figure 2.8.

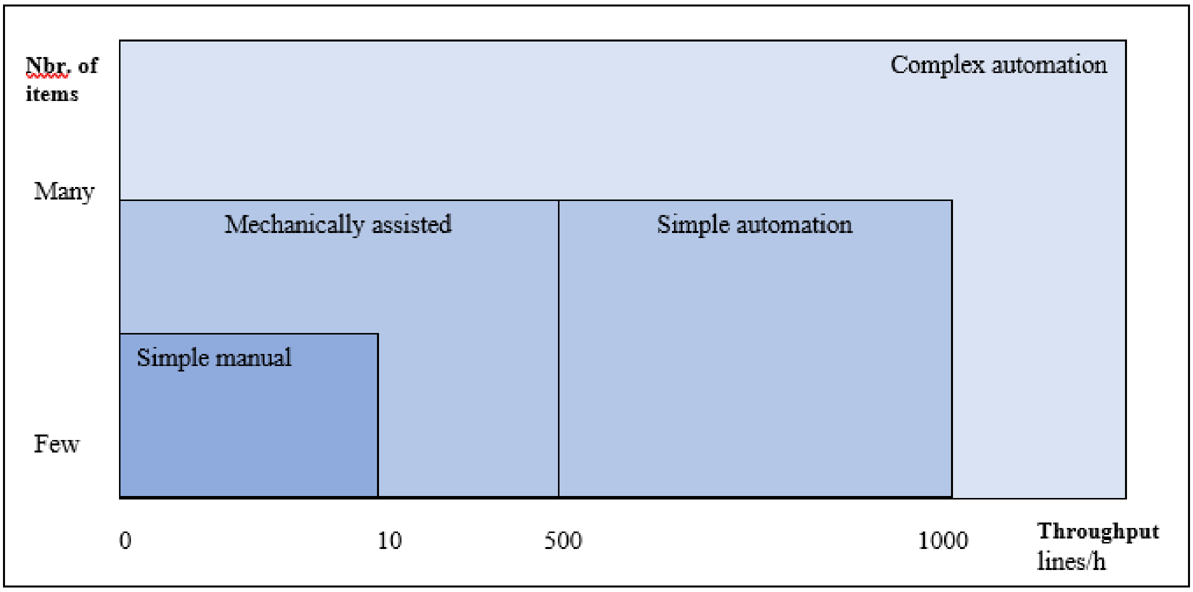

Figure 2.8. Level of automation according to Naish and Baker (2004).

It is emphasized by Naish & Baker (2004) that the numbers in the graph are very rough and that it is mostly meant to be illustration of the concepts. It is also stated that the first time automated solutions are implemented in a warehouse can make for a lengthy process with possible service dips in the implementation phase as well as an overall loss of flexibility. The plus side of automation is less reliance of human performance, improved company image and less damage on goods.

From figure 2.7 it is seen that there is a distinction between random and dedicated storage locations, also referred to as dynamic versus static slotting. Using a random location policy means that there is no predetermined location for each item and the opposite is dedicated storage. When using dedicated storage, the problem of not utilizing space might arise since on average there will be as many empty locations as there are full, which means that the utilization rate is only 50% (Bartholdi & Hackman, 2017).

When it comes to the shelves themselves, Bartholdi & Hackman (2017) describe several different ways of arrangement. Items can for instance be places in single or double-deep racks depending on how many pallets that can be stored behind each other in the same shelf lane. The benefit of double-deep racks is that more SKUs can be accessed through fewer aisles but on the other hand, more work is required to put-away and retrieve the goods. It is possible to have more slots than just two deep and possibly also unfolding the shelf lane like a drawer to reveal all items, this is called a puck-back rack. Sometimes it is beneficial to replenish a several-deep rack from behind, that type of solution is called a flow rack. A potential addition to the flow rack is a downward tilt so that the items are easily available for the picker. Counterbalance forklift trucks are generally used to move pallets. If items are stored in high locations, reach trucks are used to retrieve items and if the aisles are narrow, turret trucks are used (Berg & Zijm, 1999). To lift and transport heavy items, overhead cranes can be used and solutions that include automated cranes for picking and put-away are called AS/RS (automated storage and retrieval system).

2.5 Picking

Order picking is the activity that accounts for the largest share of labor intensity and approximately 55% of the operational cost can be attributed to this area. The activity consists of travelling to the storage location area, searching for the specific item and finally retrieving the item. In high volume industries such as retail, orders are typically large and consist of many similar picks along a common path, whereas for service parts the orders tend to consist of fewer items with a larger product variety (Bartholdi & Hackman, 2017). Table 2.7 shows an example of how sub-activities can be divided in terms of time within picking.

Activity	**Share of order picking time**
Travelling	55%
Paperwork	20%
Searching	15%
Extracting	10%

Table 2.7. Average share of total pick time per activity according to Bartholdi & Hackman (2017).

Gu et al. (2007) give a few examples of the various types of picking; single-order picking, batching with continuous sorting, batching with sorting afterwards and zone picking. The performance criteria and constraints for picking are for example picker effort and picker capacity. In order to minimize material handling cost there is a decision involved regarding picking sequence and which routes to take when picking. This is affected by where the items have been placed which creates a Travelling Salesman Problem in the warehouse (Gu et al, 2007). The simplest path to travel is down a single aisle, which is commonly found in fast-pick areas.

Chiang et al. (2011) describes four commonly used methods for reducing picking travel time or distance. The four method are determining the optimal pick path, zoning the warehouse, assigning items to the correct locations and assigning orders to batches. The methods have a lot in common and storage assignment play a key role in all of them. If storage allocation is done correctly in combination with routing, pickers can skip aisles and utilize shortcuts to minimize the travel distance. This ties together with placing items according to zones based on the turnover rate. The items with the highest turnover are naturally placed closest to the exit of the picking area. A more difficult arrangement is that through analyzing order patterns place items that are commonly ordered together close to each other hence reducing the number of stops necessary and the travelling distance.

As mentioned in the previous chapter, some warehouses have dynamic storage for the fastest moving items. This means that the picker generally is stationary and the items come to them through automated solutions (Koster el al. 2007). When picking from multiple parallel shelves it is common to travel in a serpentine fashion as shown in figure 2.9. The overall optimal pick path route can be determined by heuristic methods and by optimization. However, optimization can easily get very complicated and heuristic methods often provide a solution that is near optimal and is considered good enough (Bartholdi & Hackman, 2017, pp. 155-165).

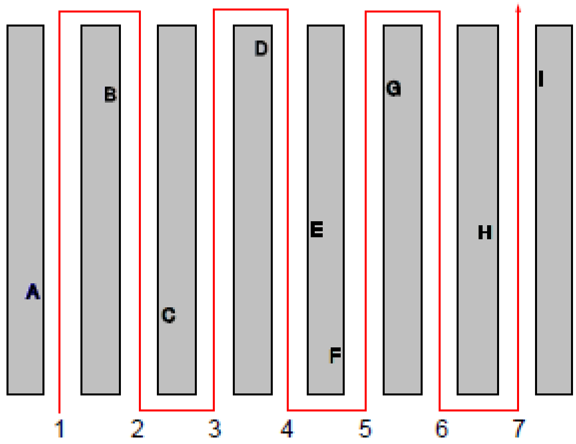

Figure 2.9. Serpentine pick path (Bartholdi & Hackman, 2017)

Another common pathing is branch-and-pick as shown in figure 2.10. Here the picker travels along a main path, breaking off into aisles when needed and returning to the path after the pick. In this case, it is better to place popular SKUs at the end of the shelves closest to the main path.

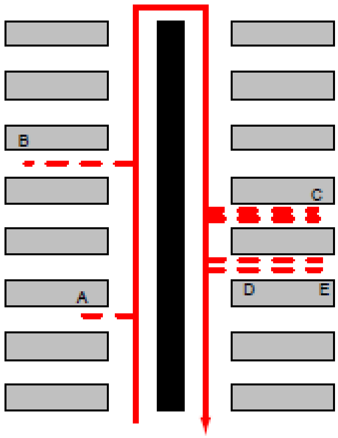

Figure 2.10. Branch-and-pick path (Bartholdi & Hackman, 2017).

As mentioned, the picking operation naturally depends on how the storing is configured. Berg & Zijm (1999) elaborate on several storing methods that determine how the picker will move. The common type of system when operating a warehouse is the picker-to-product system. This is the opposite of a product-to-picker system, which is the case when using automated solutions such as carousels. In the product-to-picker system, the picker does not have to travel between picks that are supported by the system.

Finally, Bartholdi & Hackman (2017) suggest a couple of simple guidelines to make the picking perform well. These include: use short understandable routes, give pickers guidelines as to adapt their pick path, place products along the path, and lastly it is stated that often it is not valuable to perform actual pick path optimizations.

The packing operation is sometimes considered a part of the picking operation and sometimes standalone. The principle is that the items that are picked might need to be sorted or packed in a different way that is appropriate for shipping. The operation can be labor-intensive since every item for a customer order might have to be handled. However, it can also create room for an activity that checks if the order contains the correct amounts and types of items, thus increasing order accuracy. A low order accuracy annoys the customers as well as creates additional cost through returns (Bartholdi & Hackman, 2017). Depending on the purpose of the warehouse, the packing activity might prioritize consolidation in order to satisfy customers by removing some of their handling need, this is typical for a spare parts warehouse. Another option is to prioritize speed in which case most items are shipped out in the same package that was used for storing, commonly seen in retail warehouses.

2.6 Shipping

Much of the shipping operation ties together with the receiving of goods since these operations are commonly found in the same location and share activities. The shipping operation refers to loading the goods into a carrier that leaves the warehouse. According to Gu et al. (2007), what needs to be determined is a schedule over how the carriers will arrive and leave the dock, it is also necessary to determine amount of labor needed. To do this, information about customer demand and available resources need to be gathered. The performance criteria are similar to that of the receiving meaning cycle time, layout and management policies for the docks. Before the shipping, the items usually need to be consolidated by packing them together in for example a pallet (Bartholdi & Hackman, 2017).

2.7 Information technology: WMS

The different warehouse operations can be supported by various types of technologies that improve the efficiency of the warehouse through for example documentation and real-time data. Currently, the four main types of technologies that are frequently used are: Enterprise Resource Planning (ERP), Warehouse Management System (WMS), Radio Frequency Identification (RFID) and barcode technology (Kembro et al, 2017).

ERP and WMS are software based whereas RFID and barcodes are based on hardware. An ERP system covers the whole organization from human resources and finance to inventory management and production planning and works as a platform to share information with both internal and external parts of the company (Kembro et al, 2017; Olhager and Selldin, 2003). Since the ERP, system is more of an all-inclusive database of the entire company and RFID is currently out of reach for this warehouse it will not be elaborated on further in this thesis.

Bartholdi & Hackman (2017, p. 33) state that "a WMS is a complex, software package that helps manage inventory, storage locations, and the workforce, to ensure that customer orders are picked quickly, packed and shipped." Mentzer (2002) describes it as an aid to meet the goals of warehouse management, which are to maximize service levels, space utilization and labor utilization. A WMS is included in a bigger system such as an ERP that connects the WMS to the rest of the company functions. Another difference between an ERP and a WMS is that they are intended to cover long and short time horizon respectively (Kembro et al, 2017). Van den Berg (2012) describes that an ERP system has knowledge of incoming and outgoing items as well as how they are to be handled in terms of processes in the warehouse. The WMS handles data that includes orders, shipments, staff, vehicles, customers, suppliers, layout and activities in the warehouse. Faber et al. (2002) describes various types of warehouse management systems depending on their complexity as presented below.

Basic WMS - This type of system supports the basic information that is needed to keep track of the activities in the warehouse. The purpose is mainly to register and keep information available. Stock information and location control are the types of data that is generally stored and some systems of this type can use this information to generate storing and picking instructions and display this on terminals. This type of system focuses on throughput.

Advanced WMS - The advanced WMS is capable of doing everything that the basic WMS does with additional functions. In addition to focusing on throughput, the advanced WMS also concerns planning of equipment, labor and activities in order to optimize the flow of items in the warehouse.

Complex WMS - This last type of system can optimize one or several warehouses in the supply chain by tracking and tracing every item that goes through. It supports gathering information on the operation as a whole. This is done by planning, execution and control to understand where the items are going. The complex WMS also incorporates functions that are otherwise provided by another system called a Transport Management System (TMS). Examples of these functions are managing shipments, dock operations and overall logistics planning.

Bartholdi & Hackman (2017) make a distinction between the different levels of functions that a WMS can have. Table 2.8 shows an overview of some of the different functions; see Appendix B for all of the functions.

Level of complexity	Supported functions
Basic	Receiving Put-away Location tracking Picking Packing and consolidation Shipping
High-end	Replenishment Value-added services Returns Vendor/carrier compliance Labor management
Advanced	SKU slotting Parcel shipping Traffic management Import/Export management

Table 2.8. Selection of different levels of functions in a WMS.

Implementing a WMS is not an easy task, the complex and data intense nature of the system means that it requires careful consideration and might imply changing organizational aspects and policies. The WMS also must be connected to existing systems in order to work for the overall operation. In conclusion, Gu et al. (2007) state that most warehouses could benefit from warehouse management systems. The investments are overshadowed by reduction in operational costs, increase in performance accuracy, possibility for higher levels of automation and better communication throughout the supply chain, which ultimately enhances the capability to meet customer demand.

2.8 Support tool for characterizing a warehouse

From the frame of reference, a tool for characterizing a warehouse can be developed as shown in figure 2.11. The tool profiles a warehouse according to the alternative solutions that have been identified in the frame of reference while still focusing on the receiving operation according to the research objectives (see figure 1.1) and purpose. The scope of many warehousing tools is to create a framework for redesign of a warehouse such as Baker & Canessa (2007), Rouwenhorst et al. (2000) and Mohsen (2002). Although redesigning the warehouse is not the defined objective of this thesis, some of the proposed solutions for improvement might indeed turn out to include both design, organization and operational based improvements. Rouwenhorst et al. (2000) describe that a top-down approach and working simultaneously with several areas can avoid silo thinking when optimizing a warehouse. Assarsson & Hjerén (2017) however notes that it is more common to work with each area separately e.g. Baker & Canessa, (2008); Mohsen, (2002), and Geuken & Jäger (2015) which also is the case for the tool in figure 2.11. Tompkins et al. (2010) and Gu et al. (2010) mentions requirements, constraints and objectives as a start to the framework. Just as in the frame of reference, the tool will cover each individual operation in chronological order based on operational and design aspects inspired by Gu et al (2007).

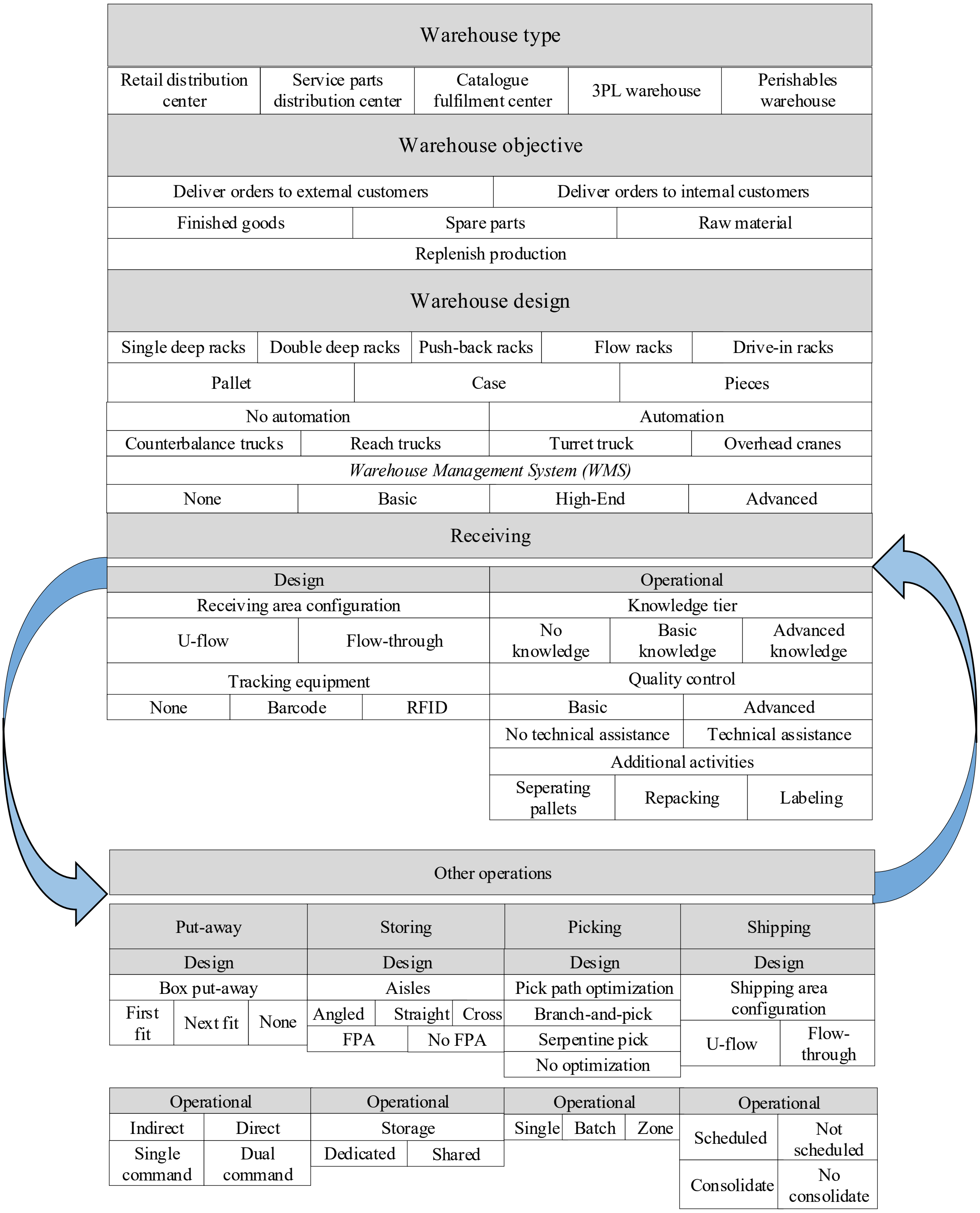

Figure 2.11. Support tool for characterizing a warehouse with focus on the receiving operation (Linse & Sandefeldt, 2018).

3. Methodology

Yin (2009) states that substance and form are key areas for the objective of a study. Substance can be represented by the question "what is my study about?" and form by "what kinds of questions are being asked?" The research questions (in this case objectives) that the study is based on is supposed to decide which research method to undertake (Saunders et. al, 2009).

According to Saunders et. al (2009) some of the aspects that need to be established within the methodology are research strategy, research technique and research procedure. Different researchers have presented frameworks with different approaches that can be used depending on the situation. In this thesis, one of the initial conditions is that it will be conducted at and for Sandvik AB, limiting the research approach to be a good fit for a single case scenario. Voss et al. (2002) emphasizes that case studies are one of the most powerful research methods concerning operations management.

