CHALMERS

Inventory reduction: an analysis on finished goods inventory focused on “Released To Warehouse” lead-time

Master of Science Thesis in the Master degree program Supply Chain Management

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Abstract

This Master's thesis is a part of the SKF cost savings-program Finished Product Stock Optimization, and more specifically to reduce the level of finished products with the status "Released to Warehouse". Through a pre-study of the targeted warehouses in Tongeren, Schweinfurt and Gothenburg, the biggest improvement potential was found in the inbound flow in Gothenburg. Through this, the focus-area became the warehouse in Gothenburg, while Tongeren and Schweinfurt acted as inspiration on how warehouse operations should be designed, and became subjects for a benchmark study.

The inbound flow in Gothenburg was analyzed by applying the two concepts "Process design" and "Capacity matching", which had a direct impact on the RTW lead-time. Four internal factors for warehouse performance were used to dissect the inbound flow in detail and to investigate how the warehouse operations correlated with the two concepts "Process design" and "Capacity matching". The empirical data indicated that the processes in the inbound flow experienced high variations in performance as a result from continuously being neglected in favor of the outbound flow. This was confirmed in the analysis, where three factors having a direct negative impact on the RTW lead-time was found: the lack of information-transparency about arriving trucks, the coordination between processes within the warehouse and how the standards for how to handle goods in the buffer were designed.

In order to improve, management must start to measure the inbound flow and increase information transparency between personnel. The information is available, but the right people are not informed, which impedes coordination and planning, leading to poor performance.

Key words: Lead-time reduction, process design, capacity matching, warehouse performance, flow efficiency

Authors remark

This report was conducted in close collaboration with SKF. Without the commitment from SKF and its subsidiaries, it would have been impossible to execute the thesis. The project was initiated in January 2013 and finished in June the same year.

We would like to show a special gratitude to key personnel involved in the project, which provided us with invaluable input and information about how the thesis should be written.

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- Ismar Tabakovic (Team-leader, SKF Logistics Services Sweden)
- Martin Ferm (Team-leader, SKF Logistics Services Sweden)
- Fikret Suceska (Team-leader, SKF Logistics Services Sweden)

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Abbreviations

ATP – Available To Promise
DOH – Dispatch Order Handling
EDC – European Distribution Center
EDI – Electronic Data Interchange
FIFO – First In First Out
GIT – Goods In Transit
GSP – Goods Standardized Pallet
ICSS – International Customer Service System
LIFO – Last In First Out
MWH – Main Warehouse
MSO – Manufacturing and Supply Optimization
FPSO – Finished Product Stock Optimization
RTW – Released To Warehouse
SKU – Stock Keeping unit
SLS – SKF Logistics Services
WASS – Warehouse Administration System
WEC 1 – Warehouse External Customers 1
WEC 2 – Warehouse External Customers 2

See appendix P for definitions on: assignment, available capacity, productivity, one in-one out, put away-frequency, efficiency, effectiveness and the size of a GSP.

1 Introduction

This chapter provides an introduction to the Master's thesis by presenting the background to the project, the purpose and the scope. The chapter ends with an outline about what the thesis will include.

1.1 Background

The business climate has changed rapidly over the past twenty years due to sophisticated Information Technology-systems and a trend towards globalization. Companies today are working on a global arena with access to customer segments all over the world. This has resulted in increased rivalry, making competition harder and more challenging to handle. With the global perspective and the opportunity to reach customers from all over the world the importance of managing the supply chain effectively to fulfill customers' demand becomes evident to stay competitive. This has led to a shift in modern business management: individual businesses do not compete as single entities but rather as supply chains versus supply chains. (Christopher, 2000)

To stay competitive, it is critical to manage the five drivers of shareholder value, all of which are directly and indirectly affected by supply chain and logistics strategy (Figure 1) (Christopher, 2011). The focal point of this Master's thesis is to reduce lead-times, which is directly connected to "Working capital efficiency". Working capital is comprised of different components, where one of the most important is the amount of inventory and how these levels can be reduced. The better a company manages its working capital; the less it needs to borrow (Scott and Brigham, 2008).

Figure 1 - The drivers of shareholder value (Christopher, 2011, p. 63)

Complex distribution networks have a tendency of generating more inventories, which in turn affects the amount of tied-up capital. By reducing complexity, and increasing transparency, will help to assess the flow-performance. When understanding which processes are prone with poor performance, it will be possible to make improvements, decreasing the amount of working capital and faster move products to the customers (Christopher, 2000).

1.2 SKF

Svenska Kullagerfabriken AB is a leading global supplier of bearings and bearing related products. They are represented in more than 130 countries and have about 15000 distributors worldwide. Their operations are supported by their internal logistics provider; SKF Logistics Services (SLS)

SLS provide SKF with warehouses and transportation services. Their network includes three different kinds of warehouses: factory warehouses regional distribution centers and local warehouses. The operations within the warehouses look very different, where the factory warehouses has larger volumes per order but fewer order-lines while distribution centers have lower volumes per order but more order-lines.

A part of SKF's product assortment is produced to stock in order to secure high availability for customers. This means that there is a large number of products that are located within the SLS distribution network, either that is in stock or on the move between warehouses. SKF has initiated an inventory reduction program named "3B", in order to improve the customer service-level and reduce unnecessary capital tied up in inventory.

1.2.1 The 3B-program and the Master's thesis contribution to SKF

The 3B-program was launched in September 2011 targeting improved customer service and inventory reduction with a purpose of more effective working capital utilization. The end-effect will enable new investments and acquisitions, through anticipated savings of 3 Billion SEK until 2015. To reach these goals the program has established both short-term and long-term activities for systematic improvements. In the area of inventory reduction there are two main initiatives: The Manufacturing and Supply Optimization-program (MSO) and the Finished Product Stock Optimization-program (FPSO).

The FPSO-program, to which this Master's thesis is connected, aims at optimizing stock levels across the entire SKF distribution network using a multi-echelon approach. This means to optimize the finished product stock from a global perspective, hence avoid sub-optimization. FPSO was initiated to enable SKF to serve customers more reliably on a pre-determined service-level at optimal inventory cost.

This Master's thesis is a part of the inventory reduction project within the FPSO-program. The objective is to analyze the product flows with the status "Released to Warehouse" (RTW) and investigate how the volume can be decreased through lead-time reductions.

1.2.2 Definition of Released To Warehouse

Within SLS distribution network, products are categorized differently depending on where in the flow they are located: production, storage, transportation etc. The categorization can be seen as an identity to know where the product is located and who has the ownership of that particular product.

RTW is a status of finished products that they receive when they are finished in the production cell. Responsibility for the Goods Standardized Pallet (GSP) is then handed over to SLS, although it is still located inside the factory. The GSP-status shifts to "in stock" when put in storage inside the warehouse; hence it is not identified as RTW anymore. When the product is picked from storage it becomes RTW once again and has this status until it is put on an outbound transport, from the warehouse to its next destination. This process is then iterated if the goods are transported to additional warehouses. When the goods are shipped from a warehouse, it receives the tag "Goods in transit" (GIT), and has this tag until it arrives at the next warehouse/customer, concluding that there are three major finished product statuses in the flow: "RTW", "GIT" and "In stock".

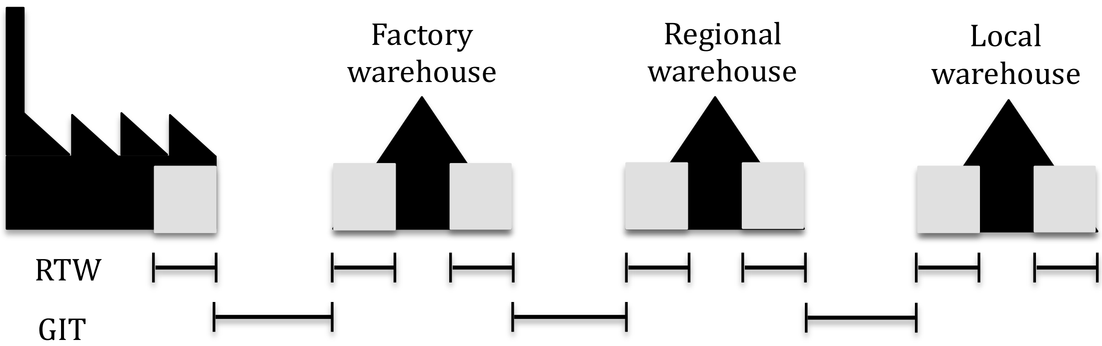


Figure 2 - Boundaries for RTW lead-time

The definition of RTW changes depending on what standpoint the viewer takes. The lead-time is not identical if the viewer examines RTW lead-time from a system point-of-view compared to the physical point-of-view (where the product is physically located). The definition that will be used throughout this thesis is:

"A finished product is classified as RTW whenever it is either inside a warehouse but not in storage, or in a production facility ready to be sent to a warehouse".

1.3 Purpose

The purpose of this thesis is to assist SKF in their effort to reduce inventory through analyzing the lead-time related to finished goods with the status RTW within the warehouses in Gothenburg, Schweinfurt and Tongeren.

In order to decrease the RTW lead-time it is crucial to identify the most time-consuming and inefficient processes within the warehouse and which activities and standards that causes the waste. The investigation will start with an open perspective and examine the RTW lead-time for all three warehouses. Each step of the internal flow will therefore be investigated on a general level to see where the bottlenecks are located and how they affect the other processes in the flow. A deeper analysis was then carried out in one focus area, where the greatest potentials for improvements were.

With respect to the above purpose, the thesis will answer the three following questions:

1. Which routines, standards and activities within the warehouses increase the RTW lead-time when they are not designed to fit the flow, and does the structural warehouse layout influence the performance?

2. What routines, standards and activities can be changed to decrease the RTW lead-time?

3. Could these solutions reduce the RTW lead-time for the other two warehouses, which has not been in focus?

1.4 Scope

The thesis focus on three nodes in SLS's distribution network. The warehouses of focus are the international factory warehouse in Gothenburg (Sweden), the international factory warehouse in Schweinfurt (Germany) and the regional distribution center in Tongeren (Belgium). The warehouses were chosen due to their strategic importance within SLS operations in Europe.

1.4.1 Pre-study

An initial study was conducted to determine what warehouse had the greatest potentials for improvements by examining the RTW lead-time for each of the three warehouses. See chapter 3.2.1 for a detailed explanation of how the pre-study was executed.

The study showed that the greatest improvement potential for reducing RTW lead-time was found in the inbound flow of the international warehouse in Gothenburg (Table 1). The major focus of this Master's thesis will therefore be to investigate the inbound flow to understand what factors has a significant impact on the RTW lead-time. The other two warehouses will still be subject for a benchmark study to establish what makes them more efficient and if there are opportunities to use their success factors in Gothenburg.

Table 1 - Summary of RTW lead-time

	RTW inbound lead-time	RTW outbound lead-time
Gothenburg	40-50 hours	15 hours
Schweinfurt	<2 hours	15-16 hours
Tongeren	<2 hours	6-7 hours

1.4.2 Scope of the study in Gothenburg

The design of the warehouse in Gothenburg is unique in the sense that it is built in five floors, as a result both the inbound and outbound operations share the same resources. To understand what routines, standards and activities that impact the RTW lead-time for the inbound flow, the outbound flow will also be considered and analyzed in order to determine how it affects the inbound operations.

There is a high degree of complexity in the warehouse due to the physical structure of the building and types of activities that are carried out in the building. The investigation will not focus on assessing all warehouse storage locations, but instead focus on assessing the performance on each floor.

To make a solid analysis of the inbound flow and reduce the complexity to a suitable level, only the three largest flows will be subject for the analysis. The three flows are: SKF Poznan (Poznan, Poland), SKF Mekan (Katrineholm, Sweden) and internal goods from Factory-D (Gothenburg, Sweden), together comprising of 80% of the total inbound volume. These flows were chosen to make sure that the suggested improvements were feasible to as many products as possible being inbound in Gothenburg.

1.5 Outline

Frame of reference – The frame of reference will present the findings from the literature study. The chapter starts by presenting the link between lead-time and flow efficiency. Within flow efficiency two concepts are presented that has a direct impact on the lead-time. Following the two concepts, four key performance factors for warehouse operations are presented. The chapter ends with a model for analyzing the empirical findings.

Methodology – This chapter will present the research method and the five steps of the research process that was used in order to conduct the study. This section will also in depth describe how the different types of data were collected and the validity of it.

Empirical findings – This chapter will present the empirical findings by sorting them according to the four success factors presented in the frame of reference. The benchmark study conducted in Schweinfurt and Tongeren will also be presented here in the same way as the data collected in Gothenburg.

Analysis and results – This chapter will present the analysis that is the basis for the discussion and recommendations. The chapter is divided, according to the model that was presented in the frame of reference, into two main sections. The first section will analyze the flow with regard to the process design and the second section in regard to how well the supply of capacity is matched with the workload. The chapter will end with answering the research questions presented in chapter 1.3.

Recommendations – This chapter will present the recommendations that will be provided to SKF.

Discussion – This chapter will present the discussion of the results identified in the analysis as well as the limitations and its applicability to Schweinfurt and Tongeren.

Conclusion – This chapter will present a concluding remark about the thesis, taking the aim and the purpose into account.

2 Frame of reference

This chapter present and explore previous research about theories relevant to the purpose, and act as a base for the model that is used for analyzing the empirical data. The chapter is divided into five sub-chapters. The first explores the concept of lead-time and explain how it is linked to flow efficiency. The second and third sub-chapters break down the lead-time in two different concepts that have a direct impact on the lead-time. The fourth investigates what factors impact the performance of a warehouse and how those are related to the lead-time. Finally, the fifth summarizes the frame of reference and present the model, which will be used to analyze the empirical data.

2.1 The relation between lead-time, tied-up capital and flow efficiency

This section defines lead-time and explains the connection to tied-up capital by presenting Little's Law. The connection to the overall efficiency of a flow is also linked to the lead-time in this chapter.

2.1.1 Lead-time

Lead-time is defined as "*the elapsed time from an internal or external customer places an order until it is delivered to its designated place*" (Farhani et al., 2011). The time it takes to procure, manufacture and distribute goods is often longer than the time a customer is willing to wait, therefore there is a discrepancy between the actual throughput-time and the customers expectations. It is therefore necessary to have a certain level of work in progress (WIP) and finished goods to secure delivery within the expected timeframe (Baker and Canessa, 2007).

The importance of time has increased over the past years due to larger market volatility, bigger customer bases and a need for availability (Leitch, 2001). This has led to increased coordination complexity across the entire supply chain as well as in each node, which has amplified the need for more timely coordinated activities. This is also the case at SKF, as top management believes that there are possibilities of cost-reductions through better-coordinated activities in the flow. Better coordination will lead to better understanding of the actual lead-time, which in turn will make it easier to meet customer expectations.

In order to measure the internal processes, a narrower concept is needed, as the lead-time is related to the overall waiting time. Noted in the beginning of this thesis, it becomes necessary to investigate the supply chain is detail. Therefore the throughput-time will be used as a measurement for the internal lead-time. The throughput-time, which is closely related to the RTW lead-time, is defined as: "*the point from when the product is allocated until the product is delivered to the customer*". Christopher (2011) describes the throughput-time for a system as the combined times of:

- Planning – order processing, source material, production planning

- Material handling – supplier lead-time, receive and inspect goods
- Assembly – process and assembly material, time spent in buffers
- Distribution – transportation, prepare goods for final customer

There is a strong connection between the throughput time and tied-up capital. This means that the amount of goods inside a system is closely related to the throughput-time. According to Little's Law (Little, 2011): "*The average number of items in a queuing system (L), equals the average arrival rate of items to the system (λ) multiplied by the average waiting time (throughput-time) of an item in the system (W)*".

$$L = \lambda * W$$

The length of a physical flow determines the amount of goods present inside, which then increases the tied-up capital. The tied-up capital can be reduced either by reducing the length of the flow or increasing the speed.

2.1.2 Flow efficiency

The throughput-time has a direct correlation to the efficiency of the system. The capacity is constrained by the bottleneck, which will determine the throughput-time, as it is determining the speed of the system (Leitch, 2001). It results in situations where there could be a lack of capacity to handle outgoing orders or incoming goods in time if not handled correctly. This will lead to further stress on the system and put tension on other processes in the flow, which are connected to the bottleneck, that otherwise would not experience any stress. Capacity is therefore a key factor, having a direct impact on the throughput-time and must be carefully planned in order to match supply and demand of capacity (Leitch, 2001). By assessing how capacity is planned in the warehouse in Gothenburg, will make it easier to understand if and where there is a mismatch between supply and demand for capacity.

Efficiency in a flow can however also be reached by either merging or eliminating processes in the flow or the activities connecting them. Materials handling and transportation activities are needed in order to bridge the discrepancy in both time and place, which occur when the processes cannot take place directly after each other. A flow with more sub-processes is therefore less effective than a flow with few processes. Redesigning and merging two sub-processes can result in reduced throughput-times and the materials handling activities connecting them can be eliminated (Johansson and Öjmertz, 1996). The two concepts: process design and capacity planning will be elaborated in greater detail in the following two chapters.

2.2 Process design

Presented in chapter 2.1.2, there is a connection between the design of a process and the throughput-time. This chapter presents the definition of a process and in greater depth illustrate the connection between a process and the throughput-time.

The aim of a process is to fulfill its customers demand by using a minimal amount of necessary resources. The process must therefore be robust enough to handle variations and allow day-to-day operations to be carried out in a standardized and efficient way. A process is defined as: "*all the activities performed to transform an input to a system into an output of the system*" (Johansson and Öjmertz, 1996). Every process must have an input in form of: equipment, labor or material with an output such as information, goods or services. However, one can also state that the input to a process consists of six elements: Machine, Method, Material, Mother Nature, Man and Measurements (Wei et al., 2006).

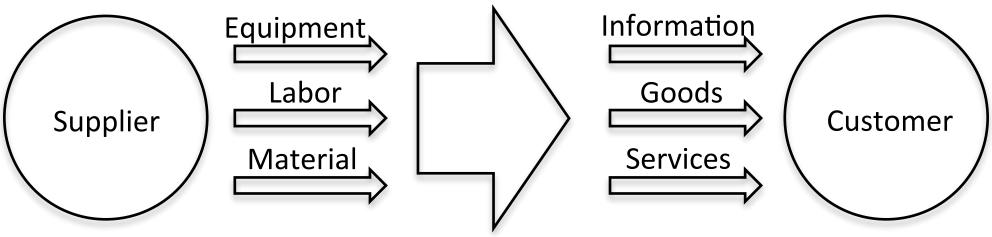


Figure 3 - Structure of a process (adapted from Bergman and Klefsjö, 2007, p.25)

According to Bergman and Klefsjö (2007), there are three different types of processes:

- Main processes – with the objective to meet external customer expectations, and refine the offered company products. Examples on processes could be product development processes, production and distribution.
- Support processes – has the purpose of providing resources to the main processes. These processes can be employee recruitment, information processes etc.
- Management processes – involves top management and concerns long-term strategy and company goals.

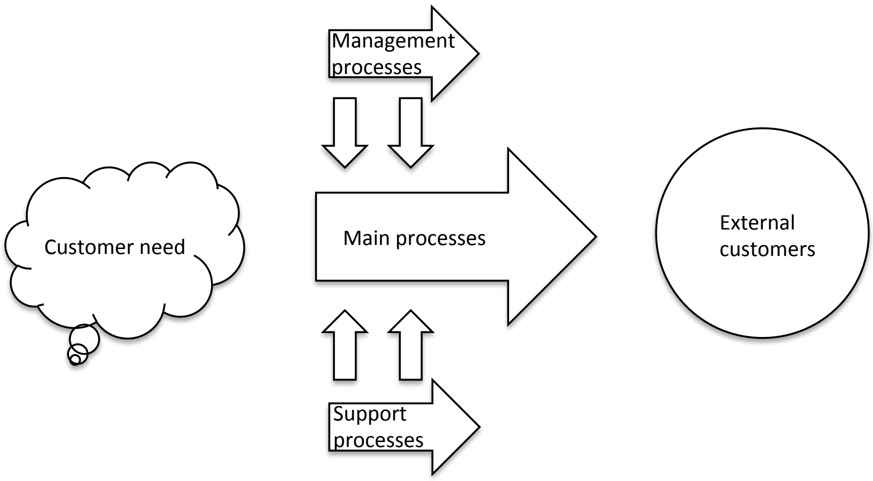


Figure 4 - Network of interrelated activities (adapted from Bergman and Klefsjö, 2007, p. 24)

In the case of SKF, it becomes important to not only investigate the actual product flow and the actions directly related to these specific tasks, but also how support processes are managed, e.g. how resources are distributed and other external parameters impact the throughput-time. It becomes evident that management processes should be included in order to link the operations within the warehouse to management commitment in order to secure actual implementation of the suggested recommendations.

2.2.1 Division of processes

Sub-processes are needed when the input to a main process has to be executed at several places and/or with idle time in between. Materials handling activities are needed to connect two divided processes, which results in that fewer sub-processes will lead to less materials handling activities. As a result, the need for division causes extra transportation or handling, requiring additional time and resources to be used, e.g. move products in and out of a buffer. To decrease the length of a material flow, the processes within the flow can either be redesigned or removed. A perquisite is a stable flow where work is synchronized. (Johansson and Öjmertz, 1996)

There are two factors causing a process to divide into sub-processes: the design of the process or the operation of the process. The design of a process is a long-term decision as it involves where activities should take place, how they are performed, who is responsible and what equipment is to be used. The design has some restrictions that could limit the optimization: fixed location, available resources, space-related capacity and competence.

The operation of a process is related to the design of the process and linked to how equipment and information is used to control the process. Restrictions in operations are primarily linked to uncertainty: demand, disturbance, economic quantities and organization, e.g. if planning is performed well the need for buffers and slack might be eliminated.

Liker and Meier (2006) present similar arguments. The first step to lean processes is by accomplishing a basic level of stability. They further present indicators that could tell if a process is unstable.

- High level of variability
- Low recognition of standardized methods or work
- Batches of WIP that are random and both in quantity and time
- Frequent use of the words: usually, normally, typically, generally

When the aim is to reduce or merge processes, Johansson and Öjmertz (1996) emphasizes the importance of taking an overall perspective to avoid sub-optimizations. To assess the performance-level at SKF, the process design and how processes are divided will help to understand the degree of standardization.

2.3 Capacity planning

Presented in chapter 1.1.2 there is a connection between capacity and throughput-time. This chapter illustrate the connection between the two and present different ways to adjust current capacity in greater depth.

The demand for capacity varies over time, as the customer demand is fluctuating in terms of time and volume. Leitch (2001) states that it results in a discrepancy between the demand for capacity and the customer demand, where too much capacity is an unnecessary expense while too little will result in system restrictions and cause delays that increase the WIP and throughput-time. He argues therefore that capacity must be planned carefully with consideration to the system environment.

Maximum capacity is the maximum volume of a specific output that a combined set of resources can create (Jonsson and Mattsson, 2009). The maximum output a process can create is when the process is 100% utilized each day, every day. This is rarely the case as the level of staffing varies over time. However, Jonsson and Mattsson (2009) argue that the nominal capacity is more interesting to measure. The nominal capacity is the level that a process has under normal working conditions and is encompassed by four variables: number of manufacturing/equipment units, number of shifts per day, amount of hours in each shift and number of days in each period. By using these parameters it will be easier to analyze the current staffing in the Gothenburg warehouse with respect to what is actually needed to cope with the demand fluctuations.

There are numerous methods for aligning the supply and demand for capacity; the two mostly used being level or chase. Leveled denote that the same nominal capacity is continuously used without regards to fluctuations in demand. A leveled strategy will result in inventory fluctuations, as there will be misalignments between supply and demand. The strength of a leveled strategy is easier planning as the same resources are used.

A chase strategy is the opposite; supply of capacity is adapted according to demand. Jonsson and Mattsson (2009) list four different actions for short-term increase or decrease of current capacity (table 2).

Table 2 - Methods for short-term increase in capacity

Action	Method
Increase/decrease capacity	Subcontracting Extra shift
Re-allocate capacity	Move personnel between different work areas
Adjust capacity	Over time Postpone meetings/training or maintenance
Re-allocate capacity requirements	Postpone customer orders

1. The first action is to change the capacity by either letting someone else perform the task with more resources or by hiring an extra shift of temporary workers.
2. The second action is to either move capacity from one work area to another or move work to another work area where there is excess capacity.
3. The third action is to increase the utilization of the company's own resources by either using overtime or re-schedule activities such as: maintenance or training.
4. The fourth action is to change the demand for outbound orders by postponing customer orders to a later time-period where there is excess capacity.

2.4 Success factors for a warehouse

This section presents four key success factors for internal operations in a warehouse. The section also covers how the success factors are related to the design of a process and how capacity is matched to the demand. These success factors will play an important role when investigating the performance of the Gothenburg warehouse. As a basis for assessing the actual performance these factors will be used.

The purpose of a warehouse is to store goods that will take longer to produce and distribute than what the customers are willing to wait (Gu et al., 2006). A properly managed warehouse should therefore know: what is stored, where it is stored and in what quantities, in order to fulfill customer expectations on time. Schleyer and Gue (2011) argues that a system with a high degree of variation for both arriving goods and the time it spends in each process will cause the throughput-time to fluctuate. If inventory and operations are not controlled in a proper manner it is a liability to the company, as both the throughput-time and stock levels will be less reliable due to the uncertainty. Both capacity and the design of processes must therefore be carefully planned in order for the warehouse to have the desired performance. Schleyer and Gue (2011) conclude that the overall performance of a warehouse is determined on how well the customer agreements are met.

Wayman (1995) lists factors for successfully controlling a warehouse, which are grouped into four areas. How well these four factors are adapted to the environment and the type of stock keeping units (SKU) being stored in the warehouse will determine the performance. The areas presented are: the warehouse layout, materials handling activities, resources and tracking and control systems.

2.4.1 Warehouse layout

The layout sets the overall boundaries for how well the warehouse performs (Wayman, 1995). It is a highly dynamic environment and it is therefore necessary to continuously evaluate the current processes and routines. If the warehouse development becomes static it will slowly fall out of control, as there will be a mismatch between the design and the flow. The layout is of high importance in Gothenburg as this warehouse is unique, which plays an important part in the throughput-time.

The layout is the first area to consider when evaluating a warehouse. The evaluation must take a number of factors into account in order to understand how well the goods flows through the warehouse. The following factors are most significant for evaluating the design of the warehouse layout (Wayman, 1995): how goods are grouped depending on their characteristics, what storing methods are used and how well the space is utilized.

2.4.1.1 *Storing methods*

The next factor to consider is where goods are stored and after what rules, suitable storing methods must be applied.

There is often a need for different storage methods, as a result of: multiple storage policies, the physical characteristics of a product, together with the time it is stored (temporarily or final location). Hansen and Gibson (2008) emphasize the importance of understanding the characteristics, movements and velocity of products moving through the warehouse when choosing an appropriate storage method. They argue the need for more then one storage method as different products have different characteristics. Lumsden (2007) lists the most common storage methods which is also confirmed by Dolgui and Proth (2010):

- High-rack storage – the most common storage method for industrial products. Pallets and boxes are placed in compartments created by vertical elements into a pallet rack. This way it is possible to store pallets and boxes on top of each other, which makes picking a specific pallet easier than deep storage.
- Deep storage – boxes are put on the floor and on top of each other building outwards from the back. Only the pallets furthest out are accessible for picking, making it a suitable method for last in first out (LIFO). The room is well utilized but provides the risk of a low inventory turnover rate with a risk of making products in the back outdated.
- Shelf box stacking – box stacking is useful for smaller items needed to be handled manually. Boxes are put together into racks creating a wall of compartments.

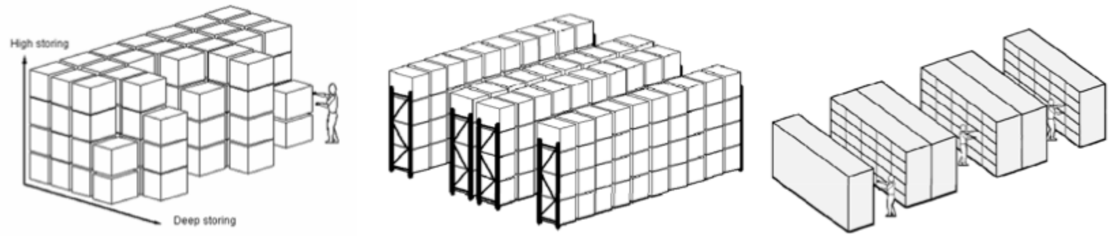


Figure 5 – Deep stacking, high-rack storage and shelf box stacking (Adapted from Lumsden 2007, p. 369-371)

Goods that are stored in buffer and in final storage need rules for how they should be picked. The two most common rules (Lee, 2006) are First In First Out (FIFO) and Last In First Out (LIFO). FIFO is more suitable for sequenced and easy-outdated products while LIFO is better suited for bulky products.

2.4.1.2 *Space usage*

To increase efficiency and utilization, Lumsden (2007) presents the principles of fixed and floating storage locations. Fixed locations means that every article-number has its own fixed location. The number of SKUs determines the size of the product area. Floating storage locations indicates the opposite; a product can be placed anywhere and just before the product is put into storage it receives its storage location. When the product is withdrawn from storage, the location is once again available for any other product. This principle reduces the number of needed storage locations as the supply and demand is better matched to the different products. It however requires that an identification system is adapted to the flow. The space usage is especially important in the Gothenburg warehouse, as the space is quite limited. By implementing the correct system it is possible to increase the throughput-time and use the space in a better way.

2.4.2 Materials handling activities

Material handling's main purpose is to link processes together and make sure that the goods are available for the next process when it is needed, in order to align the supply of capacity in a process with the demand for it. This chapter will go through how successful materials handling activities are created and the different types of activities that can be performed. Understanding how materials handling activities should be executed are essential to the investigations of the warehouse in Gothenburg, to see how they differ from the theory.

Farhani et al. (2011) states that one side of material handling is to transport small amounts of goods short distances inside warehouses, production facilities or between transportation modes. The other side of material handling is to provide the right goods, in the right time and place, hence secure a desired customer service level and provide internal functions with the material and goods needed.

Arnold et al. (2008) takes on a more general view and describes that materials handling must be aligned with the overall warehouse-management and work with the following areas:

- Optimal use of space: cost for space often stands for the largest capital cost. Temporarily storage space e.g. buffers does not add value to the customer and is only an expense caused by inefficient processes.
- Effective use of equipment and labor: materials handling equipment and labor represent the second-largest capital cost, and the largest operating cost. However, they do not work in synergies as an increase in equipment reduces the amount of staff, hence the labor cost decrease when equipment cost increases and vice versa.

In order to fulfill both optimal use of space and effective use of labor and equipment it is necessary to focus attention on three different focal points:

1. Find the equilibrium between equipment and personnel. Too much equipment and the utilization will be low, too much personnel and the labor cost will be too high.
2. Ready access to all SKUs. A prerequisite for this initiative is a well functioning stock location-system and layout.
3. Efficient flow of goods in and out of storage.

These arguments are also supported by the second rule of the Toyota production system presented by Spear and Bowen (1999) "*every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive response*". There must not be any gray areas in the communication between two people in the division of responsibility or coordination. Every action should have a purpose and be well defined so that everyone acts the same way and can expect the same outcome from that action.

How well the three focal points are met depends on how well the materials handling activities are executed and aligned with the overall structure of the warehouse and the type of goods flowing through it (Arnold et al., 2008). The type of activities can vary between different warehouses depending on what services are requested and what equipment is used.

It is furthermore important that activities are well defined. Spear and Bowen (1999) argues: "*all work should be specific as to content, sequence, timing and outcome*". A prerequisite for measuring and improve standards is to secure that the processes are stable. Work must therefore be specified and executed the same way every time. This is not only applicable for repetitive processes in the manufacturing but to all activities within a company.

2.4.3 Resources

The chapter goes through different aspects of the workforce and how it can be organized to match the supply and demand for capacity, as well as a general review of what a warehouse's equipment must be able to do.

Resources are needed as an input to processes in order to create an output of product availability and coordination (Baudin, 2004). A warehouse main resource is the staff, as they are the backbone of all operations. To support the staff there are additional equipment that should make their work easier and more efficient. The amount and complexity of equipment are mainly determined by the space and time together with the sensitivity or perishability of the product (Lumsden, 2007).

2.4.3.1 *Workforce*

Warehouses operate under great uncertainty at the same time as they are expected to provide flexibility and rapid deliveries to customers. Sanders and Ritzman (2004) argues that one solution to increase internal flexibility for a warehouse is by having a flexible workforce. They propose three different ways to create a flexible workforce: cross-training, part-time workers and floaters. Floaters do not have a fixed workstation but are assigned to a specific task or area where the need for extra capacity is the greatest. The authors state that especially cross-trained personnel and use of part-time labor can have significant impact on scheduling cost and customer service level. Yang, Webster and Ruben (2002) mentions similar methods with their earlier research such as cross training and labor-transfer. They further propose a combination of over-time and time off, where supply and demand of labor is matched from week to week. A worker can stay home one day and work over-time the next, making the staff more agile to changes in demand.

Matching the amount of personnel to the actual demand for labor is a sensitive process. Too few workers create stress for the employees, while too many is a liability for the company. In Schultz et al. (2003) article, similar methods for increased flexibility as above-mentioned researchers are presented. However, the earlier puts greater emphasize on the benefits while Schultz et al. (2003) presents some major trade-offs.

They argue that too much re-distribution could disturb the flow as tasks could be left partially undone in order to help someone who are in greater need of help, and getting back up to speed to the original task could take some time or be forgotten about, as other activities are piling up.

The greatest drawback with a more flexible workforce is regarding the level of fairness within the workforce. If a worker always can rely on getting help when falling behind, then some worker could constantly work slower while others are forced to work harder to keep customer expectations. These trade-offs cannot be disregarded and the design and scheduling of the workforce must continuously be re-evaluated. Through metrics for efficiency and, it will be easier to assess the operators actual performance to take actions against people exploiting the system.

2.4.3.2 *Management commitment*

Lloyd (1994) argues that if the right commitment does not come from higher-level management, the organization will become stiff and inflexible, as the workforce will oppose to further changes. Haapaniemi (2001) suggests that a manager have to lead with a good example showing the lower-level staff how work should be done. This means that a manager should take part in the same training and make sure that the personnel is conducting the operations in the exact right way. Liker and Meier (2006) agree with the responsibilities of a leader and states that they must set a good example and be the ones pioneering the changes. They further state that the team-leader should act as a jumper, to help where bottlenecks occur. This is a fundamental part in the lean philosophy; if a company wants to change, it must come from above. This becomes important in the case of SKF if the suggested improvements are going to be implemented and followed. By securing commitment from top-management will make it easier to make sure that the changes will be followed.

2.4.3.3 *Work organization*

Autonomous work groups - the aim with a more autonomous work group is to create flexibility and better adapt to changes in the environment through the idea that the whole group work together towards a common goal rather than work by themselves. The work performed by the group is pre-defined by standardized tasks, and the group can by themselves choose who and when to perform the tasks. The target for the group must be clear and simple as well as their decision-making boundaries. Furthermore the rules for how the behavior within the group is regulated must be well defined in order to prevent deviations from set standards and expectations. (Engström et al., 1996)

Traditional work groups - Taking on a more traditional role on how the workforce is organized. The principles of Lean production presented by Liker and Meier (2006) suggests that the work is more standardized and strictly controlled through additional but shorter work cycles. The groups are also in general smaller. Adler and Cole (1993) suggest that a group should consist of 4-5 workers where the team-leader has more decision-making power to steer the group.

2.4.3.4 *Equipment*

The purpose of equipment is to relieve workers from unsafe work methods by e.g. heavy lifting, and increase efficiency. The type of equipment in use in a warehouse is therefore largely dependent on the product and what tasks are carried out (Lumsden, 2007). Since a lack or wrongly distributed equipment will affect the throughput-time in a negative way, this parameter must be evaluated at the Gothenburg warehouse.

The most used material handling equipment for internal transportation is the forklift. It is a powerful handling tool as they can transport large quantities relatively fast and efficient inside factories and warehouses. There are many different types of forklifts and their design depends on the purpose. Forklifts designed for picking are in general smaller and the driver stands upright in the vehicle, while forklifts designed for transporting goods are generally larger and more powerful. (Luton, 1998)

Cavinato (1990) states that equipment is a large part of a warehouse's expenses and must carefully be planned and adapted to the requirements of the warehouse. Luton (1998) agrees and states the importance of adapting the warehouse's fleet of forklifts to what type of goods flow and what activities are carried out along the way, to support a smooth flow.

2.4.4 Tracking and control systems

This chapter explains different kind of control systems and present how the general order process carried out in a warehouse.

The control of a warehouse is largely dependent on what type of control system is used. A well functioning system should be able to keep updated records of what is kept in stock and what assignments are carried out at the moment. The tracking and control-systems is, as resources, a support process and does not have a direct impact on the actual throughput-time. However, it becomes crucial in monitoring the performance. By using effective systems for tracking and control it becomes easier to assess where the weakest link is situated and which sub-process is most prone to fail. These systems at SKF will be a key factor in what kind of data we will gather and how the empirical data will be presented.

Companies today are part of more complex supply chains spread out over larger areas in more volatile markets. Olson (2012) declares that each part of the supply chain has its own specialized system on different levels: to plan, execute and control inventory, ordering, distribution, forecasting etc. The common denominator for all systems is the ability to communicate and transmit information between the systems.

Information sharing improves the integration and increases the flexibility of a supply chain (Tseng et al., 2011). A well functioning information system will increase the visibility of the supply chain and help to manage new material being ordered, as well as how finished products are withdrawn from the system. Wayman (1995) agrees with Tseng, Wu and Nguyen (2011) but emphasizes that the system itself does not provide additional value. It has to be adapted to its environment to provide additional benefits.

Mentioned by Stefansson and Lumsden (2009), data exchange is an important issue when dealing with logistics. As it might be several different IT-systems containing different type of information and many participants in a logistic set-up, all are in need to access information in some way. A "virtual road" will enable a fast and error-free flow of information exchange between the involved parties (Figure 6) (Stefansson and

Lumsden, 2009). The virtual road provides a way of transfer information, similar to the physical infrastructure providing a way to transfer goods.

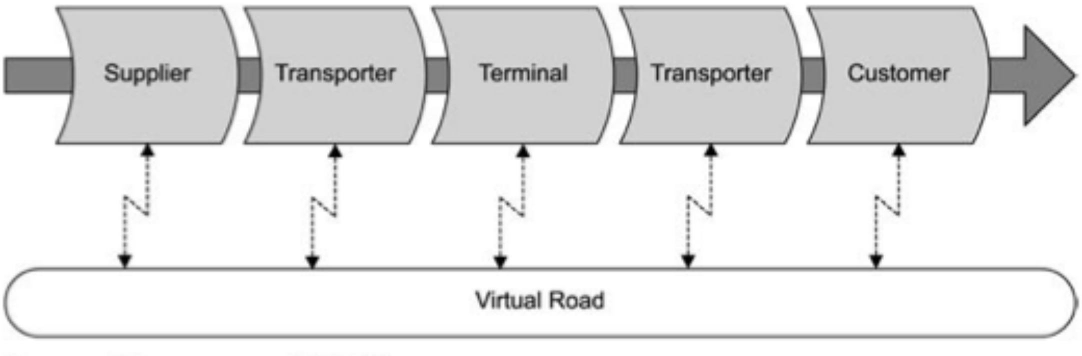


Figure 6 - Virtual road (Alvgren et al. 2007)

The virtual road can be related to Bayraktar et al. (2009) as they state that integrated information systems will increase competitiveness of the individual firm. By enabling seamless information flows, it is possible to eliminate poor supplier performance, unpredictable demands and uncertain business environments. This in turn makes an integrated supply chain having a clear advantage compared to a supply chain with a less utilized information flow.

Mentioned by Olson (2012), an IT-system may serve different purposes within a company. It could include activities ranging from production planning to material sourcing and production scheduling, logistics and distribution network optimization. It is safe to say that information technology-systems are implemented to improve operational performance (Swafford et al., 2008).

One of the fundamental functions of controlling a warehouse is the control system that keeps track of what comes in, what flows through and to whom the products are transported (Kappauf et al., 2012). Rapid development within data systems has created the so-called Warehouse Management Systems (WMS) that has the capabilities of taking cost and flow optimization into account. This means that a WMS-system should have the same capabilities as the material handling activities performed inside the warehouse. This is important in the case of SKF, where the internal warehouse system must be able to measure and keep track of the RTW lead-time.

2.5 Model for analysis

To sort out the empirical data and analyze it with respect to the purpose of this thesis, an analysis model was developed.

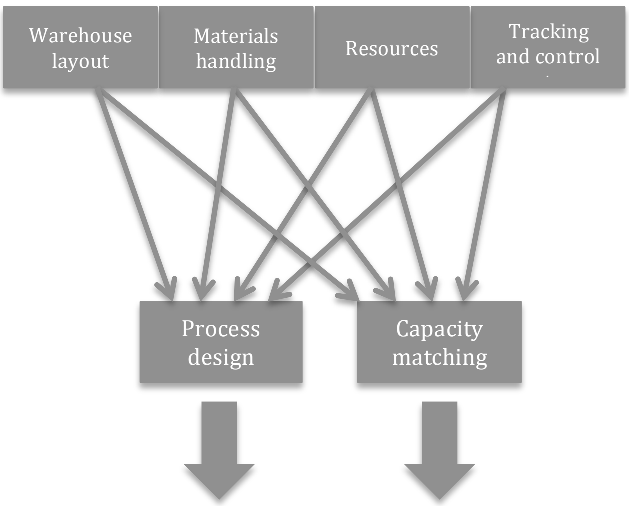
Processes with high internal variability together with an uncertain arrival rate according to theory have a direct negative impact on the throughput-time. Two separate concepts have been identified and broken down for further investigation. The two concepts are:

how well the supply of capacity is matched to the demand for capacity and how well the processes are designed to their purpose.

The two concepts has been linked to the internal performance of a warehouse by connecting the throughput-time to the overall performance of a warehouse. An article written by Wayman (1995) presents factors that determines the performance of a warehouse, which is then grouped into four areas: the design of the warehouse, how well the materials handling activities are carried out, what resources are available and how well the tracking and control systems are used.

By connecting the two concepts with Wayman's (1995) four key areas, a model for analysis was developed (figure 7). Each process in the table, in the lower section of the model, will be analyzed with respect to the two factors by breaking them down into the four key areas. Support and management processes will also be analyzed with regard to the two concepts to cover all internal operations. The purpose of the model is to sort out what factors and activities that drive the throughput-time and how they interact with other processes in the warehouse. These findings will be the foundation for the proposed recommendations, presented in the end of this thesis.

Furthermore the empirical findings, for each of the three warehouses, will be structured according to the four key areas presented by Wayman (1995).



Processes	Process design	Capacity matching
Goods receiving		
Buffer		
Automated elevator		
Put away		
Outbound		

Figure 7 - Model for analysis

3 Methodology

This chapter presents the methodology that was used to conduct this thesis. The first section presents the research approach (the abductive approach), which acted as a guide for how the empirical data was matched to the theoretical framework. Furthermore, it presents how the research process was carried out. The chapter ends with a discussion about the validity and reliability of the study.

3.1 Research approach

The abductive approach presented by Dubois and Gadde (2002) was determined as a suitable research method for the thesis, as it lets the researcher continuously re-evaluate and develop the frame of reference, empirical data and the framework as the project progresses. This process is called "systematic combining" (Dubois and Gadde, 2002). The framework should be the foundation for the analysis and help the researcher to gather information in the right places. As more data is collected and new insights about the case are found, it might be necessary to redirect the framework or the frame of reference to develop useful insights. This implies that theory and empirical data will reap the best results when combined.

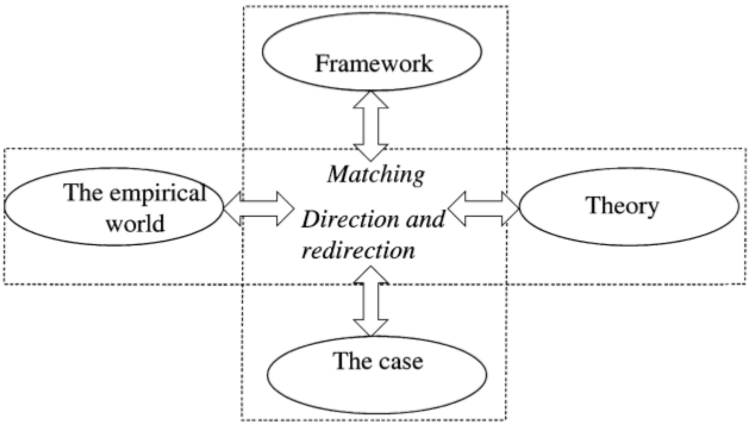


Figure 8 - Systematic combining (Dubois and Gadde, 2002)

The systematic combining hence refers to two aspects of the abductive approach. Firstly, the researchers have to evaluate how theory and empirical findings are relevant to each other, which is done continuously throughout the research. Secondly, it challenges the framework to constantly be aligned to the case. The case had a broad scope, as neither the definition of RTW nor what locations to investigate were predefined. These areas have been developed and defined as time progressed; hence the abductive approach was a good fit.

3.2 Research process

To fulfill the purpose and present the work in a clear and logical way, a roadmap was created, consisting of five steps that presents the steps that were carried out to fulfill the purpose of the thesis (figure 9). The research process was not a linear process and the authors have moved back and forth in the steps, to adapt the model and data collection depending on the development of the study.

Figure 9 - Research process

3.2.1 Preparations and initial investigations

The first step of the research process encompassed the fulfillment of the necessary parameters in order to conduct the thesis in a frictionless manner, such as establishing the area of investigation, define the research problem and choosing the appropriate methodology yielding a high validity and reliability. Due to the width of the initial scope it was decided that the study would start with a holistic approach and then narrowed down to one warehouse in order to provide solid recommendations.

Before a decision of what warehouse had the greatest potential for improvements could be taken it was necessary to define RTW as a concept and what the boundaries for it were. Observations and unstructured interviews had a fundamental role in this first part of the thesis in order to understand the operations and between which points in the flow the RTW lead-time should be measured.

When RTW was defined it was possible to assess lead-time data from the three warehouses to see where the greatest areas for improvements were. The data was provided by the IT-departments in the respective warehouses, assessed from the warehouse management systems. From what was seen in the initial study, it was decided that the inbound flow in Gothenburg had the greatest potentials for improvements and was chosen as the area for further investigations.

3.2.2 Process mapping

One of the key principles of the lean philosophy presented by Liker and Meier (2006) is "*If you can see, you can understand – If you understand you can act*". It was therefore vital to create a holistic picture of the flow to understand how processes and activities are connected to each other. It becomes easier to break them down into sub-sets to find root causes for waste, when you understand the processes and how they are linked.

The initial study was not enough to assess the root causes for waste in the warehouse in Gothenburg. A more extensive process mapping was therefore conducted where both the inbound and outbound flow was considered to create a picture of the flow and what processes it was made up of. As more insights about the flow and the operations were gained, the focus was aimed at certain areas for further investigations while others were left out. The two other warehouses were also studied, for why these processes were more efficient than the ones in Gothenburg, in order to gain further knowledge about SKF's warehouse operations.

3.2.3 Method for analysis

From the literature review, a model was developed to break down and sort out the empirical data and provide a structured way of analyzing the empirical data. The first part of the model is based on four key areas that have an impact on the warehouse performance. This performance was then linked to two concepts having a direct impact on the lead-time: how well the supply of capacity is matched to the demand for capacity, and how the processes are designed to fit their purpose. The four key areas were grouped as sub-concepts to the two main concepts as a support for identifying key drivers in the flow.

The analysis will be divided into two main chapters where the empirical data is analyzed with respect to the process design and how well capacity is matched to the operations. The analysis will look into each part of the inbound flow as well as take a more holistic view to summarize the flow.

3.2.4 Data collection

With a good understanding of the processes and activities in the flow, a more extensive data gathering was initiated. The data used to understand the flow and analyze potential drivers for RTW lead-time was collected through: an extensive literature review, interviews, benchmarking studies, observations and extractions of quantitative data. The benchmarking study in Schweinfurt and Tongeren was conducted on-site, two days in each warehouse. This was vital in order to understand how the activities and processes were conducted in warehouses with shorter RTW lead-time and to identify the main differences between these sites and the Gothenburg warehouse.

3.2.4.1 *Literature review*

The literature review was conducted in two steps. First the concept of RTW was broken down into areas that were understandable and could be analyzed. This step was carried out by reading articles and previous course literature about warehouse management, material handling and supply chain management. Once a basic understanding of the concept was formed a more extensive review was conducted where the authors focused the search to specific areas. The new review lead to the identification of four key areas that affect the performance of a warehouse, and was the basis for the structure of the empirical findings. The second step was to gather support to develop a model that could structure the analysis, through previous conducted research within warehouse management, which could determine what the most significant drivers for RTW lead-time are and how they affect the flow.

The data was gathered by using Chalmers search engine *Summon* to access scientific databases. The most commonly used databases were: Book 24/7, Proquest, Elsevier, Emerald and Sciverse. Relevant articles, E-books and journals were found by using specific key words.

3.2.4.2 *Observations*

According to Liker and Meier (2006) *Genchi Genbutsu* is a vital part of understanding solving a problem. It translates to “actual place, actual part”, which means that a person cannot solve a problem from the desk but have to go see for herself and create her own understanding of the situation. Baker (2006) presents the complexity of observation as a research or data collection method. She argues that it is sometimes necessary to take on more than just the role as an observer, sometimes being just an observer without interaction and sometimes a complete member of the group being studied.

Due to the complexity of the flow and to understand how GSPs actually move rather than what is stated in the process definition, observations was used as a method for gathering data. The method was mainly a guiding tool for further data collection but also to gather hands-on facts about the internal flows in the warehouse. The process maps collected from SKF’s internal network could only show a limited view in how goods moved. It therefore became important to expand these to see how products move not according to a process-map but how they actually flow, if the root-cause were to be found. Throughout the thesis the authors were never a member of the group and stood by as an observer.

3.2.4.3 *Interviews*

Two kinds of interviews were performed throughout the thesis: unstructured and semi-structured. Bryman and Bell (2011) argues that there are both advantages and disadvantages with the two approaches. The advantages with a more open approach are primarily related to if the researchers have limited previous knowledge about the area. However, the downside is that the answers provided will be less specific and there is a risk that some answers will be left out or ignored, while interviewing.

Unstructured interviews was chosen as an appropriate method for the pre-study, as it was not yet clear who were the best person to talk to and what process would be of interest.

Once a basic understanding of the flow was reached, unstructured interviews were changed to semi-structured interviews. This switch from unstructured to semi-structured interviews allowed the authors to first gain a basic understanding and then move further into certain areas that appeared more important. As a result, from what was learned in the initial step by going out to the warehouse and talk to warehouse personnel, semi-structured interviews was set up with managers, logistics administration and planning personnel, to focus on specific areas. The interviews were planned in advanced and the questionnaire was sent a couple of days before to make sure that the interviewee had time to prepare answers. If the interviewee had not seen the questions in beforehand, it was clarified that they had the option do deny a response. After the interview, the interviewers sat down together and discussed and summarized the interview to make sure that the key findings were preserved.

The same interview guide was used in Schweinfurt and Tongeren. Due to the fact that the interviews was set up before arrival and no information was provided for whom to interview, the authors had to adapt the interview guide as the interviews progressed.

In table 3, the interview objects are presented with title and date of interview.

Table 3 - List of people subject for interviews

Title	Location	Date
Warehousing supervisor	Gothenburg	1/2-13, 14/2-13, 21/3-13
Manager inventory management process	Gothenburg	13/2-13
Manager business Development	Gothenburg	28/3-13
Moving goods – process and optimization	Schweinfurt	8/4-13
Manager quality and environment	Schweinfurt	9/4-13
Warehouse operations manager	Tongeren	10/4-13
Team-leader	Gothenburg	15/4-13

See appendix A for a list of the interview guides that were used.

3.2.4.4 *Quantitative data*
The definition for RTW lead-time that was established together with the supervisors was not the same as in the IT-systems, which mean that not all data could be extracted directly from the WMS system: Warehouse Administration Service System (WASS). To assess the data that was required for measuring the RTW lead-time and the variation in the GSP flow, it was necessary to combine extractions from WASS with going out and physically writing down arrival times. In the sections below, the method for how the quantitative data was gathered is presented.

3.2.4.4.1 Inbound variation
The variation in when goods arrive was measured with separate methods for each of the three factories SKF Poznan, SKF Mekan and Factory-D, since the flows before arrival are not identical. These flows were chosen since they represent 80% of the inbound volume; hence the provided solutions would have the most significant impact if implemented on these flows.

Factory-D – The variation of GSPs from Factory-D was measured by extractions of the production time of all GSPs, produced during the sampling period, from WASS. The transportation time from the factory to the warehouse was then added to see when they arrived to the warehouse.

SKF Mekan – The inbound variation for SKF Mekan could not be measured in the same way due to a higher level of uncertainty for how long the GSPs are buffered at the production facility before being shipped to Gothenburg. The variation was measured by collecting data over when the GSPs left SKF Mekan and then add a transportation lead-time of six hours. The six-hour add-on was the estimated time it takes to send the goods from SKF Mekan to the Gothenburg warehouse, and the estimation was done in discussion with warehouse personnel to secure a reliable time-estimation.

SKF Poznan – GSPs from SKF Poznan have a longer transport lead-time than SKF Mekan and therefore the authors physically had to be in the warehouse and note when the trucks from SKF Poznan arrive, as they fluctuated heavily. To eliminate the risk that some trucks were left out, the forklift operators in the warehouse helped to document the arrival time for the ones that were missed. The operators did this, as most of the transports were inbound late at night, hence this was easier than for the authors to sit in the warehouse and wait for several hours just to document the arrival time.

3.2.4.4.2 Lead-times

All GSPs gets an arrival scan when they arrive to the warehouse but they are not necessarily scanned directly when they arrive. To secure that the calculated RTW lead-time was the same as the definition of the RTW lead-time, it was necessary to calculate the RTW lead-time by dividing the inbound flow in three different parts; inbound – conveyor belt for SKF Poznan and SKF Mekan, inbound – conveyor belt for Factory D and conveyor belt – storage. See table 4 for collection period and number of samples and the following sections for how the samples were collected. A sample is defined as one GSP.

Table 4 - Collection period and number of samples for inbound Gothenburg

Gothenburg Inbound	Factory-D	SKF Poznan	SKF Mekan	Automated elevator
Time period	8/2-11/4	18/3-5/4	11/3-5/4	18/3-5/4
No. of samples	18370	135	110	98

Factory-D – The RTW lead-time for GSPs from Factory-D was measured by extracting the time when the GSPs was finished in production through WASS. Since all GSPs have its own unique number, a GSP could be traced from finished in production to final storage. The time from being finished in production was measured against when the GSPs were placed in their final storage locations to assess the total RTW lead-time. To identify the lead-time from the production facility to buffer, the authors manually noted arrival time of the GSPs to the buffer, which could then be compared to the time of being finished in production. By doing this, it was possible to measure lead-time from production to buffer, from buffer to final storage, and total lead-time from production to storage.

The considerable large amount of observations can be explained by WASS, storing data about Factory-D-products for several years. Therefore, it was possible to measure the total lead-time through only extracting the time when being finished in production and compare it to time and date of arrival in storage. To assess the lead-time from buffer to storage, the lead-time from production to buffer was subtracted.

SKF Poznan and SKF Mekan – The RTW lead-time for SKF Poznan and SKF Mekan were measured using the same method; the authors physically wrote down arrival time and serial number of six GSPs from each shipment. The arrival time was then measured against when the GSPs were placed in their final storage locations to assess the total RTW lead-time. This had do be done manually as these touch points at the time was not established in WASS, hence there was not any reliable data in this part of the flow.

Automated elevator to storage – To determine how long on average a GSP were in the buffer, the time from a GSP is fetched from the buffer until it is placed in storage was also measured. There is no system point for this, and therefore had to be done manually. The time and serial number for three GSPs was documented three times every day. The point of measure was when the GSP was put on the conveyor belt leading to its designated floor. This time was then measured against when the GSPs were placed in their final storage locations.

Table 5 - Collection period and number of samples for outbound Gothenburg

Gothenburg	Outbound
Time period	12/3-3/4
No. of samples	5804

Outbound Gothenburg– Data extractions for the outbound flow could be done directly from WASS due to the fact that it was better monitored than the inbound flow. The extracted data contained products going from Gothenburg to Schweinfurt and Tongeren. The measuring points was set from the point of put on the outbound conveyor belt until put on an outbound transport. As all these GSPs have a unique serial number, it was possible to identify the total lead-time for all pallets, from put on conveyor belt to put on an outbound transport. As all GSPs must be scanned when performing these actions, the provided data is accurate, and depicts the average lead-time for a GSP for the whole outbound flow.

Outbound Schweinfurt and Tongeren – The data was extracted by the IT-department in the respective warehouse. Two month of data was suggested, but as this was difficult to attain in Tongeren, the received data was three months instead. The reason for a conservable lower amount of samples in Schweinfurt is the way the IT-department extracted data. They took 2 samples from every transport during this time, as they argued that assessing all GSPs would show a similar result.

Table 6 - Collection period and number of samples for inbound and outbound Schweinfurt

Schweinfurt	Inbound	Outbound
Time period	N/A	17/12-2012 – 15/3-2013
No. of samples	N/A	262

Table 7 - Collection period and number of samples for inbound and outbound Tongeren

Tongeren	Inbound	Outbound
Time period	N/A	1/3-26/4
No. of samples	N/A	28794

3.2.4.4.3 Number of GSPs in buffer

The amount of GSPs was counted three times everyday day during the data collection period. The collection had to be done manually by going out and counting each GSP. To see the effect of the newly implemented shift (from April 1st, 2013), the amount of GSPs were counted once again every day, two weeks after the "official" collection period ended.

3.2.4.4.4 Put away frequency

The put away frequency - how much the warehouse puts in storage every hour - was measured by extractions from WASS. The time for when a GSP was put in storage was categorized according to which hour this happened to assess how many GSPs on average was put away each hour.

Table 8 - Collection period and number of samples for put away frequency

Gothenburg	
Time period	1/3-8/4
No. of samples	18077

3.2.4.4.5 Frequency in picking assignments

The distribution in when the picking takes place during a day was measured in a similar way as the put away frequency. Extractions of when picking assignments were initiated on floor-1, floor-3 and floor-4 were extracted from WASS. These times were then summarized and grouped hour-wise, similar to the put away frequency. The samples were picked from only one day but according to the warehousing supervisor that provided the data it is representable for all days.

Table 9 - Collection period and number of samples for frequency in picking assignments

Gothenburg	
Time period	22/4
No. of samples	1275

3.2.5 Recommendations

As noted, the focal point is the warehouse in Gothenburg, which means that the solutions will be focused to fit this context firstly. When the recommendations have been developed, it will be investigated if the warehouses in Schweinfurt and Tongeren can reap any benefits from implementing the same suggestions.

The provided recommendations are based on the theoretical findings and the empirical research. The empirical research in Schweinfurt and Tongeren acts as a foundation for how efficient warehouse processes should be conducted, based on what has been seen in the pre-study (table 1).

3.3 Validity and reliability

Using the abductive approach, it was possible to go back and forth between the theory and the empirical data. By doing this, it was possible to start in a broad sense and continuously narrow down the theoretical framework according to the empirical findings. As the flow in Gothenburg is complex, data was gathered continuously, which is the reason to why not all empirical data is from the same time period. This fact will have some impact on the analysis since changes have been made in the warehouse during the data collection (e.g. new shift rotation from April 1st 2013, new routines for identification of GSPs in buffer).

The authors established new KPIs and were forced to monitor the touch points physically on an everyday basis, as these were not accessible through the WMS system. As the monitored processes were found to be unstable and include high variations, the authors sometimes encountered no or few GSPs on the move when conducting the empirical gathering. As this was the case, the low amount of observations could explain the high standard deviation in the different flows. However, as the Factory-D-products had over 5000 observations and still had a large standard deviation, the standard deviation is believed to be accurate even if the amount of observations are rather low for the SKF Mekan and SKF Poznan-flow (91 and 131). As the three flows have almost identical processes inside the warehouse, it suggests that the data is correct, and the throughput-time should be similar for all three flows.

Due to the development of the case and as new insights about the empirical world were made, new data was collected. This resulted in data being gathered during different time-periods, which could have effect the outcome and the results, as volumes fluctuate over time. However, the data has been discussed with personnel from different departments within the warehouse regarding its validity and is believed to be accurate.

Since the authors themselves counted the number of GSPs in the buffer, there is always a risk of missing GSPs. This could criticize the accuracy in figure 11 and 12 (number of GSPs in buffer). However, the counting did not put any stress on the authors and it was conducted in a structured way to make sure no GSPs were missed. Therefore, the graph and the number of GSPs in the buffer are believed to be accurate.

Some of the findings are not backed up by data-driven research, but through interviews with personnel in the warehouse (e.g. that the estimated limit for when operators start to loose control over the situation in the buffer is approximately 800 GSPs). As this type of data is difficult to assess, it was believed that the warehouse personnel could provide a fairly accurate number. Also important to note is that the actual percentage on how often the multi cycle was used have not been assessed. The authors believe that if measuring how often the multi cycle was used, the operators would recognize what was counted, and the operators would definitely conduct the multi-cycle every time, which would not depict the actual performance-level.

The maximum put away capacity (52 GSPs/hour) is also estimated through observations and interviews, which means that there is a level of uncertainty to the number. The argument to why this was not calculated through quantitative measures was because of the high number of factors affecting the put away capacity. As the processes in the warehouse operations regarding the inbound flow are unstable, it becomes difficult to assess the maximum capacity, since there is such a high degree of variation.

In order to validate the results and test different scenarios, simulations were discussed as a tool to investigate different factors' impact on the flow performance. However, as the processes were unstable, the simulation would have shown different results every time, even if no parameter were changed. As seen in the empirical data, several of the investigated observations lay outside $\pm 3\sigma$, which can be seen as a measurement on assessing if a process is stable or not (Wei et al., 2006).