3.1 Research process

Figure 3.1 shows the research process and provides a visual representation of how the methodology has been approached over time. The top half concerns activities that have to do with the academic report and the bottom half concerns activities connected to the case company.

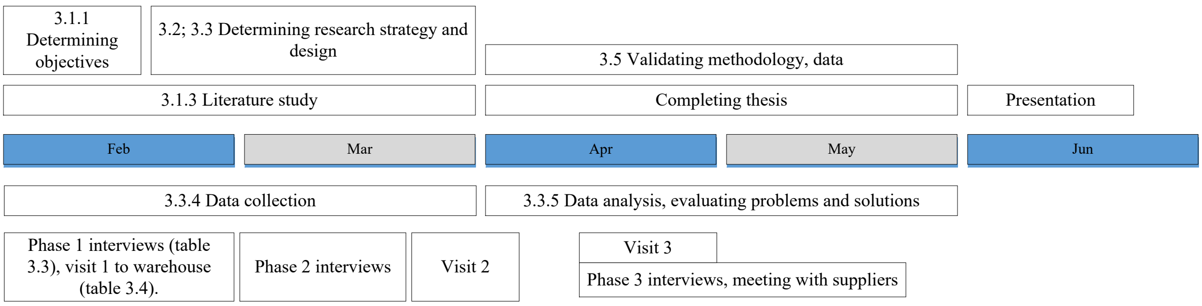

Figure 3.1. Visual representation of research process.

3.1.1 Purpose and research objectives

The step of defining a purpose and research objectives was completed together with the case company based on needs and capacity. After a brief introduction period, it was concluded that a focus on the receiving operation of the case warehouse would enable an extensive analysis as well as engage one of the major hurdles of the warehouse. The research questions were constructed based on the authors' knowledge and curiosity, the company requests, the time limitation, and the authors' professional experience in the field.

3.1.2 Case selection

Since one of the initial requirements for this thesis is that it is conducted at and for Sandvik, the case selection was done before the research objectives were set up. The Sandvik warehouse in Venlo, Netherlands, was the specified case.

3.1.3 Frame of reference and support tool

The frame of reference was constructed based on what information would be needed to fulfill the objectives. Naturally, all operations in a warehouse needed attention in the frame of reference and each operation was researched according to operational and design aspects.

Along with theory such as Bartholdi & Hackman (2017), Frezelle (2002), Gu et al. (2007), Tompkins et al. (2010), Kembro et al. (2017), Berg & Zijm (1999) and Rouwenhorst et al. (2000) it was established which headlines that would be appropriate and how to arrange the different parts of the chapter. Complementary literature has been found through various scientific databases such as ScienceDirect, ResearchGate and the Lund University search engine LUBsearch based on the keywords warehousing, warehouse management, warehouse design, warehouse layout and warehouse information systems.

The support tool for characterizing a warehouse that is shown in figure 2.11 has been developed by summarizing each section of the frame of reference based on the different alternative solutions a warehouse can have. In chapter 4, the support tool is applied using the data from this particular warehouse. In chapter 5, this is translated into problem areas by linking theory to practice.

3.2 Research Strategy

The availability of extensive and precise information in the chosen area makes a case study suitable according to Yin (2009). However, there are more factors to take into account and many other research approaches that potentially could work which is why the choice of using a single case study is validated. See table 3.1 from Yin (2009) that uses the research question type and purpose to conclude which research strategy that is suitable.

Research purpose	Question type	Suitable research strategies
Exploratory - Develop pertinent hypotheses and propositions for further inquiry	What	Survey, archival analysis, case studies, histories, experiments
Predictive - Describe the incidence of prevalence of a phenomenon or predict outcomes	Who, where, how many, how much	Survey, archival analysis
Explanatory - Establish cause-affect relationships	How, why	Case studies, histories, experiments

Table 3.1. Determining research strategy (Yin, 2009).

This table is used to determine whether the research strategy fits the research objectives. The research objectives in this case can be summarized as: *how* does the situation look today, *why* does it look like this and *how* can it be improved. The definition of a case study from several researchers is shown in table 3.2.

Author	Author’s description of a case study
Höst et al. (2011)	Understanding processes within an organization for a specific situation.
Yin (2003)	An empirical inquiry that follow a set of pre-decided procedures to investigate a real-life contemporary phenomenon using multiple sources of evidence.
Eisenhart (1989)	Strategy that focuses on the dynamics found within single studies and understanding them.
Voss et al. (2002)	Historical description of past and current events that has been concluded from different sources and can be considered one of the most powerful research methods.

Table 3.2. The definition of a case study

As seen in table 3.2 a case study includes an historical description of past and current events that has been concluded from different sources following predetermined rules, through understanding processes and dynamics. The way that it is normally performed is to combine observations, interviews and other kinds of data analysis to gather information that can both be qualitative and quantitative (Eisenhardt, 1989).

If the case is practically oriented and the purpose is to provide information, which will be used for performance increase, then the goal should not be to create new theory but to create scientific knowledge (Handfield & Melnyk, 1998). People operating within an industry want the scientific knowledge for different reasons, two of them being a method of organization and categorization, and the potential for control over the things that have been organized and categorized (Reynolds, 1971). Voss et al. (2002) presents a table (table 3.3) that explains the advantages and disadvantages of using different case choices. From this, it can be seen that the advantage of a single case study is the great depth that can be achieved.

Choice	Advantages	Disadvantages
Single case	Greater depth	Limits the generalizability of conclusions drawn. Biases such as misjudging the representativeness of a single event and exaggerating easily available data
Multiple cases	Augment external validity help guard against observer bias	More resources required, less depth per case
Retrospect cases	Allow collection of data in historical events	May be difficult to determine cause and effect, participants may not recall important events
Longitudinal cases	Overcome the problems of retrospect cases	Have long elapsed time thus may be difficult to perform

Table 3.3. Advantages and disadvantages of using different types of case studies (Voss et al. 2002).

3.3 Research Design

The research design is the logic that connects the data and the conclusions drawn to the research objectives of a study (Yin, 2009). In other words, it explains how the research strategy is used to pursue the research objectives

The nature of a case study is flexible, meaning that the objectives can change and develop throughout the course of its conduction (Voss et al., 2002). An example of a model containing seven steps for conducting a case study is seen in figure 3.4.

Order	Explanation
1	Construct a research framework and questions
2	Choose a case
3	Develop research instruments and protocols
4	Conduct the field research
5	Reliability and validity in case research
6	Documentation
7	Analysis

Table 3.4. Step model for conducting a case study in 7 steps (Voss et al., 2002).

3.2.1 The case company

Sandvik AB operates within the mining and the construction industry and was founded in 1862 in Sandviken. The employee count for the company as a whole is about 43 000 people with sales in 150 countries and with over 8000 patents. Today the company is divided into three business areas: Machining Solutions, Mining and Rock Technology, and Materials Technology. The business area in focus, Sandvik Mining and Rock Technology, is in turn divided into eight separate product areas (Heath, 2018). This report will be conducted on the area Crushing and Screening (C&S). Figure 3.1 shows an overview of the different product areas. C&S is one of the larger product areas and offers a broad product range centering around three business units; stationary crushers, breakers and mobile crushers. The main purpose of these products is to crush stone and pebble.

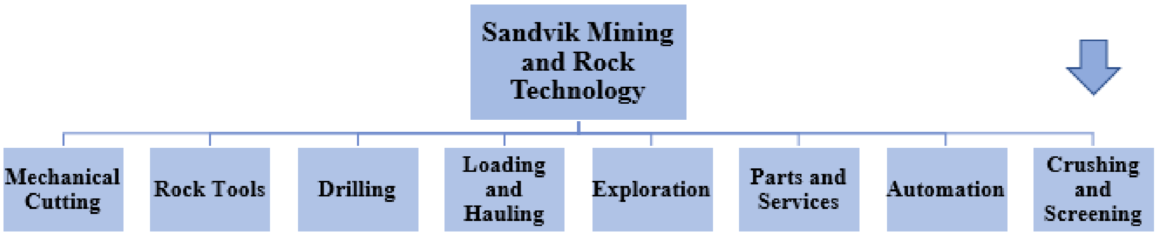

Figure 3.2. Product areas of Sandvik Mining and Rock technology.

One of the most important products in Sandvik's catalogue is the cone crusher. A cone crushers' main function is pebble crushing in varying sizes. Figure 3.3 shows a schematic of a cone crusher and its function. Pebbles are fed into the crusher, which by using rotational force crushes the pebble into smaller pieces. The cone crushers consist of four types of components: wear parts, spare parts, key components and major components. The wear parts are characterized by being large, heavy, bulky and non-stackable. The spare parts are mainly smaller goods such as nuts or bolts, which are used in larger quantities. The major components are also large and heavy; these are machined and created at the production site in Svedala. The key components are strategically important components, which vary in size and weight. The components are created from Sandvik drawings but the production of many items is outsourced to external manufacturers.

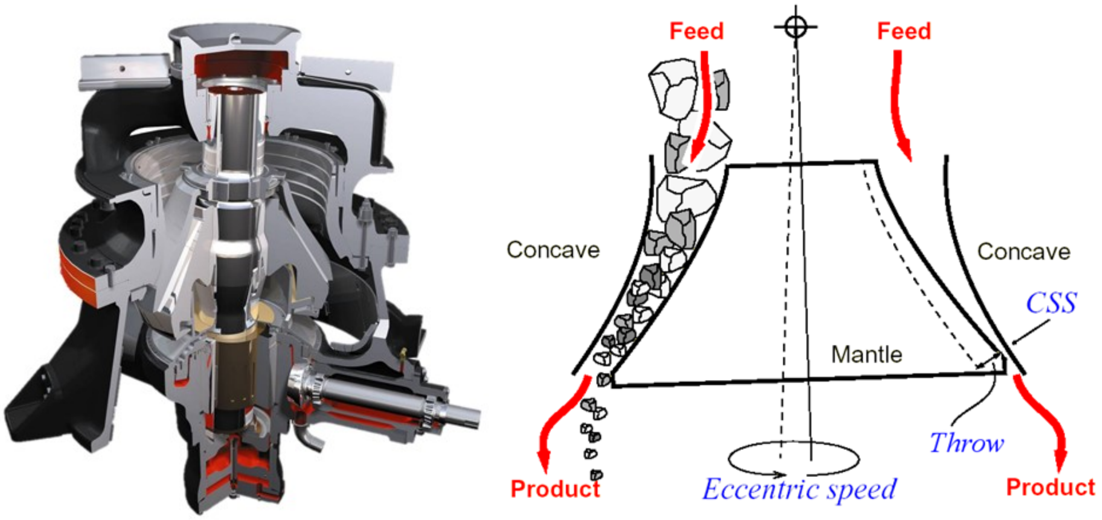

Figure 3.3. Sandvik cone crushers (Karlström, 2018).

For a long time Sandvik has had a centralized logistics strategy with one of the product areas dedicated to handling the logistics. This strategy is undergoing revision and Crushing and Screening is the first area to have their own logistics operation. That means an entire logistics operation is being set-up in a new configuration. In figure 3.4, the previous logistics setup is presented and in figure 3.5, the new logistics setup is shown.

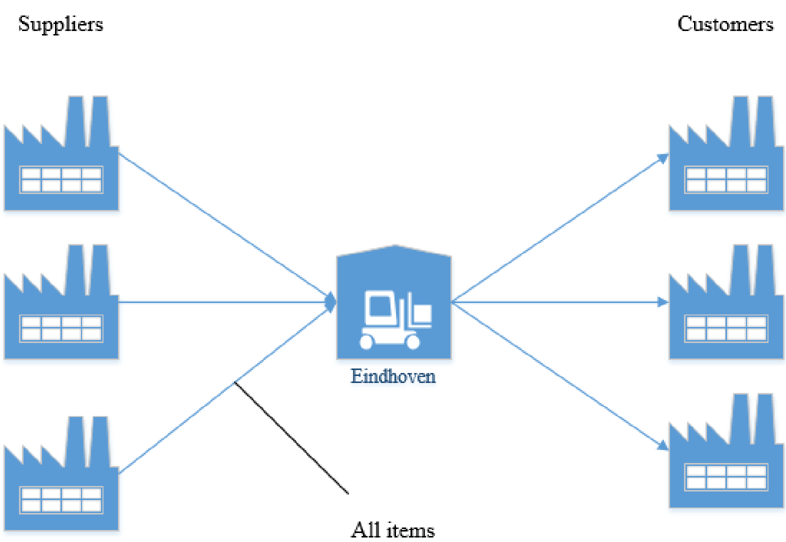

Figure 3.4. Previous logistics network of Sandvik Crushing and Screening.

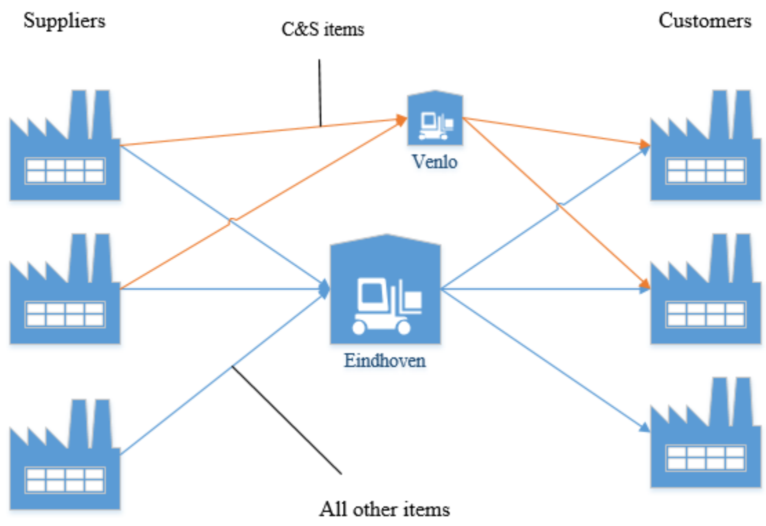

Figure 3.5. New logistics network of Sandvik Crushing and Screening (C&S).

3.2.2 Data collection methods

When gathering and collecting data there are in general two different types of information to be gathered, qualitative or quantitative. The desired type depends entirely on the objectives you want to reach. Quantitative data revolves around measuring variables and testing the relationship that exists between them to be able to prove, disprove or provide credibility to existing theories. Qualitative data is characterized by an inductive approach to gaining knowledge with the purpose of generating meaning (Leavy, 2017). Case studies are often based on qualitative data where quantitative data is used for validation (Voss et al., 2002).

In addition to data mining, observation is another way of collecting data. Voss et al. (2002) states that observation is one of the most important tools to use when developing research instruments and protocols. An observation can be conducted in the following ways: systematic observation, descriptions, analysis, and interpretation of behaviors (Saunders et al, 2009). Interviews are yet another way of collecting qualitative data; these can be divided into structured, semi-structured and unstructured depending on the purpose (Longhurst, 2003). Semi-structured interviews which mainly are used for this thesis are described to be found in the middle of structured interviews with a predetermined and standardized set of questions making them structured and unstructured in how the direction of the conversation is mostly determined by the interviewee (Longhurst, 2003)

The data collection has been conducted according to mixed method research regarding both collection and choice of data sources. Saunders et al. 2016 describes this as a method that supports interpreting, generalizing and validating results that are acquired throughout the research. To be able to acquire the in depth understanding that Voss et al. 2002 mentions for the single case study the data must be vast and available, which is the case for a large company such a Sandvik.

3.3.4 Data Collection

The data collection at Sandvik is divided into three parts; interviews with key people, observation of the warehouse and analysis of data retrieved from the Enterprise Resource Planning (ERP) system. The first step of semi-structured and unstructured interviews were done with Miguel Rocha (Vice President Logistics), Jaime Heath (External Logistics Manager) and Gustav Karlström (Logistics Development Specialist) to be able to conclude the objectives of the thesis and get an overview of the current situation within the warehouse. The interview guide can be seen in Appendix C. The next phase was to deepen the knowledge concerning the warehouse; this was done by conducting semi-structured interviews with Erwin Verheggen (Warehouse Manager) and Pascal Tielen (Warehouse Operator). The interview guide can be seen in Appendix D. When an initial selection of potential improvement suggestions for the warehouse had been made, a third phase of interviews and meetings were conducted with two different suppliers of the case warehouse, as well as an IT specialist within Sandvik, see table 3.3.

Phase	Date	Name	Function	Topic
1	05 Feb 2018	Miguel Rocha	VP Logistics Services	General information of the European logistics structures of Sandvik in which the warehouse is included and future work.
	07 Feb 2018	Jamie Heath	Logistics Manager	The logistics network of Sandvik C&S and Sandvik's new decentralization strategy that is the reason for this thesis.
	12 Feb 2018	Gustav Karlström	Logistics Development Specialist	The ERP system in which all data concerning the Venlo and Eindhoven warehouses can be found and how to navigate the database.
2	13 Feb 2018	Pascal Tielen	Warehouse Operator	General information and tour of the Venlo warehouse on site as well as each individual process, equipment, products etc.
	14 Feb 2018	Erwin Verheggen	Warehouse Manager	Validation of the author's version of the as-is analysis of the warehouse.
	8 March 2018	Gustav Karlström	Logistics Development Specialist	Validation all data and initial versions of the improvement suggestions.
	14 March 2018	Pascal Tielen	Warehouse Operator	Follow up interview regarding specific issues and improvement potential in the warehouse.
3	25 April 2018	Supplier A, 2 representatives	Key Account Manager, Logistics Specialist	Discussion regarding packaging solutions of incoming items connected to improvement suggestion 2 (see chapter 6).
	26 April	Luc Teeuwen	IT System Specialist	Information regarding WMS and discussion regarding improvement suggestion 1.
	02 May 2018	Supplier B, 2 representatives	Warehouse Manager, Area Manager	Discussion regarding packaging solutions of incoming items connected to improvement suggestion 2.

Table 3.5. Interviews conducted.

The quantitative information received concerning the processes was found by data mining in the company's ERP system, see table 3.6.

Section	Source and retrieval month	Data period	Type of data	Analysis of data
General	ERP item stockroom balance, February	01 Feb 2017 - 01 Feb 2018	All items in the two warehouses	Found total number of SKUs and available SKUs, number of used and unused pallet locations, number of broken case locations
Receiving	ERP purchase order report, February	01 Feb 2017 - 01 Feb 2018	All items coming in to the warehouses	Found inbound orders and orderlines per time unit, found top 10 suppliers
Receiving & put-away	ERP sales order report, April	01 Jan 2018 - 01 April 2018	All items that are included in the customer orders	Found number of orders that had arrived at the warehouse but were not available to ship
Storing	ERP item stockroom balance, March	March 2018	All items in the Venlo warehouse	Found the location of every C&S item in the warehouse to create a map
Picking & shipping	ERP sales order report, March	01 Feb 2017 - 01 Feb 2018	All items that are included in the customer orders	Found outbound orders and orderlines per time unit. Found average number of items per order
Supplier meetings	ERP purchase report, April	01 April 2017 - 01 April 2018	All items coming in to the warehouses	Found items connected to the specific supplier, the dimensions, packaging, amounts etc.