4 Empirical findings

This chapter presents the empirical findings from the warehouses in Gothenburg, Tongeren and Schweinfurt. Within the three warehouse-sections, there is an explanation of the layout, the materials handling activities and the distribution of personnel. The fourth factor in the model for analysis (tracking and control systems) is explained after the three warehouse-sections, as the same system is used in all three sites.

The warehouses in Gothenburg, Schweinfurt and Tongeren have different characteristics, operate under different conditions and serve different purposes. Gothenburg and Schweinfurt are international warehouses, which mainly serves large customers who order directly from the factory e.g. OE-manufactures, while the warehouse in Tongeren is a regional distribution center that serves the after market and retailers. The characteristics of the customer orders are therefore different. The international warehouses comprise of 5% of the total order-lines while handling 50% of the volume in Europe. The regional distribution center (Tongeren) handles 85% of the order-lines but only 25% of the volume in Europe.

The international warehouses have a longer planning horizon as their customers order larger quantities and fewer types and some who share the order books with SKF. Tongeren has a more uncertain environment where it must carry a large part of the SKF assortment and have to be able to support customers much quicker due to breakdowns etc. This is the case as Tongeren is a regional warehouse with a bigger focus on serving the aftermarket with spare parts. This makes it hard to forecast for which products are most likely to be sent, as breakdowns are hard to predict.

4.1 Gothenburg

This chapter covers the warehouse in Gothenburg. It will cover three areas: the layout, the materials handling activities conducted within the warehouse as well as how the personnel is distributed together with other resources, such as equipment.

4.1.1 Warehouse layout

The factory warehouse in Gothenburg serves mainly the production facilities in Gothenburg (Vehicle Parts, Factory-E and Factory-D), SKF Mekan in SKF Mekan and SKF SKF Poznan in Poland. There are also some other both internal and external customers that store goods in the warehouse. The warehouse is also a hub for goods sent from other factories and warehouses to customers in Finland and Norway. The goods is cross-docked and consolidated with other orders for further shipment later the same day. However, incoming goods for distribution to Swedish customers are not received here and are outsourced to an external service provider, as there is not enough capacity in the warehouse to handle these volumes. See appendix B – appendix E for pictures of the layout.

4.1.1.1 *Warehouse flow*

The medium bearings produced in Factory-D are sent under ground via an elevator and forklifts through a pathway connecting Factory-D with the warehouse. The external goods arriving from, SKF Mekan and SKF Poznan are inbound through two loading docks on floor-1. Goods produced by Vehicle Parts who is located internally in the premises of Gothenburg, are generated by customer orders. This means that those GSPs are inbounded on the first floor and during the same day sent up to the second floor, to be consolidated with other orders and sent out from floor-2.

This warehouse is unique within SKF as it is the only warehouse where products are stored on different floors. It is comprised of five floors serving different purposes. Three automated elevators connect the different floors with each other. One elevator operates on all floors except the second floor, which makes this elevator dedicated to inbound goods only. The other two elevators run across all floors and are dedicated to sending outbound goods to floor-2.

There is an aspiration to have an equal flow of products from all floors as well as between the inbound and outbound flow. A priority rule determines where goods should be placed to minimize a risk that one of the three conveyor belts are clogged. There has been an ABC-classification to optimize which products should be located closest to the elevators. However, the classification has not been updated according to set standards and a possibility of having an out-of-date product priority might be the case.

See appendix F for a process map of the inbound flow.

4.1.1.2 *Floor-1: Goods receiving and warehousing*

The first floor is comprised of a buffer for inbound goods and a storage area. The storage area is made up by high-racks with a capacity of 4200 GSPs, utilized to about 80%, similar to the other floors. Goods designated to the first floor are mainly medium bearings and products from SKF Mekan. There are additional storage areas under Factory-D called LAD-1, where some of the products from Factory-D are located together with bulkier products that do not fit in the warehouse high-racks. They do not fit since the production-facility and SLS have different standards for some products. The storage method for this area is deep stacking.

There are additional storage locations in an adjacent building to the warehouse (Storage-E) where goods for heavy picking are stored. The area is equipped with additional equipment to support the heavy movements.

4.1.1.2.1 Inbound transportation

Arriving goods are offloaded at two loading docks. Internal transports have a fixed delivery schedule organized according to a milk-run route. External transports do not currently have slot times for when the trucks arrive and it creates an uncertainty for external transportations as the trucks can vary both in terms of number of trucks and delivery time every day. SKF Mekan notifies the number of trucks each day, creating some ability to plan ahead. The arrival times for trucks from SKF Poznan are harder to plan as their delivery time depends to a greater extend on traffic and how the trucks can catch the ferries departure time.

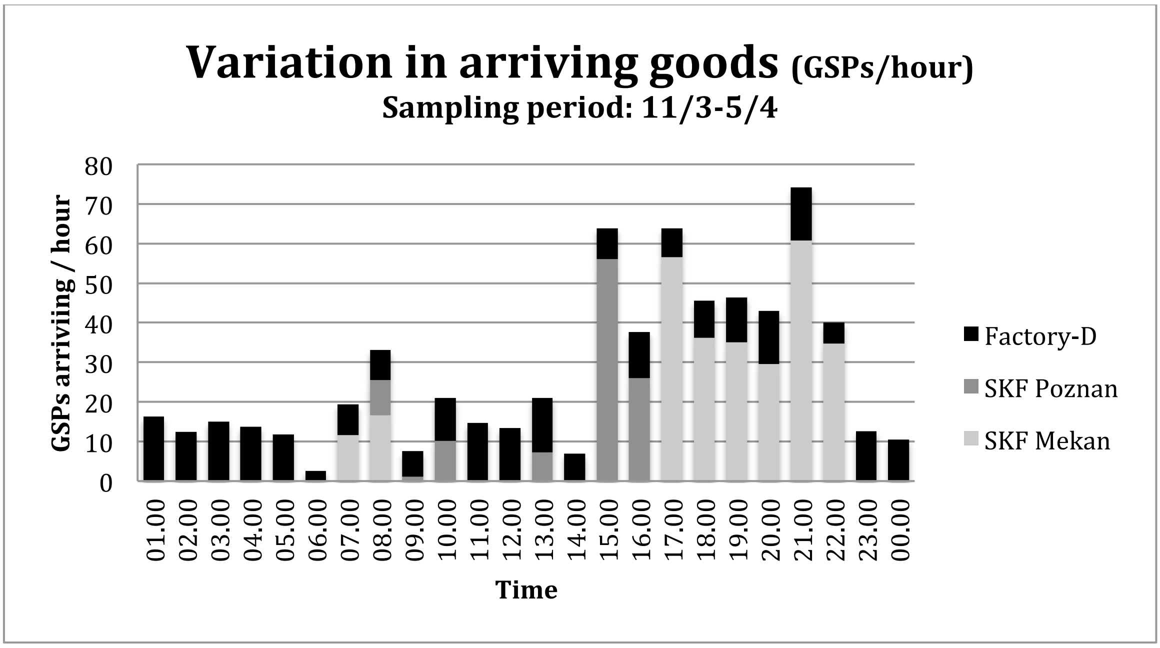


Figure 10 - Amount of GSPs that arrive to the warehouse every hour

Figure 10 shows the variation in how many GSPs on average arrives from the three factories during one day. Goods from Factory-D arrive at the same pace as the production facility's takt-time. Goods from SKF Mekan are told to arrive in the evening between 17:00 and 22:00. However if management believes that there is not enough capacity to unload the trucks in the evening, they are postponed until the next morning. Due to the longer transportation distance from SKF Poznan, these trucks are harder to control, but the goal is to arrive in the afternoon. The distribution of volume between the three flows is presented in table 10.

Table 10 - Distribution of volume between the three flows

Factory-D	SKF Poznan	SKF Mekan
39%	16%	45%

4.1.1.2.2 Buffer zones

The buffers purpose is to create a decoupling point to even out variations between the need for capacity and the actual capacity in the warehouse. One part of the buffer is composed of painted lines on the floor together with signs hanging from the ceiling. The other half of the buffer only has signs on the pillars showing the operators where one area starts and the other ends. All these zones are comprised of deep-stacking storage methods.

There have not been any explicit routines for where and how GSPs are grouped in terms of arrival date and to what floor they are going, which makes it hard for the operators to understand what GSPs should be prioritized. To get an understanding of what GSPs has been there the longest there is a whiteboard, with a schematic overview of the buffer, to write down at what date the GSPs arrived and to what location they are going. However, only the GSPs placed inside the zones will be marked on the whiteboard. This new standard has just recently been implemented and the whiteboard has during the time of the data-gathering not once been fully updated. Operators are also not supposed to put GSPs together if they are going to different floors, but if the GSPs are mixed the operator marks them with a sign as “unsorted”. When there is too much goods in the buffer, GSPs are put wherever there is space at the moment, which results in GSPs placed in walking- or forklift-pathways.

One zone in the corner of the buffer is reserved for outbound goods. There are no visual markings for this buffer other than a sign pointing to the area. When there are large volumes of outbound goods from floor-1 there is a risk of goods placed in driving lanes of the forklifts. The purpose of this area is to enable picking even when the outbound flow is clogged. So to eliminate the risk that the operator has to wait to put a GSP in the elevator, they will drop it off in the outbound zone.

The buffer in the basement of Factory-D is connected to the warehouse through an internal pathway, making transports between the two facilities fully in-house. Goods produced in Factory-D are sent to the basement by an automated elevator. Next to the elevator there is a buffer where goods are placed for consolidation for easier transportation into the warehouse or because lack of space in the buffer.

Figure 11 and 12 presents how the amount of GSPs fluctuates in the buffer from week to week (see appendix L for numbers). The period of data gathering for this particular investigation was first between 19/3-5/4 and then between 2/5-24/5, to see if the new shift-rotation had an impact on the buffer. The blue bar is the main buffer on floor-1, whilst the red bar is the temporarily buffer adjacent to the vertical elevator beneath Factory-D. According to the team-leaders, it becomes difficult to manage the GSPs within the buffer when the number of GSPs exceeds 800 and control is slipping away. Important to note is that this number has been assessed through interviews, hence not something that has been investigated through data-driven research.

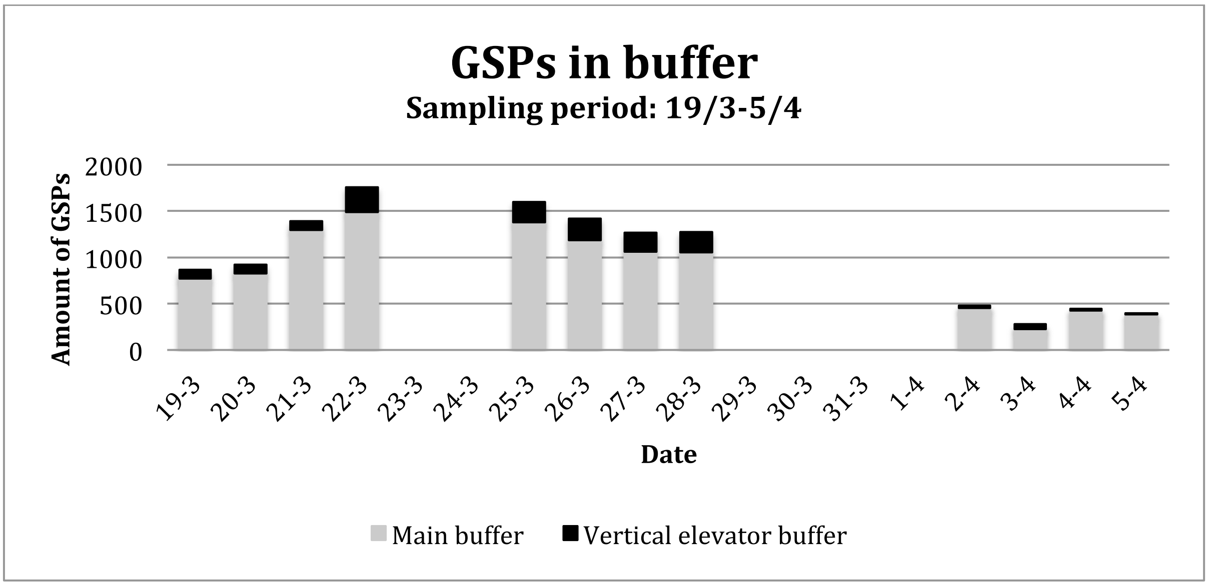


Figure 11 - GSPs located in buffer 19/3 - 5/4

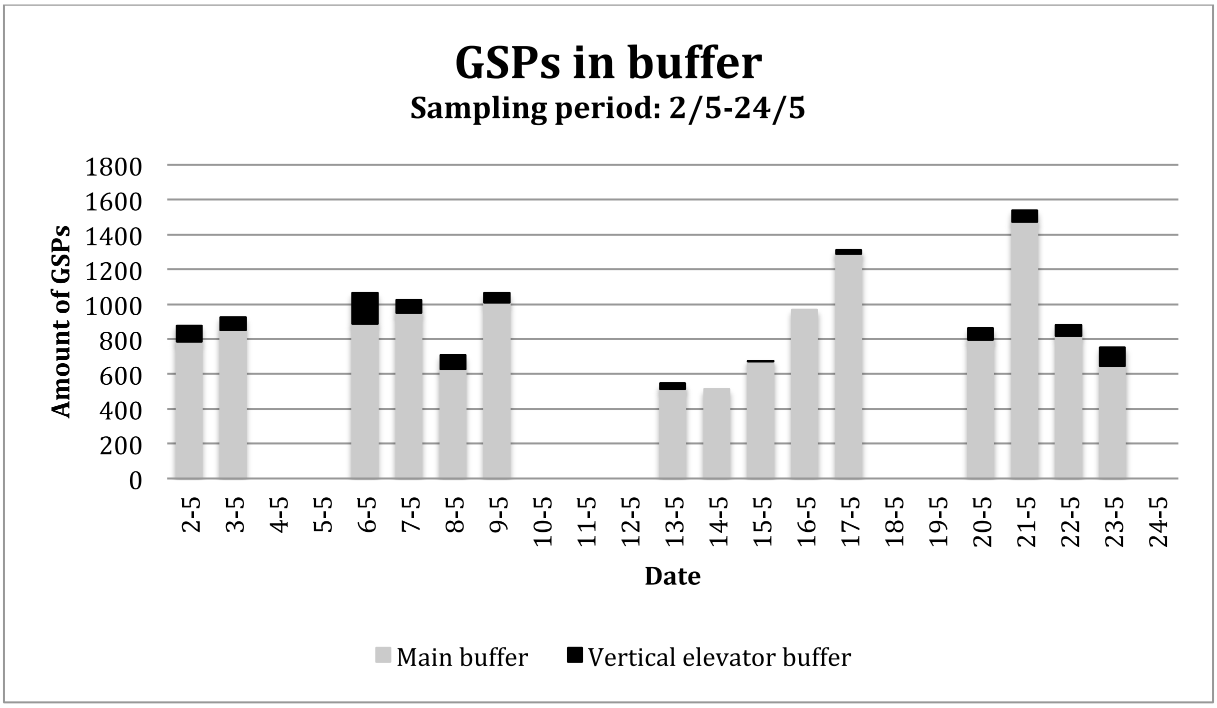


Figure 12 - GSPs located inside the buffer 2/5 - 24/5

4.1.1.3 *Floor-2: Loading area, goods receiving and warehouse*

All outbound operations take place at this floor. As mentioned earlier, this floor receives goods from two of the three automated elevators. GSPs are transported on a conveyor-belt to two stations where they are weighted, strapped and labeled. They are then lifted off the conveyor-belt and taken to its designated outbound area. GSPs are consolidated according to destination before loaded on the transportation unit. Each destination has its own area with painted isles on the floors and signs hanging from the ceiling and pillars.

Outbound transport-modes are: truck, sea, air and train depending on the characteristics of the order. There are three loading docks for truck transports, two loading docks for container transports and one dock for inbound goods that are kept in storage on the second floor e.g. Factory-E.

4.1.1.4 *Floor-3: Warehouse-office and warehousing*

The third floor is mostly used for storage but also has office space for warehouse administration. Goods in storage at this floor are mainly goods from Factory-D, SKF Mekan, SKF Poznan, some just-in-time products to SCANIA and components from India. The storage method is high-racks with a capacity of about 12 300 GSPs.

4.1.1.5 *Floor-4: Warehousing*

The fourth floor is only used for storage with high racks and has a total capacity of about 12 900 GSPs. There are mainly Factory-D-products and some SKF Mekan-components at this floor. Some components from SKF Mekan are located exclusively here, as they must be handled with special equipment.

4.1.1.6 *Floor-5: Management, logistics administration and inspection*

This floor is divided into several sections, mainly office-space, customer returns and defects. Defected products have to be sent to the SKF lab located a few hundred meters from the warehouse. If there is only a scuff on the package, it is being repacked and sent to a lower floor where it is being registered in storage. Returns are controlled and a new label is created if it is OK, and then put in storage. From April 1st, all goods on this floor should be moved to the high racks on floor-1.

4.1.2 Materials handling activities

This section will cover the activities conducted within the warehouse. The focal point is the activities being executed directly to a GSP.

4.1.2.1 *Inbound flow*

The three major inbound flows are, as mentioned earlier, goods from Factory-D, SKF Poznan and SKF Mekan. As these products are stored on all floors, it is important to remember that one truckload often is designated to several floors, and the average distribution between floor-1, floor-3 and floor-4 is equally 1/3 for the three flows Factory-D, SKF Mekan and SKF Poznan.

4.1.2.2 *Factory-D*

Step 1: Notification

When the production cell is finished with a GSP, the operator prints a WASS-label and puts it on the GSP. From now on SLS is responsible for the GSP. From the point when the label has been printed, SLS has 3-4 days (depending on from what factory the GSP is coming from) to move the GSP to its designated storage area in the warehouse.

Step 2: SLS pick-up (floor-2)

An operator recognizes that a GSP in the outbound area of one of the production cells is ready to be picked-up. The operator picks up the GSP and takes it to the automatic elevator (located inside Factory-D).

Step 3: GSP travels to floor-1
The GSP is sent one level down via the automatic elevator, and is released onto a conveyor belt. The average time from notification to this step is 42 minutes. The belt goes through a strapping machine where some products are strapped depending on what type of medium-bearings the GSP contains. The conveyor belt moves the GSP about 10 additional meters to the end of the belt. From here an operator fetches the GSP.

Step 4: Fetching GSP (floor-1)
An operator lifts of the GSP from the conveyer belt and puts it either in the buffer area next to the conveyor belt or directly in the main buffer if there is space available. They have recently started to inbound scan the GSP when the operator takes it. If there is lack in time, the operator sometimes ignores the scanning and focuses on emptying the elevator.

Step 5: fetched from buffer (floor-1)
An operator fetches the GSP from the buffer and scans it. Depending on the characteristics of the GSP it will be sent to different locations. As there are storage locations on all five floors in the warehouse, beneath Factory-D and in storage area E, WASS tells the operator where it should be put. If the GSP is designated to the first floor he or she puts it in storage directly. If WASS suggests it should be placed on another floor (3-5), the GSP is placed on another conveyor belt connected to one of three additional automatic elevators.

Step 6: Elevator (floor-1) to floor-3, floor-4
Depending on the product, the GSP will be sent to floor-3 or floor-4. When the GSP is put on the conveyor belt the operator presses a button on the belt telling the elevator where the GSP is going. It is possible to put two GSPs on top of each other in the elevator to send up more GSPs at the same time.

Step 7: Arriving at floor-3, floor-4
The conveyor moves the GSP to the end of the belt where a truck-operator fetches it.

Step 8: Transportation from conveyor to storage
The operator scans the GSP and WASS tells which high-rack to put the GSP in. He or she then takes the GSP to that place where both the barcode on the rack and the GSP is scanned and the inbound flow for the medium bearings is complete.

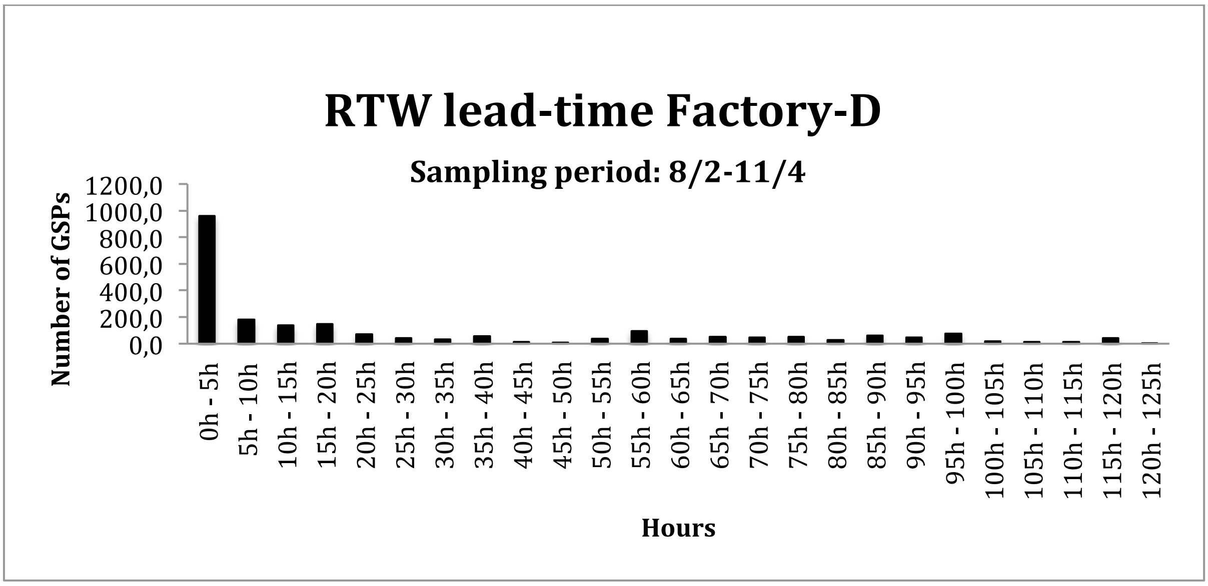


Figure 13 - The RTW lead-time for Factory-D

Figure 13 depicts the number of GSPs from Factory-D and the amount of time it takes from unloading to put in storage on floor-3, floor-4. Although it is clear that a very large amount of all investigated GSPs has a throughput-time of less than 5 hours (40%), there are a great number of outliers, all of which are not shown in this graph, as it would not fit if all observations were included.

Table 11 - Summary of RTW lead-time for Factory-D

	Factory-D
Average (hours)	39,5
Standard deviation (hours)	59
Max (hours)	503
Sample period	8/2-5/4
Observations	18370
RTW lead-time target (hours)	72

Although the amount of observations in this particular flow exceeded 2500, the standard deviation is quite high (59 hours), the average throughput-time is almost 40 hours and the maximum time to storage is close to 500 hours.

4.1.2.3 *SKF Mekan and SKF Poznan*

Step 1: Empty truck (floor-1)

Trucks from SKF Poznan and SKF Mekan arrive at one of the two loading docks on floor-1. The operator responsible for putting GSPs on the elevator empties the truck and puts the GSPs in one of the available zones in the buffer on the first floor. The GSPs need to be sorted due to the fact that WASS distributes them throughout the warehouse to create a smooth flow. Sometimes there might not be enough time or space to sort the GSPs at arrival and they are put together with old ones for to be sorted later.

The operator scans the GSP and the barcode representing the zone where he or she puts the GSP. This is done in order to know where the GSPs are located within the buffer. There are no visual aids to notify operators of truck arrivals. Sometimes, the truck-driver has to wait for his truck to be emptied as operators are occupied with other activities or on break.

Step 2: Putting GSP on conveyor belt (floor-1)
The GSPs should be fetched according to the first in FIFO-principle. However, as the operators themselves are responsible for doing this by visually checking the whiteboard and as this standard is not yet fully implemented it has been observed that newer GSPs has been taken before old ones. The operator should empty the entire zone before starting with the next one to eliminate the risk of LIFO.

Depending on what storage location the GSP is going to it is either placed on the conveyer belt for the inbound elevator or fetched by another operator who puts it in storage on floor-1. If the GSP is going to floor-3 or floor-4 the operator presses a button at the belt to tell the elevator what floor it is supposed to go to. The GSP is then moved to the designated floor automatically by the elevators.

Step 3: Transportation from automated elevator to storage
The operator scans the GSP, where WASS tells the operator which high-rack to put the GSP in. He or she then takes the GSP to that place where both the barcode on the rack and the GSP is scanned and the inbound flow for SKF Poznan and SKF Mekan is complete.

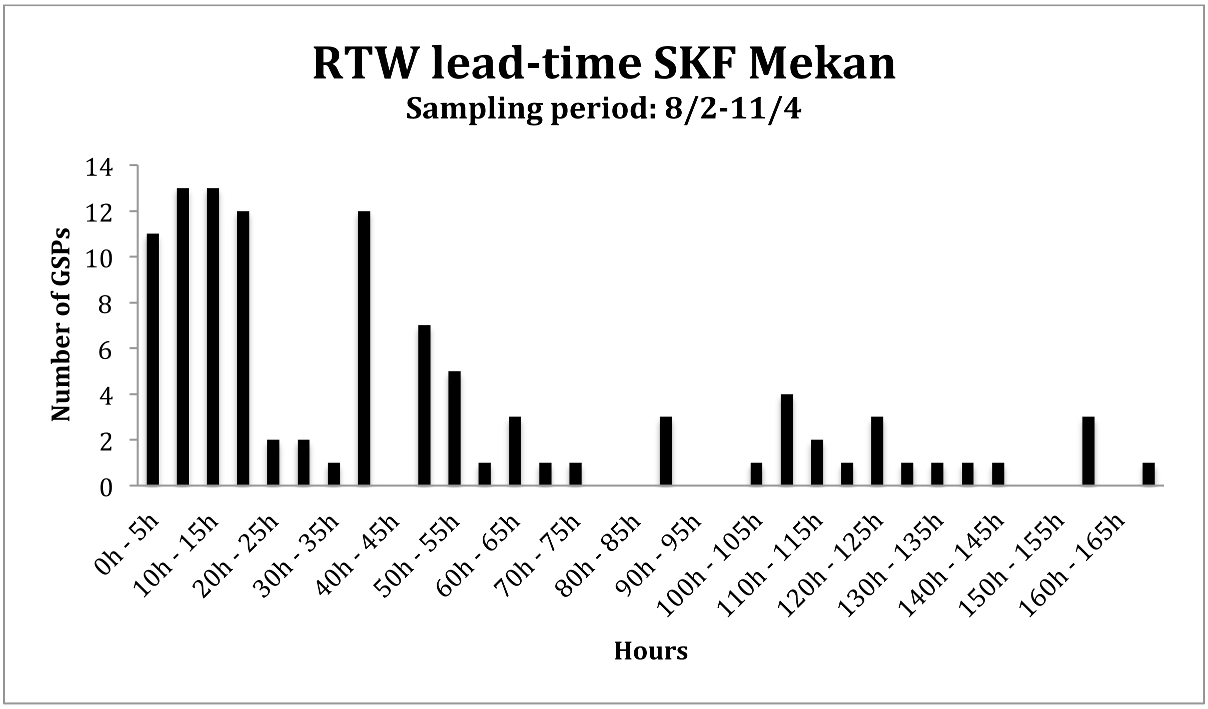


Figure 14 – RTW lead-time for SKF Mekan

GSPs arriving from SKF Mekan show a similar pattern as the GSPs coming from Factory-D. The majority of GSPs are put away within 40 hours but with a large number of outliers.

Table 12 - Summary of RTW lead-time for SKF Mekan

	SKF Mekan
Average (hours)	52
Standard deviation (hours)	58
Max (hours)	282
Sample period	11/3-8/4
Observations	110
RTW lead-time target (hours)	72

As seen in Table 12 and mentioned above, it is evident that the throughput-time to storage for this particular flow fluctuates heavily. The average time is 52 hours with a standard deviation of 58 hours and a maximum time of 282 hours.

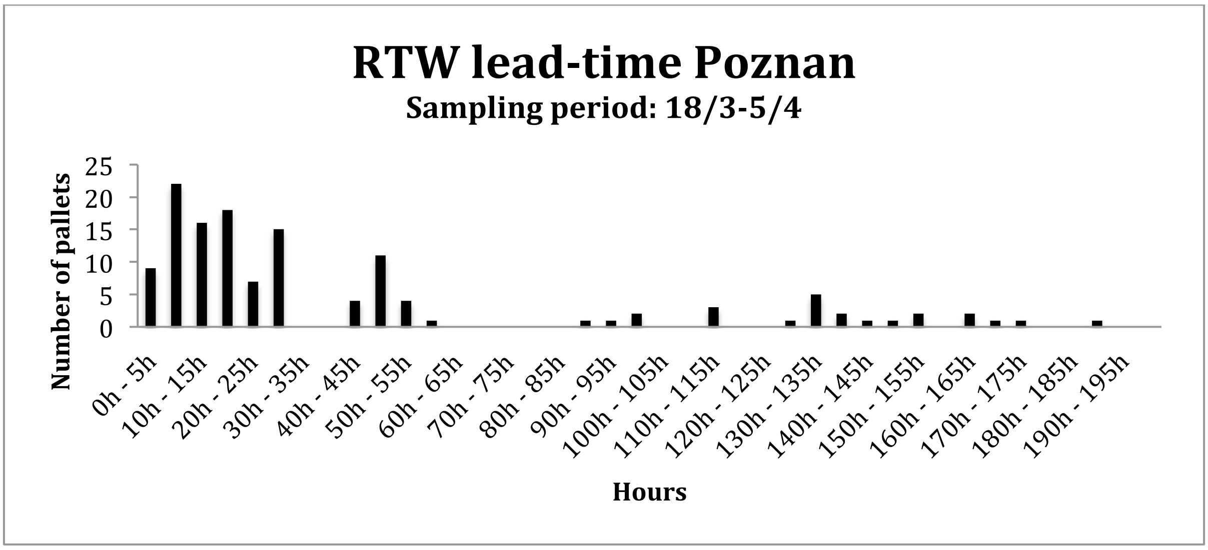


Figure 15 - RTW lead-time for SKF Poznan

The throughput-time for SKF Poznan is similar to SKF Mekan. As can be seen in figure 15, the largest amount of GSPs is put in storage within 30 hours.

Table 13 - Summary of RTW lead-time for SKF Poznan

	SKF Poznan
Average (hours)	48
Standard deviation (hours)	61
Max (hours)	286
Sample period	18/3-5/4
Observations	120
RTW lead-time target (hours)	96

Table 13 is similar to both Factory-D and SKF Mekan, where the average throughput-time is 48 hours with a standard deviation of 61 hours. The maximum time for a GSP was 286 hours, which is similar to SKF Mekan.

4.1.2.4 *From buffer to storage location*

To see how long the GSPs are located in the buffer the average time it takes to transport a GSP from the buffer to storage was measured.

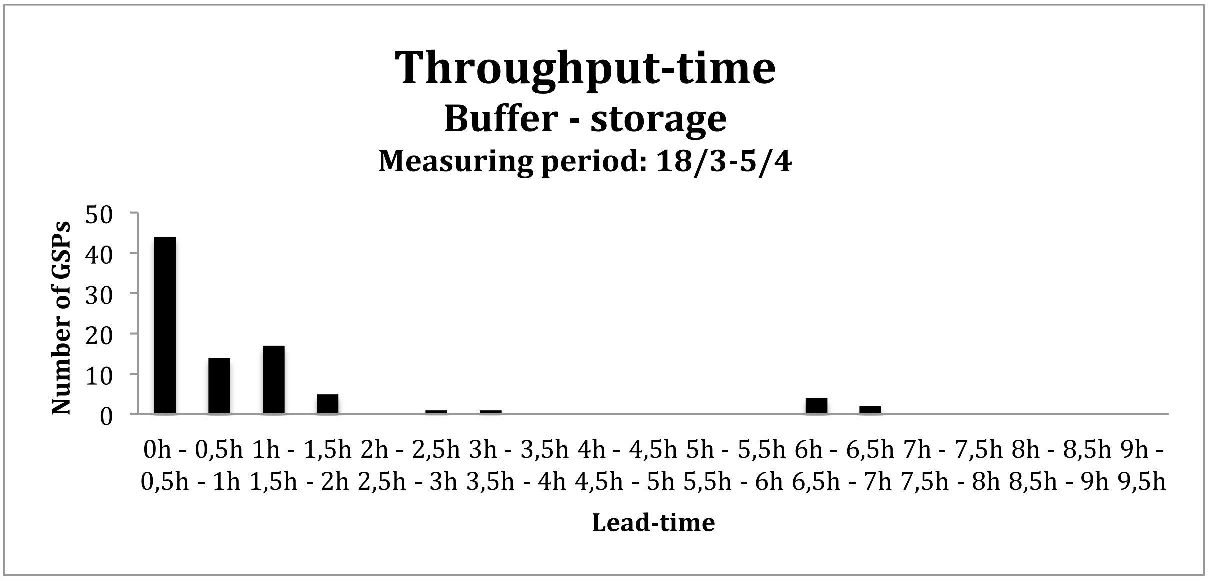


Figure 16 - Throughput-time for a GSP from the conveyer belt on floor-1 to storage

Figure 16 presents the throughput-time for a GSP to travel from the conveyor belt on floor-1 to its designated storage place either on floor-3, floor-4. The y-axis shows the accumulated amount of samples with the throughput-time marked on the x-axis. As noted in the graph, it is evident that most of the GSPs has a throughput-time in this process-step of maximum two hours, although there are some GSPs experiencing a considerable longer throughput-time.

Table 14 - Summary of throughput-time from the conveyer belt on floor-1 to storage

	Automated elevator - Storage
Average (hours)	2,7
Standard deviation (hours)	5,2
Max (hours)	23,8
Sample period	18/3-27/3
Observations	98

Table 14 depicts the gathered data. The average time to storage is approximately 2,7 hours (2 hours and 42 minutes) with a maximum time of approximately 24 hours and a standard deviation of about 5 hours.

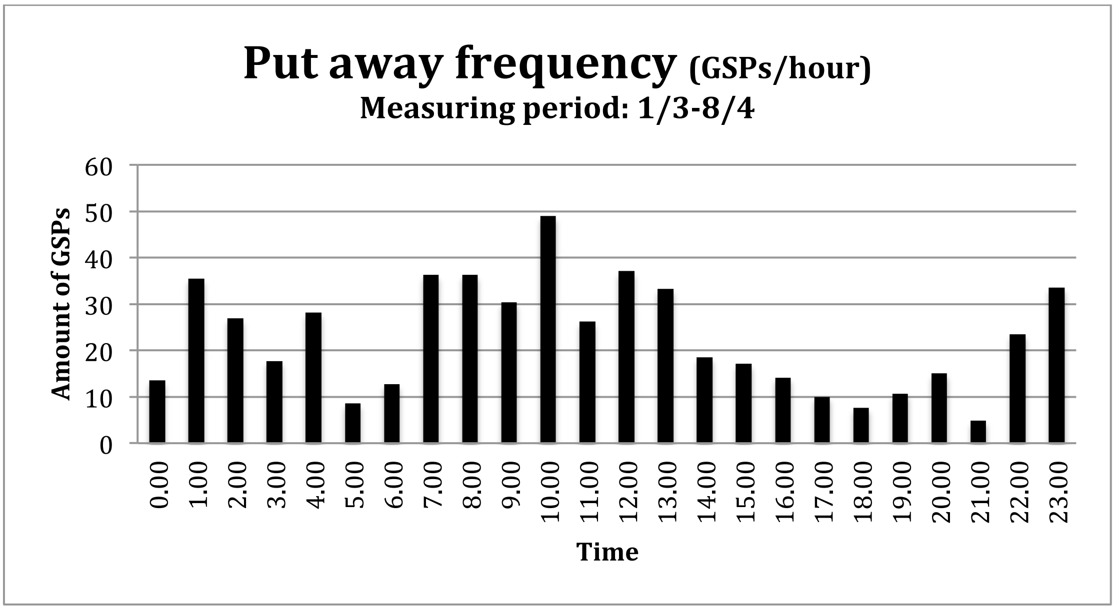


Figure 17 - Amount of GSPs, from Factory-D, SKF Poznan and SKF Mekan, the warehouse put in storage every hour

Figure 17 depicts the amount of GSPs on average from Factory-D, SKF Poznan and SKF Mekan, put in storage every hour during a day. Floor-3 and floor-4, including the elevator, have a total handling capacity of 22 GSPs/hour (Jankulovksi et al., 2012) and the operator on the floor-1 can under normal circumstances put away about 30 GSPs/hour. However, this is largely dependent on that the GSPs are stacked and sorted in the buffer in a correct way, and that their storage locations are located next to each other. This gives the warehouse an estimated maximum put away capacity of 52 GSPs/hour.

4.1.2.5 *Outbound flow*

Step 1: Picked up from storage
The operator receives a pick list in the computer in the forklift, showing which GSP to pick. The GSP is fetched from storage and scanned manually to confirm pick-up in WASS.

Step 2: Put in elevator
The GSP is put in one of the two automatic elevators that will send the GSP to the packaging area on floor-2. When it is put on the elevator conveyor belt, the GSP is scanned once again. An internal transport label is printed and put on the GSP before it is sent down with the elevator.

Step 3: Labeled and weighted
When the GSP arrives at floor-2 it is transported by conveyer belts to the weighting station, where the label is scanned to confirm the right weight. If needed it is being strapped. When the weight has been controlled a new label is printed and the old is thrown away. After a transportation label is printed, it is ready for transportation.

Step 4: Put in buffer before transportation

An operator picks up the GSP and puts it in a buffer with other GSPs going with the same transport. To know where the other GSPs are located, the operator scans the GSP to see where the other GSPs in the same shipment are located, and puts it where they are. When the first GSP in a transportation consignment is put in the buffer, it is scanned when put there. The following GSPs are put in the same location and scanned accordingly.

Step 5: From buffer to transportation unit
The GSP is fetched to be loaded in the transportation unit and at the same time scanned by the operator [status: 85].

Summary of the statuses for the outbound flow:
22 – An order for a GSP to be picked is created but not yet released
50 – The order is released by the transport unit and is now available for picking
60 – The GSP has been picked up by a forklift
65 – The GSP is sent down in the elevator to the outbound area
70 – The weight of the GSP has been confirmed and a transportation label is printed out
75 – The GSP is put together with other GSPs on an outbound area and is waiting to be loaded
85 – The GSP is on the transportation unit and the transport is approved for outbound destination.
90 – The order is closed and the shipment has left the facility

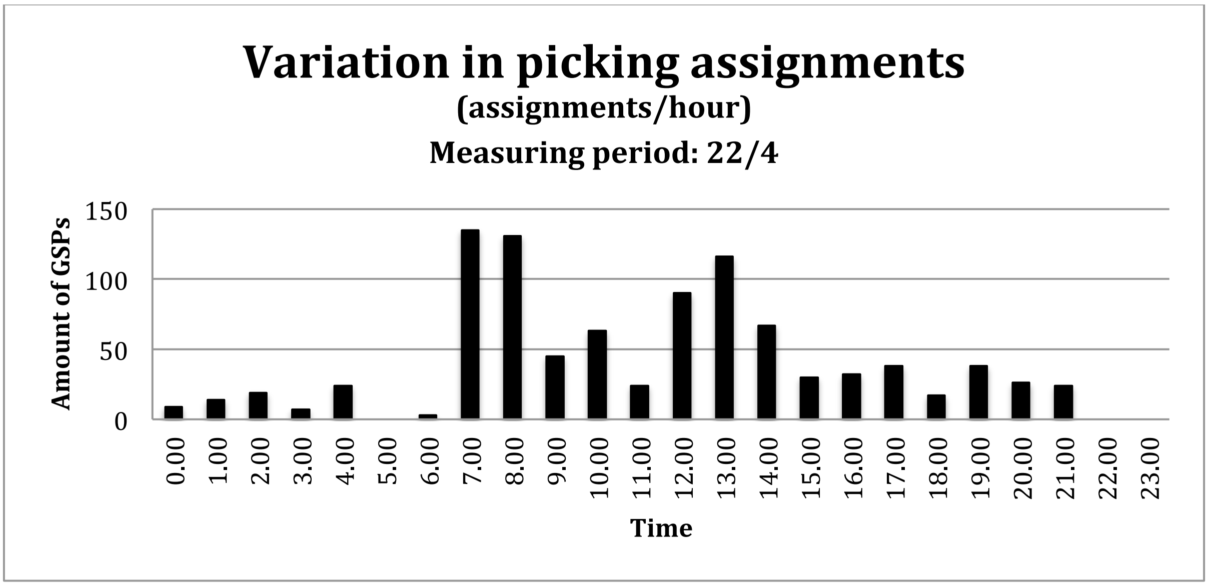


Figure 18 - Amount of assignments conducted on average every hour

Figure 18 depicts the amount of assignments performed every hour in the warehouse. By simplifying an assignment, it is possible to state that one assignment equals one GSP. The assignment is registered when the GSP is put on the conveyor belt leading to the outbound area on floor-2. This is the first step in the outbound flow.

Table 15 - Summary of outbound RTW lead-time

	Outbound
Average (hours)	14
Standard deviation (hours)	13
Max (hours)	104
Sample period	12/3-3/4
Observations	5805

As can be seen in table 15, the average throughput-time from storage to an outbound transport is 14 hours. The standard deviation is almost as high (13 hours).

4.1.2.6 *Shared activities between inbound and outbound*

Operators at floor-3 and floor-4 driving the side-loaded forklifts are both responsible for order picking and fetching GSPs inbound from floor-1. To increase the flow efficiency, SLS launched the project "multi-cycle". When the operators has dropped-off an outbound GSP on the conveyor belt, they should pick up a GSP from the inbound conveyor, making it possible to carry out assignments both ways. This project is temporarily put on hold due to system problems, but the operators should still take one in and one out. The operators argue that it is too time-consuming to work like this, as they cannot keep up the pace on the outbound assignments. This happens if the inbound pallet and the outbound pallet are located in racks far from each other. In these cases, the operator can ignore to pick up inbound GSPs or skip picking assignments and focus on one flow only. This mainly occurs when the pickers fall behind on their pick-lists.

4.1.3 Resources

Inbound and outbound activities share the same resources. This creates a need for prioritization of how they should be distributed or re-distributed. The general rule is to prioritize the outbound flow as it is connected to the service level and the measured KPI's whilst the inbound flow does not affect those KPI's in the same way.

4.1.3.1 *Personnel*

The personnel are divided in two schemes that together make sure that the warehouse is staffed every hour of the day and some hours of the weekend.

The day scheme is comprised of four teams with seven operators in each team. They are rotated around a four-week schedule, working three weeks as a day shift and the fourth week as the evening shift. The dayshift is divided into three areas, not necessarily the same amount of operators in each team, as this depends on the current workload. One team is responsible for the first floor, one team for the second floor and the third team are spread out over the three remaining floors. The teams are self-governed in the sense that they are responsible to make sure that all responsibilities in their area are covered. They decide who works at what station at the regular startup meeting every morning before they start working. See table 16 for the structure of the different shifts.

Operators who work in the shift-scheme work according to a rotation schedule; one week nights with start on Sunday and end on Friday morning, one week evenings, with start Monday and end on Friday, one week days, with start on Monday and end on Saturday and then one week off. This rotation scheme has been in place from 1st of April 2013, where there now is a more even distribution of personnel throughout the day.

Table 16 - Summary of the shifts in Gothenburg

Teams	Working hours	Breaks	Work days	No. of People
Day-Scheme				
Day	06:48-15:30	09:00:09:18 11:18-12:00 14:00-14:18	Monday-Friday	21 (3x7)
Evening	14:00-22:00	30min When depends on workload	Monday-Friday	7
Shift-scheme				
Night	21:48-06:00	02:00-02:20	Sunday-Friday	5
Evening	13:48-22	30min When depends on workload	Monday-Friday	5
Day	05:48-14:00	09:00-09:20	Monday-Saturday	5
Off-work			Monday-Friday	5

The warehouse used to have temporary staff as a tool for adjusting the supply of capacity, which they could utilize the same day in order to increase the capacity. This option is today much harder to use for several reasons. Where the most significant reason found, was the fact that they haven't used this option for some time and the access to trained staff is limited. See figure 19 for a graph over the maximum capacity during a regular day. On a normal day the staffing is on average 92%. This number takes only short-term absences into account. Observations has been made where the operators sometimes take longer breaks than agreed, making the idle-time longer than it should, which affects the current capacity. This observation is not general for the entire workforce and believed to be isolated happenings.

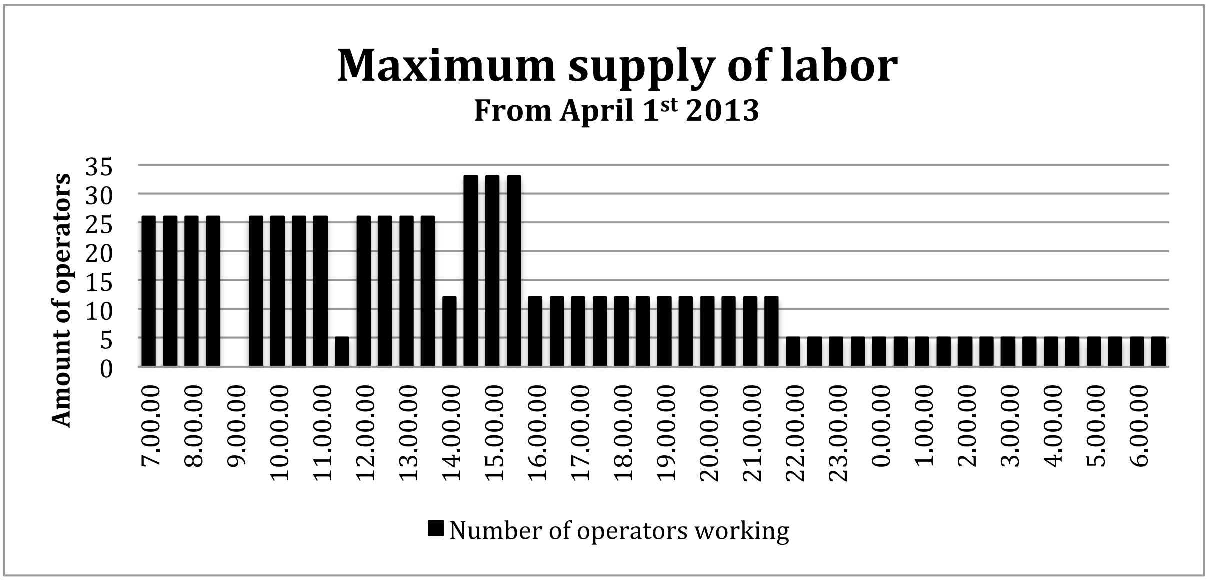


Figure 19 - Maximum supply of capacity with 100% attendance

4.1.3.2 *Team-leaders*

To coordinate the work and secure that goods are sent away according to the delivery schedule, there are four team leaders. Their job is to makes sure that the operations run smoothly and that available resources are used in an efficient way. They try to even out the workload for the picking assignments by sending operators to the floor in which the capacity is needed the most. They rotate around four positions:

- Goods receiving – Help out and coordinate work on floor-1 so that the buffer does not get clogged and that the oldest GSPs are sent up first.
- Order handling – Coordinate work regarding order picking, packing and loading. This person is also responsible for releasing orders for the early shipments while the rest is taken care of by customer service.
- Quality – Handles return of damaged inbound GSPs and quality problems related to the outbound flow e.g. wrongly picked orders.
- Evening – Coordinate work that takes place during the evening.

The team-leaders should be out in the warehouse 20% of their time but try to be out more if time allows. This depends greatly on their current position and back-office workload.

When problems occur, it is the team-leaders responsibility to handle the situation. The operators can call any of the team-leaders who then decide what actions are to be taken. If it is severe enough they will call for external help otherwise they will handle it by them selves.

4.1.3.3 *Work areas*

This section presents the different work-areas within the Gothenburg warehouse, grouped according to floor. It also states the responsibilities for the operators working evenings and nights.

Floor-1

- Vertical elevator – Empty the conveyor belts and make sure that the elevator always is running smoothly. Also responsible for put away goods designated to the LAD-1 storage area.
- Storage area E – Picking orders from storage area E and put away inbound goods designated for that area.
- LAD-1 storage – Picking goods from LAD-1 storage area and put it in the elevator for transportation to floor-2, as well as fetch goods from the buffer next to the vertical elevator and transport it to the elevator.
- PLO-1 storage – Put away/pick full GSPs on floor-1.
- Picking – Picking orders from the high rack storage.
- Goods receiving – Manage the inbound area by emptying arriving trucks, sort GSPs according to the floor and load GSPs into the elevator.

F**loor-2**

- Packaging – Responsible for checking the weight of the GSPs, print a transportation label and stripe them if needed.
- Loading – Responsible for picking GSPs from the conveyor belts, consolidate them into full shipments and then load them onto a truck or container.
- LAD-2 storage – Picking from LAD-2 storage area.
- Packaging – Products are packed into parcels, not GSPs, for shipment.

Floor-3

- Order Picking – Picking less-than-full-GSP-orders from the high rack storage.
- Side-loaded forklift – Picking full GSP-orders and put away inbound.

Floor-4

- Order Picking – Picking less-than-full-GSP-orders from the high rack storage.
- Side-loaded forklift – Picking orders of full GSPs and put away inbound goods.

Night and weekend

- Vertical elevator – Same responsibilities as during the day but more emphasize on helping out other operators.
- Goods receiving – Same responsibilities as during the day.
- Side-loaded forklift on floor-3 – Put away.
- Side-loaded forklift on floor-4 – Put away.
- Load outbound trucks – GSPs that are ready for transportation are fetched from the outbound area and loaded into the transportation unit.

The operator responsible for the vertical elevator is supposed to help out with other duties when the operator has time. However there are some operators that persist on only being responsible for emptying the elevator, similarly to the day shift when there are more people working.

4.1.3.4 *Resource distribution*

The schedule for the next day is created in the afternoon before the team-leaders end their shift. It only shows what floor the workers should be at and does not specify what work area he or she should be at. To determine how many are needed on each floor they look at what resources are available and how many are absent together with what types of order-lines are released in WASS. Areas that must be covered at all times are first secured and the rest of the available workers are then distributed according to capacity needs. At the start of the morning shift the schedule is then re-evaluated and corrections are made if new information about additional absents or change in picking volume have surfaced. Even if an operator is assigned to a certain area he or she is encouraged to help out elsewhere if there is time or need.

The team-leader who has the position of order handling, monitors the outbound flow throughout the day to if there is a need for changes in the distribution of resources. He or she checks the type and amount of released orders in WASS as well as talks to customer service about the current situation. This person rotates only the order-pickers while the team-leader who is responsible for goods receiving are responsible for the re-distribution of personnel on floor-1. In the evening, the team-leader talks to the customer-service department about the current workload and how resources should be distributed.

Breaks are spread out, making sure all operations are not idling simultaneously, except for one hour during the lunch break. This creates an uneven distribution of working capacity throughout the day. This could cause situations where operators are hindered to work as someone else is on break. The following situations were found during the data gathering:

1. The operators who drive the narrow aisle forklifts on floor-3 and 4 prioritize outbound goods and therefore do not empty the inbound conveyor-belts, preventing the operator on floor-1 to load the elevator with additional inbound goods, causing a disruptive flow.
2. A truck has arrived to floor-1 with goods from SKF Poznan or SKF Mekan and is waiting to be unloaded with the responsible operator being on a break.
3. The operators handling the weighting stations have their breaks while operators on floor-3 and 4 still are working. The team-leaders should help out during the breaks but they are not always available.

4.1.3.5 *Equipment*

The primary resources are the forklifts. All forklifts are equipped with scanners and connected to the warehouse IT system WASS, see Chapter 4.4.1.2 for further description of WASS. It is therefore possible for operators to receive picking orders and report inbounded goods directly from the forklift. When an operator accepts a new picking order he or she will see it on their screen where the GSP is located and a transportation label will be printed out in the forklift to attach on the GSP before it is sent down. Similarly the operator will see on the screen where WASS suggests is the best place to put an inbound GSP.

The distribution of the forklifts between the floors depends on the workload and where the most picking assignments are. It is possible to move a forklift from one floor to another through a large elevator. There are three different kinds of forklifts that are used in the warehouse: Side-loaded forklifts, counterbalanced forklift and order picking forklift.

The standard for packaging GSPs are on half-EUR pallets with two pallet collars. If there are fewer products in the GSP then what are required for two collars, only one collar is used. The maximum height of a GSP is three collars, as more collars would result in that the GSP would not fit in the high-racks. When they are deep-stacked, as they are in the buffer area on floor-1, they are stored with maximum of five GSPs high.

Some goods from Factory-D are not suitable to store with GSP collars and are therefore only strapped to the GSP without any other external protection. They are consequently harder to deep-stack, as they only can be stored three high.

4.2 Schweinfurt

This section covers how the warehouse in Schweinfurt operates. It presents the layout, the materials handling activities and the resources used to conduct the different operations within the warehouse. See appendix G for a picture of the layout.

4.2.1 Warehouse layout

The warehouse in Schweinfurt is an international warehouse and the same type as the warehouse in Gothenburg. The major part of their storage goods is from their own factory and goods designated for the German market, but they also store some components and raw material for the production facilities. The warehouse is also a hub for cross-docking goods for the German market and Eastern Europe.

The warehouse is located in the same area as the two other manufacturing plants, for which they serve as storage location. All goods that will be stored in the warehouse are inbounded at the goods receiving area while cross-docking goods and outbound goods are handled in the outbound dispatch area for shortest possible transportation distance.
The warehouse is built in one floor with an automated storage system as the primary storage method that has a capacity of handling 180 GSPs/hour. The picking storage is however regular high-rack storage used by the picking trucks. The major transportation is made through a conveyor system, transporting the GSPs to and from storage.

4.2.1.1 *Goods receiving*

The warehouse has three loading docks located right next to the automated storage and retrieval system and handles external goods only. Internal goods are offloaded outside of the warehouse from the loading zones.

External transports

The warehouse does not have slot times for their external inbound transports, similar to Gothenburg. However, they assign all trucks a certain time that they should arrive at the docks. Their control method is instead focused around a first come-first served-principle. Management believes this is a better system due to traffic problems and that it can be extremely hard for drivers to calculate an exact arrival time.

Internal transports

The warehouse management argues that there really is no need to know when the internal trucks arrive as the containers only contains around 15-24 GSPs at the same time, while there is a greater need to know when the external trucks arrive as they can carry up to 80 GSPs at the same time.

The inbound area is directly connected to a buffer where goods can be temporarily stored if the conveyor belts capacity is not enough, e.g. due to several transports arriving at the same time. The buffer can be accessed from three ways, eliminating the risk of GSPs being blocked. The two factories work around the clock while the warehouse only work between 06:00 and 22:00. As a result there is a workload peek at the start of the shift at 06:00. If there is not enough capacity to put GSPs on the conveyors they are loaded into the buffer and put away later the same morning. The buffer is by rule emptied every day so that no GSPs are left over night. There are a few exceptions to these rules, e.g. if there is a large container arriving at the end of the shift. In that case the area will be emptied in the morning.

When there is a problem with GSPs they are lined up, with walking space between the rows, in the middle of the inbound area. The most common problem is that the scanners cannot read the barcode on the labels due to different standards. It occurs mainly from destinations that do not have the same capabilities e.g. India and Mexico.

All GSPs are automatically weighed and measured before they are sent away to the automated conveyor belts. If a GSP does not fulfill the requirements there is a manual quality station on the other side of the conveyor belt, where GSPs are checked. If necessary, they are sent back to the factory or repacked on a new GSP. From here, there is a conveyor belt leading up to the high-rack storage, where the goods are stored.

The conveyor has six loading belts, four for regular and two for urgent shipments, which merge into one before the quality-station and then goes into an automated elevator. This elevator operates between two floors only, and the connecting conveyor belt on the second floor leads into the high-rack storage location. The conveyor belt sends the GSP to the right destination with the help of ID-scanners, making it a very robust automated storage system.

EUR-pallets are also inbounded together with all other goods but since the conveyor belts cannot handle EUR-pallets they are stored separately in their own high-racks adjacent to the outbound area. The EUR-pallets are therefore driven to the other side of the warehouse for storage. However, there are currently building a new inbound gate for EUR-pallets right next to their storage location in order to reduce the internal transportation. Some products are too big to be stored on a EUR-pallet, and are instead deep-stacked next to the dispatch area.

4.2.1.2 *Picking and Packing*

There are two types of retrieval orders: replenishment of picking location and full GSP orders. When a picking location reaches the re-order point an automated order is sent through WASS to retrieve a new GSP and send it to the unpacking station for preparation before being transported to the high-rack picking location. The unpack station unstraps the GSP, takes of the lid and removes unnecessary protecting plastic. Full GSPs are retrieved in a similar manner and sent by the conveyer system to one of two packing stations. There are two packing station available but the second station is only used for high volume days when the first packing station cannot handle the volume.

Less than full GSP picking is done in a separate location from the automated storage system. Picking has its own high-racks, which is continuously replenished having 19000 storage locations. The picking locations are determined through an ABC-classification where category-A products are located in the center of the picking area and category-B and C located towards the sides.

The packing stations for picking-assignments have two functions; preparing an empty GSP for the forklifts to pick up at the start of a picking assignment and pack the finished picking assignments. The station is designed to allow a smooth flow where the forklift enters inside the packing station and slides off a GSP with a finished picking assignment to the left and at the same time slides on an empty GSP from the right.

Products packaged in box cartons, due to their size, have a separate packing station where they are handled. They are handled in the same way as GSPs but in a smaller system where they are sorted on a conveyor belt into destinations and then consolidated with other boxes into GSPs.

4.2.1.3 *Outbound*

The outbound operation is similar to the operations in Gothenburg, where goods are sorted and consolidated after destination in buffers. The buffer is located in the middle of the warehouse, which gives the operators the ability to pick goods from both sides of an isle of GSPs, although some goods are stored against walls, but this is mainly cross-docking goods in the outbound room where space is more limited. The buffer zones are floating and their size can be adapted to the shipments need. They are marked by painted lines together with signs hanging from the ceiling for easy identification.

The picking is generally done the day before, which increases the amount of goods in the dispatch area. The reason for this is to have a buffer against uncertainty and same day orders.

4.2.2 Materials Handling Activities

This section covers the activities of handling the GSPs in Schweinfurt.

4.2.2.1 *Inbound flow*

The incoming goods come from different destinations. They are grouped as internal and external goods, depending on if they arrive from the adjacent factory or from other places further from the warehouse. The internal goods are sent via a 3PL-provider from the factory to the transportation docks in the warehouse. The flow is initiated by the forklift-operator in the factory, pushing a button when he has filled a container with goods. This signals the 3PL-provider to pick up the consignment and take it to the dock at the warehouse. This throughput-time (from pushing the button to arrival at warehouse) should be 60 minutes at most. These containers usually consist of 15 GSPs and there are about 34 containers arriving to the warehouse docks each day. However no arrivals occur on Saturdays and Sundays, as the warehouse does not operate on weekends.

The external transports arrive at random times, but the transport planners at SLS tries to level out the arrival times to even out the product flow as much as possible. There are about 20 daily truck arrivals, consisting of roughly 80 GSPs each.

Step 1: The truck arrives at the inbound docks and the driver notifies the supervisor on duty. The supervisor checks so that the right amount of goods is on the truck and then notifies an operator how many GSPs should be offloaded and hands over responsibility to that employee.

Step 2: The operator then takes the GSP onto one of three conveyor belts where the automated system takes over. If there is no space on the conveyers, the GSPs are placed on the warehouse floor just inside the dock on a designated area. Important to notice is that the consignment is put in the middle of the floor in order to access it from both ends. This is important as they are working according to the FIFO-principle, so the GSP put furthest in should be the one taken out first.

Step 3: The GSP is transported through an automated checkpoint where its size is confirmed. The GSP can have one, two or three GSP collars, and depending on which one it has it will be given a designated spot in the storage rack. In this step, WASS designates a storage location for the GSP.

Step 4: It is then sent to the second checkpoint where the theoretical weight is checked with its actual weight. There is a tolerance (+/- 3%) e.g. if the GSP is wet, but if it however should differ more than that, it is being pushed onto another conveyor belt leading to a manual quality station where the goods are checked. If they are within the weight limit, they are sent onto an elevator, taken one floor up where another conveyor belt takes them to the automated storage.

Step 6: The system scans the GSP automatically when arriving to its designated storage area and the inbound flow is complete.

The throughput-time from put on the inbound floor to registered in storage is a matter of hours, if not minutes. There is always an emphasis on taking the goods directly from the inbound transport to the conveyor belt leading to the storage racks, but if several transports arrive at the same time they are first offloaded onto the floor and then put on the conveyor belt.

4.2.2.2 *Outbound flow*

The outbound flow is comprised of three flows; two designated to external customers and one for internal customers. The external flows are comprised of full GSPs and picking assignments, whilst the internal flow is the replenishment of new picking pallets from the high bay-storage to the picking-area.

Full GSP:

Step 1: The order is released automatically from the order handling system, International Customer Service System (ICSS) to WASS, WASS fetches the GSP from the storage racks via conveyor belts (dedicated to the outbound flow) to the outbound area. The supervisor, responsible for managing an even outbound flow within the warehouse, determines which of the two packing stations it should be sent to in order to keep an even flow between the two.

Step 2: As the storage area is located one floor above the regular warehouse floor, the GSP is transported down via one of two elevators to the respective weighting station where it also is being labeled.

Step 3: From here, a forklift-operator takes the GSP and puts it in the designated outbound-spot depending on its destination. These spots are floating, which means they are changed every day in order to cope with different sizes on the transports.

Step 4: The operator then put the goods onto the outbound truck and the outbound goods for full GSPs are complete.

Picking assignments:
Step 1: The order is released automatically from ICSS and the supervisors then determines when the order should be picked.

Step 2: A forklift-operator takes an empty GSP from one of the three picking stations and tells WASS to give him or her an assignment.

Step 3: The picking order that should be finished the soonest it prioritized by WASS, and sent to the operator. He then picks the different items from the picking storage and return the complete picked GSP on a conveyor belt adjacent to the empty GSPs used in step 2. Important to note is that the high-rack storage situated one floor above is not the same storage area as the picking storage. This will be explained in more detail shortly.