Table 3.6. Collected data.

The observations (table 3.6) of the warehouse was conducted during three visits to the site focused on firstly understanding the layout of the warehouse and secondly observing the flow of goods. This information could then be verified by using data from the ERP system.

Visit	Date	Purpose
1	12 Feb – 15 Feb 2018	First tour of the warehouse, general information, conducting interviews
2	12 Mar – 16 Mar 2018	Follow up interviews, verifying of analysis, timing of certain processes, deeper understanding
3	24 Apr – 26 Apr 2018	Meeting with supplier, interview with IT specialist, concluding discussions

Table 3.7. Warehouse visits.

The data from the ERP served the purpose of verifying the information received from other sources as well as to identify problems that could not be seen directly by observing and interviewing. To find improvement suggestions based on the identified problems a funnel approach was used where a larger number of suggestions were boiled down to a few through discussion (see chapter 6). The most prominent improvement factors were then further developed and investigated to be able to provide the case company with elaborate solutions.

3.3.5 Data analysis

To identify the problems that exist in the warehouse the theory concerning each operation was compared to the case warehouse through the tool in figure 2.11. By combining this with information acquired from interviews, observations and meetings, the list of problems was created. The main issue (that customers are not getting their orders on time) was given when the project started and all problems were traced back to this main issue in order to show how each of them contribute.

The approach to finding and evaluating problems was similar for all and can be described through an example of how the first problem (see table 5.1) was identified. Through an initial evaluation of the warehouse based on the first interview of phase 2 (see table 3.5) it became known that the arriving items were manually put into the system by an operator. This information was then put into the support tool were it could be seen that the warehouse lacked any type of scanning technology such as barcodes. From the second interview in phase 2 it was revealed that sometimes several hours each day was devoted to look for newly received. This is a result of that the temporary storage locations in the receiving dock are not trackable. In combination with this, it was revealed through studying the ERP system that items that are waiting in the receiving area are not available for ordering. Considering all this, it was concluded that the lack of a tracking system in the receiving area indeed is a problem for the warehouse since it directly contributes to creating customer backorders. All problems are described in chapter 5.

To transform the problems into improvement suggestions, an approach similar to how the problems were found was used. Based on theory, the support tool and gathered data it was concluded which tools that exist within warehousing that could be used for redressing each problem. When an initial draft of a solution had been made, it was elaborated on further. This elaboration could for example be reaching out to appropriate actors. An example of how this was done concerns the first solution regarding changing packaging solution for incoming items. When it had been established that the items were stuck in a repacking process, suppliers were contacted to evaluate if different packaging solutions could simplify the way that warehouse operators work. When improvements had been identified, the most significant ones were chosen as suggestions for the case company based on how vastly they would impact the warehouse and how they would fit the purpose of the thesis.

3.3.6 Documentation

Every possible data point was recorded during the warehouse visits. Pictures and notes were taken to ensure that the correct information was documented. During the interviews, the responses were transcribed and sent back to the interviewee for inspection and validation. Lastly, for the data collection using the ERP system all data sheets were saved and categorized.

3.5 Reliability and validity

Reliability and validity are two separate matters that share many aspects. Yin (1994) has outlined how different types of validity and reliability cases can be evaluated, see table 3.8. *Construct validity* refers to the correct operational measures for the studied concepts, *internal validity* refers to the strength of potential relationships that exist between parts in a research, *external validity* refers to if any generalized conclusion can be drawn and lastly, *reliability* refers to if the study would yield similar results if repeated (Voss et al., 2002).

Test	**Case study tactic**	**Phase of research in which tactic occurs**
Construct validity	Use multiple sources of evidence Establish chain of evidence Have key informants review draft case study report	Data collection Data collection Composition
Internal validity	Do pattern matching or explanation building or time-series analysis	Data analysis
External validity	Use replication logic in multiple case studies	Research design
Reliability	Use case study protocol Develop case study database	Data collection Data collection

Table 3.8. Validity and reliability according to Yin (1994).

All gathered information was checked through multiple sources to verify each result. Multiple interviews were conducted with different people, multiple visits were made to the warehouse and all data gathered were compared to at least one other Sandvik warehouse. All results concerning the warehouse were presented to key people within the case company to assure that no misinformation was collected. Meredith (1998) says that there is no need to strive for external validity since a case study is not supposed to represent an entire population.

Reliability refers to if the study can be replicated. In this thesis, one of the key aspect that might vary is the information received from the interviews. There is a possibility that when asked about problems in the warehouse, the respondents exaggerate issues that affect their everyday life but might not be crucial to the overall setting. To reduce this error, all information was collected from different sources and all data gathered from the interviews were transcribed and verified by the respondent.

One general aspect that can influence the validity of a research is how trustworthy the literature is. All sources, references, articles and books have been found is from recognized and reputable databases. All the information has been peer reviewed and can therefore be judged to be trustworthy and eligible for usage. The information has also been compared and evaluated through cross checking the references found within the literature study.

4. RO1: Applying support tool

Following the support tool in 2.11, this chapter will provide an empirical review of the entire case warehouse.

4.1 Warehouse type and objective

The different product areas of the case company are moving towards having their own logistical operations. One reason for this decentralization is that the product areas gain full visibility and access to their own stock. In addition, the new supply chain network makes it easier for the product areas to control the material flow of key components, wear parts and spare parts through and their modes of transportation. The case warehouse will supply the customers as well as replenish other warehouses across the world. This particular warehouse is consequently a spare parts warehouse and supplies both internal and external customers.

4.2 Warehouse design

Figure 4.1 shows a map of the warehouse layout. The warehouse handles all types of packaging levels including pieces, cartons, pallets and items that are larger than a pallet. There is no form of automation in the warehouse, all items are being handled manually or by fork lift truck. Table 4.1 shows the available equipment within the warehouse. The equipment is not owned by Sandvik but is leased from a local company in the Netherlands. This means that Sandvik can change equipment if the warehouse would require it. According to Tielen (2018), the equipment is more than enough to handle the needs of the warehouse.

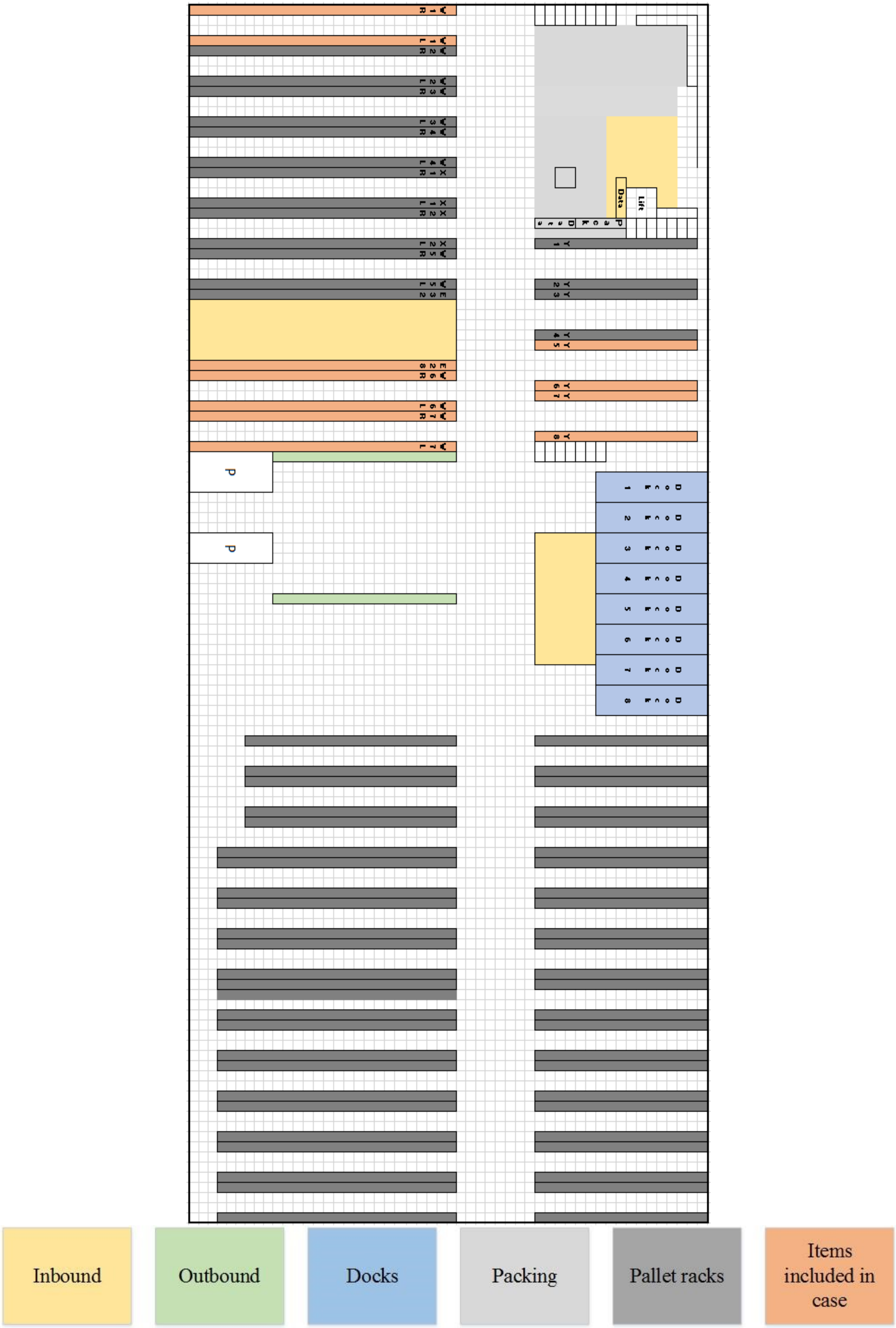

Figure 4.1. Map of the main floor.

No warehouse management system is currently in place and locations and items are tracked using manual input. Meaning that all actions concerning receiving, put-away, storage and picking need to be made at one of the two terminals located in the warehouse. Similarly, the current system does not use barcodes or any other type of scanning.

Equipment	Amount
Counterbalance trucks	5
Reach trucks	4
Overhead cranes	2

Table 4.1. Equipment available in the warehouse.

4.3 Warehouse operations

Figure 4.3 shows the overall process flow of the warehouse. Following the support tool, each operation will be covered according to operational and design aspects.

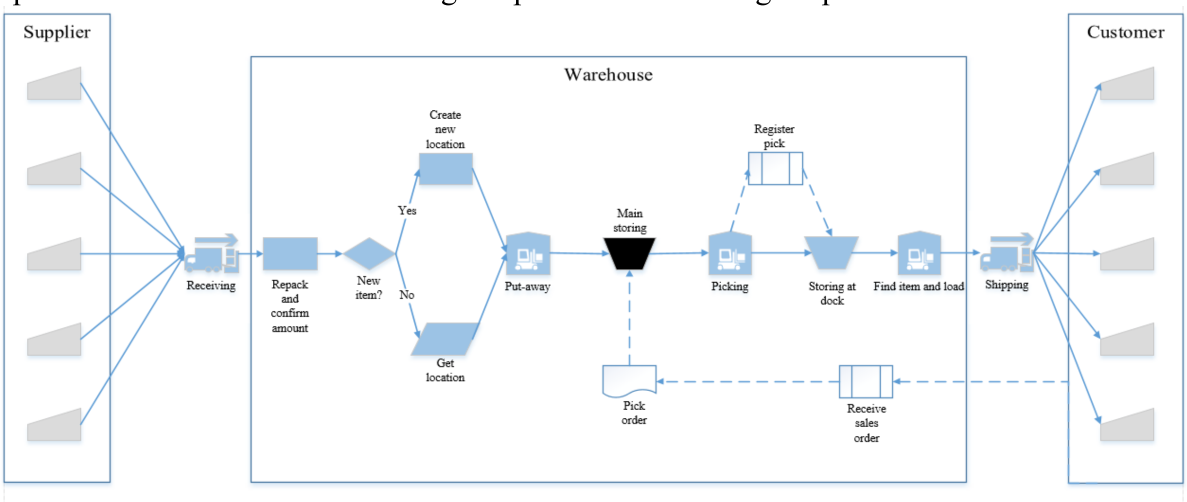

Figure 4.2. Process flow of Sandvik warehouse in Venlo.

4.3.1 Receiving

Input: Warehouse manager (Erwin), Warehouse employee (Pascal), Purchasing data (ERP), SKU data (ERP), Suppliers extract (ERP)

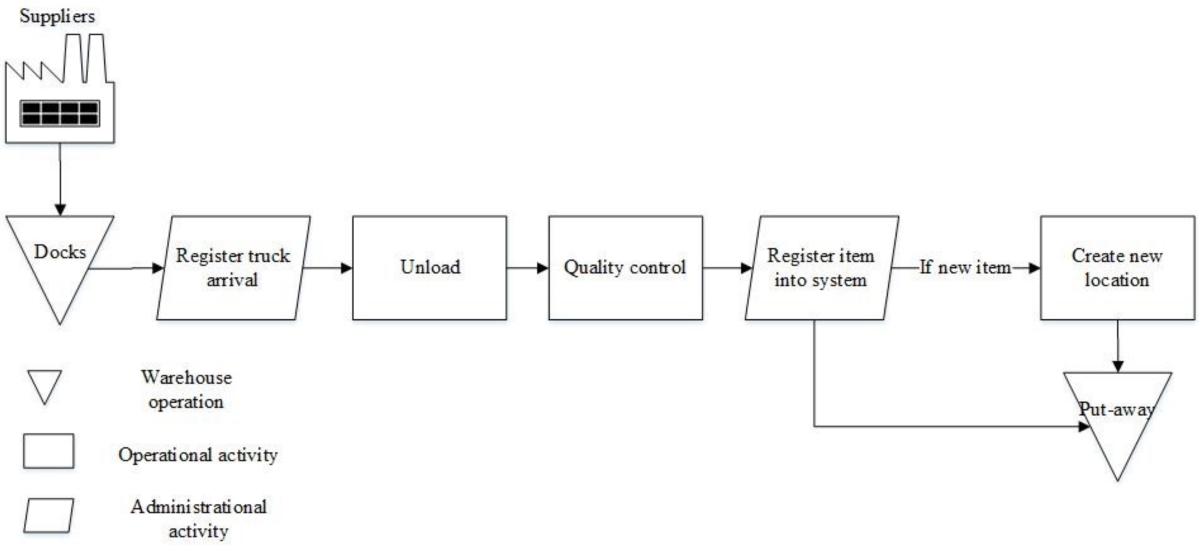

Figure 4.3. Process flow of receiving.

Figure 4.3 shows each activity that is carried out within receiving, from the arrival of a truck to put-away. The warehouse has many different suppliers that deliver a variety of components and materials. These suppliers have been investigated and ranked according to their importance to the warehouse. The primary factor being the amount of orderlines received at the warehouse, see figure 4.5. When ranking suppliers, Verheggen (2018) agrees on that the amount of orderlines is the aspect that has the largest effect on the operations. The table is intended to identify the largest improvement potential.

Supplier	% of purchase orders	% of items received	Average purchase quantity	Average sales quantity	Ratio Purchase: Sales
A	9,75%	2,04%	7,25	4,53	1,6:1
B	6,48%	0,6%	3,22	1,28	2,5:1
C	6,4%	2,48%	13,43	2,62	5,1:1
D	5,77%	36,98%	222,12	22,22	10:1
E	5,02%	0,37%	2,54	1,45	1,8:1
F	3,86%	1,09%	9,81	2,62	3,7:1
G	3,13%	1,38%	7,59	2,66	2,9:1
H	3,07%	20,45%	230,79	23,04	10:1
I	2,92%	0,59%	7,02	1,75	4:1
J	2,72%	0,27%	3,5	1,66	2,1:1

Table 4.2. Suppliers ranked according percentage of received orders. The supplier names have been censored.

Eight docks are located on the main floor that are used for both receiving and shipping for every item in the warehouse. Seven of the eight docks are identical and parallel while the last dock, also parallel, is narrower and intended for smaller shipments coming in by either truck or forklift. The truck arrival times are coordinated by the warehouse office and before the truck arrive at the warehouse, they communicate a second time to confirm which shipping dock to use. When the trucks first arrive, they register at the warehouse office to confirm the arrival in an ERP system.

When the goods have been unloaded by forklift trucks or sometimes by hand, the next step is to move the items from the receiving area to the packing station. Whether an item should be moved to the packing station is determined by the size and amount of the order. Orders only containing large items in low quantities goes directly to put-away. After the items arrive at the packing station, the next step is to assess the goods, both concerning quality of components and the condition in which they arrive. Warehouse staff carry out the assessment manually. The factors that they inspect are for instance defects in the product, correct order and product numbers, type of packages and type of labelling. The only data concerning the physical product that is stored is either as “acceptable” or as “unacceptable”. Meaning, no data is stored concerning the other stages of the assessment. Through sampling, different types of arrival packages have been identified, presented in table 4.3. The case company does not ship out items to customers that contain supplier logotypes or names, meaning that all items that are not received in neutral or Sandvik labeled boxes need to be repacked. After the arriving packaging type has been confirmed the goods either go directly into the next operation, put-away, or to be repacked and relabeled. During repacking, the orders are placed on the packing table, counted and batched together and then placed into the new correctly labeled box.

Arrival condition	Comment
Sandvik labeled boxes	Mainly from Sandvik's own production units and a few selected suppliers
Supplier labeled boxes	Goods arriving in boxes with supplier logos or names on them
Blank boxes	Plain boxes without any logos or names
EU-pallet	Component placed directly on a EU-pallet
Non-standard pallets	Either for goods to large or of too high quantity for a EU-pallet

Table 4.3. Possible arrival package for goods into the warehouse.

To get an overview of the general receiving aspects, data has been gathered from the ERP system. Data gathered concerning inbound flow is presented in table 4.4 and the most common order-sizes can be seen in figure 4.4. The throughput goal (the time it takes for an item to go from receiving to being ready for picking) of the receiving has been set 24 hours.

Inbound data
45 orders/day
92 orderlines/day

Table 4.4. Inbound data (ERP-system).

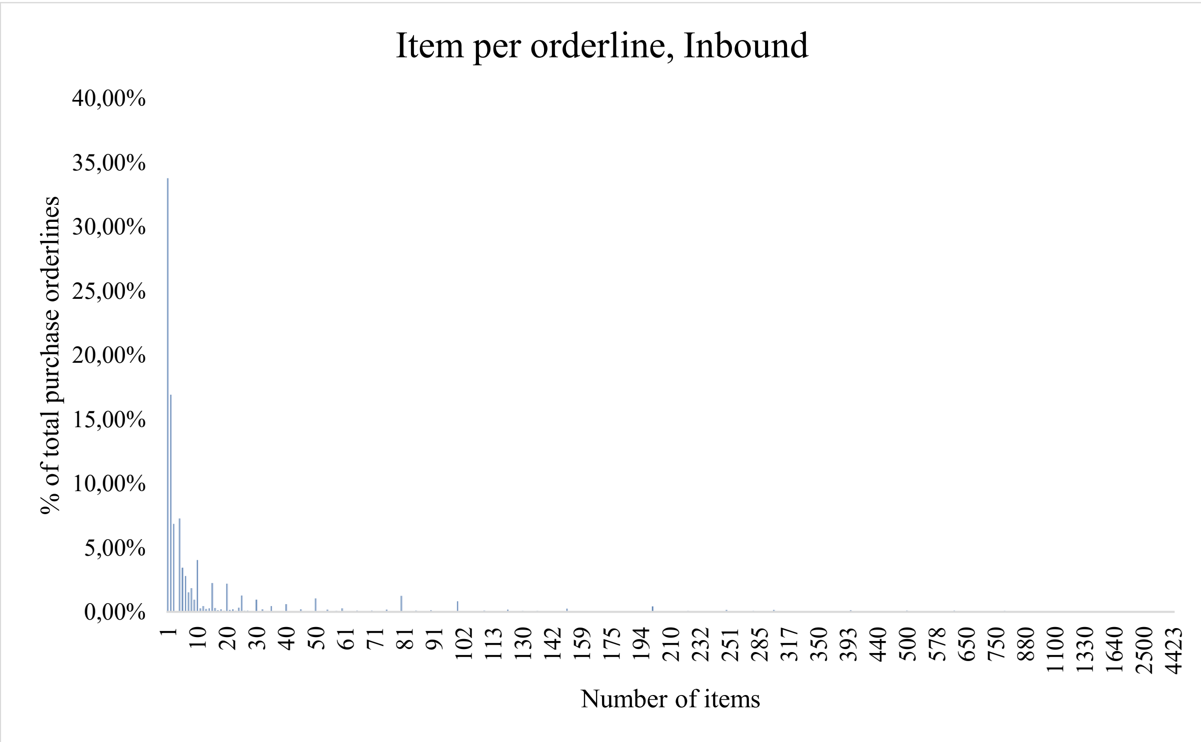

Figure 4.4. Items per incoming orderline, 2017.

Figure 4.5 show the receiving pattern for orderlines arriving into the warehouse. Some variations exists but these variations are currently not taken into consideration when taking decisions regarding the inbound flow of the warehouse. According to Heath (2018), the variation do not affect the warehouse enough to base decisions on.

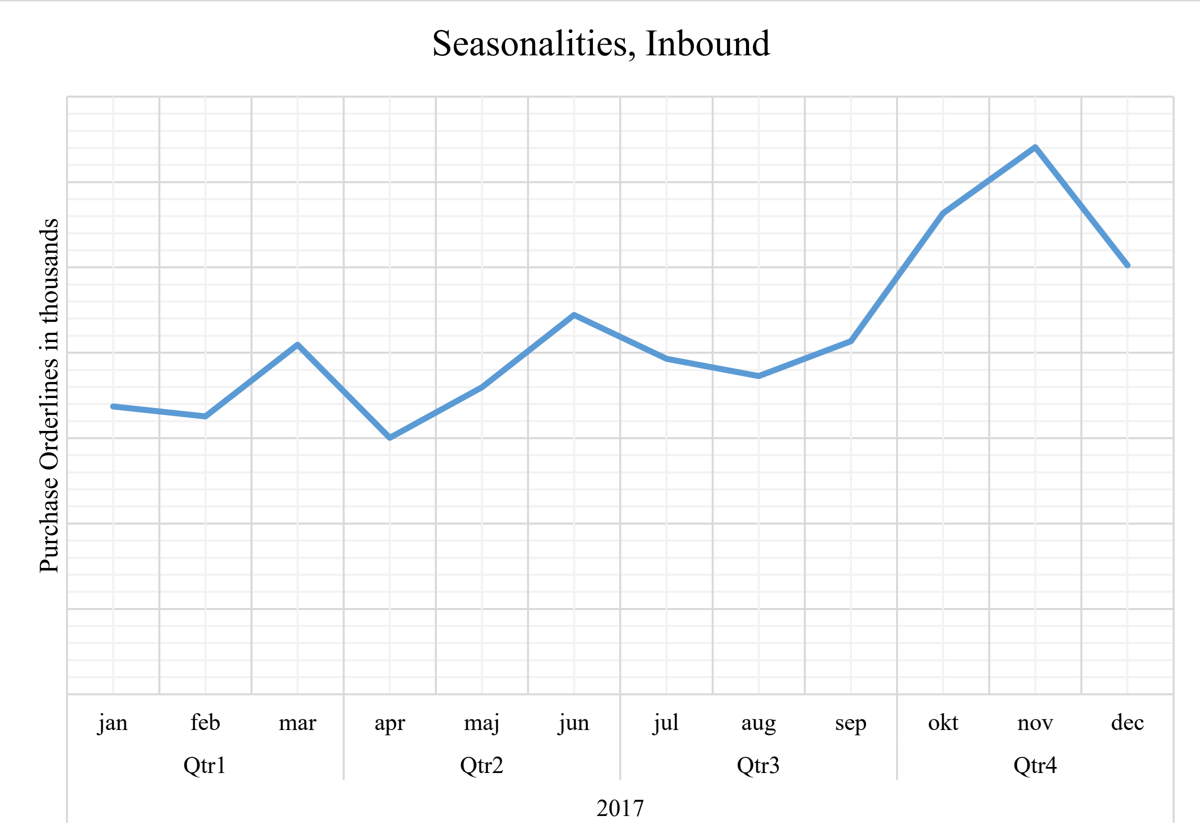

Figure 4.6. Seasonalities within inbound based on orderlines.

4.3.2 Put-away

Input: *Warehouse manager (Erwin), Warehouse employee (Pascal), Item Stockroom Balance (ERP)*

The warehouse uses a dedicated storage system. The operator manually checks, by searching the warehouse system, if a location exists within the warehouse for that specific item when it arrives. The system can track the total quantity of this item currently residing within the warehouse and at which locations these items are placed, but cannot track how many items each location holds. Meaning that if the item is found in the system the operator must check if the location is empty. If the location is not empty, the operator must go back to the terminal to find a new location to check. If all the currently assigned locations are full then a new location has to be created through searching the warehouse for available space. Each item can have up to 10 different locations assigned to it.

If the item is new to the warehouse and consequently is not in the system, the operator has to search for available locations within the warehouse and assign one of these locations to the new item. Aside from the size restrictions on some of the locations, no systematic approach or strategy has been implemented to facilitate the slotting.

4.3.3 Storing

Input: *Warehouse employee (Tielen), Visits to the warehouse, Item Stockroom Balance (ERP)*

There are four different storing areas within the warehouse. Firstly, the main floor which can be seen in figure 4.1 has an area of 13 500 sqm and has 12 m ceiling height. The main floor stores pallets in 8 m tall shelves with single deep racks configured after EU-pallets. All items in this area are picked by forklift. Products that weigh between 23 kg and 1 ton are stored in the main area. The second area is the mezzanine, figure 4.7, which is 650 sqm and a 6,5 m ceiling height. In the mezzanine, smaller items weighing less than 23 kg are stored on shelves to be picked by hand. The third area is the yard, which covers 5900 sqm and has single-deep racks that are 5 m tall. In the yard, items are stored that weigh more than 1 ton or that are too large to fit into the wide storage locations on the main floor. Lastly, the fourth area is the tent which is 400 sqm and 6,18 m in ceiling height. In the tent, mostly packing material like plywood and pallets are stored as well as lubricants for the crushers. An overview of the item weight per area can be seen in table 4.5.

Warehouse area	Weights of items stored
Main floor	23 kg – 1 ton
Mezzanine	<23 kg
Yard	>1 ton
Tent	<100kg

Table 4.5. Weight of items per area.

The number of storage locations can be seen in table 4.6 and the amount of locations dedicated to the case items can be seen in table 4.7. Figure 4.2 shows the map of the main floor with items that belong to the case product area highlighted in orange, figure 4.7 shows the mezzanine with highlighted case items as well.

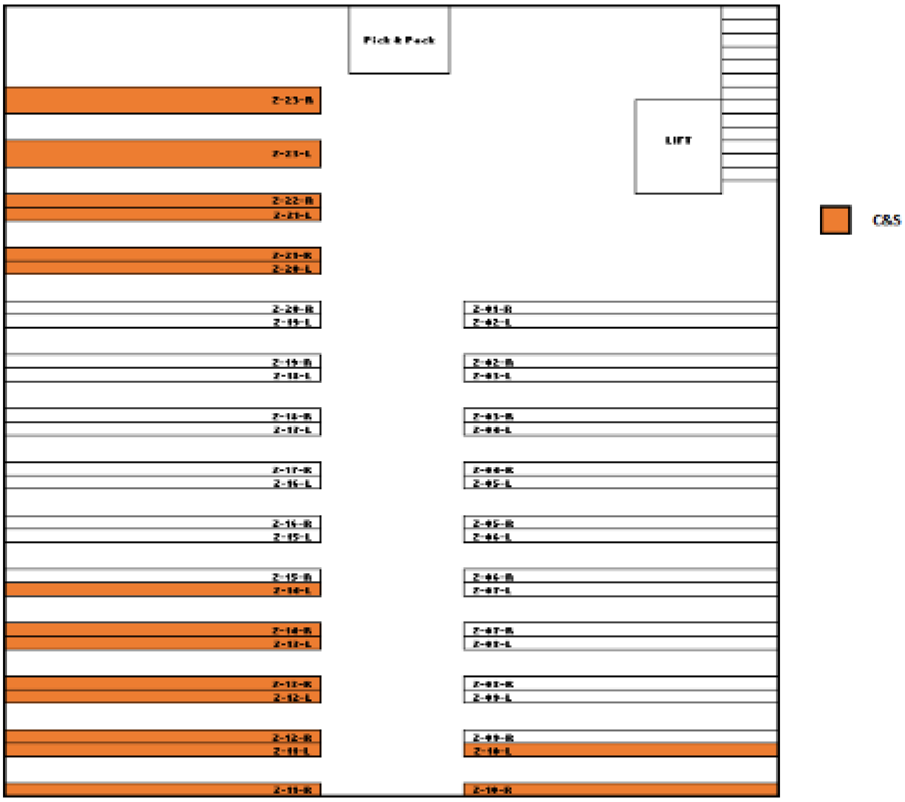

Figure 4.7. Map of the mezzanine

Area & Type	Amount of bin locations
Main floor – conventional racking	4100
Main floor – narrow aisle racking	5100
Main floor – wide aisle racking	1800
Mezzanine – shelf racking	9000
Yard – conventional racking	1200
Yard – ground storage	700
Tent – ground storage	50-250

Table 4.6. Storage locations within the Venlo warehouse and area.

Crushing and Screening locations	Amount of bin locations
Main floor – all types	1275
Mezzanine – shelf racking	2891
Yard – all types	754

Table 4.7. Storage locations occupied by C&S.

The average inventory value within Venlo and the previous Eindhoven warehouse over 35 weeks can be seen in figure 4.8**.** The values in the graphs have been censored but the trend that the overall stock within C&S have increased over time can still be observed.

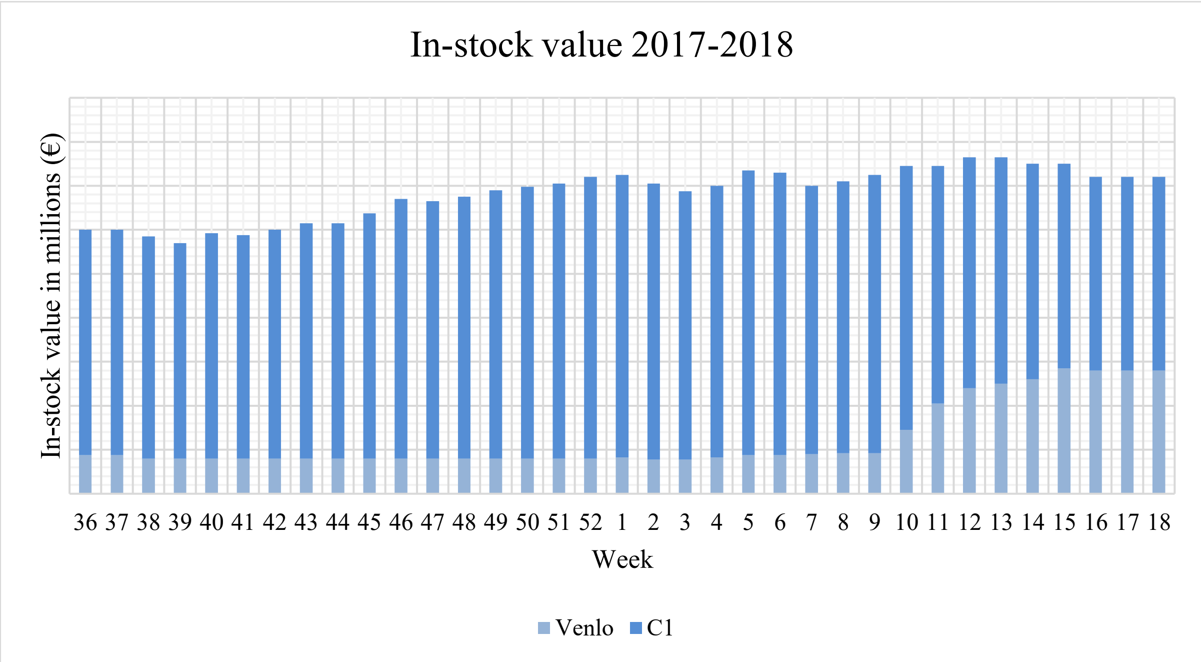

Figure 4.9. In-stock value in Venlo and Eindhoven over 38 weeks.

4.3.4 Picking

Input: *Warehouse employee (Pascal), Sales Orders (ERP), Item Stockroom Balance (ERP)*

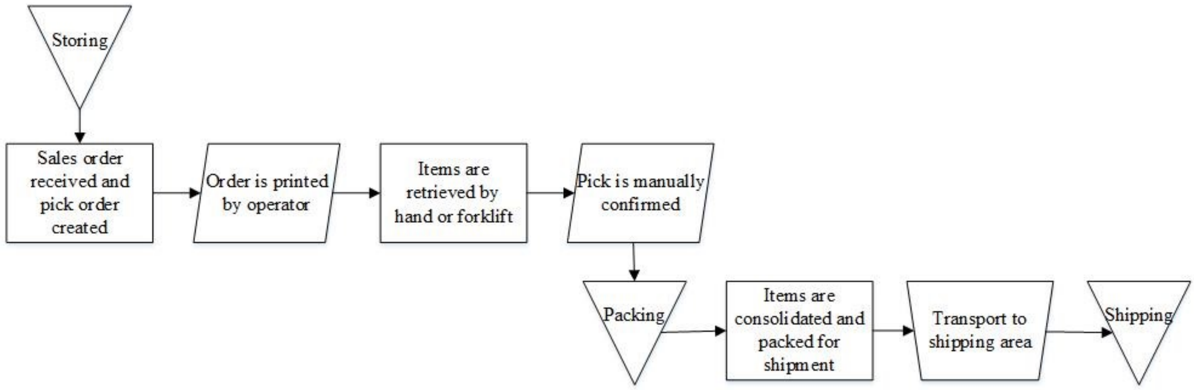

Figure 4.9. Process flow of the picking and packing operation.

The warehouse office receive a notice from the sales team that an order has been created. The warehouse office registers the order into the ERP system to let the warehouse operators know that an order has been placed. The operator manually prints a physical copy of the order containing picking information. The operator can then start to pick the order by bringing the items to the packing area to be consolidated for shipping. The lack of scanners in the warehouse means that items are crossed of manually on the pick list. Except for when picking from the yard, the warehouse pickers operate by single-order picking. When collecting items from the yard, orders are piled together and picked at the same time to minimize the use of the special equipment needed to gather items. The activities included in the picking and packing operation can be seen in figure 4.9. Table 4.8 shows general outbound data.

Outbound data
99 orders/day
262 orderlines/day
1,83 inventory turns/year

Table 4.8. Outbound data (from ERP system).

When the order has been picked, the operator either places it in the packing area or transports it directly to the shipping docks. When consolidation and packing has been completed, the operator uses the terminal to register that the items are ready for pick-up.

The case company uses an item classification based on how often an item is requested by customers each year. The classification codes can be seen in table 4.9, where item classified as W or X are considered high runners (Karlström, 2018). How often items with the classifications are picked and shipped can be seen in figure 4.10.

Classification	**Times requested by customer**
W	>30
X	11-30
Y	7-10
K	5-6
L	3-4
Z	1-2
O	Non-moving

Table 4.9. Item classifications.

Figure 4.10. Item activity divided per item classifications.

Regarding packing, orders are consolidated on pallets and moved to the shipping area. Since the items are already repacked during the receiving process, the outbound packing is not as time consuming. When consolidating, the operator confirms that the items have been packed in the correct quantity.

4.3.6 Shipping

Input: *Warehouse manager (Erwin), Warehouse employee (Pascal), Sales Orders (ERP),*

When shipping, an operator collects the order from temporary racks that are located close to the docks. To find the items, a physical list of printed that provides information on what to ship. The amount of items per outgoing orderline can be seen in figure 4.11.

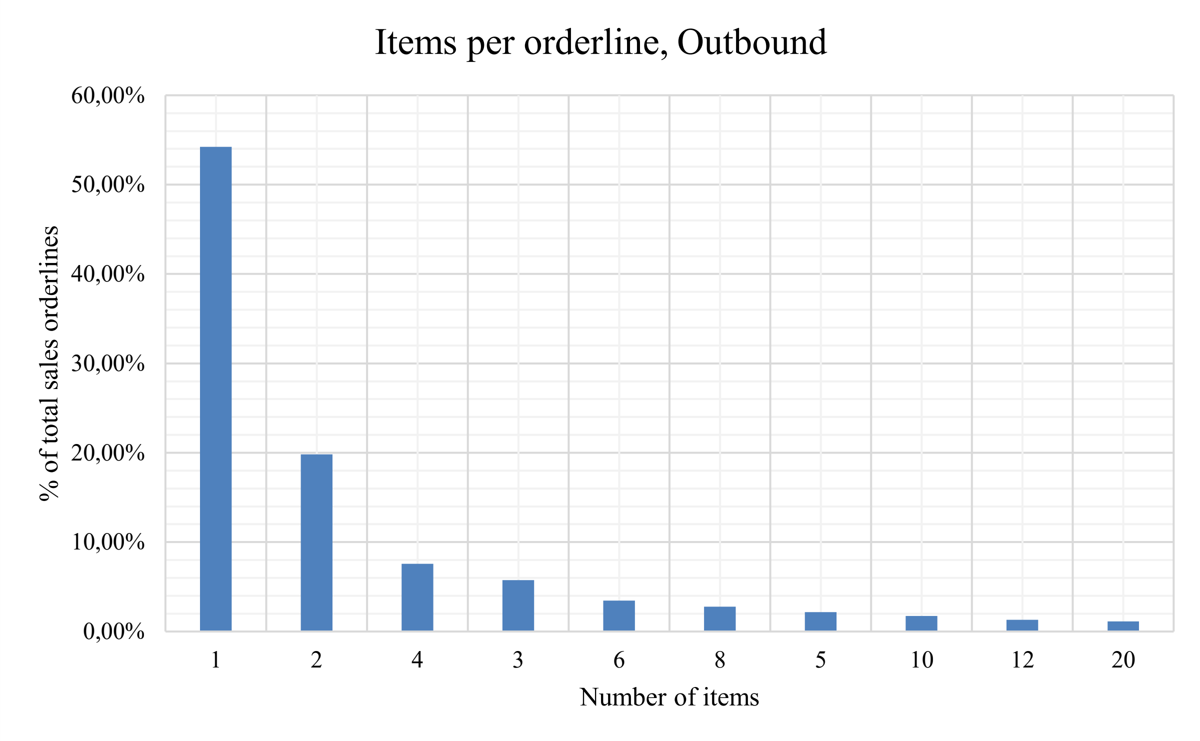

Figure 4.11. Items per outgoing orderline, 2017.