Step 4: Similarly as with full GSPs, the picked GSPs are weighted and labeled and then ready for being sent to its dispatch area.

Step 5: A forklift-operator moves the goods to the pre-determined outbound area where it is consolidated with other packages outbound for the same destination.

Replenishment of picking storage:
The picking storage is replenished through the automated storage. The conveyor belts used for the outbound goods are also used for this purpose. The GSP is sent via its own dedicated elevator down to the first floor where it is put on a conveyor belt. This belt can hold approximately 10 GSPs and is continuously off-loaded by a forklift-operator, who replenishes the picking storage with these products. The products on these racks are grouped according to an ABC-analysis.

It is possible to place an order until two hours before departure. The reason is to be flexible towards customers but at the same time have buffer to cope with any problems prior to departure.

4.2.3 Resources
Resources in the warehouse are not shared between inbound and outbound activities as they are in Gothenburg. The resources are instead divided into three areas: goods receiving, picking and packing and outbound, where each area has its own personnel and equipment. Even as demand for capacity varies over time, the same amount of resources is kept in each area. There are some situations where one area could borrow resources from another area. One example is if it is little to do in the picking area, some operators will be sent to help out to load full GSP-orders in the outbound area.

When deviations occur, there is a clear and short line of communication between workers, supervisors and support functions. It is a clear focus on elevating problems and deviations immediately. The manager for Quality and Environment spends roughly 40% of his time in the warehouse to investigate and talk to people about current problems.

4.2.3.1 *Personnel*

There are two shifts working in the warehouse, where one shift works during the day and one shift during the evening. The personnel rotate between the two shifts, working one week, days and one week, evenings.

Table 17 - Summary of the two shifts in Schweinfurt

Teams	Working hours	Breaks	Work days	No. of People
Day	06:00-14:00	08:42-09:00 11:30-12:00	Mon-Fri	54
Evening	14:00-22:00	18:00-18:30	Mon-Fri	47

As there are no rotations between the areas there is a clear understanding of how many operators are available in each area. There are 5 operators in goods receiving during the day and 4 during the evening, 41 operators in picking and packing during the day and 37 during the evening and 8 operators in outbound during the day and 9 during the evening.

If there is need for extra capacity, management can schedule additional work time for the personnel, so that they start working earlier in the morning or work later in the evening. There are some regulations for how this can be used, as workers never can have more than 100 hours of saved overtime. When this happens the operator have to take a week off to reduce their time account.

4.2.3.2 *Work areas*

This section presents the different work areas in the warehouse.

Goods receiving

- Unloading – Responsible for unloading arriving trucks and put the GSPs on the conveyor belt if possible, otherwise put them in the buffer zone or on the floor in the middle of the inbound zone.
- Quality checkpoint – If the weight of the GSP is incorrect, it needs to be checked so the right product and quantity is in the GSP.
- Return goods – returning goods reported into the system and put in storage.

Picking and packing

- Order picking – Picking less than full GSP orders from the high-rack storage.
- Packaging – Responsible for packing GSPs prepared by the order pickers. The weight is checked, it is being striped and a transport label is printed.
- Consolidating orders – pick up GSPs from the packing stations and put them in the outbound area.

Outbound

- Load trucks – Pick GSPs from the dispatch area and load them onto a transportation unit.

4.2.4 Equipment

The equipment is very similar to Gothenburg. However, the conveyor belts are executing most of the movement inside the warehouse, as forklifts are mainly used to consolidate orders and load them onto a transportation-unit.

Every morning the managers see what type of orders are to be picked and then distribute the workers after what type of forklift they need. The same rule applies to equipment as to personnel, where they are not shared between the work areas. If there is a great need for extra equipment they can borrow this from another work area.

The main types of packaging are the same as in Gothenburg with two-collar-GSPs. The warehouse is also equipped to handle EUR-pallets. Goods are stored on EUR-pallets due to special customer requirements.

Some bearings produced in Schweinfurt, e.g. for wind turbines, are extremely large and require special boxes. They are custom made for the bearing and have built in legs that make them accessible for forklifts.

4.3 Tongeren

This section covers the European Distribution Center (EDC) in Tongeren. It goes through the warehouse layout, the materials handling activities and the resources used.

Tongeren is located in the eastern part of Belgium, close to the German border. The warehouse consists of three buildings: MWH (Main warehouse), WEC 1 (Warehouse External Customers 1) and WEC 2 (Warehouse External Customers 2). MWH handles all ordinary goods flowing through the hub while WEC 1 handles all cross-docking goods and non-standardized picking/packing and WEC 2 is dedicated to external customers. As WEC 2 only stores goods for external customers that warehouse will not be a part of the benchmark study.

4.3.1 Warehouse layout

EDC is categorized as a regional distribution center. The main difference compared to Gothenburg and Schweinfurt is that it serves a different market with lower volume in each order. (See appendix H and appendix I for layout).

4.3.1.1 *MWH*

The main warehouse handles all major product flows going through the Tongeren facility. There are five inbound docks, which are directly connected to the two conveyor belts dedicated only to inbound goods. From here, the goods are sent to an automated storage and retrieval system.

The picking operations in the warehouse is organized in what most similarly can be described as packing cells, where the forklifts either fetch empty GSPs, to begin picking, or drop off a GSP, from a finished picking assignments.

There are three heavy picking-stations and two unpacking-stations, dedicated for replenish the high-racks for picking goods that connected directly to the high bay-storage via conveyor belts. Furthermore, there are three packing-stations for less than full GSP and four additional stations for smaller carton boxes.

The packing area for less than full GSPs consists of four stations, each capable of handling 10 GSPs at the same time. When packed, the GSP is taken to the outbound area located only meters away, depending on which dock the goods are supposed to depart from.

All loading-docks are equipped with electrical light boards, which notify when a truck should arrive or departure, and how many GSPs should be off-loaded.

4.3.1.2 *WEC 1*

Cross-docking goods are received through one of the twelve docks, which are equipped with electrical boards, making it possible for the operators to see how many GSPs are supposed to be offloaded, where the truck comes from and the goods final destination. Within this area, there are storage racks covering the 20-meter high walls on all sides, and besides this there is also space in the middle where goods can be temporarily stored while handled. The products are grouped according to destination.

The non-standardized picking/packing-products are located in the same building, grouped according to an ABC-analysis. This means that products being picked most frequently are located closest to the picking-station to minimize travel distance. There is one picking/packing-station for heavy goods and one station for lighter and smaller goods. The smaller goods-area has one conveyor belt where all finished boxes are placed. This belt is then dividing the flow in 24 packing stations depending on their destination. The station for heavy picking has one belt in total, making it easier to follow the FIFO-principle.

4.3.2 Materials handling activities

The chapter describes the material handling activities for MWH and WEC 1.

4.3.2.1 *Material Handling Activities MWH*

This sub-chapter describes the materials handling activities conducted in MWH

4.3.2.1.1 Inbound

Goods are first received through one of the five docks dedicated only to inbound trucks. The operator fetches the GSPs from the truck and directly puts it in on one of the two inbound conveyor belts. However, goods arriving from certain countries must receive clearance from customs before proceeding, making a buffer zone necessary before the conveyor belts. Next part of the inbound flow is a quality check. It is conducted to check weight and measurements to secure that the GSP is according to standard. This step is the same as the one conducted in Schweinfurt.

The GSP is taken with conveyor belts to the high-rack storage. The storage is about 100 meters deep, 25 meters high and has a capacity of storing 60 000 GSPs. Products are grouped according to an ABC-analysis, and at the same time spread out in several aisles to hedge against a breakdown on one of the seven automatic cranes. The total outbound capacity is estimated to 200 GSPs/hour regardless of GSP standard.

4.3.2.1.2 Outbound

When a retrieval order from the automated storage system from WASS is received, the system send the GSP to one of four areas: replenish the picking/packing storage in MWH, replenish the picking/packing storage in WEC 1, outbound assignment for full GSP or outbound for heavy picking (>17 kg).

Replenish picking/packing storage in MWH:
GSPs are taken via conveyor belts to one of three stations. From here, a forklift-operator fetches the GSP and puts it in a designated GSP location in the picking/packing storage. WASS automatically suggests a spot for the GSP depending on what is available and in accordance with the ABC-analysis.

Replenish the picking/packing storage in WEC 1:
Via conveyor belts, it is sent to a station similar to the three stations for replenishment of the picking/packing storage in MWH. A forklift-operator takes the GSP from here to another conveyor belt taking the GSPs to the other building, as mentioned earlier.

Outbound assignment for full GSP:
It is automatically transferred to a packing station adjacent to the above-described stations. An operator controls the weight, prints a transport label and takes it to the outbound zone.

Outbound for heavy picking (>17 kg):
The GSP is received in the station and the desired number of parts is picked from the box with the help of lifting equipment. These are loaded into a new GSP and the other one is sent back to the high bay-storage.

Picking:

Picking is done with forklifts from another storage location with high-racks. WASS tells the operator what goods and in what quantity should be picked and also gives suggestion to what packaging alternative should be used, either GSP or cartons. When an assignment is finished the GSP or box is dropped off for weighing and labeling. After being packed, the GSP and box are positioned in front of one of the seven outbound docks depending on their destination. When a truck arrives, a forklift operator loads the goods into the trailer and the outbound sequence is complete.

4.3.2.2 *Material Handling Activities WEC 1:*

The WEC 1 activities consist of picking and packing, offloading and on-loading cross-docking goods as well as replenishments of the picking/packing-storage locations.

Picking and packing is executed via two stations, one station for full GSPs and one for carton boxes, where the operator first fetches an empty GSP and returns to the station for strapping and labeling the GSP. Picking-assignments are handled in the same way as the other warehouses, through WASS.

Replenishments are done via MWH through a conveyer belt connecting the two buildings, and are automatically initiated. The GSP is from the conveyer taken with a forklift directly to its designated storage location, determined by WASS.

There are five employees dedicated only to the on- and offloading of trailers. When the trucks arrive the operators off-load the GSPs and sort them in the middle of the outbound area. If for some reason cross-docked goods have been offloaded in MWH, the conveyor belt connecting the two buildings transports the GSPs to WEC 1 in the same way as the replenishments of the picking/packing-storage area. There is in total 12 docks for both inbound and outbound goods.

4.3.3 Resources

Fast and rapid communication is very important in EDC. Management emphasize that it is of great importance that everyone knows what is going on and that information must run frictionless through all levels of the organization. When there is a problem, similar actions are taken in Tongeren as in Schweinfurt; operators call the technical department to elevate the situation in order to take action.

Management further believes in discipline and flexibility, as a way to handle the uncertainty. They emphasize the importance of never being idle and that everyone should be busy with something. If however personnel are idle, they should be redistributed to help another work area to level out the capacity. As a control mechanism for this, they conduct spot checks for; when operators take a break, how long these breaks are and when they quit. By doing this, they can monitor the actual working time for each operator, providing transparency in work ethics. The most important aspect of this is the security of knowing that everyone is productive and work as they should.

4.3.3.1 *Personnel*

EDC employs roughly 180 people within warehouse operations. They are divided into three shifts, working around the clock. The three shifts are distributed according to a day shift, an evening shift and a night shift (Table 18). To organize and control these, there are two planners and one supervisor responsible for each shift. The planners are responsible to coordinate the work and make sure that the workload is evenly distributed while the supervisor has the overall responsibility.

Table 18 - Summary of the three shifts in Tongeren

Teams	Working hours	Breaks	Work days	#People
Day	06:00-14:00	08:00-08:10 10:00-10:30 11:30-11:40	Mon-Fri	60
Evening	14:00-22:00	16:00-16:10 18:00-18:30 19:00-19:10	Mon-Fri	60
Night	22:00-06:00	00:00-00:10 02:00-02:30 04:00-04:10	Mon-Fri	60

4.3.3.2 *Work areas*

There are 10 work areas in MWH and 8 in WEC-1. These areas range from:

- Unloading trucks
- Preparing GSPs
- Picking
- Packing
- Loading

The amount of workers in each area is highly dependent on the current workload. It is therefore difficult to generalize how many workers are suitable for each area. As a result, the staff is cross-trained and supervisors keep a detailed schedule over every workers skills and capabilities in order to assess what competence is available each day.

Certain positions require more or finer skills, which means that some operators are more frequently used in certain areas. These areas are for example loading of trucks, as this task requires certain skills about how to load a truck and make the weight evenly distributed in the trailer.

Operators are further not rotated between the different shifts and there is also a limited rotation between the warehouses. There are approximately only 10-15 operators trained in the other warehouses operations, but these tasks are fairly limited and linked to routine tasks.

4.3.3.3 *Changing capacity*

The environment in EDC is different and less predictable compared to Gothenburg and Schweinfurt. As a result they have become very flexible in terms of increasing or decreasing capacity. This is possible due to the use of temporary workers hired through an agency pool. By using the agency pool, they have the ability to change their outbound capacity by 30% within 48 hours.

Every Thursday morning there is a resource meeting with the warehouse manager, the supervisors, the planners and a representative from the agency pool deciding how many workers will be needed during the next week. The desired amount of workers is first determined by checking how many regular operators are absent due to e.g. sickness, holiday and study-leaves. The group then analyzes the net change in order lines for the previous week: number of picked order-lines vs. number of incoming order-lines. The change is then compared to last year's data.

On Tuesday mornings there is a follow-up meeting where the previous Thursday is evaluated to see if there is a need for adjustments in the schedule. They then have the possibility to make changes in this week's capacity depending on the amount of order lines.

The work schedule for the next day is created in the afternoon, confirming the amount of operators needed for tomorrow. However, this is not a fixed schedule and planners evaluate the actual capacity on each workstation every 30 minutes to level out capacity. Operators are informed about these rotations via messages sent to their computers in the forklifts.

There are two additional tools used to change the capacity: order pulling and less than fulltime staff.

When an order is placed in WASS, depending on the order type it is scheduled a certain number of days ahead. If there is excess in capacity, it is possible to pull an order from a later date to increase the workload. By doing this they can use the available excess-capacity right now and decrease the demand for operators in the next days i.e. reduce the number of temp workers or allow more holidays.

The "less than full time"-staff is SKF employees that work a certain number of days each week. They are people who either go to school or have other businesses, working mainly Mondays and Thursdays.

4.3.4 Equipment

The equipment used in EDC is similar to the equipment used in Schweinfurt and Gothenburg. There is however a larger amount of picking equipment, as the order-lines per order is higher and the volume of each order is lower.

Due to the need for flexibility and ability to move operators from one work area to another, if the amount of a certain type of order-line increases, they need more forklifts than operators. This fact lowers the equipment utilization rate but increases their agility to changes in short-term demand.

4.4 Tracking and control systems

This section covers the information technology-systems used at SKF. It will go through the primarily systems used, which are directly connected to the warehouse operations.

4.4.1 IT-systems

The same warehouse management system, WASS is used for all three of the warehouses that are a subject of this thesis. Gothenburg and Schweinfurt has a common order handling system while Tongeren uses a separate system. WASS and the order handling system ICSS will be described in the next two sections.

4.4.1.1 *International Customer Service System*

The interface between sales-, production- and warehouse systems is called the ICSS. The systems main purposes are to bring orders together for both external and internal replenishment, check orders against availability, and allocate stock and delivery-time fixing. ICSS also determines from what warehouse the product should be shipped depending on what the stock availability is and where the customer is located. This means that a product can be picked from one warehouse and routed through another before it is delivered to the customer.

4.4.1.2 *Warehouse Administration Service System (WASS)*

The control system that all larger warehouses within SLS use is called the Warehouse Administration Service System (WASS). Its purpose is to control the flow through the warehouse and help reduce friction in the various activities executed in the warehouse. The system supports all necessary activities and functions needed in a large warehouse: inbound goods, replenishment, picking and packing, loading and inventory control. The system operates in real-time and has the capability of communicating with other systems e.g. customer order handling, transport arrangements, production planning etc. WASS also has the ability to communicate with other internal control systems within the warehouse such as conveyors, AGVs and automated storage and retrieval systems.

Forklifts within the warehouse are equipped with computers and scanners connected to WASS. It is therefore possible for operators to directly receive assignments created by the customer order handling system. Picking lists are arranged and released so that goods are picked as short in time as possible before the transport leaves. The real-time capability also allows supervisors to have a continuous control over how much is picked and if they are according to schedule.

WASS also helps putting away inbound goods by suggesting where the best location for storing a unit is, both in terms of establishing a smooth flow but also in terms of size and physical similarity.

4.4.1.3 *Release of orders*

In Gothenburg, the transport department is the gatekeeper. They are responsible for creating trips according to the agreed throughput-time and maximize the utilization-rate. They consolidate orders into one transport consignment to reduce the handling activities for shipments sent to the same destination.

Customer orders are first received through ICSS and then checked against stock availability. If there are enough goods in stock, a pick-list is created in WASS and planed onto a transportation unit. All truck-transports are generally planned 24 hours prior to departure. In general, orders scheduled in the afternoon are released in WASS in the morning and picked soon after. Orders sent in the morning are however not released by the transportation department but by the team-leaders.

Due to the short picking-time, the transport department has more time to move and re-arrange orders. They can also pull order from a later date onto an earlier transport. This is not done to optimize resource utilization but rather the fill-rate, which is of great importance. As a result, the picking time is shorter and the fill-rate is almost 100 %.

In Schweinfurt, the supervisors release the orders in a similar manner as the transport department in Gothenburg. Orders are released the day before being scheduled on a truck. This is done to hedge against variability and secures handling-capacity for rush orders. In Tongeren, the planners release the orders' as they are the personnel with best understanding of the flow and current workload.

4.4.1.4 *Planned RTW lead-time*

The planned RTW lead-time differs between the warehouses. The SKF Poznan-flow in Gothenburg has 4 days from receiving goods until being available in storage and ready for picking, whilst Factory-D and SKF Mekan has 3 days. Schweinfurt does have an agreed RTW lead-time for their inbound goods, but it is not monitored since the agreed lead-time is far below the goal. Tongeren has 2 hours to empty a truck but no fixed RTW lead-time for when it is supposed to be available in storage.

The planned RTW lead-time for outbound orders from Gothenburg with destination Schweinfurt or Tongeren is 15 hours. The orders are released 06:48 when the morning shift starts and the orders must be executed before the cut of time at 22:00. Schweinfurt and Tongeren do not plan around the same throughput-time, as they instead apply backwards scheduling. From the cut-off time, 2 hours before the departure time it is calculated how much time the operators will need to pick all assignments in a trip, package them and load them onto the truck. The characteristics and size of the trip will then determine how much time the operators will need to finish the assignment.

Table 19 - Summary of the internal planned RTW lead-times

Throughput-time	Gothenburg	Schweinfurt	Tongeren
Inbound	72 hours	N/A	2 hours to empty a truck
Outbound	15 hours	N/A	N/A

5 Analysis and results

This chapter presents the analysis and results of the inbound flow in Gothenburg. The analysis was conducted by combining the model for analysis, presented in chapter 2.5, and the empirical findings. The chapter will end with answering the research questions presented in chapter 1.3.

5.1 Process design

This section analyzes the flow with regard to how the inbound processes are designed and performing to identify specific activities, routines and standards that are not designed to fit the flow.

5.1.1 Goods Receiving

From what has been seen in figure 10 it is clear that there is a low level of coordination of inbound transports except for the continuous flow from Factory-D. Several interesting aspect has been found in the empirical data from the three flows. Noted in empirical findings of this report, section 4.1.1.2.1, there are regulations for when trucks should arrive, e.g. the trucks from SKF Mekan should arrive in the evening, but as the arrival-times is not evaluated by the warehouse department, a high level of uncertainty is possible.

5.1.1.1 *Factory-D*

Bearings manufactured in Factory-D are sent to the warehouse by forklift and conveyor belts, which make it unnecessary to apply slot-times. Looking at the variation in the inbound flow from the Factory-D (figure 10) it is a stable and smooth flow that is easy to predict, with an average inbound 11 GSPs/hour and a standard deviation of 4 (see appendix K for calculation). Further examination of figure 10 makes it clear that the incoming GSPs from the factory fluctuate between 2 – 16 GSPs on average per hour. This flow would become subject of investigation as the relative fluctuation between 2 – 16 is about 800%, but seeing to absolute numbers, this flow is rather even compared to SKF Poznan and SKF Mekan.

5.1.1.2 *SKF Poznan*

Trucks arriving with goods from SKF Poznan have greater fluctuations than Factory-D. The trucks have been observed to arrive in the morning around 08:00 and until 16:00, with most goods arriving after 15:00. Comparing this with Factory-D, it becomes clear that this flow is prone with heavier fluctuations in arrival times, making it harder to predict as they occur more in a random manner. The average inbound flow of GSPs is 5/hour with a standard deviation of 12 (see appendix K for calculation). The uncertainty in the flow together with randomness in the arrival of the trucks increases the importance of strictly controlling the flow in order to coordinate these transports with the other warehouse activities.

Two main reasons have been found in the empirical data as to what causes the uncertainty: a lack in internal control and the distance between SKF Poznan and Gothenburg. The route includes ferries, which has an impact on the lead-time since they only depart on specific times, making it critical to not miss the scheduled time, and the long distance makes the timing more difficult.

5.1.1.3 *SKF Mekan*

The inbound flow from SKF Mekan contains larger volumes than the trucks from SKF Poznan (as can be seen in figure 10), and even though the standard deviation higher, it is less volatile than the goods from SKF Poznan (see appendix K for calculation). As seen in figure 10, the major part of the total inbound volume occurs between 15:00-22:00, where SKF Mekan is overrepresented. It is important to note that the trucks from SKF Mekan are advised when departed, which makes it easier to estimate arrival-time, hence there should be a better possibility to coordinate. However, although being advised, a lack in information sharing has been observed as the forklift-operators on floor-1 claims to have no information about when the trucks are supposed to arrive. The information is available but not sent to the operators handling the goods. This is clearly a matter of communication discrepancy and goes against what (Stefansson and Lumsden, 2009) says about the flow of information; that it must be complete through the flow in order to reduce uncertainty.

Besides this, trucks are occasionally re-scheduled to the next morning if there is a lack in resources available to offload the goods in the evening. By this action the total lead-time increases roughly 12 hours. It seems that there is a design error in the process, which causes a mismatch between the supply and demand for capacity as a result of lack of planning tools for how the flow should be managed.

5.1.2 Handling GSPs in buffer

Examining figure 16 proves that most of the total RTW lead-time is spent inside the buffer since the time from the GSPs are fetched from the buffer to storage is much shorter than the total RTW lead-time. It is interesting to see, especially in figure 13, that almost 40% of the GSPs are received within 5 hours and still the average RTW lead-time is 41 hours. This is a clear argument that the FIFO-principle is not followed and that there are GSPs left in the buffer as a result of discrepancies in the handling process. The two reasons that have been found as to why GSPs are left in the buffer are: goods blocked by new GSPs put in front and that there are too many GSP in the buffer, resulting in the GSPs closest to the conveyor belt is moved first. As a result, if all zones are filled and new goods are placed in the middle of the buffer outside of the zones, they will likely be picked as it becomes easier to handle them first. This clearly goes against what Farhani, et al. (2011) states about materials handling activities: the purpose of materials handling activities is to provide the right goods in the right time, something that is clearly not done in the warehouse.

A gap in the standard for how operators' work has been observed, as they do not work in the same way, which contributes to the increased uncertainty regarding the goods receiving process. The same structure and discipline experienced in Schweinfurt and Tongeren is not present in Gothenburg. The great emphasis on "one touch" has helped them to improve their goods receiving-area, which can be seen in how they work. Especially in Schweinfurt, the well-defined processes have given them a robustness allowing them to handle variations and identify problems very quickly. As noted during the visit to Schweinfurt, everyone had a clear focus on eliminating waste and always try to optimize the output, from management to ground staff. Besides this, the information transparency makes it possible to elevate problems right away. A reason for the Gothenburg warehouse being less efficient is the layout. There are several floors, which make coordination more difficult, and as several of the automated processes in Schweinfurt and Tongeren are manually executed in Gothenburg, it becomes even more important to coordinate activities and personnel.

Due to the fact that WASS assigns a storage-location for every GSP by distributing them equally over floor-1, floor-3 and floor-4, creates a need to sort and re-arrange the GSPs, depending on their storage location when they arrive to the buffer. With this in mind the deep-stacking method used in the buffer in combination with GSPs stacked against walls is a clear problem to the performance. As been observed in Schweinfurt, the goods receiving-area is designed to never stack GSPs against walls, in order for them to be accessible from several directions. This method is hard to apply in Gothenburg due to its layout constraints. It could be possible if the buffer constantly was emptied and that the only GSPs in the buffer were the ones just offloaded, as it otherwise would be hard to navigate in the goods receiving-area. This would also make it easier for the operators to sort the GSPs directly at arrival.

The shift rotations together with the deep-stacking principle cause further challenges to the performance in the buffer. If the operator handling the goods receiving-operation has emptied some GSPs in one zone, but hasn't had time to send everything up there will be some GSPs left in that storage zone. There is a chance that the next operator will continue somewhere else and leave that half empty zone blocked for new GSPs. This creates situations where it is important for the next operator to empty the half filled zones and continue where the previous operator stopped for two reasons; first it will prevent the possibility of newer GSPs blocking old ones and secondly it will free up space for future inbound goods.

One situation has been observed where the FIFO-principle is deliberately set aside. GSPs from Vehicle Parts are taken in on the first floor and almost immediately sent up. Those GSPs do not occupy the same capacity as the GSPs going to floor-3 and floor-4 as they are sent up in another elevator. However, the goods receiving-operator still has to load them in the elevator. The ideal situation would be if the GSPs could be prepared when they are first inbound in storage area-E and then taken directly to the outbound dispatch area on floor-2, instead of being loaded once again onto a truck to be taken in on floor-1. It would save capacity from the goods receiving-operator if the GSPs instead could be driven straight away from storage area-E to floor-2, which is physically possible. There is however some challenges that needs to be resolved in order for this to be implemented. The GSPs needs to be merged into the outbound conveyor system, as they need to be weighted and given a transport label. If this could be achieved, capacity and space could be freed-up and relieve the operators on floor-1 from goods that are just cross-docked.

In the current flow, GSPs arriving at the vertical elevator should be sent to the buffer at floor-1 directly. However, when the buffers breakpoint is reached, GSPs sent to the vertical elevator are kept in the buffer zone next to the vertical elevator. As a result, GSPs tend to be kept there even after capacity is freed up. This results in newer GSPs being handled earlier, which contradicts with the FIFO-principle. The reason for this could be that they do not measure how long these GSPs have been in the buffer and that other GSPs that are marked on the white board are sent up first.

As can be seen in appendix L, there is on average 957 GSPs located in the buffer. Since the distribution of the three inbound flows are 17% for SKF Poznan, 43,5% for SKF Mekan and 39,5% for Factory-D (appendix K), the average GSPs located in the buffer can be segmented in these three categories. As noted in appendix N, the percentage of overdue GSPs are 9%, 14% and 7% respectively for the three flows SKF Poznan, SKF Mekan and Factory-D. By analyzing these numbers, there is on average 97 GSPs (14+58+25) overdue in the buffer, with an estimated total value of 1 MSEK. As these products should be located in storage and be available to customers, it is 1 MSEK worth of stock that is tied up in unnecessary capital.

Table 20 - Unnecessary tied-up capital

	SKF Poznan	SKF Mekan	Factory-D
Distribution of inbound flow/24h (%)	17%	43,5%	39,5%
Distribution of inbound flow/24h (GSPs)	163	416	361
Distribution of overdue GSPs (%)	9%	14%	7%
Distribution of overdue GSPs	14	58	25

5.1.2.1 *Organization and identification of GSPs in the buffer*

At the start of the thesis there were no visible standard for identifying GSPs in the buffer and sheets of paper were used to identify which floor the GSPs should be sent to. In order to determine how long the GSPs had been in the buffer, the operator had to look at the GSP-label. This action supports what has been seen in the lead-time graphs, that some GSPs are forgotten or lost in the buffer due to lack in visible control. It is evident that the identification system was not sufficient to handle the day-to-day operations, which goes against what Arnold, Chapman and Clive (2008) argue; there must be a location-system for how and where goods are place in order for the warehouse to function.

During the execution of this thesis, a new standard for identifying goods was implemented in the buffer. It was a whiteboard showing when GSPs arrived and to what location they were designated. This method has made it easier for the operators to follow the FIFO-principle and given the team-leaders a better picture over how many GSPs are designated to a certain storage area, as it will help in planning resources, e.g. if there is an overrepresentation of GSPs to floor-4, the personnel should be redistributed accordingly. However, due to the fact that they only mark what date the GSPs arrive and not the hour, theoretically it could differ up to 24 hours between the arrival times of two GSPs, since goods are received from Factory-D 24/7. Furthermore, only GSPs in the marked zones are listed on the whiteboard, which means that GSPs in the center of the buffer is not listed, nor are the GSPs from Factory-D, located in the buffer next to the vertical elevator marked. This means that there is a gap in the standard that could lead to those GSPs being left in the buffer longer than three days.

Due to the fact that the system was recently implemented, it is too early to evaluate the result of the implementation, as there is a potential learning curve. It will however eliminate the risk of having overdue GSPs in the buffer, as the operators knows how long the GSPs have been in the buffer. Then it is a question of how well the standard is followed so that the oldest GSPs actually are taken first and not the ones that are closest to the elevator.

Today it is still allowed to place GSPs in any zone as long as it is marked on the whiteboard. It creates flexibility to adapt the size of the zone according to the size of the inbound shipment. However, GSPs designated for the same storage location are then not always grouped together, hence could be scattered in several zones. By assigning a fixed amount of buffer space to a storage location (e.g. floor-3) will make it easier to see how many GSPs are designated to a certain storage area. If the space for a storage area is full, GSPs will then either have to be put outside the zones, or older GSPs have to be sent away. It could give incentives to disregard the FIFO-principle as GSPs placed in zones causes movement challenges for the forklifts. However, it elevates the problem of too many GSPs in the buffer, and that an area in the warehouse is lagging or falling behind. This restriction of flexibility can be seen as contradictory but it is in line with Liker and Meier's (2006) findings: problems need to be elevated and taken care of immediately.

5.1.2.2 *Handling of accumulating GSPs*

As been seen and confirmed by the team-leaders, there is a critical limit in the volume that divides the inbound processes even further, which is assumed to occur when the amount of GSPs reach about 800, as stated by the team-leaders. As long as the number of GSPs is kept below this limit the operators has the necessary space to sort the incoming goods with respect to its designated storage location. When the number of GSPs reaches this breaking point, the operators start to loose control and cannot perform the activities as they are meant to, due to the lack of space and coordination. It is evident that there are no routines for how to act when this limit is reached, and incoming goods are handled by "in the moment solutions". This goes against what Spear and Bowen (1999) argues. There must be clear routines and agreements for how to conduct the work, as can be seen in Schweinfurt and Tongeren.

When the buffer reaches the break point, the GSPs are first off-loaded in any available space and then sorted, adding an extra handling activity. If the goods receiving-area were constantly empty it would be easier to sort an entire inbound shipment directly after which floor the GSPs are going. This is only possible by continuously making sure that the elevator is moving and sending GSPs up to storage.