Information of customer demand seasonalities can be seen in figure 4.13**.** As for inbound, the low variations in outbound seasonality are not considered significant enough to change the warehouse operations.

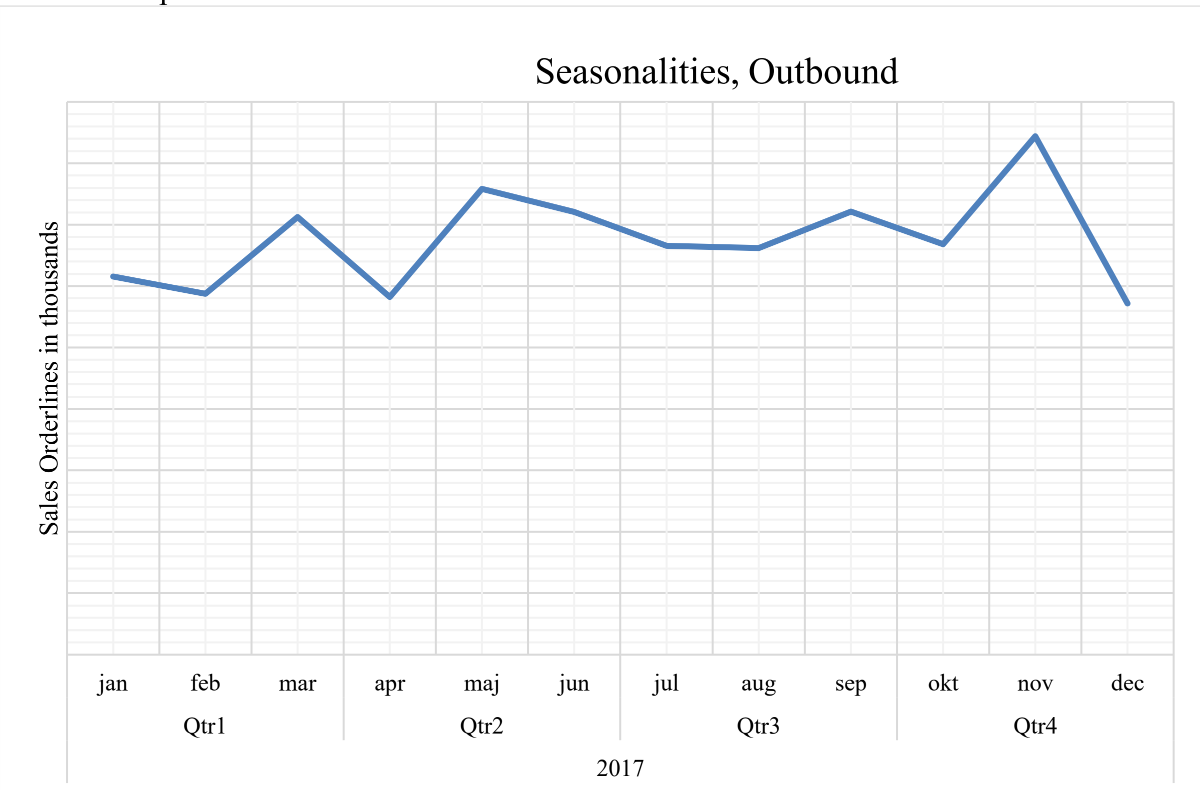

Figure 4.12. Seasonalities of outgoing goods based on orderlines.

4.3.7 Warehouse management system, Scanware

Input: *IT system specialist (Teeuwen), User guides Scanware.*

Figure 4.13 shows an overview of systems used by other product areas within the case company. Scanware is a WMS that some parts of the company uses that covers transportation planning and basic warehouse management.

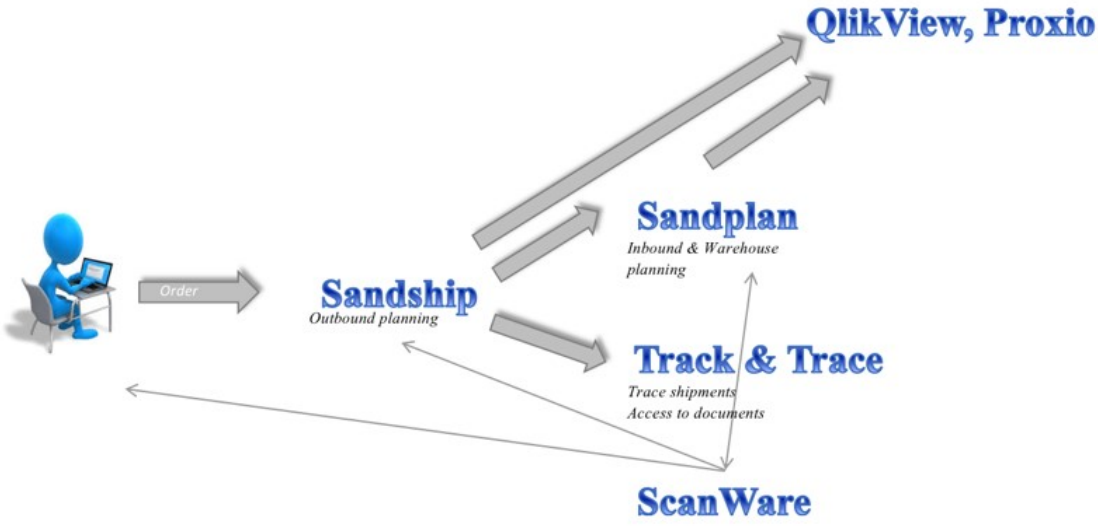

Figure 4.13. Overview of some of the system available at Sandvik

Scanware exists in three different forms, a web based program, a terminal based program and a mobile-based program. All these contain practically the same function with the difference being the level of detail. Figure 4.14 displays the functions available within Scanware. Most of those functions are self-explanatory and are supposed to interact with an ERP system.

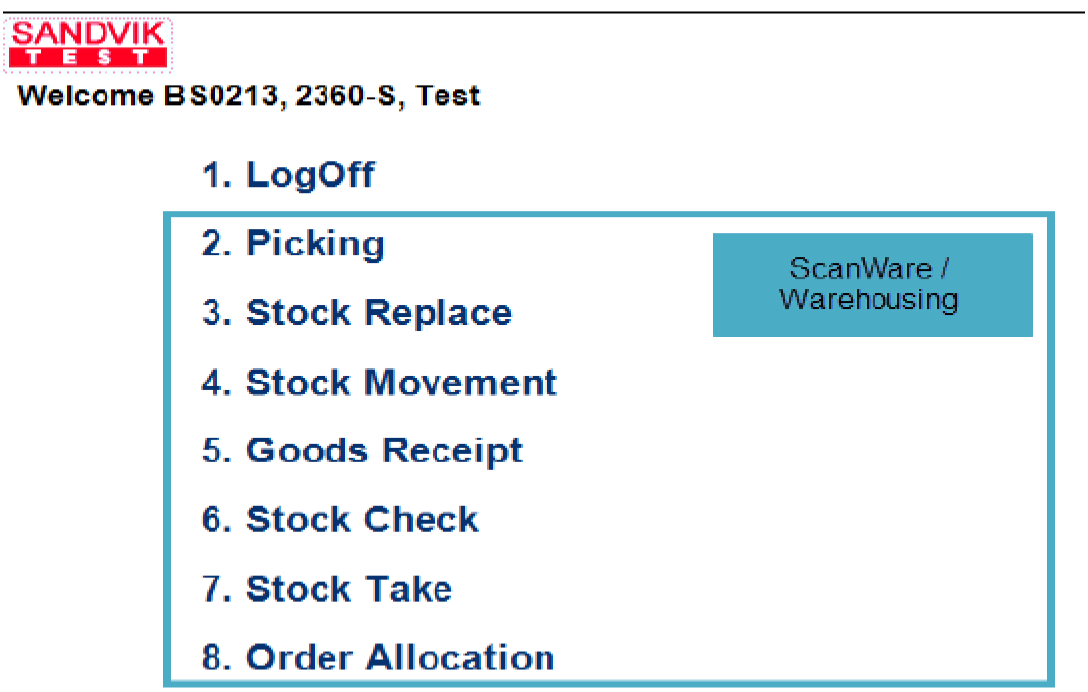

Figure 4.15. Basic functions available in Scanware.

Regarding the unloading, Scanware generates a loading list for both the carrier and the receiver, which is generated automatically through barcode scanning. If the shipment is incomplete, Scanware will relay this information to the operator when the barcodes are scanned. Scanware can through scanning show information about the shipment and print the correct labels for each item. After the labels are created, the item can be put-away and Scanware will generate possible locations based on length, weight or other physical aspects. During the put-away, both the location and the item is scanned which means Scanware then knows which quantities items are stored in at each location. Regarding picking, Scanware will create an order ranking based on critically set by the warehouse office. The orders can be picked either as a full pallet, cartons or pieces and the WMS will keep track on how much that is left in every location. Scanware can also be configured to single, batch or zone pick depending on the warehouse needs and can combine sales orders from the same customer. After the pick is done, Scanware will generate the net weight of the orders, this can be manually corrected and Scanware will use the new weight in the future. For Scanware to be able to operate at full capacity within a warehouse it needs handheld scanners and terminals.

4.4. Support Tool

Based on all sections of this chapter the warehouse can now be fitted into the support tool as shown in figure 4.15. The highlighted alternatives are the ones that apply to the case warehouse.

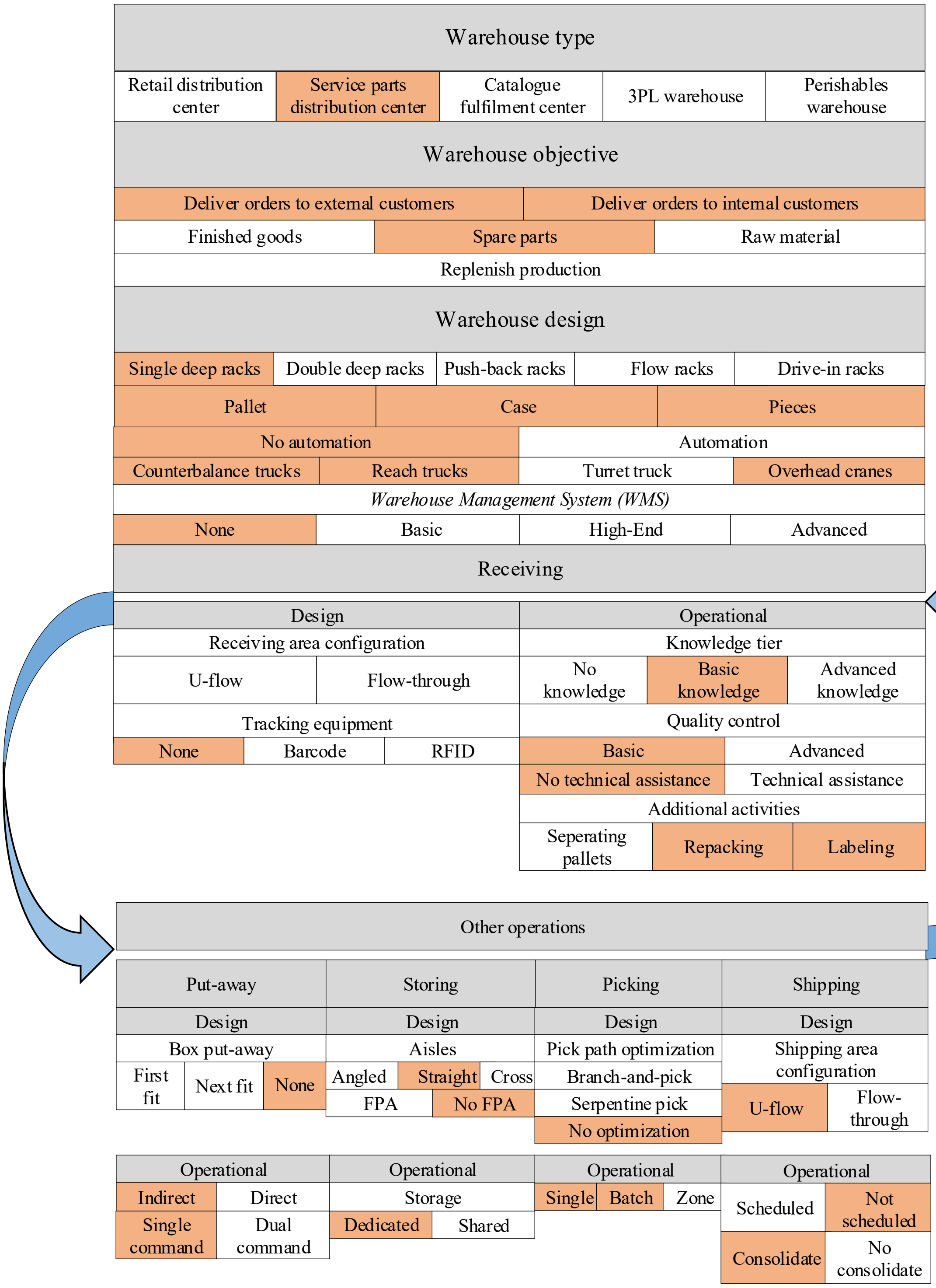

Figure 4.15. Applied support tool.

5. RO1: identifying issues

This chapter is centered on the second part of Research Objective 1. The purpose of the chapter is to examine the main problems of each operation in the warehouse and connect these to the overall warehouse function.

The current general issue for the warehouse is the outstanding sales orders, meaning that customers are not getting their orders on time. According to Heath (2018), this trend of creating backorders has been increasing since the redesign of the logistics network. The constraining factor for the new warehouse is consequently time. Therefore, everything that is analyzed is done with the intent of reducing the time items spend in the warehouse. A summary of the issues that have been identified in the warehouse is presented in table 5.1.

Identification number	Operation	Description
1	Receiving	Item are not tracked within the receiving area
2	Receiving	Indirect put-away leads to double handling within receiving
3	Receiving	Unnecessary travel between shipping area and receiving area
4	Receiving	Orders need to be counted manually when arriving
5	Receiving	Items need to be repacked when arriving into the warehouse
6	Receiving	Items need to be relabeled when arriving into the warehouse
7	Put-away	Item quantity is not tracked at each separate location
8	Storing	Items are not stored per pick frequency
9	Picking	Physical paper picking lists reduce flexibility and picking efficiency
10	Packing	Some items need specially created packages for shipping
11	Shipping	Items are not tracked within the shipping area

Table 5.1. Identified problem areas within the Venlo warehouse.

5.1 Receiving

<table>
<tr><th colspan="6">Receiving</th></tr>
<tr><td colspan="6">Design</td></tr>
<tr><td colspan="6">Receiving area configuration</td></tr>
<tr><td colspan="3">U-flow</td><td colspan="3">Flow-through</td></tr>
<tr><td colspan="6">Tracking equipment</td></tr>
<tr><td colspan="2">None</td><td colspan="2">Barcode</td><td colspan="2">RFID</td></tr>
</table>

<table>
<tr><td colspan="6">Operational</td></tr>
<tr><td colspan="6">Knowledge tier</td></tr>
<tr><td colspan="2">No knowledge</td><td colspan="2">Basic knowledge</td><td colspan="2">Advanced knowledge</td></tr>
<tr><td colspan="6">Quality control</td></tr>
<tr><td colspan="3">Basic</td><td colspan="3">Advanced</td></tr>
<tr><td colspan="3">No technical assistance</td><td colspan="3">Technical assistance</td></tr>
<tr><td colspan="6">Additional activities</td></tr>
<tr><td colspan="2">Seperating pallets</td><td colspan="2">Repacking</td><td colspan="2">Labeling</td></tr>
</table>

Figure 5.1. Activities within receiving from the support tool.

Within receiving the goal for the intake time is 24 hours. This goal is not fulfilled right now as the actual time it takes for newly received items to be available for picking is varying between 3-7 days. This bottleneck means that optimizing operations downstream will not increase the warehouse throughput. The first thing that happens in the receiving operation is that incoming trucks are coordinated by an administration office on site. This office does not have control over purchasing functions, distribution resource planning (DRP) nor any sales within the case company. This means that the office's influence is limited to only handling the arrivals based on the warehouse capacity. In addition, goods are not tracked within the ERP system until they have been received and put into shelves. Which means when a purchaser places an order and schedules it to arrive the next day, he or she cannot see how many goods that currently are waiting in the receiving area to be put-away. Likewise, the personnel in the warehouse cannot see the urgency status of the items until it has been registered in the ERP system. Figure 5.1 shows that no current tracking equipment is available in the receiving. This is the first issue, items are not tracked within the receiving area meaning that quantities can build up and items that are more urgent will not be prioritized.

Figure 5.1 shows that no flow configuration exists within the receiving area. Large items that are arriving one-by-one directly on a pallet are quality controlled at the receiving dock. They are then registered at a terminal in the receiving area and are ready for put-away. The smaller items that arrive in multiples on a pallet are instead transported from the receiving area to the packing station for quality control. The weighted average quantity for inbound orderlines is 24 items, meaning that the average orderline consists of small items. Table 5.2 shows all orderlines containing quantities below 2, between 2 and 50 items, and above 50 items. Orderlines containing more than 2 items need to be transported to the packing station. This is the second issue, items arriving at the receiving area are not directly put-away which results in double handling and delays.

Inbound quantities	**% of total orderlines**
Quantity ≥ 50	7,9
50 > Quantity > 2	41,4
Quantity ≤ 2	50,7

Table 5.2. Quantities for inbound orderlines.

The distance between the docks and the packing station is about 60 m, which is travelled several times per day, and the distance is always travelled by forklift. According to Verheggen (2018) the average operating speed for the forklifts is 8 km/h. When in the packing station, some of the items are stored right on top of it, in the mezzanine. For these items, the travel distance is necessary since it would have to be travelled anyway. These are the items arriving in quantities larger above 50. The other items, quantities between 2 and 50, are stored in pallet racks on the main floor. For these items, the distance is considered unnecessary travel. This is the third issue; items need to be transported between the receiving docks and the packing station instead of being directly put-away.

At the packing station, the items need to be quality controlled mainly to check that the right quantity and correct type has arrived. From figure 5.1, it can be seen that all quality control is done without technical assistance meaning that the operator must count every item by hand. If items are already batched into standardized quantities, the warehouse trusts that these batches contain the correct amount (Tielen, 2018). Table 5.2 shows how many orders arrive in quantities above 50. However, it is not possible to see which are batched before entering the warehouse but according to Tielen (2018) and Verheggen (2018), approximately 30% of these orders needs to be counted by hand. This is the fourth issue, orders needs to be counted manually when arriving into the warehouse.

Another problem presents itself when looking at the additional activities (figure 5.1). Items received in supplier labelled boxes need to be repacked into case company labeled boxes. An average time of 65,2 s has been measured for one repack within the warehouse, see table 5.3. If that time is multiplied with the packaging material, table 5.4, for the warehouse it can be calculated that approximately 8 hour each day is spent on repacking. For bags, the time was approximately half the time it took to repack a cardboard box. In summary, suppliers pack the items right before they are shipped to the warehouse only to have the warehouse repack all items as soon as they get there. This is the fifth issue, items needs to be repacked when arriving into the warehouse.

Trial	Folding the box (s)	Applying tape (s)	Placing item in box (s)	Adding protection (s)	Attaching label (s)	Placing box on pallet (s)	Total (s)
1	9	7	5	20	14	7	62
2	10	6	7	25	14	6	68
3	10	7	6	25	14	6	68
4	8	7	5	23	17	6	66
5	9	7	7	24	12	6	65
6	9	5	5	24	12	7	62
7	9	8	7	22	15	7	68
8	7	6	7	28	15	6	69
9	6	6	5	19	14	7	57
10	10	7	5	25	14	6	67
Average	8,7	6,6	5,9	23,5	14,1	6,4	65,2

Table 5.3. Time spent repacking.

Material type	Estimated annual amount for C&S
Corrugated cardboard	139 589
Bags & film	115 342

Table 5.4. Packaging material used during 1 year.

An alternative packaging solution that items may arrive in is blank boxes (without any logotypes). These items only need to be labeled, not repacked. An average time of 14,9 s for labeling has been acquired, see table 5.5. In this scenario, no data exists regarding how many labels are used but according to Tielen (2018) approximately 30% of the items needs to be labeled. This the sixth issue, items need to be relabeled or simply labeled when arriving into the warehouse.

Trial	Write item number (s)	Print label (s)	Apply label (s)	Total (s)
1	10	2	4	16
2	8	2	5	15
3	8	2	3	13
4	9	2	3	14
5	10	2	7	19
6	6	2	7	15
7	6	2	5	13
8	7	2	5	14
9	7	2	6	15
10	8	2	5	15
Average	7,9	2	5	14,9

Table 5.5. Time spent on creating and applying a label.

5.2 Put-away

<table>
<tr><th colspan="5">Put-away</th></tr>
<tr><td colspan="3">Design</td><td colspan="2">Operational</td></tr>
<tr><td colspan="3">Box put-away</td><td>Indirect</td><td>Direct</td></tr>
<tr><td>First fit</td><td>Next fit</td><td>None</td><td>Single command</td><td>Dual command</td></tr>
</table>

Figure 5.2. Activities from put-away from the support tool.

The current workflow where items are transported to the packing station after having been received induces indirect put-away, see figure 5.2. Items arriving either are new to the warehouse or have been stored there before. When putting away a new item there is no system for selecting the storage location. The operator simply looks at the item specification and places it in an available empty location. For the items that already exist within the warehouse their locations are recorded, but not the number of items stored in each location. An example of this is, an item arrives to the warehouse and an operator finds a location that is dedicated to this item. However, when arriving there he notices that the location is full causing him to go back to the terminal to find another location. One item can be stored in 10 different locations and the system does not keep track of how many items are located in each of these 10. There is no data concerning how often this occurs but according to Tielen (2018) it happens on a regular basis, several times every day. This is the seventh issue; item amount is not tracked at each location, which this leads to time loss and additional work. Also, when working manually there is always a risk of human error for example, when entering the item number into the system instead of scanning it. This small risk concerns receiving, put-away, picking and shipping.

5.3 Storing

<table>
<tr><th colspan="5">Storing</th></tr>
<tr><td colspan="3">Design</td><td colspan="2">Operational</td></tr>
<tr><td colspan="3">Aisles</td><td colspan="2">Storage</td></tr>
<tr><td>Angled</td><td>Straight</td><td>Cross</td><td>Dedicated</td><td>Shared</td></tr>
<tr><td>FPA</td><td colspan="2">No FPA</td><td></td><td></td></tr>
</table>

Figure 5.3. Activities within storing from the support tool.

The storing within the warehouse is dedicated, seen in figure 5.3. This in itself is not an issue but within storing the problem is the same as for put-away: no systematic approach is used when finding a storage location. Meaning that the dedicated locations do become an issue since they are not adjusted to the pick frequency. Figure 5.4 shows 10 of the high runner item locations. These items are also not stored on the first rack level; some of the fast moving items are stored as high as the tenth level. This is the eighth issue; items are not stored according to pick frequency.

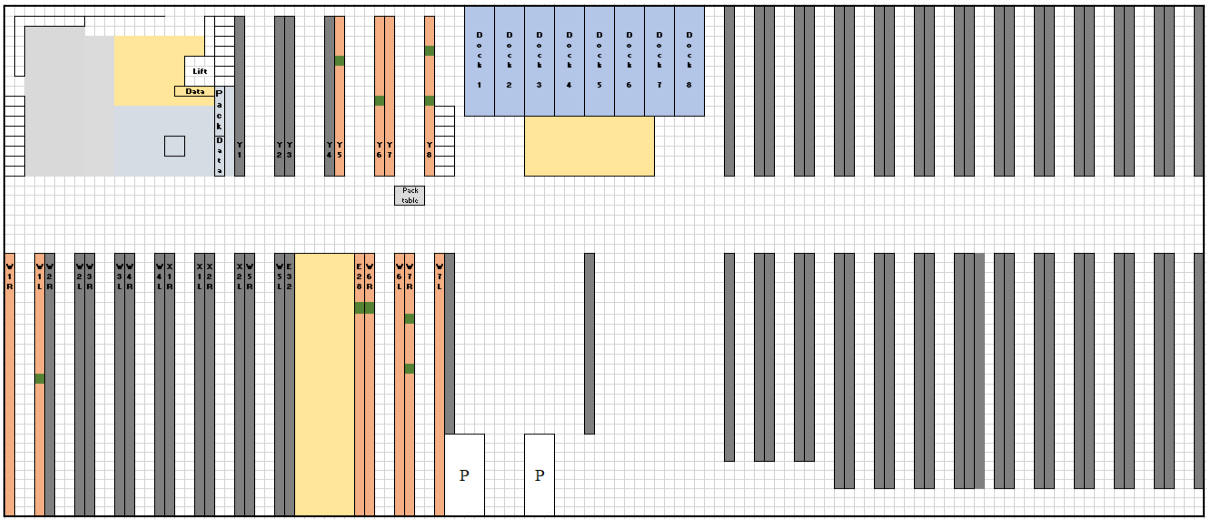

Figure 5.2. High runner locations shown in green.

5.4 Picking

Picking			
Design	Operational		
Pick path optimization	Single	Batch	Zone
Branch-and-pick			
Serpentine pick			
No optimization			

Figure 5.5. Activities within picking from the support tool.

The picking strategy is usually single order picking with the exception being when items are picked in the yard. There is currently no WMS operational within the warehouse meaning that no order optimization is being carried out. This, in combination with the fact that the current system cannot track exact amount at each location makes picking an unnecessarily time consuming process. No pick route optimization is carried out within the warehouse, seen in figure 5.5. However, theory suggests that pick route optimization generally is a complicated process that in the end might not yield any large improvement.

When starting a pick, paper sheets are printed and used to track the items and when an item has been picked, it is crossed off the list. This manual paper system limits the efficiency and makes any other sort of picking aside from single order troublesome. It also adds an extra step in going back to the terminal to confirm an order. This process takes time and limits the amount of orders that can go out any given time since there is only one terminal available. Aside from this, the risk exists that the paper might be lost during picking leading to additional time loss. This is the ninth issue, physical paper picking lists limit picking efficiency, which in turn increases the time items spend in the warehouse.

Most items within the warehouse are stored on regular EU-pallets or in the mezzanine shelves but the warehouse also receives items, which are larger than an EU-pallet. The larger items usually arrive in custom-made containers from the suppliers. This in itself is not considered an issue for the warehouse since the warehouse have the capability to store them. However when consolidating, these items need to be repacked in new custom-made containers that usually has to be manufactured through carpentry. Table 5.6 shows how much time is spent on carpentry for a selected supplier. For this supplier the warehouse receives the large items in quantities of 3 and ship them out in quantities of one. This is the tenth problem, custom made packages need to be custom made for certain products.

Activity	**Value**
Full time employees working in carpentry	7 people/shift, 2 shifts
Hours per shift	8 hours
Working days per year	200 days
Total	22 400 hours/year
Time spent of specific supplier	1,5 % of working time
Total	336 hours

Table 5.6. Time spent of carpentry for a specific supplier.

5.5 Shipping

<table>
<tr><th colspan="4">Shipping</th></tr>
<tr><td colspan="2">Design</td><td colspan="2">Operational</td></tr>
<tr><td colspan="2">Shipping area configuration</td><td>Scheduled</td><td>Not scheduled</td></tr>
<tr><td>U-flow</td><td>Flow-through</td><td>Consolidated</td><td>Not consolidated</td></tr>
</table>

Figure 5.6. Activities within shipping from the support tool.

In the shipping area, the items are stored in temporary locations when awaiting pick-up. The reason for this is that the outgoing orders are not scheduled, seen in figure 5.7. The issue here is that the warehouse has no tracking of these locations, which creates a need to manually look for items when they are supposed to be shipped out. According to Tielen (2018), up to 30 minutes can be spent looking for a single item. Table 5.7 shows all orders being shipped out in quantities two or less and approximately 15% of these need to be looked for in the shipping area for an average of 15 minutes. This is the eleventh issue; items cannot be tracked within the shipping area making the warehouse lose time each time something has to be looked for.

Outbound Quantities	**% of total orderlines**
Quantity > 2	67,1
Quantity ≤ 2	32,9

Table 5.7. Outbound order quantities.

6. RO2: Suggest solutions based on the receiving operation

This chapter is focused on improvement suggestions in the receiving operation and to determine how these suggestions impact the entire warehouse.

All identified issues are based on two aspects, information flow and labor. These two aspects are connected to the overall performance of the warehouse and individually impact the time each items spends therein. The information flow influences the efficiency of the operations and the labor determines work capacity. The combination of efficiency and work capacity is the total throughput. This is a simplified statement, other factors affects the warehouse as well but these two aspects are sufficient for the purpose of this thesis.

Recalling chapter 1.2, this thesis operates on the belief that the receiving operation of this warehouse is holding the overall performance back. In this case, the main issue is the inability to meet the customer demand, which is caused by several shortcomings that are described in chapter 5. Based on these issues we present a number of improvement suggestions for the receiving operation. The suggestions will be described and then ranked according to how many of the identified issues they solve in combination with an implementation risk based on disruptions of the daily operations.

6.1 Suggestion 1: Change packaging solution for incoming goods

The first suggestion is based on issue 5 in table 5.1; item needs to be repacked when arriving into the warehouse. Incoming items often have the suppliers' logotypes or names on their packages and therefore needs to be repacked into Sandvik boxes upon arrival. This means that half of the total packaging material used by the warehouse and the supplier is waste and more importantly, the receiving operation in the warehouse is burdened by the need to repack large numbers of items every day. This improvement suggestion is based on simplifying the workflow in the receiving operation and involves reaching out to suppliers and working together to change the packaging solutions for the items that need repacking.

During the course of the research, this approach was tested on two of the ten suppliers presented in table 4.5. See table 6.1 for a summary for one of the suppliers that this improvement suggestion has been tested on. Supplier C is one of the larger suppliers for the case company and accounts for 2,48% of all received goods within the warehouse. The goal of the visit to supplier C was to discuss if they were able to pack items directly in case company's boxes that are provided to the supplier. The arguments being that since the supplier already packs items into boxes, it would not cause interruptions in the workflow to use a different packaging solution. And since the new boxes are provided by the case company, the supplier's logistics cost would be decreased. Supplier C agreed that this solution was implementable. Table 6.1 presents the repacking time that items from supplier C cause in the receiving operation based on several parameters.

Activity	Value
Corrugated boxes/year (pc.)	139 589
Plastic bags & films /year (pc.)	115 342
Supplier C % of received items	2,48 %
Total boxes/year Supplier C (pc.)	3 462
Total bags/films year Supplier C (pc.)	2 860
Time per box repack (min)	~ 1
Time per bag repack (min)	~ 0,5
Total repack box time/year (h)	57,7
Total repack bag time/year (h)	23,8
Total time spent repacking Supplier C (h)	81,5

Table 6.1. Supplier C repacking time.

Implementing this solution means removing the need to repack items in the receiving operation. For this supplier only, the suggestion would save the warehouse approximately two weeks of work for a full time employee (81.5 hours) by reducing the time it takes for goods to be received. The solution was also discussed with supplier I, that provide items with custom made packaging. They too agreed on that it would be a feasible improvement to manufacture a packaging solution that works for the case warehouse before shipping. Table 6.3 shows an estimate of how much time that could be saved in the receiving operation by having all top 10 suppliers (including supplier C and I) pack items in case company boxes before shipping.

Activity	Value
Corrugated boxes/year (pc.)	139 589
Plastic bags & films /year (pc.)	115 342
Top 10 suppliers % of received items	66,25 %
Total boxes/year top 10 suppliers (pc.)	92 478
Total bags/films year top 10 suppliers (pc.)	76 414
Time per box repack (min)	~ 1
Time per bag repack (min)	~ 0,5
Total repack box time/year (h)	2 312
Total repack bag time/year (h)	637
Total time spent repacking top 10 suppliers (h)	2 949

Table 6.2. Estimation of time saved by implementing the improvement suggestion on all top 10 suppliers.

The material cost for the case company does not change since the packaging material already is purchased in the current scenario. The freight cost of packaging material between the case company's packaging supplier and the item supplier might however increase depending on the geographic locations. This freight cost is however a small percentage of the total logistics cost for this product area.

The labeling activity of incoming items at the case warehouse is also supposed be carried out at the supplier site. On average, the time to label a package is 15 seconds, which this is done for 30 % of all items. 15 seconds for a very large amount of items quickly adds up to hundreds of hours each year, which is time that can be saved in the receiving operation. The result is shown in table 6.3.

Activity	Value
% of items relabeled	30
Time spent relabeling/ item(s)	14,9
Total time spent of relabeling/year (h)	869
% of items being repacked at suppliers	66,25
Total time saved through repacking (h)	576

Table 6.3. Estimation of time saved through relabeling.

Combined, the suggestion has the potential to save around 3500 hours of work in the receiving operation, which is labor that now can be used throughout the other operations, improving the overall efficiency of the warehouse. In conclusion, this suggestion will solve issue 5, 6 and 10.

6.1.2. Risk analysis

Concerning the calculations, the packaging material data is derived from a percentage of the material usage at the previous warehouse in Eindhoven. This serves as a sufficient estimate for the warehouse in Venlo. Another aspect to consider is that the material usage for each supplier is assumed proportionate to the amount of items received from that supplier. This creates an error since the exact material usage per supplier is not used.

Regarding implementation, the amount of work needed depends on how willing the supplier is to pack items in case company boxes and bags. Based on the visits to the two suppliers, who were positive toward this kind of collaboration, the suggestion can be seen as a win-win situation since both the supplier and the case company will save money. When the preparatory work is done the actual change of the workflow in the warehouse will not be difficult, making this a low risk suggestion. The time horizon for this suggestion is short meaning that it has a low implementation time and could show results directly.

6.2 Suggestion 2: Redesign receiving area

This suggestion is created to solve issues 2 and 3. The reason why items are double handled is the same reason as why items need to be transported to the packing station for every arrival. This reason is that the packing station and the receiving docks are not located in the same place. It is known that the minimum distance between the receiving docks and the packaging station is 60 m. The warehouse has 92 inbound orderlines per day and on average 24 items per orderline (table 4.5). Out of the 92 orderlines, 41.4% of the items need to be transported to the packing station. Based on observations and interviews the number of orderlines that can be carried on a single forklift truck ranges from 1-2. This means that in the worst-case scenario all the incoming orderlines that need to be repacked has to be transported one by one to the packaging station. See table 6.4 for a summary that includes different scenarios based on how many orderlines that can be carried on a fork lift truck.

General			
Parameter		**Value**	
Ratio		41,4 %	
Inbound orderlines/day		92	
Orderlines that needs packaging/day		38	
Distance travelled (m)		120	
Forklift operating speed (km/h)		8	
Scenario 1		**Scenario 2**	
Orderlines per forklift	1	Orderlines per forklift	2
Travelled distance/day (km)	4,6	Travelled distance/day (km)	2,2
Travel time/day (h)	0,56	Travel time/day (h)	0,28
Travelled distance/year (km)	1142	Travelled distance/year (km)	572
Travel time/year (h)	140	Travel time/year (h)	70

Table 6.4. Time and distance spent travelling from the docks to the packaging station.

Between 2-4 kilometers, each day and 70-140 hours each year are spent driving between the docks and the packing station. The detour that the warehouse operators have to take is built into the current setup of the receiving area and cannot be avoided in this configuration. The suggestion is centered around moving the packing station closer to the shipping and receiving docks to avoid this detour. By redesigning the receiving operation as shown in figure 6.2 the arriving items will be directly put into the packaging station instead of being put on hold in the temporary racks that currently are located there. In the new design, items that are going to be shipped or have been recently been received are taken directly from the docks to the packaging station without having to travel 60 m to and from the previous location.

The benefit of placing the packaging station in this configuration does spill over to the other operations in the warehouse. It is known that items are not stored concerning pick frequency in the warehouse's current state. If the suggested redesign is used, slotting the items in a more efficient way is easier than it would have been today. The reason being that today the entrance point and exit point of the picking are not in the same location as seen in figure 6.1. The current warehouse cannot be set up as neither a flow-through nor a u-flow because if the items are centered on the exit point of the picking operation they will be farther away from the entry point. This will solve issues 2 and 3 since it will remove the double handling and the travel distance.