When the amount of GSPs reaches above 800, there the challenge of where to temporarily store the GSPs becomes evident. This is not only a coordination challenge but more important a safety issue as GSPs are put in the driving lanes and walking isles. The problem must be triggers in the process that elevates the problem earlier and gives the ability to work proactive instead of being reactive and apply overtime.

5.1.3 Put away

The lead-time from elevator to storage is on average 2 hours and 42 minutes, where the longest observed time was approximately 24 hours. According to the team-leaders, this is beacaue of GSPs sent to the wrong floor, which then are put to the side until someone brings it to the right floor. This is possible since the operator manually press a button to guide the GSP to the designated floor. As there are human errors this is one reason to why some GSPs are sent to the wrong storage location. Both Schweinfurt and Tongeren have fully automated conveyor-systems all the way to the automated storage facilities, making it less prone to human errors, such as misguided GSPs.

The operator on the first floor is capable of putting two GSPs on the conveyer belt but the workers on floor-3 and floor-4 can only take off one GSP at a time. This makes the storage-process more time-consuming than the process of putting them on the belt. Furthermore the operators putting away goods must also register the GSP in the storage location. With this in mind, the current bottleneck in this process is the forklift-operators (Jankulovski 2012) taking the GSPs from the belt to its designated final storage location. In order to cope with the high amount of GSPs on floor-1, it becomes clear that the warehouse personnel on floor-3 and 4 have to offload the incoming GSPs at a steady pace in order for the workers on the first floor to send up more GSPs.

The operators are told to use multi-cycle (one in-one out), which means that every time one GSP is put on the outbound belt on floor-3 or 4, one GSP is also taken from the inbound belt to storage. But as everyone does not follow this principle there is a gap in how the routines are designed compared to how the routine is actually executed. This concludes that the warehouse personnel are working in different ways, which makes the processes less robust and more difficult to control. One of the arguments presented was operators' did not have the time to apply this principle due to the heavy focus on the outbound flow and the sometimes long driving distances between where the inbound GSP should be placed and where the outbound GSP were to be pick.

It has been suggested that the current ABC-analysis need to be re-examined and updated to the current flow. If there was a functioning ABC-analysis, the driving distances between picking and put away assignments could be reduced. This would then make it more feasible for the drivers to use the one-in one-out-principle.

There is furthermore no sense of urgency regarding the inbound flow. If there were, the operators would take one-in one-out. There should not be dips in the put away graph if everyone worked after the same standards and routines. The forklifts must be moving continuously, as they are the bottleneck. Every minute they are idling is a minute lost in the system. Furthermore there must be an emphasize on that inbound operations are the focus during the night, as there is less outbound activities, to make sure that the flow is continuously moving and that the they at least reach 27 GSPs put away per hour.

The put away capacity is estimated to 52 GSPs/hour on a regular day, which in comparison with the actual put away frequency of 23 GPSs/hour, gives an average efficiency of 44%. It is clear that for a large part of the day there should be excess capacity to handle the three peeks (figure 10), but with an average efficiency of 44% that results in 9 times during the day where the inbound volume is larger than the current put away frequency. This shows that there are factors within the warehouse processes that disrupt the flow, preventing it from reaching the maximum capacity, e.g. sorting and stacking pallets in buffer for later handling. It is therefore a fact that they cannot handle the inbound volume by the current routines and activities to put away enough goods, which then results in accumulating GSPs. In order to reach a state where GSPs are not accumulating the warehouse must reach a put away frequency of at least 27 GSPs/hour equivalent to an increase of about 17%.

Table 21 - Inbound volume vs. put away frequency

	Inbound	Put away	Average increase
GSPs/hour	27	23	4
GSPs/24h	645	552	93

As the multi-cycle not is continuously used, the required ramp-up of 17% will be possible if the forklift-drivers handling the put away operations on floor-1, floor-3 and floor-4 would apply this principle two more times every hour. This will result in a put away frequency of an additional 6 GSPs, which is above the required amount of 27 GSPs every hour.

This ramp-up will be possible by doing one of two things: increase productivity or increase the number of operators. As can be seen in appendix J, the amount of GSPs being put away fluctuates during the day. By adding 4 GSPs to the put away-amount each hour, hence increasing the put away-frequency to 27 GPSs/hour, the needed increase in productivity becomes 4%, 11% and 13% respectively for the day shift, evening shift and night shift.

Looking into the amount of operators instead, an increase of 4%, 11% and 13% respectively for the day shift, evening shift and night shift suggests one additional operator within the day shift, one additional operator during the evening shift and one additional operator during the night shift. See table 22 for a summary of the calculations.

Table 22 - Desired increase in productivity or operators

	Day	Evening	Night
Current productivity (assignments/man-hour)	4,11	3,11	6.26
Needed productivity (assignments/man-hour)	4,26	3,44	7,06
Current capacity (amount of operators)	26	12	5
Needed capacity (amount of operators)	27	13	6
Increase	4%	11%	13%

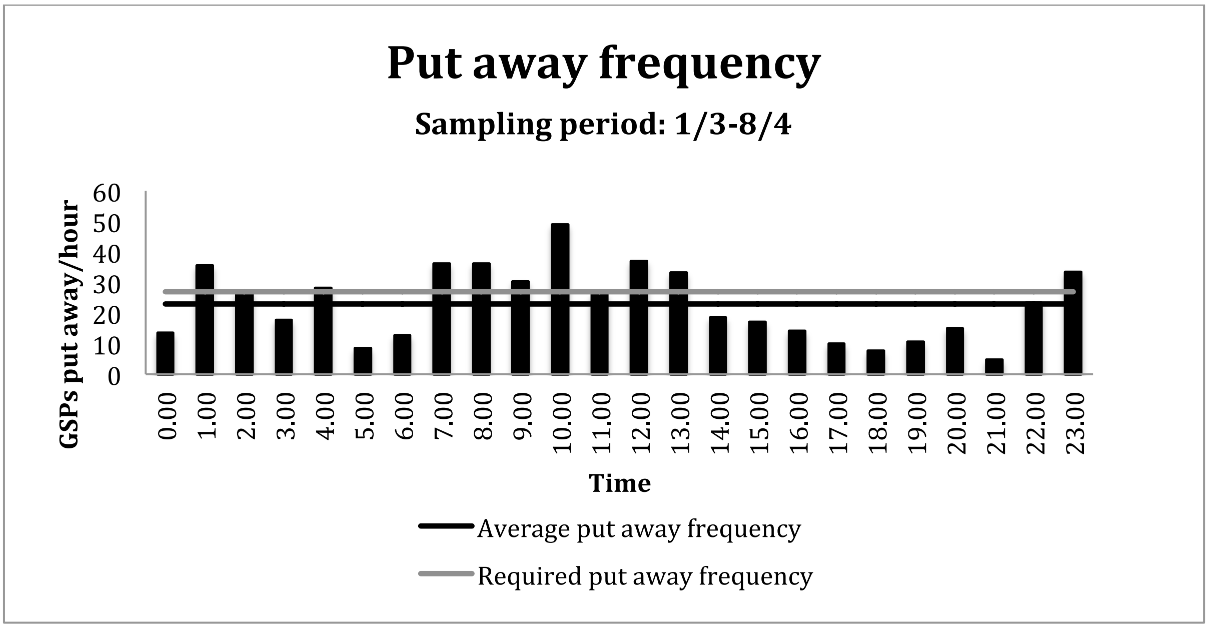


Figure 20 - The current put away frequency compared to the required

There is a spoken agreement that inbound goods should be prioritized during the night. Looking at absolute numbers, more GSPs are put away during the day, but taken the supply of capacity into consideration the productivity during the night is actually higher than during the day (see appendix J). This proves the prioritization of the inbound flow during the night. With a capacity of 52 pallets/hour it is possible to store 440 GSPs between 22:00 – 06:00, but they only manage to put away 200 GSPs during this time interval. The average put away-frequency is believed to be at the same level during the night even though there are fewer workers present, since there is an explicit focus on the inbound flow, hence the workers should only conduct activities within this flow, sending goods to storage.

The put away frequency decreases between 14:00 and 16:00, although this is when there are most operators in the warehouse. Stretching this further, it means that the new shift starting at 14:00 is not working with put GSPs in storage, as can be seen in figure 20. This shows that the coordination of work does not function, as it should. When the evening shift starts at 14:00 and the maximum supply of capacity is reached (figure 20), The amount of put away-GSPs are constantly declining. This could be a result of that the operator in the buffer has to prioritize other activities instead, which then would be a discrepancy in the process design that puts work out of synch.

When the operators have a break between 02:00 and 02:20 it is obvious that the average number of put away GSPs should decline between 02:00 and 03:00, as can be seen in figure 20. However, there is a remarkable dip in the put away-frequency between 05:00-07:00 although the same capacity is available during this time as during 04:00, where the frequency is more than twice as high. No alternative activities have been identified that would make up for the loss in the amount of put away GSPs at this time.

5.1.4 Taking on a holistic view

Summarizing the bars of the put away frequency graph (figure 17), the average number of GSPs put in storage is 23 GSPs/hour. With an average amount of GSPs in the buffer of 957 (appendix L), the throughput time for the buffer will be 42 hours. This correlates with the calculated RTW lead-times that were extracted from WASS.

The process of managing inbound transportation is a clear challenge for the inbound flow. There is a great level of uncertainty, which makes it hard for the operators to plan their work. This proves that the element: Measurement, presented by Wei et al. (2006), is missing in the inbound process. The coordination between the buffer to floor-3 and floor-4 has also proven to be a problem for the warehouse. Finally, no routines has been found for how they should work proactively with the operations and everything is done by reacting to what is coming in. If the warehouse had the possibility to plan the inbound transports with slot times and coordination with the 3PL-companies, it would be easier to level out capacity and coordinate the work between the floors. By coordinating arrival times and level out the inbound flow by matching the number of inbound GSPs/hour with the put away-frequency, will reduce the accumulating GSPs even without any improvements in the put away frequency.

Due to the fact that floor-1, floor-3 and floor-4 are connected via elevators, the personnel on these floors have to communicate in order for their work to be leveled.

However, during the observations it seemed as they worked separately with little or no communication. The only information the goods receiving-operator gets is from two monitors on the first floor displaying the conveyor belts on the other floors. The operators on floor-1 cannot be sure when the operators will take GSPs from the conveyer, as the conveyors are emptied when the operators driving the side-loaded forklifts has time. It shows that there is as a gap in the put away-processes, making the inbound flow unstable and unreliable. In order to stabilize the inbound flow there must be better communication between the operators and standards for how they work.

Examining this on a more detailed level, there is a need for coordination between the floors. The personnel on the first floor needs to be synchronized with the personnel on the other floors to make sure they do not work with activities that are not aligned. When prioritizing the outbound flow during the day, the personnel on floor-1 must be informed about how this is done to adapt their work after how much they can send up and to what floor.

The status on the outbound operations is clearly displayed on a monitor presenting an overall picture of the current situation. Remarkably, nothing is displayed for the inbound flow. To increase the sense of urgency for the inbound flow there should be indicators displaying the actual condition on the inbound flow. This could for example be articulated through displays measuring the inbound flow with respect to the put away frequency to assess if GSPs are accumulating in the buffer. Such a tool will help in giving transparency in the inbound flow-performance, which will help in making proactive decisions before chaos has occurred and as a result reduce the throughput-time.

5.2 Capacity matching

This section analyzes the flow with regard to how well the available resources are adapted and distributed to fit the flow.

5.2.1 Matching inflow with resources

Seen in figure 10 and mentioned earlier, the inbound flow increases between 15:00 – 22:00. The total flow fluctuates from 20 to 75 GSPs/hour, which is a ramp-up of 400%. This makes it evident that there should be a different distribution of personnel between 15:00-22:00 compared to before 15:00. Looking at amount of operators during an ordinary day (figure 19), the distribution is clearly focused on operations during the daytime, as there are more people present during the day than during the night, even though the largest inbound volume occurs in the evening.

There are 26 workers between 07:00 – 13:30, concluding that this is when the most activities take place. At 14:00, one shift-team ends, and at the same time the evening-employees start (one team with ordinary workers and one shift-team). This creates a spike in amount of workers in the warehouse, and between 14:30 to 15:30 there are 33 people present, making it the highest amount of working personnel during the day. This finding is rather interesting as the number of workers decreases drastically at 15:30, which is when the number of inbound GSPs has the highest increase. As can be seen in appendix J, the overall productivity is 3,85 GSPs/man-hour. Since there are 12 operators present at this time, they can together put away 45 GSPs/hour, and as the inbound flow is on average 50 GSPs at this time, there will be a 5 GSP-accumulation. To cope with this, it becomes evident to either make the processes more efficient or redistribute the number of operators. It is a clear misalignment between the supply and demand for capacity for inbound transports.

Further analysis of figure 10 show that most GSPs from SKF Poznan arrives at 15:30, the same time as the regular day-shift ended its working day. This postpones the offloading-activity since there are no personnel due to the shift rotations. During the most hectic inbound flow, there are just 12 employees present, concluding that either there is a mismatch in how people are distributed, or that there are too few workers at the inbound operations on floor-1. It is however important to note, which will be analyzed in greater depth later, that the outbound operations on floor-2 demands more operators, and this is potentially the one reason to why it sometimes is a lack of personnel at floor-1.

Comparing the amount of workers with the utilization-rate, one can conclude that in general, there is a 10% absent-rate, there is no trend on either absents increasing or decreasing. This in addition to the above discussion shows that it is possible to say that the problem is not absent personnel from the regular workforce, but rather that the entire workforce could be potentially too small, or that there are people are working inefficiently.

Although the team-leaders plan so that there should be workers present at the different workstations, sometimes there was not anyone present in the goods receiving area when a truck arrived. As most trucks arrived late in the afternoon, one possible answer for an empty dock could be wrongly distributed people within the warehouse. This is a subject of poor communication, as there is no one that expedites the drivers when they arrive if the operator handling the goods-receiving work area is not there, making the offloading-process delayed. This is quite different from Schweinfurt and Tongeren, as they have clear routines for what person the drivers should contact when they arrive.

Within the outbound flow, there were sometimes too much goods to be sent out, making the conveyor belts on floor-3 and floor-4 full of GSPs, which hinders the operators on floor-3 and floor-4 to send additional goods out. Instead of focusing on the inbound flow some operators waited for the flow to start to move again. With this in mind, appears that the workstations are static with a lack in information transparency between the operators. This results in poor communication, which in turn creates inertia and a division of processes. According to Johansson and Öjmertz (1996), a division of processes leads to an increase in throughput time. This leads to lower utilization of workstations, which becomes an issue, as the labeling and weighting-machine could be idle when responsible operators have their breaks. In this case the team-leaders try to cover this work area if they have time to do so. It is a matter of matching capacity according to actual demand in the different processes.

5.2.2 Coordination between work areas

The focus on outbound goods causes problems in the buffer. If the operators on floor-3 and floor-4 do not empty the conveyors, no GSPs can be sent up, which makes GSPs accumulating in the buffer. The opposite situation has also been observed. If the operators on floor-3 and floor-4 focus on putting goods in storage and at the same time several trucks arrive at floor-1, the operator managing the inbound goods on floor-1 will experience lack in capacity as he needs to offload the transports at the same time as sending goods up. It is a situation of shortage in capacity, as the operator cannot handle all activities at the same time. If there is a shortage of capacity and the team-leaders do not have the resources to put two operators in goods receiving, they should help out. As been presented in the previous chapter there is an uncertainty for when trucks arrive. This might not correlate to when the team-leaders have the time to help out, therefore the utilization of this resource could be very shifting. These two situations prove that there is a low level of coordination between the floors.

Mentioned in 4.2.4, the different warehouse-processes become static and there are no clear routines for how the operators should help out even though they are encouraged. This becomes particularly problematic when the operator responsible for the goods receiving-process is on a break, as there is no one replacing him during this time. This results in an uneven flow, as there is no one else that loads the elevator with new GSPs during the operators break. Goods designated to storage area-E and floor-1 could still be put away as other operators are handling these areas. So even though the elevator has the capacity of sending goods, the speed of the inbound flow is dependent on that operator. This operator has to handle multiple tasks and balance the flow. If several trucks arrive at the same time there is still only one operator responsible for emptying them. As a result, the operator has to both send goods up and empty incoming transports simultaneously.

During the empirical data gathering, the authors have observed operators handling the vertical elevator work area standing still doing nothing. The suggested reason, as been observed, is that some of the employees are static in their work, not helping their co-workers. Instead, the personnel should have a free flow of communication between the different processes to help each other in order to get the products through as frictionless as possible. Having a free flow of communication between the buffer at the vertical elevator and the inbound operations at floor-1 will help to even out the utilization of the goods-receiving-operator as the vertical elevator-operator will help whenever there is time to spare. According to Liker and Meier (2006), a high level of variance and a low recognition of standardized work are two significant signs on problematic conditions in any work-environment, which will lead wrongfully decision about the environment and how it should be handled.

The outbound flow is better monitored than the inbound flow due to the fact that they have more touch points and monitor how many picking assignments they have to manage every hour. There are several reasons, the most important being the significance of keeping customer promises and to secure departure on time. The throughput time from storage to an outbound transport is roughly 14 hours (table 15) for goods designated to Tongeren and Schweinfurt.

As noted in several interviews, there is an explicit prioritization on the outbound flow. It seems logical, as the customers should not wait longer than the agreed delivery time and as a result the inbound flow is always a second priority. The study in Tongeren and Schweinfurt has shown that their outbound flow is organized in another way as it is handled by a separate group of operators. In Gothenburg, the inbound flow and the outbound flow are interrelated as the same operators handle both flows. The operations in Schweinfurt and Tongeren are working with less friction and it seems that two separate flows are easier to handle.

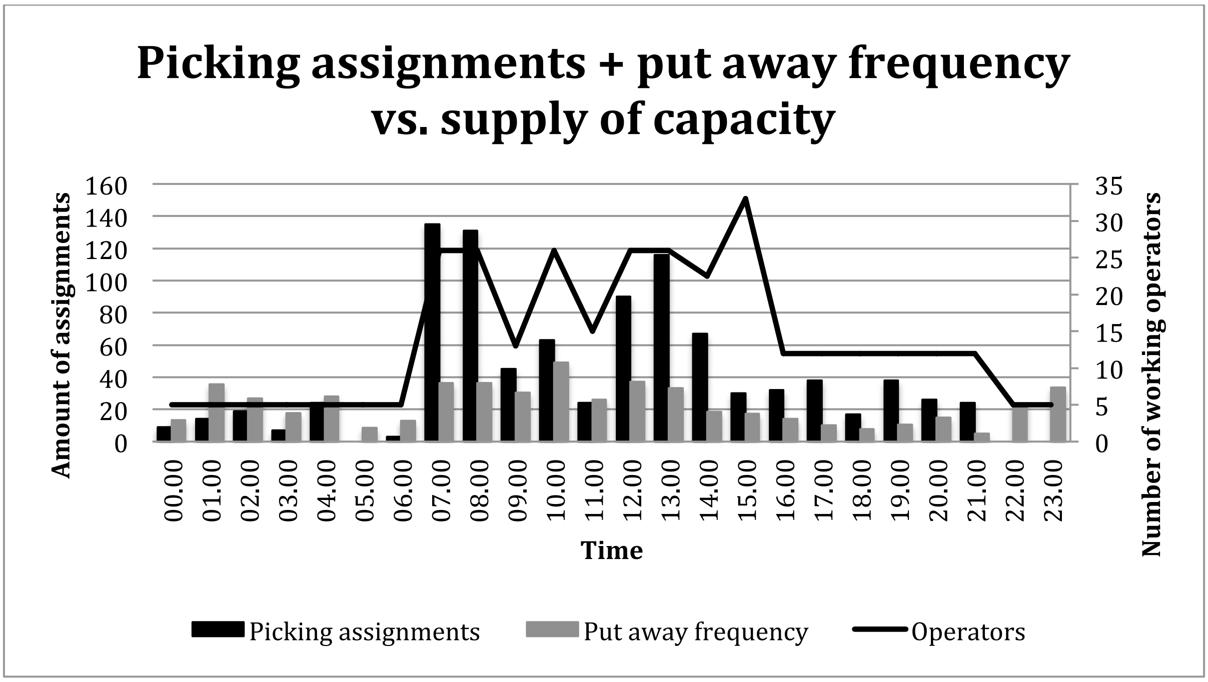


Figure 21 - Amount of conducted work compared to the number of operators available for work

Figure 21 shows the amount of work conducted in the warehouse every hour compared to the number of operators working during those hours. It is clear there is no positive correlation between available man-hours in the warehouse and how much work is conducted. In absolute numbers, more work is conducted per hour (GSPs put away plus picked GSPs) during the day than during the night, 110 assignments/hour vs. 31 assignments/hour (see appendix J). However, adjusting for the available capacity, the night shift is more productive with 6.5 performed assignments per available man-hour vs. 4.1 performed assignments per available man-hour during the day (see appendix J).

From this graph it is evident that the same amount of work is conducted in the evening as during the night (37 assignments/man-hour during evening, 31 assignments/man-hour during night) even though the number of operators are fewer in the night shift (see appendix J). This results in more than doubling the productivity (6.3 vs. 3.1) for the night shift compared to the evening shift. This drop in productivity is most likely due to operators have to handle the increased volume of inbound GSPs to the buffer, by sorting and organizing the area.

5.2.3 Resource distribution

The planning situation in Gothenburg is complex since both inbound and outbound operations share the same resources, and that there is a low level of transparency in the when goods arrive to the warehouse. As the outbound flow is prioritized during the day, the sufficient resources must be secured to that flow. At the same time the inbound flow must not be forgotten, and even though the goods must leave in time, goods has to be received and made available for picking as soon as possible after its arrival to the warehouse. Further challenges are caused by the organization of the work groups and the fact that they are very autonomous. As a result it is hard for the team-leaders to control the operators in detail, due to the fact that decisions related to how and where the operators work is made together on the morning meeting.

Re-prioritizations in the processes have only been observed for the outbound flow where the operators can be moved between the different floors. As this flow should be prioritized this action is only logical. However, through this action there is no consequence analysis for how the reprioritizations affect the inbound flow. When personnel are moved to another floor, no information is given to the operators on the first floor, making the coordination difficult, as there is lack in information transparency.

Furthermore, there is no need to distribute more operators to the inbound flow if the forklifts on floor-3 and floor-4 do not empty the conveyors. So from an inbound planning point of view the best decision is to secure resources to the side-loaded forklifts, which are the bottlenecks, to make sure that they are always running so that GSPs can be sent up. It is therefore important that the team-leaders continuously follow up and make sure that the inbound conveyors are moving.

As been observed, supervisors sometimes did not know why the operators were not in their designated work areas. Since this phenomenon has been observed close to breaks and shift endings, it seems as some of the operators stretch their breaks. Due to the fact that it is hard for the warehouse to temporarily change capacity, it is important that the capacity is utilized as much as possible. The team-leaders have a great responsibility to make sure that the flow is running smoothly and coordinate personnel depending on the current capacity. This implies that they always should know where the operators are and who is working where. This is a difference from both Schweinfurt and Tongeren where work ethics is of high standard. Both the warehouses make sure that the workers are where they are supposed to be and that they are on time.

5.2.3.1 *Adapting capacity*

Adapting the capacity to the current situation is a crucial factor (Leitch, 2001). Tongeren has proven to be extremely agile as they can ramp up or down capacity by 30% within 24 hours. The warehouse in Gothenburg could benefit greatly from use of a similar function to handle the peaks or eliminate short-term disturbance. This has not been possible in the same sense as before since there is less temporary staff available.

Even though it is hard to use an agency pool there are still other alternatives worth evaluating. One possible solution, which is presented by Jonsson and Mattson (2009), is to borrow personnel from another work area, in this case an operator from Factory-D. However, there is still a learning curve in order to handle the tasks, which could eliminate the short-term gain. This leads to the fact that it is even more important for the team-leaders and managers to work with internal coordination and how the resources are used.

The new shift rotation launched April 1st 2013 was believed to improve the situation in the warehouse, as it would provide them with an estimated 10 additional working hours (see appendix M) and a smoother distribution of capacity. It is too early to make any conclusions regarding the new rotation, but from the graphs in figure 11 and 12 it is clear that it has contributed to improvements, but there is still a large amount of GSPs in the buffer on floor-1. This is further proof that the disturbances experienced in the inbound flow are not mainly a capacity issue but rather a coordination and process design challenge. From what has been seen in the empirical data, it is however not possible to conclusively determine that there are too few operators in the warehouse from time to time due to the high variance in the inbound processes. In order to answer this statement there has to be process stability.

The bottleneck in the outbound flow is as presented the weighting and labeling stations, and it is therefore important that these stations are operating at all times. The team-leaders should therefore make sure that when operators on the weighting and labeling station takes a break, someone else covers for them. If there is no one available, the team-leader should cover that work area during the break.

5.2.3.2 *Resource meeting*

What makes Tongeren so efficient is how they plan their resources by having a great transparency within the warehouse. The resource meetings allow different parties to be involved and decide how many operators they will need and how they should be distributed. Having the same kind of meetings in Gothenburg will be beneficial for several reasons.

Better coordination – Discussing the current situation in the warehouse together. By having the inbound volume compared to amount of released order-lines will result in easier decision-making for how activities should be coordinated. When GSPs are accumulating on floor-1 should be discussed and how it could be resolved before it is a subject of planning overtime. If this can be evaluated on a regular basis, in addition to create an action plan for how both flows should be managed will prevent sub-optimizations. Johansson and Öjmertz (1996) supports this as all processes should be examined at once and not process by process, which will lead to sub-optimizations.

Increased transparency – Representatives from different levels of the organization takes part and shares their work. This will increase the transparency of everyone's work, which will improve the understanding of each other. Situations where misunderstandings occur can now much easier be eliminated e.g. that trucks are re-scheduled without informing other departments, as it affects their work too. A meeting where also top management participates and shares their insights about the current situation is also important for the motivation and progress of the operational units. This would then be aligned with what Lloyd (1994) says about management commitment: that managers must set a good example for the workers to motivate them.

A forum for discussion – The meeting would also act as a forum where current issues can be dealt with. Not only will problems come to the attention of top management but also to personnel in other departments, which could have a solution to the problem. This would especially be good for the inbound flow as problems here would for the first time be elevated over the entire organization.

The participants in the resource meeting are preferably the same people that take part in the meetings in Tongeren: warehouse manager, operational managers and team-leaders. Since the organizations do not look the same, a representative from the transport department in Gothenburg should preferably also take part in the meeting to support with insights about order releasing and inbound transports.

5.3 Measuring and follow up inbound performance

What has been seen in Tongeren and Schweinfurt is that these warehouses do not measure the inbound RTW lead-time. The first scanning is conducted automatically when it is put on the conveyor belt, making it difficult to assess the "real" time from the inbound truck to storage. It is no use in measuring this time since it is so short, according to the warehouse personnel. It is a matter of minutes from the offloading-dock to put in storage, concluding this step is unnecessary to measure.

In Gothenburg the inbound GSPs should be scanned manually when offloaded, making it possible to measure the actual time from entering the dock to being put in storage. This step is more important in Gothenburg as the process of handling the GSPs is done manually and the fact that the variance is so high.

As the warehouse is largely measured on broken promises to customers, the KPIs are focused on the outbound part of the flow. It results in the fact the inbound flow is not getting measured and improvements here are not getting any traction. If there would be internal KPIs providing more transparency on how the inbound flow is performing, it would help warehouse personnel to easier detect when the inbound flow is getting out of control. This will help them to work more proactive to reduce the “fire-fighting”-solutions and overtime.

What is quite remarkable are the non-standardized measuring points used. As SLS is responsible for the warehouses and measuring the performance in each warehouse, it seems logical to measure the warehouses within the same points in the flow. Without a transparent comparison it seems difficult to understand which warehouse is performing best and which warehouse is performing worst. One could argue that the most important thing is to look at the big picture and the overall lead-time for a warehouse to understand how they are performing, but this does not help in assessing weak-spots within the warehouse.

By measuring the warehouses in the same points within the flow will provide a better understanding about how the flows are working in detail. This will make it easier to understand which warehouse has the most efficient processes in different parts of the flow. By knowing this, other warehouses can study “best-practice” and replicate it.

5.3.1 Suggested KPIs to increase transparency and assess performance

As a result of the gap in the KPIs measuring the inbound flow-performance, it becomes hard for management to implement improvements that will make a difference. Stated by Liker and Meier (2006): “*what gets measured gets done*”, meaning that change will only be possible if decisions and actions are based on the actual situation. Three new KPI will therefore be presented as a tool to increase the transparency in the inbound flow to better understand its performance over time. The suggested KPIs will as a first step increase awareness and the actual performance in the inbound flow by measuring the suggested touch-points. When understanding how the flow is functioning, it will be easier to control and redirect the flow in order to be more efficient.

<u>KPI 1: Measure amount of GSPs in buffer</u>

In order to increase the transparency in the inbound flow, which is critical according to the empirical data, there is a need for implementing new KPIs. As been noted, most of the inbound time occurs in the buffer on floor-1, making this part of the flow important to monitor to avoid overtime and overdue GSPs. A suggestion is therefore to start counting the actual number of GSPs within the buffer each day. By doing this it is possible to sooner detect when the amount of GSPs in the buffer reaches a critical point and easier to take actions to avoid an escalating situation.

KPI 2: Measure incoming transports and amount of GSPs on each transport
By measuring how many transports arrive each day, and the amount of GSPs on each transport will make it understandable for how the inbound flow fluctuates. As been noted, slot-times are about to be implemented, which will help greatly to understand how the flow fluctuates, and plan capacity accordingly. This is however a first step to assess for when it is appropriate for trucks to arrive to take out peeks in the work load.

KPI 3: Amount of GSPs put on the inbound conveyor belt each hour
As mentioned earlier in the analysis, it is important that the inbound elevator is utilized as much as possible to never let the forklifts on floor-3 and floor-4 become idle. By measuring amount of GSPs sent each hour it will make it possible to assess the performance of the flow from the buffer and onwards. Benchmarking the maximum capacity (22 GSPs/hour) with the actual GSPs sent up will provide transparency in how the coordination and prioritization is working.

5.4 Answer to research question

This section provides the answers to the research questions.

5.4.1 Research question 1

Which routines, standards and activities within the warehouses increase the RTW lead-time when they are not designed to fit the flow, and does the structural warehouse layout influence the performance?

There are factors that have been found to have a negative impact on the RTW lead-time. The lack of information transparency and coordination between workstations has a direct negative impact. As decisions are made without assessing the overall product flow, the personnel is continuously working with fire fighting, hence structured work methods with standardized routines does not occur, which impedes the product flow, e.g. the FIFO-principle is not followed.

The identification method used to organize the buffer has also been found to have a negative impact on the RTW-lead time as GSPs are forgotten and newer GSP are put away before.

As highlighted throughout this report, the Gothenburg warehouse is unique with its five floors of operations. As the layout makes it more difficult to have information transparency, it becomes difficult to coordinate activities. Therefore, it is concluded that the layout design impacts the performance, and having one floor with all operations should be considered a better alternative, as the warehouses in Schweinfurt and Tongeren.

5.4.2 Research question 2
What routines, standards and activities can be changed to decrease the RTW lead-time?

Given the current situation with a flow of high variation within the warehouse processes and unreliable RTW lead-time, the first step should not be to decrease the RTW lead-time, but to improve the standards to stabilize the inbound flow. When a standard-level is reached it will be possible to make improvements, hence reduce the lead-time. To assess a stable flow, all operations need to be standardized as to sequence and work method. This is important to know the maximum capacity, and to plan the inbound flow on correct decisions created to fit the flow.

As most of the RTW lead-time is located in the buffer, it becomes evident that the biggest potential for improvement is located in this part of the flow. To create a reliable flow, all GSPs put in the buffer needs to be noted with date and time of arrival in order to apply the FIFO-principle. This makes sure the same standard is followed by all workers, which would secure a stable inbound process.

The accumulating GSPs in the buffer is not only because of a lack in coordination within floor-1, but also a matter of utilizing the forklifts on floor-3 and floor-4, which are the bottlenecks. As for now, the forklifts are not maintaining the one in-one out-principle, which leads to a clogged inbound conveyor belt on floor-1. There is no actual prioritization on always sending inbound goods to storage, leading to longer lead-time-to storage than necessary.

5.4.3 Research question 3
Could these solutions reduce the RTW lead-time for the other two warehouses, which has not been in focus?

The proposed solutions are tailor made for the warehouse in Gothenburg, as this has been the focal area in the thesis. It must be noted that the improvements can be applied in similar warehouses at other SKF-sites. However, as the improvements mainly has a focus on stabilizing processes and level out the inbound flow, the solutions will only have a positive effect on warehouses struggling with this. As both Schweinfurt and Tongeren have a stable flow of inbound goods, and processes being conducted in a standardized way, the provided solutions will not reap any significant benefits for these warehouses.

6 Recommendations

This chapter presents the recommendations, stemming from the analysis and the frame of reference. The recommendations are presented and organized according to where they take place, but they have been developed from an overall perspective to avoid sub-optimizations. The analysis has proved that the inbound flow and its processes are prone with heavy fluctuations, concluding that the recommendations will be aimed towards reducing the variance rather than to reduce the RTW lead-time.

6.1 Goods receiving

1) Measure arrival time to assess performance (Tomorrow) – It is necessary to measure arrival time in order to monitor the inbound flow. To do this, an extended whiteboard should be installed in the buffer. On this the operator offloading the GSPs should note when the transport arrived and its amount of GSPs. The team-leader is then responsible for assessing this information and documents it into an Excel-file, available for all team-leaders. By doing this, the inbound flow will be continuously monitored and easier to understand

2a) Establish fixed transportation lead-times for external transports (Within three months) – To further increase the transparency in the inbound flow exact goods-in-transit lead-times should be established in negotiation with the 3PL companies. This means that the time a truck is advised can differ but from the time it leaves it is certain that it will arrive at a specific time. This will create a better planning environment, where activities can be matched to when trucks arrive.

2b) Level out arrival time for SKF Poznan and SKF Mekan (Within three months)
In order to avoid a chaotic situation in the inbound flow and to be able to cope with the incoming GSPs, it is necessary to level out the incoming goods. It is suggested to keep focus on the afternoon and evening, and to keep the transports separated with one or two hours. This is important to keep the work structured and plan for the next transport before it is arriving.

2c) Tighten time-window (Within six months)
Assuming the trucks are leveled-out during the afternoon and evening, a next step would be to tighten the time-windows for when they should arrive. Instead of allowing a 60-minute time-window, an even shorter time-span will improve the planning in the warehouse since the inbound flow is controlled in more detail by doing this.

3) Install a whiteboard with estimated time of arrival and amount of GSPs being inbound on floor-1 (Within three months) – The expected arrival time and the amount of GSPs inbound at a certain time will be noted on this whiteboard. The transport department should do this as soon as they receive the advised e-mail from the respective location (SKF Poznan/SKF Mekan). When implementing this, the transport department will communicate the expected arrival time to the staff on floor-1, which will increase the information transparency, with the possibility of planning the activities more efficiently. By assessing the expected lead-time and also monitoring the actual lead-time makes it possible to benchmark these numbers to assess the 3PL-performance.

6.2 Buffer

1) Evaluate whiteboard performance (Tomorrow) – To secure that the FIFO-principle is followed the whiteboard, presenting the current situation, must be continuously updated. The team-leaders should be responsible to follow-up and make sure that the whiteboard represents the current situation. The performance of the whiteboard should be discussed and evaluated on the morning meetings, to emphasize on the importance of the standard.

2) Extend whiteboard (Tomorrow) – GSPs located in the buffer next to the vertical elevator are today not listed on the whiteboard. By extending the whiteboard so that also these GSPs are included, would lower the risk that they are left here due to favor of the ones listed on the whiteboard in the main buffer.

3) Establish handover-meetings (Three weeks) – To improve the coordination between shifts and secure that no activities are left half done. The operator whose shift ends, goes through which GSPs should be taken first, where there are half emptied zones and if there are any special circumstances, with the new operator whose shift just begun.

4a) Assign goods from Vehicle Parts to a specific zone (Three months) – The GSPs from Vehicle Parts occupies today a large area of the center of the buffer, which hinders the forklifts from moving around. By assigning the zone to the right of the loading docks, the GSPs would be removed from the center and create more room for moving around.

4b) Lock buffer zones to specific storage locations (Six months) – By locking the zones to a specific storage location, GSPs are naturally grouped together, which in an easy way will display how much goods are going to a specific storage location. It would also elevate performance problems, which would result in accumulating GSPs, before they cause stress on other processes. This method would however make the buffer static but if the put away performance can be improved, so that GSPs are not accumulating, will results in a more logic flow in the buffer.

6.3 Put away

1) Establish a standard for "One in-One out" (Tomorrow) – Due to fact that the forklifts on floor-3 and floor-4 are the bottlenecks for the inbound flow but not the outbound flow, it is of greatest importance that the "One in-One out" principle is followed. In order to secure that everyone works with this principle, there must be a standard that explains that this is a part of the work and that there is not an option to drive only one way with GSPs. It is furthermore important to educate the operators of the importance of the principle and how it affects the flow. A simple method to continuously remind the operators of the standard is to put up a sign next to the conveyer belts that says "one in-one out".

2) Measure put away-frequency performance (Three weeks) – When everyone works according to the "One in-One out" principle, the put away performance across all three floors should be measured. The results should be evaluated and discussed with the operators to see what were the causes for good or bad performance. This will allow the team-leaders to understand in greater depth where waste is located and in greater depth go in analyze specific time intervals. Stretching this further, it will be necessary to segment the floors in the specific storage locations in order to get a more detailed view on the performance in the warehouse.

3) Communicate workload between floors (Three months) – To understand how the workload varies and how resources should be distributed in consideration of both the in- and outflow. The team-leaders should monitor the workload of inbound goods on floor-1 and the volume of assignments on floor-3 and floor-4. When there is a need for redistributing between the higher floors it is communicated to floor-1 to let them know where operators are so that they only can send goods up to that floor. Communication the other way is done from floor-1 to floor-3 and floor-4, when there is a considerable amount of goods designated to one of the floors, to see if it is possible to send an extra operator to that floor.

4) Resource meetings (Six months)
When the above suggestions have been implemented, it is of great importance to keep monitoring the warehouse performance and the capacity matching in order to work proactively and understand the actual warehouse performance.

On a weekly basis there should be a resource meeting where the performance of the warehouse is discussed, including the amount of incoming GSPs, the development of GSPs in the buffer and the put away-performance. These points represent the input, execution and output of the inbound process and will determine the overall performance of the warehouse regarding the inbound flow. Key people that suggested to attend are; the General Manager of SLS Sweden, Warehouse Manager Sweden, Warehouse supervisor and Team-leaders, to get a transparent view on the operations from management to operational employees.

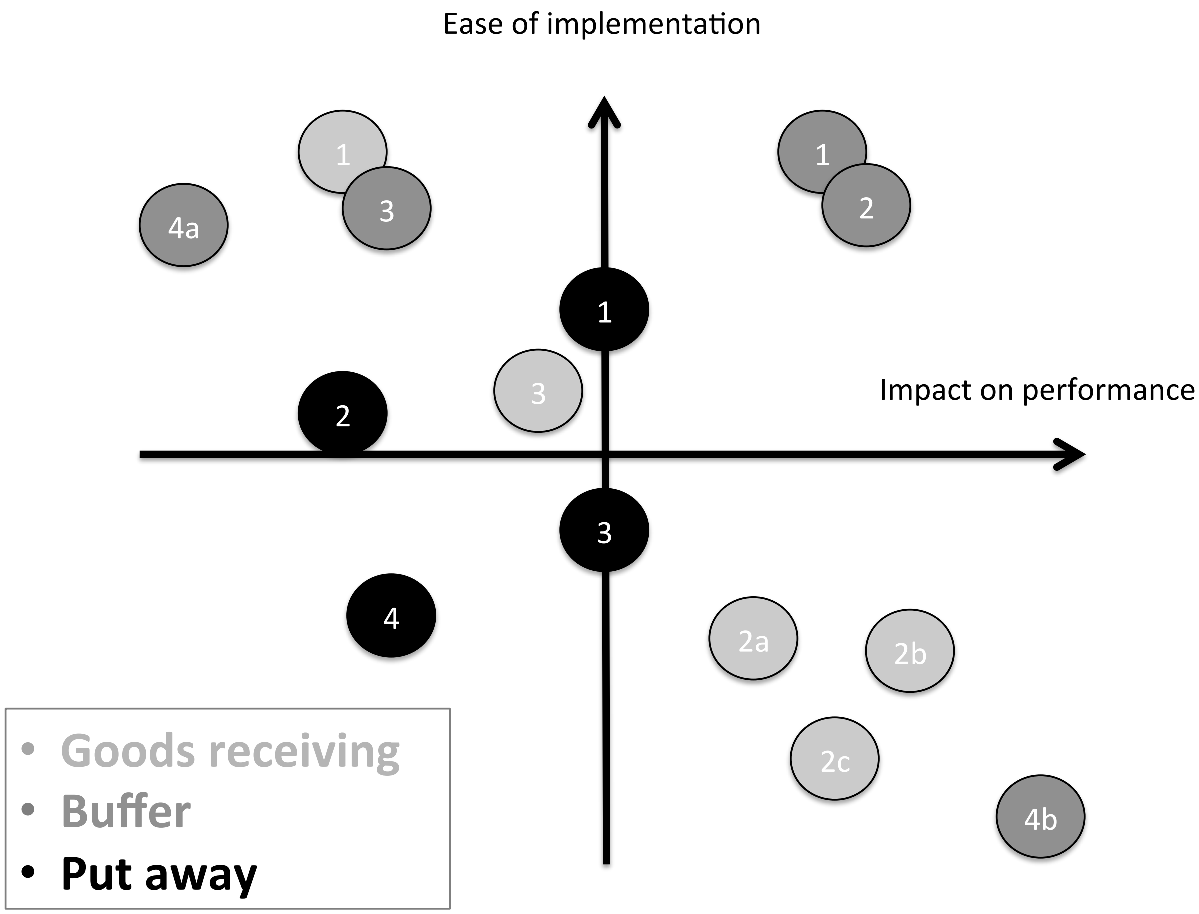


Figure 22 - Implementation-matrix

7 Discussion

This chapter presents a discussion of the results found in the analysis and put them into the two concepts presented in the model used for the analysis. The chapter also discusses the limitations of the results as well as a generalization of them to whether Schweinfurt and Tongeren can reap benefits from findings.

7.1 Process design

This section discusses how the process design contributes to the RTW lead-time and what implications the result from the analysis has on the design of the processes.

7.1.1 How do the results contribute to reducing RTW lead-time?

The warehouse inbound processes have proven to be not optimally designed to fit the flow, which has caused the inbound RTW lead-time to fluctuate greatly. This originates from the fact that the inbound flow previously has been handled secondly in favor of the outbound flow. The inbound process has therefore been divided in two sub-processes, with additional materials handling activities in between, resulting in that GSPs first have to be placed in the buffer and then either placed in the elevator or placed in storage on floor-1. GSPs spend most of the RTW lead-time inside the buffer waiting to be taken to its storage location, since the put away process is not optimally designed. This is in line with Johansson and Öjmertz (1996) argument: sub-processes are needed when the input to a main process has to be executed at several places and/or with idle time in between.

Due to the high variance and instability in the inbound processes, that has been shown in the empirical findings and later proven in the analysis, the recommendations should therefor be aimed at first reducing variance and eliminate the tail, rather than reducing RTW lead-times. This is in line with what Liker and Meier (2006) states: “Processes fraught with randomness and chaos tend to lead us to incorrect conclusions about what is real, what is possible and what’s not.” (The Toyota Way). If the tail could successfully be eliminated would also result in that the 97 overdue GSPs that on average sit in the buffer will disappear.

7.1.2 Implications from the result

A high degree of uncertainty has been found in the inbound flow. The arrival of SKF Mekan-transports fluctuates greatly in the evening and although they are advised before they departure it still does not reduce the uncertainty, as this is not communicated to the operators. The arrival time for trucks from SKF Poznan fluctuates but not as much. Without proper routines regarding how to handle arriving goods provides the next processes with difficult prioritization in how they should work. Although Factory-D-products have a short distance to the warehouse, the empirical data shows great fluctuations in the RTW lead-time, which is interesting. This is results from that the buffer do not divide product flows, hence handle all incoming goods in the same way.

The great uncertainty in arrival time for inbound goods strengthens the fact that the KPIs are not aligned with the inbound flow, as the warehouse is only measured on the outbound goods, which have left the inbound flow to be handled ad hoc. In order to reduce the uncertainty, better information transparency about incoming goods is needed. The first step in improving information transparency is to make sure the information flow frictionless (Bayraktar et al., 2009). The suggested KPIs are one step to decrease variability, as the KPIs will make it possible to monitor how the inbound flow is fluctuating, how the amount of GSPs in the buffer is fluctuating and to which degree the bottleneck is utilized. As these factors have not been measured before, they are believed to increase transparency and raise awareness in how the inbound flow is performing. Schweinfurt and Tongeren have been successful in this by involving all employees in the overall warehouse performance through e.g. regular meetings and continuously getting back to employees about their performance level.

It is clear that there are coordination problems between the floors and between shifts, as there is little understanding in how workers prioritize between the inbound and the outbound flow. This stems from a lack of information transparency as well as a lack of sufficient routines for how the different work areas should be coordinated. This goes against what Johansson and Öjmertz (1996) states about process design: A process must have sufficient conformity and posses such routines in order to handle the day-to-day work. However, it must be noted that the structure of the warehouse imposes challenges to the process design due to the multiple floors.

The identification method used for organizing GSPs in the buffer has been found to also have gaps in its design. The situation has improved since the new routines were implemented, such as the whiteboard in the buffer, but there are still room for improvements, as it has been observed that the whiteboard was not updated correctly once during the study. This means that there is still risk that GSPs are forgotten in the buffer and that the FIFO-principle could be set-aside in favor for GSPs more easily accessible. Although the implementation of a whiteboard is a step in the right direction, it does not consider GSPs placed outside the buffer zones, nor does it elevate overdue GSPs.

The amount of GSPs in the buffer fluctuates heavily, ranging from approximately 350 to 1800. Although there is a general perception that control is slipping away when the buffer reaches 800 GSPs, no explicit routines have been found regarding how to handle the situation when the 800-limit has been reached. As for now, the only way to deal with such a situation is by applying over-time, which is both expensive and put further tension on the workforce. In order to handle the situation, the warehouse supervisors and managers should work proactive and elevate problems as soon as they are identified.

7.2 Capacity matching

This section discusses how the capacity matching contributes to the RTW lead-time and what implications the result from the analysis has on the matching of supply and demand in capacity.

7.2.1 How do the results contribute to reducing RTW lead-time?

The lack in information transparency provides an environment prone with friction and is a result of barriers between personnel in the warehouse. This is not directly connected to increased lead-times for RTW products, but they are affected indirectly through poor decision-making, as decisions are based on not fully understanding the consequences. Poor information sharing regarding the arrival times of incoming transports results in bad planning in how to match supply and demand of capacity, and as a result a significant increase in the RTW lead-time. This is in line with Leitch (2001), who argues that it is important to match supply and demand of capacity to reduce the throughput-time and amount of work in progress.

7.2.2 Implications from the result

To reduce the RTW lead-time, it is evident to utilize the bottleneck to its maximum, as this is the slowest process in the system, hence the pacemaker. In the inbound flow, the bottleneck has been identified as the side-loaded forklifts on floor-3 and floor-4, as they have to simultaneously work with both the inbound and outbound operations. This suggests an equal priority between the outbound and the inbound flow and should not be a problem, as been seen in previous graphs that there can be peeks in both the inbound and outbound flow at once.

As Factory-D has a stable supply of goods, this flow should be easy to predict and therefore easy to match regarding supply and demand of capacity. SKF Poznan and SKF Mekan goods arrive after 15:00, implying that a greater emphasis on the inbound flow during, the afternoon and evening than during the morning and mid-day is needed. Especially since the staff is reduced significantly at 15:30.

The analysis suggests a greater information transparency, which will help in understanding where to focus attention during certain time spans.

Since the forklifts on floor-3 and floor-4 are working with both inbound and outbound operations, these operators need to be coordinated with personnel on floor-1 regarding the inbound flow, and personnel on floor-2 regarding the outbound flow. Instead of individually determining which flow to focus on, it seems as a better solution to coordinate everyone towards the same objective. A coordinated staff synchronized throughout the warehouse will secure the same throughput time every time, making it easier to implement robust processes, which is a prerequisite for reducing the RTW lead-time, as noted by Liker and Meier (2006). This is in line with Engström et al. (1996), arguing that well defined processes is a prerequisite to prevent deviations from set standards.

As stated in 5.2.3.2, coordinating employees is mostly about alignment and less about implementing new high-tech equipment. By continuously having check up-meetings about the warehouse performance will provide better information utilization, making people more involved in what is happening, as can be seen in Schweinfurt and Tongeren.

There should not be any significant cost with this implementation as it merely is a matter of involving the right people through e.g. meetings, hence not any specific investments. As the inbound and outbound flow share resources, assessing when transports arrive is important to plan and coordinate how to share resources, and is a reasonable first step in fulfilling the purpose of decreasing the RTW lead-time.

7.3 Limitations

The empirical data only considers three largest flows (SKF Poznan, SKF Mekan, Factory-D). These flows do however represent about 80% of the total inbound volume, concluding they have the most impact on the warehouse performance. However, the impact of the goods from Vehicle Parts has not been considered and even though they do not occupy the same capacity in the elevator they still require capacity from the operators on floor-1.

Since the product flows are complex to monitor in detail, there has been generalizations when the capacity was estimated. This was necessary since there is a lack in standardized routines, making it complex to calculate the exact capacity and instead of using an estimation.

It must also be noted that after the empirical data was gathered, a whiteboard was implemented in the buffer, which indicates that the performance has changed. This might be the case as the whiteboard helps the operators to follow the FIFO-principle in a much better way.

Besides this, the focus has been to investigate the inbound flow of goods in the Gothenburg warehouse; hence the outbound flow has not been analyzed in the same depth. This creates a risk that the complete picture of how the recommendations provided will impact on the outbound flow.

7.4 Can Schweinfurt and Tongeren reap any benefits from Gothenburg?

Since the warehouse in Gothenburg has a rather unique layout with its five floors of operations, the provided solutions are developed with this in mind. However, there are some findings possible to apply in the context of Tongeren and Schweinfurt, the most significant being the inconsistent KPIs in the three warehouses. Since they are not measured in the same touch points, it is impossible to benchmark the warehouses with each other to assess "best practice".

The same resources are shared for both inbound and outbound operations. This is different compared to Schweinfurt and Tongeren since the inbound- and the outbound flow are separated in these warehouses. Besides this, Schweinfurt and Tongeren possess a highly advanced automated storage and retrieval system, which reduces the overall friction in the warehouse. The complexity in coordination is therefore not as great in Schweinfurt and Tongeren as in Gothenburg.

However, the findings are still relevant for the two warehouses on a general level. Regardless of the activities and structural design; transparency and coordination has not only been proven important in Gothenburg but also according to the theoretical data.

7.5 Area of further investigation

Stated in section 7.3, this thesis has only focused on the three largest flows (Factory-D, SKF Poznan and SKF Mekan). Since 20% of the inbound goods are not considered in the design of the recommendations, it will be necessary to investigate these flows as well. It is not safe to say, but the improvements are believed to have a positive impact on all flows, as the improvements are mainly focused on assessing stable processes, which is a prerequisite in all operations in order to improve their performance.

During the thesis a new organizational system with a whiteboard was implemented in the buffer. It is believed that these routines have had a positive impact on the performance of the buffer. The data however was collected before the system was implemented and the result has not been measured or considered. By measuring the RTW lead-time once again would determine if this has had has an impact and if management should continue to develop this system.

When the put away frequency was calculated only the overall performance was assessed, hence no deeper segmentation of the different storage locations was made. To further understand if there are GSPs designated for specific storage locations that are overrepresented in the tails of the RTW lead-time graphs, a deeper segmentation of the put away frequency could prove this. E.g. by segmenting the products according to which storage-location they are designated to.

8 Conclusion

The purpose of this thesis was to contribute to a reduction in the RTW lead-time in product flows in the three warehouses in Gothenburg, Schweinfurt and Tongeren.

During the initial data gathering it became evident that the biggest potential for lead-time reductions was within the inbound operations in the warehouse in Gothenburg, hence the focal point became this warehouse. The warehouses in Schweinfurt and Tongeren were used to conduct a benchmark study to explore best practice in order to understand how efficient warehouse processes were executed.

The complexity of the operations in Gothenburg is unique as the warehouse is built in five different floors (Schweinfurt and Tongeren only have one) making processes more time consuming, as goods are sent manually through elevator to the different floors.

The empirical data collection is comprised of the three largest flows (SKF Poznan, SKF Mekan and Factory-D), together covering 80% of the total inbound volume. However, as it was impossible to assess the RTW lead-times within the warehouse, new touch points was established.

Some data could be accessed directly through WASS, which results in that the amount of observations varies greatly between the flows, and could be a subject of criticism to the validity of the empirical results. It is however believed to depict the environment in the correct way as the findings were discussed and approved by Six Sigma Black Belt-employees at SLS.

The theoretical findings are aligned to first focus on stable processes. This is believed to be the basics in order to reduce the lead-time, as lead-time reductions are hard to achieve if having unreliable processes.

The theory is conclusive focusing on the same two key points to reduce lead-time, which are to match supply and demand of capacity and to design the warehouse processes in the right way. Within these two aspects, there are three key points to cover in order for a warehouse to work efficiently:

- Coordination between processes – Work need to be synchronized in order for the processes not to break down and cause additional handling activities.
- Standardized routines – Everyone have to work in the same way to reduce deviations in a process. Without standardized work-routines, changes will not have an effect.
- Transparency – To understand the environment, and how operations are interrelated, there is a need for transparency in communication. Otherwise, sub-optimizations will occur, impeding the performance.

The processes in the inbound flow experience great fluctuations in its performance. Looking at this from the perspective of Little's law it becomes evident that there is a problem with the speed of the system as the average arrival time has on average been higher than the throughput time within the system.

To reduce the RTW-lead time the obvious would be to aim improvements that both would speed up the system and shorten the length of the system to decrease the throughput time. As a result of the instability in the inbound flow it becomes impossible to reduce the RTW lead-time, as strengthen by the theory. The first priority is to achieve continuous stability to decrease the variance. When understanding when and how much goods will arrive, it will be easier to follow the standardized work routines for how to handle these products in a structured way.

The fluctuating inbound flow is connected to the low-level of transparency, both in communication and coordination. Problems must be elevated immediately, and the right personnel have to get access to the right information in order to plan and carry out activities in an efficient way.

There is a need to increase the sense of urgency in the importance of the inbound flow. From the fact that the KPIs used today are directed towards to the outbound flow, there is little knowledge about how the inbound flow actually performs on a day-to-day basis. As strengthen by theory, what gets measured gets done, meaning that KPIs implemented in the inbound flow will increase awareness and the efficiency. The following three KPIs are suggested, and are the same used when the empirical data collection was conducted:

- KPI 1: Amount of GSPs in buffer
- KPI 2: Amount of GSPs inbound at what time
- KPI 3: Amount of GSPs put on conveyor/hour

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Appendix A – Interview guides

Interview guide "Warehousing supervisor" – 1/2-2013

Questions regarding the product flow in general

- When is a product classified as "finished" in the system?
- How is this communicated to the next part handled in the flow?
- Are products between the Factory-D and warehouse here in Gothenburg classified as GIT?
- How does forklifts know when they should pick up the goods in buffer #1?
    - How long can they lie there?
- What parameters influence how and where the products are stored?
- At what point does the product get a suggestion for storage space?
- Do you have flow charts/steering documents about the production/warehouse operations?
- How does different batch sizes affect the possibility to directly put products into storage?
- Are the warehouse only using WASS, or are there any other IT-systems working with the warehousing?

Inbound area to storage location

- When are articles reported as being in the warehouse?
    - How is this done? [Manually/automated/IT-driven]
- Are products from other locations directly sent into the warehouse or are there any preconditions before?
    - When do these products stop being GIT
- How do you know where to place the GSPs in the warehouse [warehouse spot]?
- How are they transported there? [Standardized pathway/automatic movement]
- What types of storage methods are used?
- How and when are products reported as being in storage?

From storage location to outbound area

- How is the picking of a product in storage initiated?
- How is it collected? [Mode of transport/pathway/priority between products]
- Where is it buffered? [Outbound goods]
- How is this communicated to relevant parties handled? [SLS, customer]
- When is the status changed from "being in storage" to "pick up by SLS"?
- Who is responsible for getting the product, and when is the status changed from "pick up by SLS" to "Goods in Transit"?
- Is responsibility handed over?

Interview guide "Warehousing supervisor" – 14/2-2013

General questions

- How are shifts and staff managed within the warehouse to secure the service level?
- What service-level is SLS desired to operate within?
- What service-level does SLS operate within today?

- Regarding the warehouse operations, what type of equipment does SLS possess and use on a daily basis?
    - Are they working accordingly?
    - Is the equipment capacity enough for SLS to deliver on time?

Interview guide "Warehousing supervisor" – 21/3-2013

- What goods are inbounded on floor-1 and sent directly to floor-2 to cross-dock?
    - Internal goods only?
    - How often does the internal transports arrive?
- Are all Large-products stored on floor-2?
    - If not, where are the others stored? And where do they arrive in the warehouse?
- How does the routines look like for Large-products arriving at floor-2?
    - Can you take us through the steps?
- What is the distribution of orders during a typical week?
    - Same amount of orders every day?
    - When is the peak?
- How are the working shifts distributed over this week, and how is personnel distributed within the shifts?
    - How are breaks taken by the shifts?
- Do the inbound transports from SKF Poznan/SKF Mekan have designated GSP spots on floor-1? Are there standardized spots for GSPs at all?

Interview guide "Manager inventory management process" – 13/2-13

Questions regarding the Organization

- Can you give us a general description of distribution network
- Which countries is SLS operating in?
- Who does SLS answer to?
- What operations are SLS conducting?
- What kind of customers do you have? (Internal/external)
- What services do SLS offer?

Questions regarding the Resources

- How many people work in Gothenburg? (1200 globally)
- Do you believe SLS is working as it should today, or should something be changed? =IF(yes): What?
- Do you see any specific challenges on a global perspective?

Questions regarding the Operations

- How are shifts and staff managed within the warehouse to secure the service level?
- What service-level is SLS desired to operate within?
- What service-level does SLS operate within today?
- What do you think is the biggest difference if comparing the Gothenburg International warehouse with other International warehouses?
- Which IT-systems does SLS use?

- Regarding the warehouse operations, what type of equipment does SLS possess and use on a daily basis?
    - Are they working accordingly?
    - Is the equipment capacity enough for SLS to deliver on time?

Interview guide "Manager business Development" – 28/3-13

- Can you give us a description of what you do?
- How are trips created?
  - How are orders received in WASS?
  - How long are the orders in WASS before they are released for picking?
  - Is there a difference in when the orders are released depending on the transport mode?
- What agreements do you have with the 3PL companies that handle the goods from SKF Mekan and SKF Poznan?
  - When should these transports arrive on a normal day, and is this pre-alerted?
  - Is there any follow up on the performance of the 3PL companies?

Interview guide for Schweinfurt and Tongeren

Questions related to warehouse design

- Can you walk us through the organization of the building
    - Are there any temporarily storage zones for where goods are placed before being put into storage? E.g. while sorted or consolidate
    - Why is it not put away directly?
- How do workers identify where goods are temporarily stored?
    - How are signs, floor markings etc. used to identify where goods has been placed and how long they have been there
- Overall capacity
    - What is the warehouse storage and handling capacity?

Questions related to materials handling activities

- What activities are carried out throughout the flow from the GSPs loaded off a truck to it is placed in storage?
    - Is there a work standard for how activities are carried out and in what sequence?
    - What priorities are there between different activities
- Transportation
    - How are slot times used for inbound and outbound?
    - What is the frequency of inbound and outbound transports?

Questions related to resources

- How are resources coordinated to match supply and demand for capacity?
    - How are resources distributed or shared between shifts, groups and areas?
    - Are they dedicated to a certain process or activity?
- What type of equipment is used?
    - How are they used to make, work easier?
- How is the personnel organized?

    - What types of shifts are there and how do they rotate?
    - Are the shifts matched so that the supply of capacity is matched up with the demand for labor?
    - How activities are divided within the shift (rotations, cross-training)
    - If there is a spike in outbound or inbound volume, how do you handle this?
    - How are personnel distributed to match the demand?

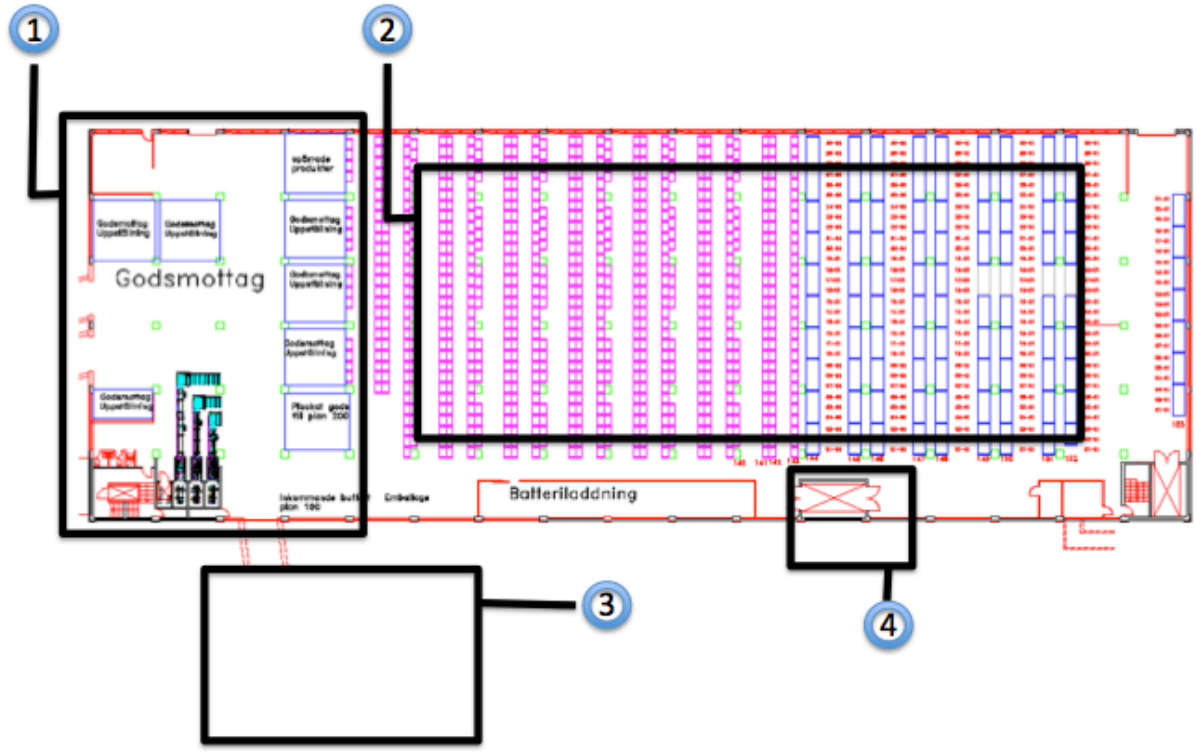
Questions related to IT-systems

- What IT-systems used?
    - How are they used control the flow?
- How is information communicated between personnel/forklifts about assignments and activities?