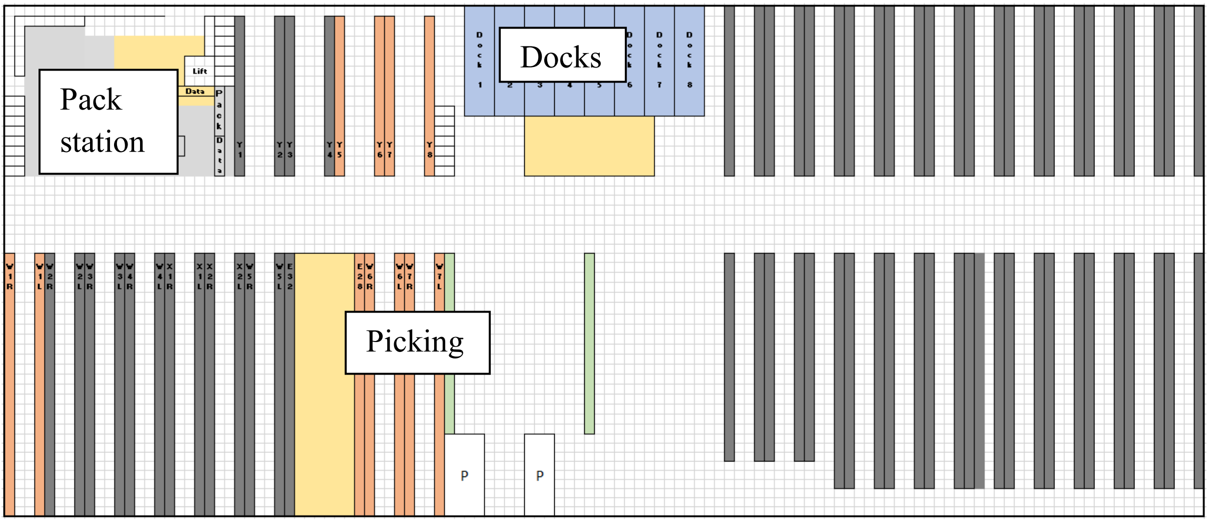

Figure 6.2. Pack, pick and dock locations.

The new configuration plus a suggestion on how the faster moving items can be stored is shown in figure 6.2. The green sections show the most convenient locations for the fastest moving SKUs. In addition to locating them at the end of the shelfs, the items are suggested to be stored at the lower levels of the shelfs while using the levels above as bulk storage replenishment. An additional benefit of this is that the 10 locations that each item can be stored in are located on top of each other, removing the need for the picker to potentially manually search through 10 different locations for every pick. This will improve issues number 7 and 8 since the high running items will be stored in the most convenient locations.

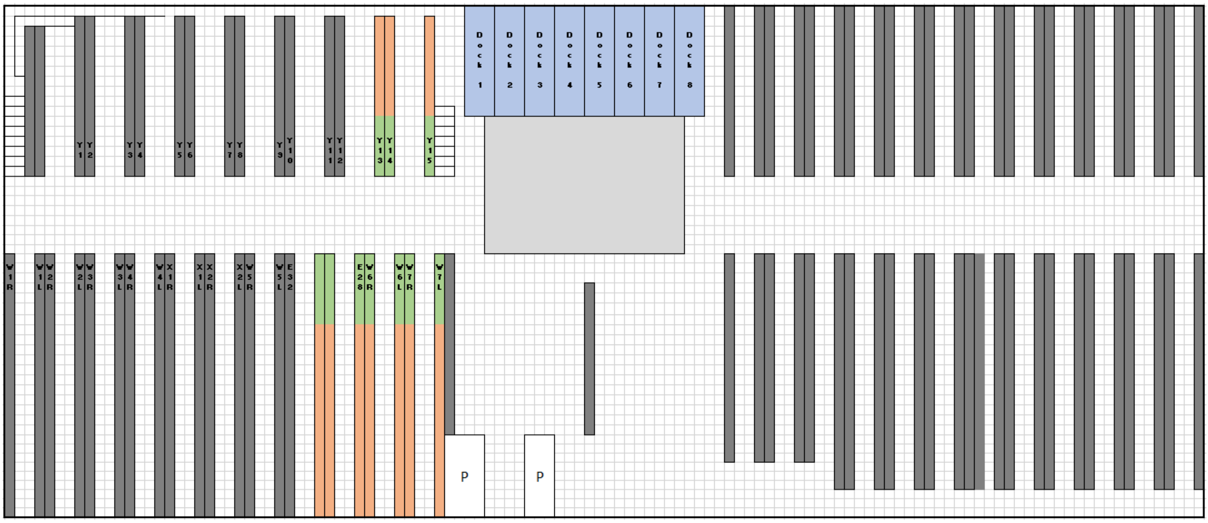

Figure 6.3. Suggestion of fast runner locations (green).

6.2.1 Risk analysis

Firstly, the suggested design does not require any alterations to be made to overall structure since the space where the new pack station is suggested to be is currently just filled with items that are not intended to be there. Naturally, there is a set-up cost for new shelves that are suggested to be placed in the packing station's previous location. The suggestion will require the warehouse to reduce its throughput volumes during the days of implementation. No calculations has been made into for how long the operations would need to be slowed down but it is fair to assume that it would take more than one day just to carry out the redesign. Before the redesign can start, it has to be determined exactly how the new receiving and packing station should be configured with regards to aspects such as specific dimensions. Based on these aspects the implementation risk for the redesign is considered very high. The time horizon for this suggestion is high since it, as mentioned, will require preparatory work and a planned implementation period when the warehouse will be shut down or operate at a reduced capacity.

6.3 Suggestion 3: Implement a warehouse management system

As mentioned in the beginning of chapter 6, a factor that connects many of the issues within the warehouse is the information flow. Within receiving, issue 1, 4 and 6 are closely connected to the information flow. This suggestion regards implementing a warehouse management system (WMS). Recalling chapter 2.7 where theory on information systems is presented, we know that WMS can be divided into basic, advanced and complex on a general level. Table 6.3 shows the functions of a basic WMS and the warehouse needs that connects to these.

Level	Activities supported by WMS	Warehouse needs
Basic WMS	Receiving Appointment scheduling Quality assurance Work-order management Put-away Location tracking Picking Packing and consolidation Shipping	Track inbound locations Slot items Track storage locations Remove physical documents Track outbound items

Table 6.3. Basic WMS functions vs. warehouse needs.

The functions receiving and shipping are the base of any WMS, in this context the terms means that the system keeps track of receipts of incoming inventory and the outgoing shipments. By doing this, it will always know exactly what is stored in the warehouse at any given time as well as keeping track of payments through receipts upstream and invoices downstream. The next step in the WMS functions is the stock locator system, which concerns the inventory of stock locations parallel to the inventory of items. By keeping track of each individual location, the activities connected to storing can be directed.

For this particular case the most important aspects for a system to cover is to start tracking each individual location instead of only tracking the inventory of products. This is done practically by scanning each item coming into the receiving docks with hand scanners instead of using physical documents and putting everything in by hand. This means that it is recommended to choose a vendor that also is able to provide scanners. For the time being it is not recommended to reach out to look for complex or advanced WMS features such as pick path optimization and more sophisticated scanning measures such as RFID tags. The reasoning behind this is that the basics need to be covered first, which is expected to already have a substantial effect on the efficiency.

6.3.1 WMS specification

Based on the analysis the following section describes what features a WMS at this site is recommended to have.

Item inventory - Record of all individual items covering identification measures, weights, dimensions, amount per case and activity.
Location inventory - Record of all individual storage locations in the warehouse, their position and capacity in terms of weight, size and convenience. Convenience is based on how far the location is from the packing station and a location on a lower floor is more convenient that on an upper floor.
Layout - Doors, docks, racks, shelves, aisles, packaging and shipping stations, terminals, and so on.
Scanners - Portable hand-scanners, mounted terminals and scanners in forklifts and stationary terminals by the packing stations. Each package needs to be fitted with a barcode that holds the information mentioned above. This will then be used to scan the item into the system when it arrives to the warehouse. The barcode is initially suggested to be printed in the warehouse when the item arrives, in the future it might be worth to look into having suppliers print them.

An example of a WMS that is used within Sandvik is a system called Scanware. According to the different levels of complexity, this system falls into the basic category. The needs of the warehouse are mostly concentrated around the basic category but some can also be found in the other two as seen in table 6.5. The background of the needs of the warehouse are given in chapter 5 and the details of how Scanware is used is described in section 4.3.7. The levels of complexity that go beyond basic are presently not critical for the warehouse to focus on, just implementing Scanware will address the majority of the information flow related problems. High-end and advanced options such as SKU slotting, labor management and vendor collaboration can be done manually as shown in some of the other improvement suggestions and still improve the warehouse.

The WMS would directly solve issues 1 and 4 within receiving. Issue 6 would be improved since now the relabeling would not have to take place in a separate area but could be done directly when the items arrive. This means that the items still would need to be relabeled but the process would be more efficient. Regarding the other operations there are several issues which could be resolved. The exact number of items that currently is available in each storage location would be shown. The WMS would also track the number of items waiting in the shipping dock and remove the physical papers entirely from the warehouse. This means that the WMS would in addition to the receiving issues solve issue 7, 9 and 11.

Level of complexity	Supported functions	Needs	Scanware
Basic	Receiving	X	X
	Appointment Scheduling	X	X
	Quality Assurance	X	X
	Work-order management	X	X
	Put-away	X	X
	Location tracking	X	X
	Picking	X	X
	Packing and consolidation	X	
	Shipping	X	X
High-end	Replenishment	X	
	RF-directed operation		
	Cycle counting		
	Carton manifesting		
	Vendor/carrier compliance	X	
	Value-added services		
	Trailer manifesting		
	Configurability		
	Pick/put to light		
	Yard management	X	
	Wave management		
	Task interleaving		
	Flow-through processing		
	Returns		
	Labor management	X	
Advanced	SKU slotting	X	
	Multi DC view		
	Edi capability		
	Impact analysis		
	ASP capability		
	Parcel shipping		
	Traffic management		
	Import/Export management		

Table 6.5. Comparison between Scanware and the warehouse needs.

6.3.2 Risk analysis

As mentioned in chapter 2.7 the implementation of a WMS can be troublesome and long-winded. It is definitely not unheard of that companies set an unrealistic deadline for when the implementation of a WMS should be completed. These types of systems need to be configured to suit the particular business and properly connected to the ERP system, which usually is a challenge. Aside from this, the warehouse also needs experienced personal to assist during the entire process. If people without experience tries to implement a WMS they are not familiar with, it could result in even more disruption to the warehouse operations than before. Other potential errors for this case is that the data provided by the user is not sufficiently rich to utilize the WMS at its fullest. It is up to the user to produce clean data, which means that the inventory must be accurate at all, times as well as updated when it comes to product and packaging dimensions. We also recommend the company to be careful about optimizing the warehouse without making the appropriate preparations to avoid "optimizing a broken warehouse", this could even result in losing overall efficiency.

When changing the way operators work it is important to provide sufficient training in how to use the new system. Otherwise, there is a risk of the operator returning to the comfort of the old ways of working. Aside from sufficient training, the right tools need to be available in combination with the WMS. As mentioned, the WMS requires different types of scanners to function and these scanners need to be user friendly and adjusted to fit the WMS system. However, the implementation would not cause any disruptions for the warehouses' daily operations. Through all the other factors the amount of work required would be high but the implementation risk for this suggestion will still be low since no disruption will occur. The time horizon for the implementation will be considered low in comparison to the redesign because experience from implementing the suggested WMS, Scanware, already exists within Sandvik. This experience will remove some of the preparatory work that otherwise would be needed.

6.4 Suggestion 4: Hire more personnel

The capacity constraints of the warehouse can be broken into space and labor. If the labor could be improved either by increase of capacity or efficiency the ability to meet customer demand is enhanced. This suggestion to hire more personnel is based on issues 4, 5 and 6 in table 5.1.

Currently the warehouse employs six full time employees for handling the items included in this case. Out of those six, two employees are usually working within receiving. From chapter 2 it is known that Little's law can be used to calculate how much capacity each employee needs to handle per hour. By using the inventory turnover, average number of items and average items per inbound orderlines the required orderlines per hour is calculated and scaled with number of employees. This will generate an approximation for the total amount of items used in a year. This, divided by the average amount of items per inbound orderline and the hours the staff work during a year will result in how many orderlines each employee needs to handle every hour. To benchmark this number, it is compared to the warehouse in Eindhoven through the same calculation. The result is displayed in figure 6.3; according to this, the Venlo warehouse should hire 1-2 additional operators in the receiving operation. The problem of many backorders at the case warehouse also indicates that an increase in overall staff should be evaluated. The method used to calculate this result could also be used to calculate the appropriate staffing for the entire warehouse. The result from the calculations is shown in figure 6.4 and suggests that the warehouse should increase the staff by 4 operators in total. 2 of those 4 should be placed in the receiving operation. The numbers used for the calculations are confidential which is why the graphs have been censored.

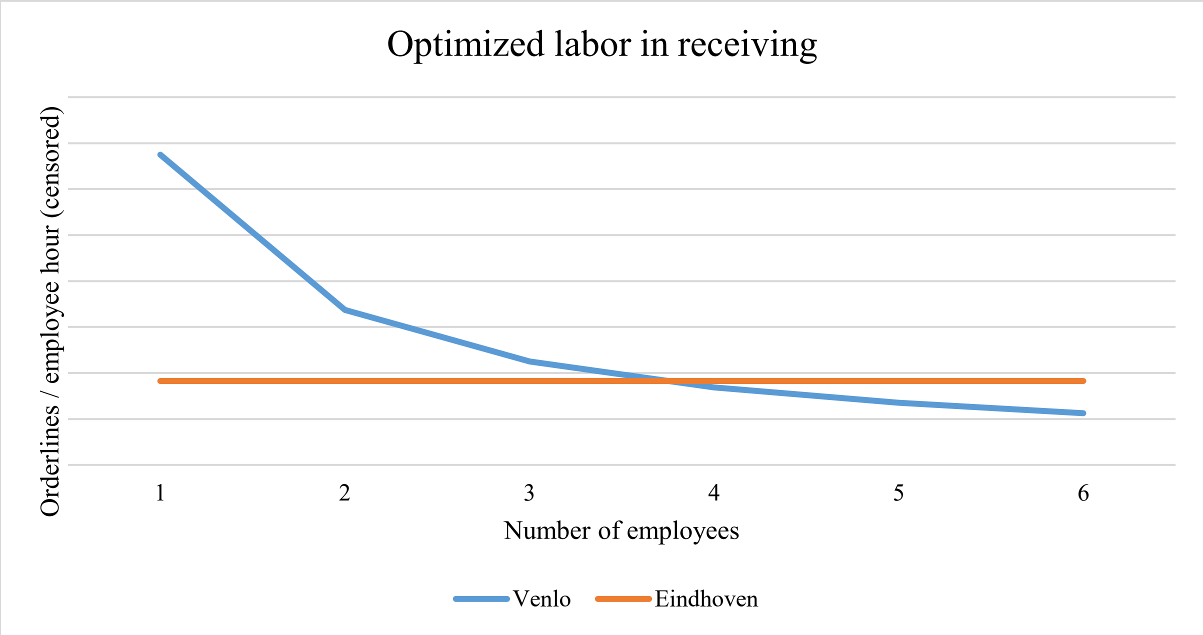

Figure 6.3. Comparison between inbound orderlines per employee between Venlo and Eindhoven where the Eindhoven workforce is constant.

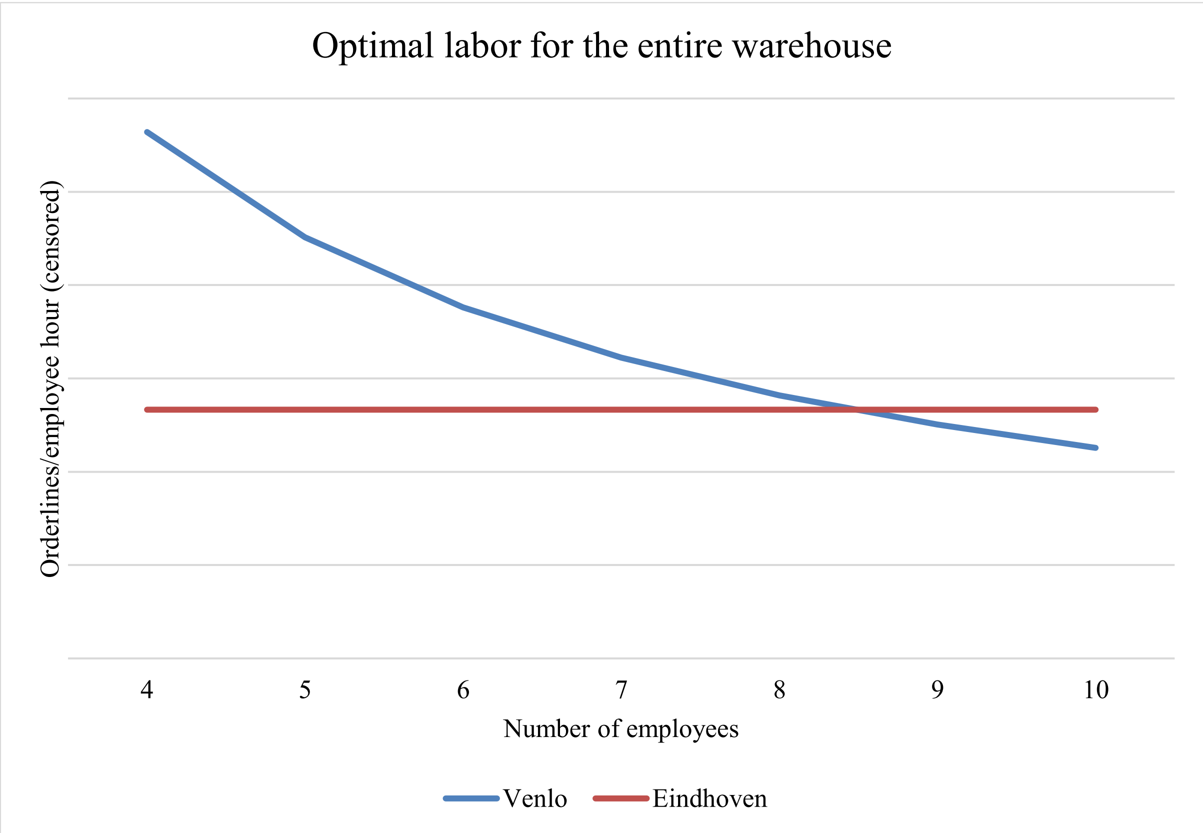

Figure 6.4. Comparison between inbound and outbound orderlines per employee between Venlo and Eindhoven where the Eindhoven workforce is constant.

Issues 7, 8 and 10 would have a reduced impact on the warehouse since more personnel would increase the throughput at each of these operations. For the other issues in the warehouse it would have to be investigated if even more personnel would benefit the operations.