Interview guide "Team-leaders" – 15/4-2013

- What are your responsibilities?
    - Do you have different responsibilities?
    - Do you also help out with operational activities?
- How much do you control how the operators work?
    - How are resources prioritized between the floors?
    - Are there re-prioritizations during the day?
    - What decides if the operators work according to "one-in one-out"-principle?
    - Do you have meetings where the distribution of resources is discussed?
- What information do you get about incoming goods?
- Is it you or the transportation department who releases the orders?
- If there is a problem and something breaks how is this handled?
    - How is this communicated up to management?
- Are there occasions when the operators responsible for the weighing station are on break while the rest of the flow is still running?
- When a picking location is empty how is it replenished?
- What are your official internal lead-times?

Appendix B – Layout Gothenburg floor-1



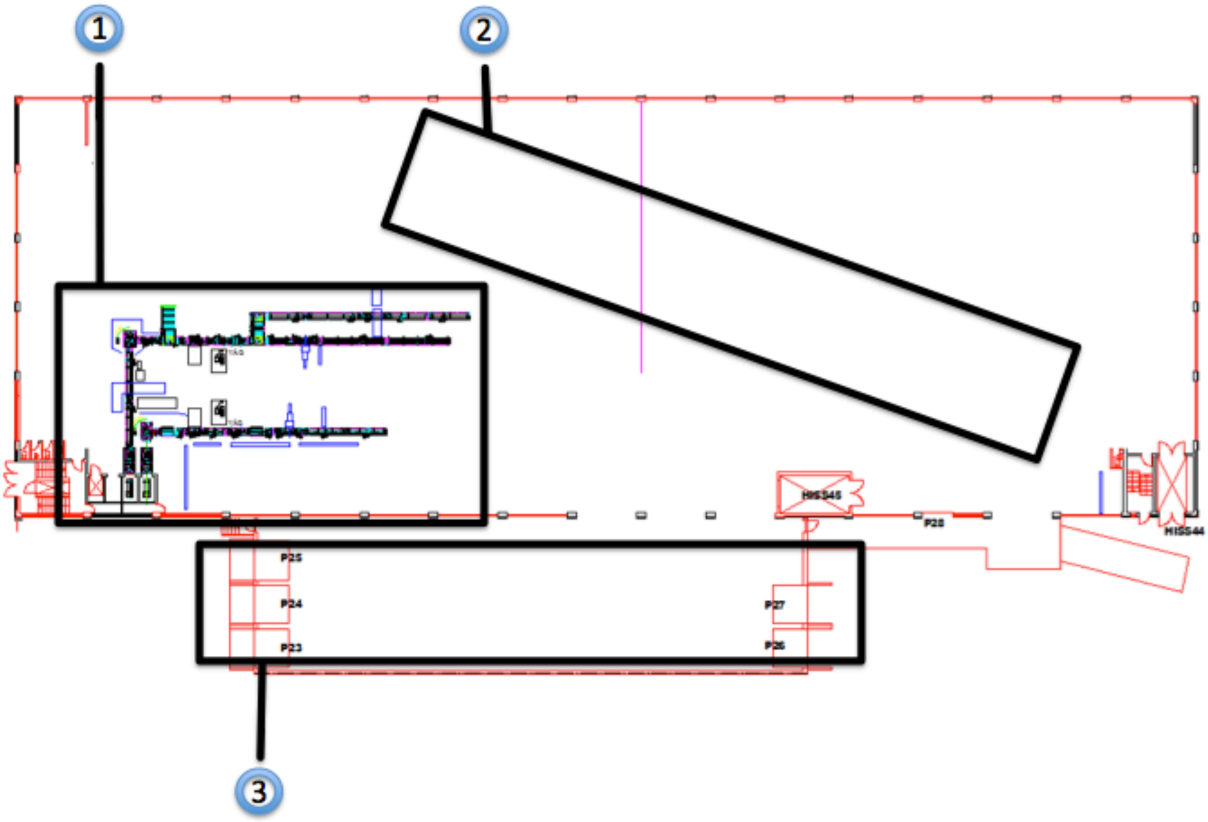
1: Main buffer

2: Storage area

3: Vertical elevator and vertical elevator buffer

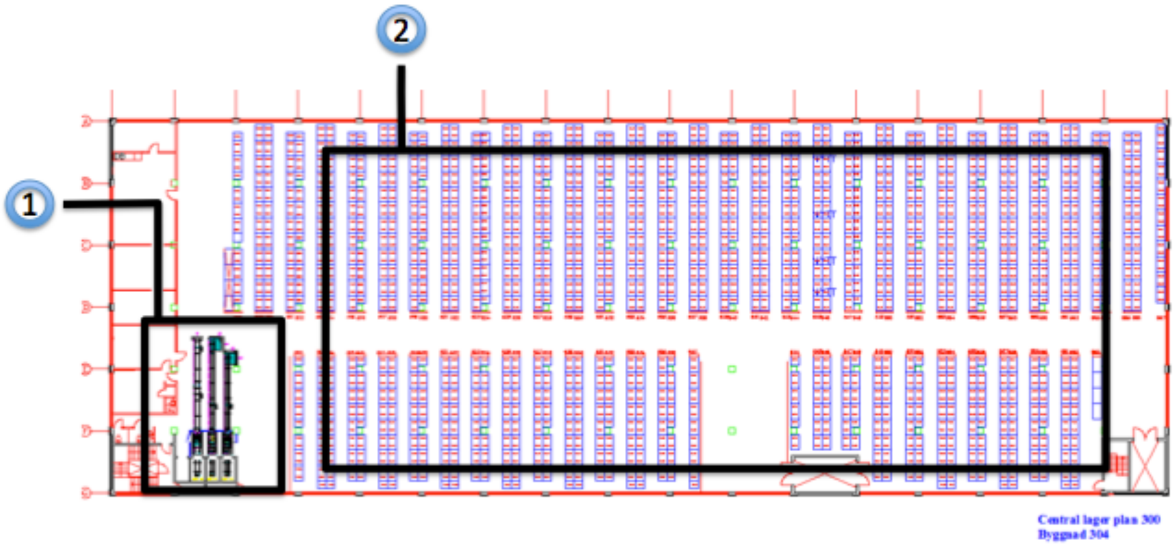
4: drive path to storage area-E

Appendix C – Layout Gothenburg floor-2



1: Automated conveyor belts connected to the automated elevators
2: Temporarily buffer for outbound goods
3: Outbound docks

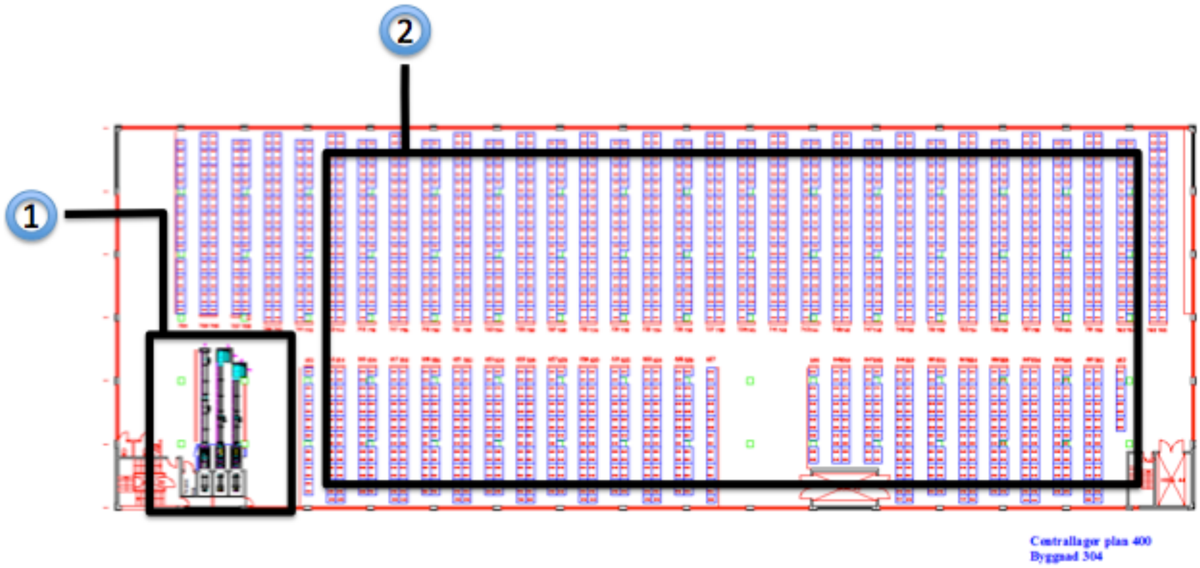
Appendix D – Layout Gothenburg floor-3



1: Automated elevators

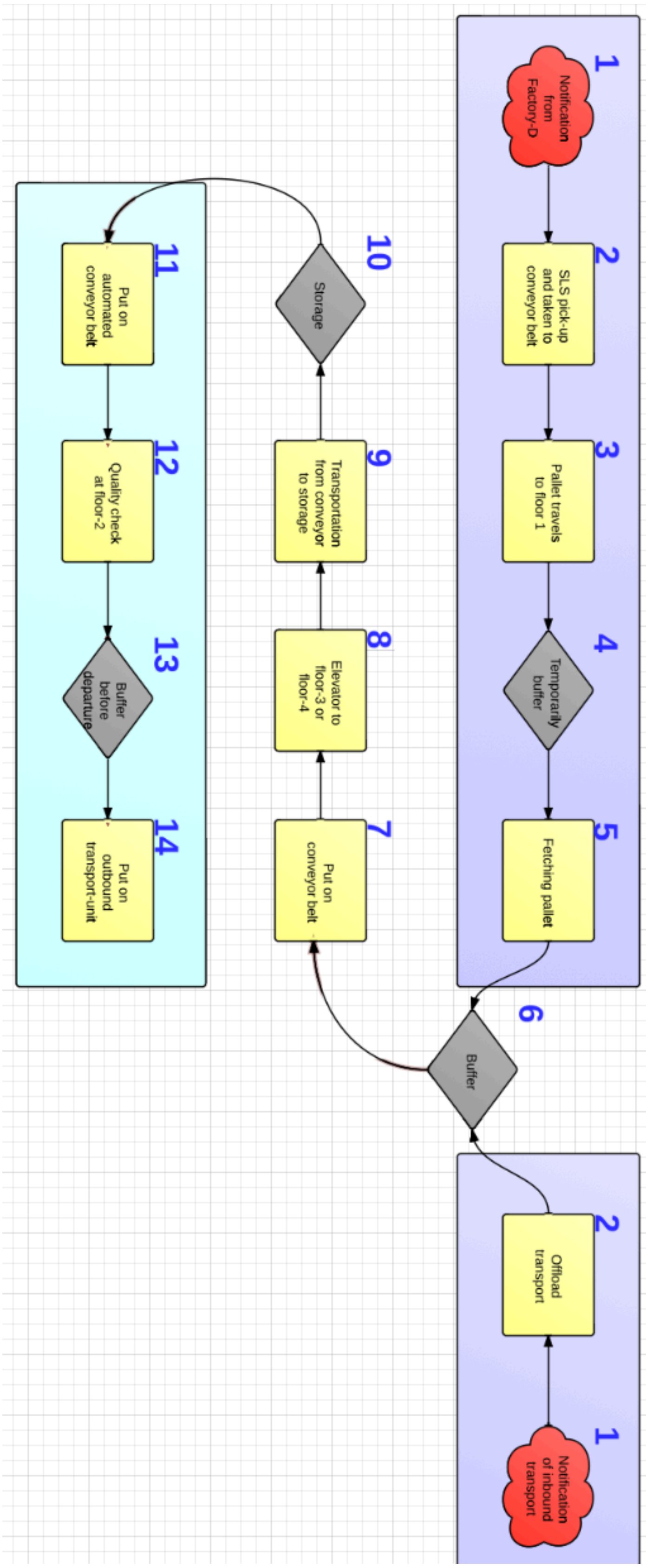
2: Storage locations

Appendix E – Layout Gothenburg floor-4

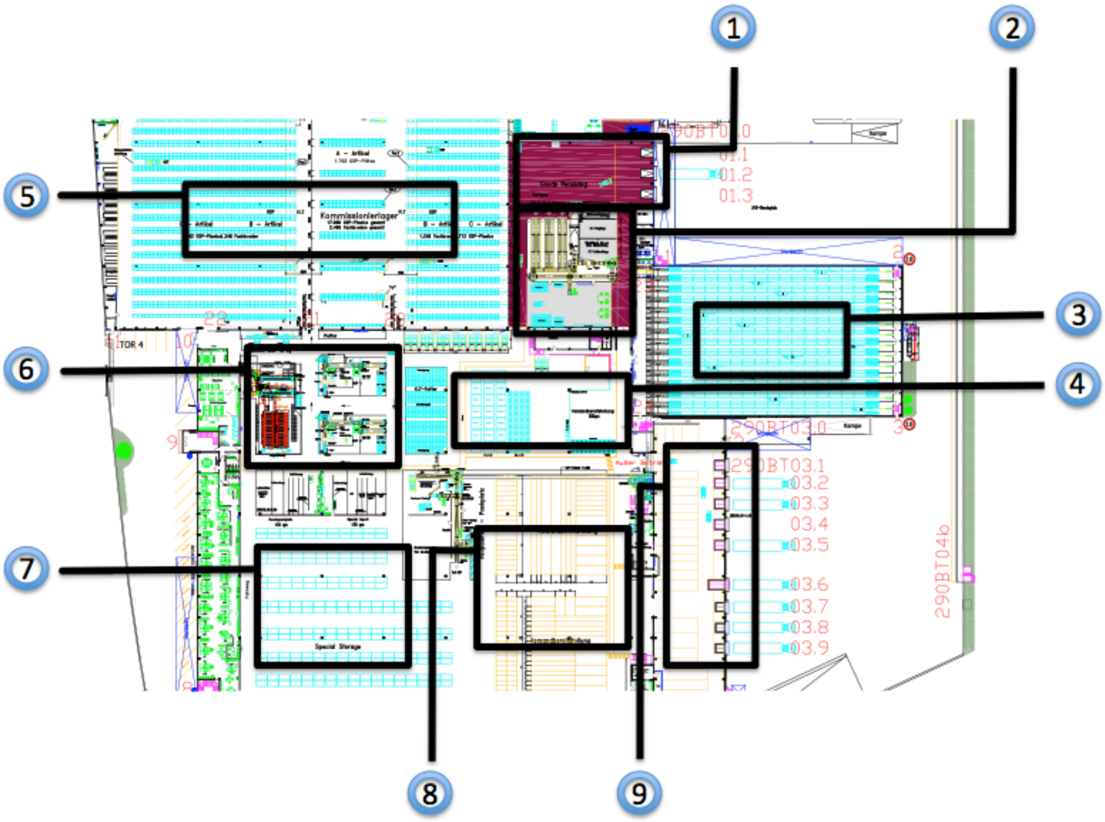


1: Automated elevators
2: Storage locations

Appendix F – Process map of inbound flow in Gothenburg



Appendix G – Schweinfurt



1: Three inbound docks + buffer space before conveyor belts

2: Three conveyor belts for inbound goods + quality check-department if GSPs are rejected

3: Automated storage system

4: Packing-station full GSPs

5: Picking-storage

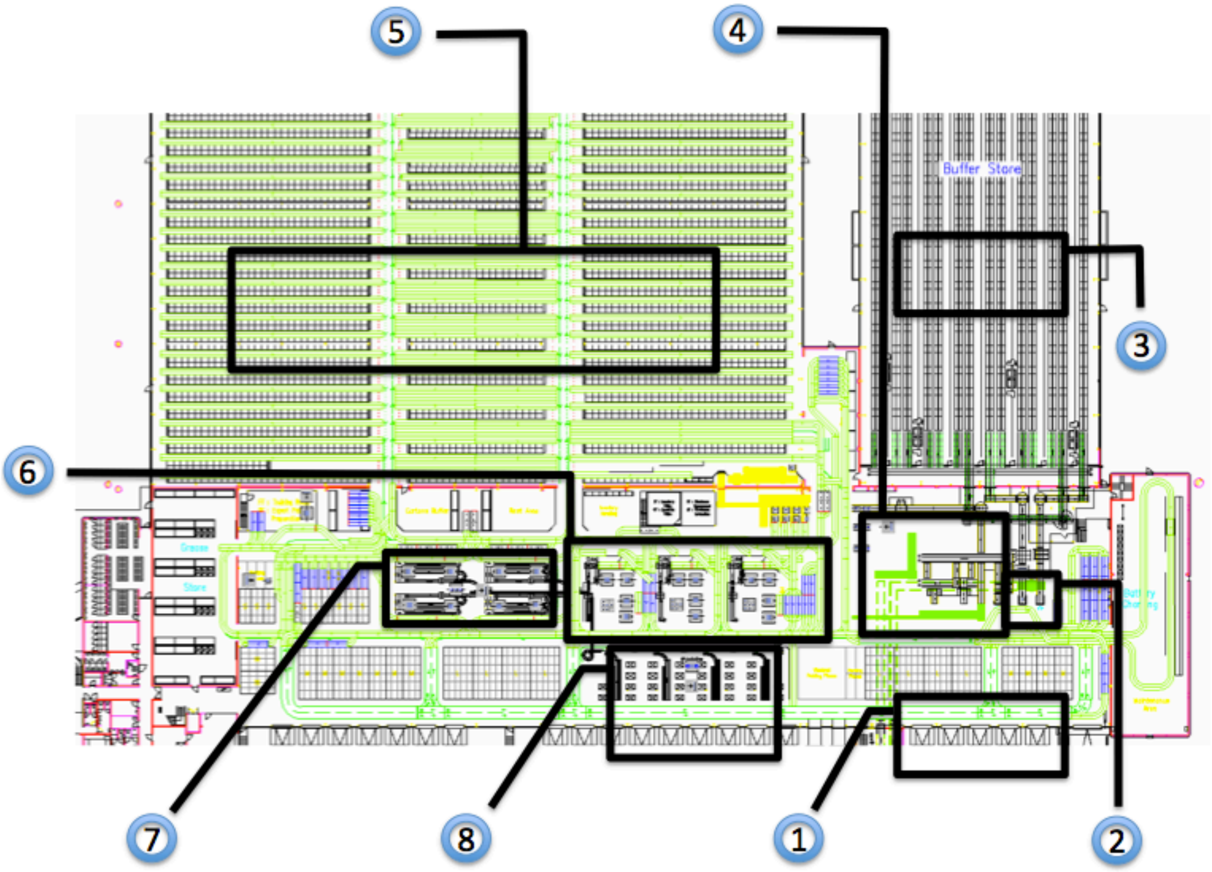
6: Packing-station for picking-assignments

7: Automated storage system

8: Outbound area

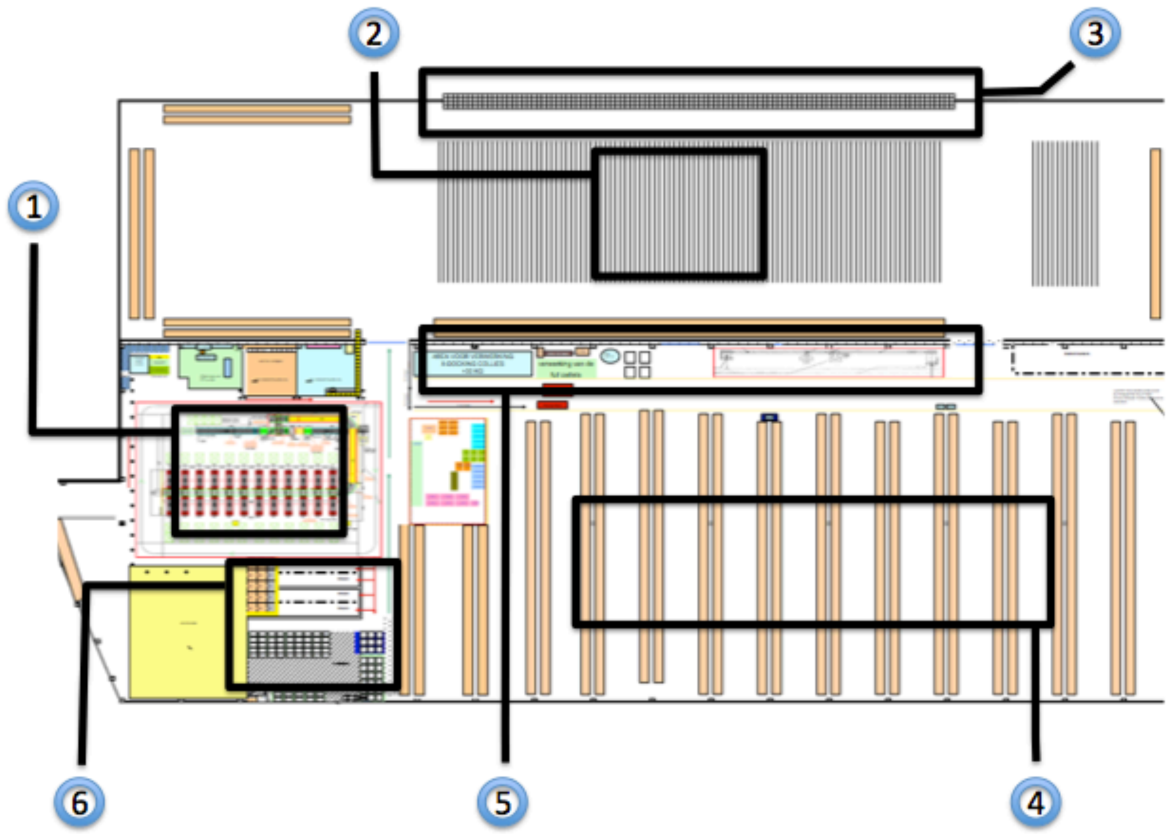
9: Outbound transport docks + buffer area for cross-docking goods

Appendix H – Tongeren MWH



1: Inbound docks
2: Conveyor belts for inbound goods
3: High bay-storage
4: Replenish-belts for picking/packing storage + heavy picking station
5: Picking-storage
6: Packing-station for GSPs
7: Packing-station for carton boxes
8: Packing station of carton boxes into GSPs

Appendix I – Tongeren WEC 1



1: Pick/pack-location for carton boxes and smaller items
2: Area for cross-docking goods temporarily stored when between transports
3: Transportation docks
4: High-rack storage
5: Pick/pack-location for EUR-pallets (larger goods)
6: Storage for smaller items

Appendix J – Productivity measurements

hour	GSP put away/h	deviation	abs. deviation	GSP inflow/hour	GSP IN - OUT	man hours	put away/man hour	picking assignments	picking/man hour	total assignments	total ass/man hour	Remark	break corrected total assignments /man hour
0:00	14	11	11	11	-3	5	2.71	9	1.80	22.53	4.51		4.5
1:00	36	16	16	16	-19	5	7.11	14	2.80	49.53	9.91		9.9
2:00	27	12	12	12	-14	5	5.39	19	3.80	45.94	9.19	Break	6.2
3:00	18	15	15	15	-3	5	3.55	7	1.40	24.75	4.95		5.0
4:00	28	14	14	14	-14	5	5.63	24	4.80	52.16	10.43		10.4
5:00	9	12	12	12	3	5	1.71	0	0.00	8.56	1.71		1.7
6:00	13	3	3	3	-10	5	2.55	3	0.60	15.75	3.15		3.2
7:00	36	19	19	19	-17	26	1.39	135	5.19	171.25	6.59	shift change	4.4
8:00	36	33	33	33	-3	26	1.40	131	5.04	167.28	6.43		6.4
9:00	30	8	8	8	-23	26	1.17	45	1.73	75.41	2.90	Break	1.9
10:00	49	21	21	21	-28	26	1.88	63	2.42	111.97	4.31		4.3
11:00	26	15	15	15	-12	26	1.01	24	0.92	50.19	1.93	Break	1.3
12:00	37	13	13	13	-24	26	1.43	90	3.46	127.06	4.89		4.9
13:00	33	21	21	21	-12	26	1.28	116	4.46	149.28	5.74		5.7
14:00	19	7	7	7	-12	33	0.56	67	2.03	85.56	2.59	Break	1.7
15:00	17	64	64	64	47	29	0.59	30	1.03	47.13	1.63	shift change	1.1
16:00	14	38	38	38	24	12	1.18	32	2.67	46.16	3.85		3.8
17:00	10	64	64	64	54	12	0.84	38	3.17	48.03	4.00		4.0
18:00	8	46	46	46	38	12	0.64	17	1.42	24.63	2.05		2.1
19:00	11	46	46	46	36	12	0.89	38	3.17	48.72	4.06		4.1
20:00	15	43	43	43	28	12	1.25	26	2.17	41.00	3.42		3.4
21:00	5	74	74	74	69	12	0.40	24	2.00	28.81	2.40		2.4
22:00	24	40	40	40	17	12	1.96	0	0.00	23.53	1.96	shift change	1.3
23:00	34	13	13	13	-21	5	6.71	0	0.00	33.56	6.71		6.7

	total assignments	total ass/man hour
Day-shift	109.46	4.11
Night-shift	31.32	6.26
Evening-shift	37.27	3.11

Appendix K – Inbound distribution of GSPs to floor-1

	Factory-D	Poznan	SKF Mekan	Total average GSPs/hour
1:00	16.1	0	0.0	16
2:00	13.9	0	0.0	14
3:00	14.1	0	0.0	14
4:00	13.7	0	0.0	14
5:00	12.3	0	0.0	12
6:00	2.6	0	0.0	3
7:00	7.9	0	11.6	19
8:00	7.7	8.8	16.6	33
9:00	6.1	1.1	0.0	7
10:00	11.8	10.2	0.0	22
11:00	14.7	0	0.0	15
12:00	13.7	0	0.0	14
13:00	15.5	7.3	0.0	23
14:00	6.8	0	0.0	7
15:00	7.4	56	0.0	63
16:00	11.0	26	0.0	37
17:00	6.7	0	56.6	63
18:00	8.8	0	36.2	45
19:00	10.4	0	35.1	45
20:00	12.9	0	29.6	42
21:00	12.9	0	60.7	74
22:00	5.3	0	34.8	40
23:00	12.4	0	0.0	12
0:00	10.3	0	0.0	10
TOTAL GSPs	255	109	281	646
% of total	39.5	16.9	43.5	100.0
Average	10.6	4.6	11.7	26.9
StdDev	4	12	19	

Appendix L – Number of GSPs in buffer

Date	Time	Main buffer	Vertical elevator buffer	Total
3/19/13	12:15	770	95	865
3/20/13	13:00	824	100	924
3/21/13	14:00	1294	97	1391
3/22/13	15:20	1489	270	1759
3/25/13	12:50	1378	223	1601
3/26/13	12:40	1183	239	1422
3/27/13	12:40	1060	211	1271
3/28/13	12:12	1051	226	1277
4/2/13	12:40	453	27	480
4/3/13	12:50	227	52	279
4/4/13	12:10	423	25	448
4/5/13	16:30	386	13	399
5/2/13	12:15	785	94	879
5/3/13	12:00	853	74	927
5/6/13	13:30	890	175	1065
5/7/13	13:45	950	76	1026
5/8/13	12:30	627	81	708
5/10/13	14:15	1009	56	1065
5/13/13	12:45	515	30	545
5/14/13	12:30	512	0	512
5/15/13	11:05	671	3	674
5/16/13	12:40	968	0	968
5/17/13	12:20	1289	22	1311
5/20/13	13:00	797	64	861
5/21/13	12:20	1474	65	1539
5/22/13	17:30	820	62	882
5/23/13	6:50	647	107	754
Average		865	92	957

Appendix M – Available capacity before and after 1st April

Maximum capacity before 1st April (hours)						
			Total Day	Total Evening	Total Night	
Regular personnel	8	h	218.2	54.4	55	
Shift Personnel	11	h				
Team leader	6.4	h				
Total						327.6

Maximum capacity after 1st April (hours)						
			Total Day	Total Evening	Total Night	
Regular personnel	8	h	203.2	94.4	40	
Shift Personnel	8	h				
Team leader	6.4	h				
Total						337.6

Appendix N – Overdue GSPs for Factory-D, SKF Poznan and SKF Mekan

Factory-D				
Overdue GSPs	OK	In one day	In two days	In three days
1221	17149	15147	16307	17149
7%	93%	82%	89%	93%

SKF Poznan					
Overdue GSPs	OK	In one day	In two days	In three days	In four days
12	123	78	104	114	123
9%	91%	58%	77%	84%	91%

SKF Mekan				
Overdue GSPs	OK	In one day	In two days	In three days
15	95	56	77	95
14%	86%	51%	70%	86%

Appendix P – Definitions

- **Assignment**: One assignment = one GSP. This is assumption, as one assignment could include several GSPs. However, when discussing this with the warehouse managers, this simplification was believed to be accurate enough to support our data.

- **Available capacity**: available operators during a certain time period

- **Effectiveness**: Successful in producing a desired or intended result

- **Efficiency**: A level of performance that describes a process that uses the lowest amount of inputs to create the greatest amount of outputs

- **GSP**: A GSP is half the size of a EUR-pallet and measures 0,8 X 0,6 meters.

- **One in-One out**: The activity the forklifts use when they move one GSP in to storage and at the same time take one GSP out of storage, so they never drive empty.

- **Productivity**: $\frac{assignments\ executed}{man-hours\ available}$

    - Note! The productivity is calculated differently depending on what to take into consideration. E.g. the productivity for the inbound flow is calculated only with respect to amount of put away, whilst the total productivity is calculated with respect to total assignments executed.
    - A generalization here is the assignments split on all workers available in the warehouse, not dependent on their specific task. This means that even though an operator has other duties than just executing put away or picking, those actions will decrease productivity

- **Put away frequency**: The amount of GSPs being scanned as “in storage” during a certain time-span