6.4.1 Risk analysis

The data used for the calculations is received from the ERP system and is assumed correct which also was confirmed by a company supervisor. The case company representatives also felt that the needs of the current warehouse situation justifies a potential increase in staffing. The implementation risks include an adjustment period for the new employees, cost for the employees compared to the savings as well as actually finding the right employee. There are also other factors to consider before hiring new personnel, both economic and social, such as the availability of workforce in the geographic area. These aspects need to be considered and evaluated further. The time horizon for this suggestion is considered to be low since the personal optimization is something that could start right away.

6.5. Ranking the suggestions

The suggestions are ranked according to how many of the identified issues that are solved in combination with how large the disruption of the daily operations is as well as how much time is required to implement the solution. A final score for each suggestion is showed in table 6.6 with regard to this. Implementation risks have been ranked as 1-4 as follows, very high (1), high (2), low (3) and very low (4). The amount of issues solved multiplied with the implementation risk gives the final score.

Rank	Suggestions	Solved issues within receiving	Solved issues within other operations	Implementation risk	Final score
1	Repacking	4, 5, 6	10	4 (Very low)	16
2	WMS	1, 4, 5, 6	7, 9, 11	2 (High)	14
3	Optimizing the staff	4, 5, 6	7, 8, 10	2 (High)	12
4*	Redesign	2, 3	8	1 (Very high)	3

Table 6.4. Ranking the solutions.

The highest ranked solution is the WMS, more specifically Scanware. When improving a warehouse, one of the most important areas to focus on is the information flow. The information flow unlocks potential for other improvement throughout the entire warehouse and is considered a basis for more technologically advanced improvements. This solution will require implementation of scanners, forklift truck mounted terminals, and connection to the ERP but very few if any disruptions for the warehouses' daily operations. The second highest ranked solution is the packaging collaboration with the suppliers. This solution solves four of the issues and only requires the case company to start discussion solutions with the other 8 supplies. During the two supplier meetings already carried out, the suppliers were very positive towards having a closer collaboration with the case company. This solution will not induce any disruptions in the daily operation. The third suggestion is the increasing staff. This requires a recruitment process and a training period. Recruiting and training new operators can be a lengthy process, which is enhanced by the fact that the supply of workers is short in the geographical region.

*The last suggestion will both require initial work and an implementation period where most of the operations will be disrupted. This puts the implementation risk at very high and since the number of issued it solves is low, the suggestion is ranked poorly. However, this suggestion carries much potential to further improve the entire warehouse by eventually redesigning the storage area from a picking perspective, which is a suggestion for future master's theses.

7. Conclusions and future research

This chapter answers the research questions and evaluates the performance of the support tool based on its ability to characterize the case warehouse, how it can be used to identify problems, and how it can be used to identify improvement suggestions as well as how to connect these to the receiving operation.

7.1 Research objective 1: Characterize the warehouse based on operational and design aspects and identify the problems that can be found within.

For the scope of this thesis, the result from applying the support tool is an adequate overview of the different options in the case warehouse. The tool shows a spare parts warehouse that supply both to external and internal customers. It handles all types of storage units, stores them in single deep racks and has no automation or warehouse management system. It also provides design and operational aspects for every operation based on major warehousing literature. In general, it can be stated that the warehouse operators have very little technical assistance and all activities are performed on a basic level. The result of RO1 was eleven identified improvement areas within the warehouse whereof six was in the receiving operation.

The first problem within receiving is that items are not tracked within the receiving area. This means that the warehouse staff does not know which, where and how many items are stored here. This leads to stock build up and urgent items not being prioritized even though outstanding sales orders exist. The second problem is that items arriving to the warehouse are not directly put-away, instead they are put on hold in temporary locations waiting to be stored properly, this incurs double handling. The third problem is that items need to be transported between the receiving docks and the packaging station before being put-away which leads to excess travel. The fourth problem is that incoming orders needs to be counted manually which consumes time. The fifth problem is that items arriving from some suppliers need to be repacked into different packages, this consumes additional time. The sixth issue is that items need to be relabeled to show the correct order number.

Concerning the other operations of the warehouse five problems were identified. In put-away, the problem is that item quantities are not tracked at every location. This means that an employee might have to visit several locations before finding one where there is space for the item. In storing, items are currently not stored with regards to pick frequency. This means that items that are being picked often are not stored in the most convenient locations. In picking, physical papers are currently used as tool within picking which limits the efficiency and increase the time spent on each pick. The second identified problem within picking concerns the packing. Items in the warehouse sometimes need custom made packages before they can be shipped out to customers which requires additional labor. Lastly, within shipping the identified problem is that items cannot be tracked in the shipping area. This means that when a truck arrives to pick up a shipment the employees need to physically look for the items.

7.2 Research objective 2: Suggest improvements focused on the receiving operation and determine how the impact the entire warehouse.

Analyzing the identified problems led to four solutions that improve the receiving operation as well as other operations. These four solutions could be implemented separately or together and each one increases the throughput of the overall warehouse. The conclusion of this research objective is that the receiving operation indeed can be a bottleneck for this or potentially any warehouse. The first improvement suggestion regards changing packaging solution for incoming goods. Even though the actual process of implementing this solution concerns factors that are located outside of the warehouse, the purpose of the solution is to change the way of work in the receiving operation. By collaborating with suppliers and having them pack items in neutral or case company boxes, the repacking activities in the warehouse for these items are removed. Redesign of the receiving area is the second improvement suggestions. By moving the packing station closer to the shipping and receiving docks, the potential to configure the warehouse according to item pick frequency is enhances. This solution also incurs a direct improvement in shape of reduction of everyday travel time for the operators.

Similarly, to the first improvement suggestion, the third one concerning implementing a WMS is implemented by reaching further than just the receiving operation. However just as with the first one, the purpose is to change the way of work in the receiving. Some of the major issues in the warehouse comes from an inefficient information flow which is exactly what a WMS addresses. By being able to enter and retrieve information more quickly the performance of the receiving operation will increase which affects the entire warehouse. The last solution, to hire more personnel is based on the fact that each operator in the receiving operation has to carry a substantial workload in order to enable all incoming items to be stored. Increasing the number of operators in this operation will enable goods to flow faster into the other operations even if it does not affect the efficiency. By using Little's law and benchmarking with other warehouses an estimate of how many operators that are appropriate for the receiving area as well as the entire warehouse was made.

7.3 Contribution to case company

The thesis assisted in profiling the warehouse and identifying problems by using warehousing literature, quantitative and qualitative data. The project strengthens the argument for focusing on improving logistics by confirming both known and unknown issues and proposing solutions. Some of the issues concerns areas that the case company already have given thought, such as having too few operators in the warehouse. This project confirms this as an issue and proposes a way of approaching it in an early stage of the warehouse implementation. The purpose was successfully executed and the result for each solution is presented is chapter 6. The solutions reduce the negative impact that the identified issued had on the warehouse throughput. By widening a bottleneck upstream, other operations will also have increased efficiency. For example, if goods are packed differently before entering the warehouse, they do not need to be packed again after picking. Another aspect is simply saving time and labor. Labor no longer needed within receiving can be redirected to other operations. By analyzing this and other warehouses using this approach the case company can potentially increase efficiency and decrease overall operating cost of their logistics network. The vast literature study that is the basis of the support tool means that the work of many researchers is incorporated into this approach, enabling the case warehouse to configure their warehouse is a way that is more closely aligned with established theory.

7.4. Future research

The future research is divided into improvements for the support tool, further research for the case company and general research areas that could be investigated by using this project as a base. The support tool could be expanded to include more aspects, for example a time dimension and a table of different warehouse types connected to potential solutions in each one. Through this, the tool would not only present the current activities but also show the most time consuming ones. By including scenarios that explain the needs of different warehouse types, it can act as an aid when benchmarking and simply comparing different solutions that exist in practice and theory. Through adding more theory, it could be expanded to include other parts of the supply chain to get a better overview of how the warehouse fits in the network. The support tool is based on general literature in this field, meaning that applying it to other companies is possible.

Due to the very basic state of the warehouse, more advanced technologies than warehouse management systems were not considered. Technologies such as internet of things, video technology, pick to voice, pick to light, and automated solutions are all potentially beneficial to the warehouse in the future. A spare parts warehouse such as this is generally not the type that gets fully automated due to the large variety of SKUs, but e.g. product-to-picker systems for selected items are certainly viable to consider. Another future research area for the case company could be to connect all levels of the supply chain, not just warehousing, when identifying improvements. This is partially done in this project but due to the limitations there is still more to be researched. Cooperation with suppliers through for example VMI and Kanban could be investigated further.

This thesis works as an empirical study that shows that receiving is sometimes being underestimated when optimizing a warehouse. According to the results of the study, improvements in the receiving has the potential to improve the entire warehouse and possibly other parts of the supply chain as well. Currently, most studies on warehousing focus on the picking operation. This thesis challenges the view that the picking operation has the most potential for savings by suggesting that the operations are closely connected and that upstream operations possibly affect the warehouse more than current theory suggests. Since the strategy of using a single case study means that the solution is not necessarily generalizable to other warehouses, future research includes expanding the study to cover several cases to facilitate improving any warehouse through the receiving operation. If multiple studies would confirm the hypothesis, this is an area with plenty of potential for further future research.

References

Ackerman, K. B., (1997). Practical Handbook of Warehousing. Springer US.

Assarsson, E. Hjerén, R., (2017). Effektivisering av lagerhantering vid kraftvärmeverk. Lund University.

Aminoff, A. & Kettunen, O. & Pajunen-Muhonen, H., (2002). Research on Factors Affecting Warehousing Efficiency. International Journal of Logistics. 5(1). pp. 45-57.

Baker, P. & Canessa, M., (2009). Warehouse design: A structured approach. European Journal of Operational Research. 193(2). pp. 425-436.

Bartholdi, J. J. & Hackman, S. T., (2017). Warehouse & Distribution Science. Supply Chain and Logistics Institute, Atlanta.

Blomqvist, T., (2010). A warehouse design framework for order processing and materials handling improvement - Case Etra Oy. Department of Business Technology, Aalto University School of Economics.

Chiang, D. M. H., Lin, C. P., & Chen, M. C., (2011), The adaptive approach for storage assignment by mining data of warehouse management system for distribution centres. Enterprise Information Systems, 5(2), pp. 219-234.

Eisenhardt K. M., (1989). Building Theories from Case Study Research. The academy of Management Review, 14(4).

European Commission EDG (Enterprise Directorate General), (2004). Minerals Planning Policies and Supply Practices in Europe, Extended Summary. Department of Mining and Tunnelling, University of Leoben, Austria.

Faber N., (2015), Structuring Warehouse Management: Exploring the Fit between Warehouse Characteristics and Warehouse Planning and Control Structure, and its Effect on Warehouse Performance. Erasmus University Rotterdam.

Frazelle E., (2002). Supply Chain Strategy: The logistics of Supply Chain Management.

Galankashi, M. R., Helmi, S. A. & Hashemazhi P., (2016). Supplier selection in automobile industry: A mixed balanced scorecard. Alexandria Engineering Journal. 55, pp. 93-100

Geuken, F. & Jäger, L., (2017). Developing a Warehouse Layout Design Framework for Fast Growing Companies: A Case Study at Oatly AB. Lund University

Gu, J., Goetschalckx, M. & McGinnis, L.F., (2007). Research on warehouse operation: A comprehensive review, European Journal of Operational Research. 177, pp. 1-21.

Gu, J, Goetschalckx, M, & McGinnis, L.F., (2010), Research on warehouse design and performance evaluation: A comprehensive review. European Journal Of Operational Research, 203(3), pp. 539-549.

Hackman, S. T., Frazelle, E., Griffin, P., Griffin, S. & Vlasta, D., (2001). Benchmarking Warehouse and Distribution operations: An Input-Output Approach, Journal of Productivity Analysis, pp. 79-100

Handfield, R. & Melnyk, S., (1998). The scientific theory-building process: A primer using the case of TQM, Journal Of Operations Management, 16(4), p. 321-339.

Heath, J., (2018). External Logistics Manager, Sandvik [Interview] (21 March 2018).

Höst, M, Regnell, B, & Runeson, P., (2011). Att Genomföra Examensarbete, Studentlitteratur, Lund

Jonsson A. L., (2008). Warehouse benchmarking results: a comparison of wholesale and manufacturing warehouses. Texas University Department of Industrial Systems Engineering.

Karlström, G., (2018). Logistics Development Specialist, Sandvik. [Interview] (15 February 2018)

Kembro, J., Danielsson, V. & Smajli, G., (2017). Network video technology: Exploring an innovative approach to improving warehouse operations, International Journal of Physical Distribution & logistics Management, 47(7), pp. 623-645.

Koster, R. D., Le-Duc, T. & Roodbergen, K. J. (2007), Design and control of warehouse order picking: A literature review, European Journal of Operational Research, 155, pp. 481-501.

Lee, H., (2002). Aligning Supply Chain Strategies with Product Uncertainties, California Management Review, 44(3), pp. 105-119.

Linse, F. & Sandefeldt, J., (2018). Evaluating and Improving a Spare Parts Warehouse in the Mining Industry – a Case Study at Sandvik AB.

Longhurst. R., (2003). Semi-structured interviews and focus groups in Clifford N and Valentine G educations, Key methods in geography Sage, London 117(32).

Manzini R., (2012). Warehousing in the Global Supply Chain - Advances Models, Tools and Applications for Storage Systems. Springer.

Moharana, U.C. & Sarmah, S.P., (2017). Joint replenishment of associated spare parts using clustering approach. The International Journal of Advanced Manufacturing Technology. 94(5-8), pp. 2535-2549.

Mohsen, M. D. Hassan, (2002). A framework for the design of warehouse layout', Facilities, 13/14, p. 432.

Naish, S. & Baker, P., (2004). Materials Handling: Fulfilling The Promises. Logistics & Transport Focus, 6(1), pp. 18-26.

Olhager, J. & Selldin, E. (2003). Enterprise resource planning survey of Swedish manufacturing firms.

Rouwenhorst, B., Reuter, B., Stockrahm, V., van Houtum, G., Mantel, R. & Zijm, W., (2000). Warehouse design and control: Framework and literature review, European Journal of Operational Research, 122(3), pp. 515-533.

Schell, C., (1992). The Value of the Case Study as a Research Strategy. Manchester Business School.

Statista, (2018). Total revenue of the top mining companies worldwide from 2002 to 2016 (in billion U.S. dollars). [Online] Available at: https://www.statista.com/statistics/208715/total-revenue-of-the-top-mining-companies/
[Accessed 04 April 2018].

Stewart, T. P., (2010). Access to Raw Material. When Government - Business Cooperation Benefits the Overall Economy: The case of Rare Earth Minerals and Processed Materials. [Online] Available at: http://www.stewartlaw.com/article/ViewArticle/560
[Accessed 04 April 2018].

Tompkins, J. A., White, J.A., Bozer, Y.A. & Tanchoco, J. M. A., (2010). Facilities planning. John Wiley & Sons

Van den Berg, J., & Zijm, W., (1999). Models for warehouse management: Classification and examples. International Journal of Production Economics, 59(1), pp. 519-528.

Van Weele, A. J., (2014). Purchasing and Supply Chain Management. Cengage Learning.

Voss, C., Tsikriktsis, N., Frohlich, M., (2002). Case Research in Operations Management. International Journal of Operations & Production Management, 22, pp 195-219.

Yin, R. K., (2009). Case Study Research: Design and Methods, Fourth Edition. Sage publications.

Appendix A

Design and operation problems			Decisions
Warehouse design	Overall structure		▪ Material flow
			▪ Department identification
			▪ Relative location of departments
	Sizing and dimensioning		▪ Size of the warehouse
			▪ Size and dimension of departments
	Department layout		▪ Pallet block-stacking pattern (for pallet storage)
			▪ Aisle orientation
			▪ Number, length, and width of aisles
			▪ Door locations
	Equipment selection		▪ Level of automation
			▪ Storage equipment selection
			▪ Material handling equipment selection (order picking, sorting)
	Operation strategy		▪ Storage strategy selection (e.g., random vs. dedicated)
			▪ Order picking method selection
Warehouse operation	Receiving and shipping		▪ Truck-dock assignment
			▪ Order-truck assignment
			▪ Truck dispatch schedule
	Storage	SKU assignment	▪ Assignment of items to different warehouse departments
			▪ Space allocation
		Zoning	▪ Assignment of SKUs to zones
			▪ Assignment of pickers to zones
		Storage location	▪ Storage location assignment
			▪ Specification of storage classes (for class-based storage)
	Order picking	Batching	▪ Batch size
			▪ Order-batch assignment
		Routing	▪ Routing and sequencing of order picking tours
			▪ Dwell point selection (for AS/RS)
		Sorting	▪ Order-lane assignment

Appendix B

Level of complexity	Supported functions
Basic	Receiving Appointment Scheduling Quality Assurance Work-order management Put-away Location tracking Picking Packing and consolidation Shipping
High-end	Replenishment RF-directed operation Cycle counting Carton manifesting Vendor/carrier compliance Value-added services Trailer manifesting Configurability Pick/put to light Yard management Wave management Task interleaving Flow-through processing Returns Labor management
Advanced	SKU slotting Multi DC view Edi capability Impact analysis ASP capability Parcel shipping Traffic management Import/Export management

Appendix C

Interview Guide for DC Venlo 13 February

Background and purpose
A few weeks before the DC is operational for Crushing and Screening products. The purpose of this visit and interview is to get a grasp of the processes in the warehouse in order to identify improvement potential.

Interview questions

1. From receiving to shipping; what are the main activities?

Fast pick area?
Dedicated or shared storage?
Number of Employees
Equipment
Picking strategies
WMS?

2. What are the most time-consuming activities?

Appendix D

Interview Guide for DC Venlo 14-15 of March

Background and purpose
The DC in Venlo is now operational for Crushing and Screening products and the study visit to the site has two different purposes.

Purpose 1: Verify with a manager at the warehouse that the information in the as-is analysis (that now is near completion) is correct and change it if inaccurate. Also, find the ratio between inbound and outbound deliveries that is missing from the as-is.

Purpose 2: This part refers to the second objective of the thesis which is to focus on the inbound flow in the DC. Identify and confirm problem areas such as supplier packaging. It has been assumed that it is the supplier packaging that is the reason for the need to repack all items when they arrive at the warehouse and this needs to be confirmed, for instance excessive supplier logotypes and wrong types of packages. The purpose is also to get a general grasp of the other problems that might be present in the inbound.

Interview questions for purpose 2, inbound logistics

1. From receiving to storing; what are the activities in the inbound flow?
2. In the inbound flow; what are the most time-consuming activities?
3. What issues can be found in this process
4. Is there a problem with excessive branding from suppliers (logotypes and so on)?
5. Is time wasted on repacking?
6. Would it be beneficial to have the suppliers pack items differently?
7. Follow up questions regarding new information that might arise during the interview.
8. Is there any additional information that you think is relevant for our project?

Observation Guide for DC Venlo 14-15 of March
Observe the flow
Visually observe the different activities to confirm that they match the as-is analysis
Measure
Get a grasp on how much time the different activities consume, in particular repacking