A study on layout design for a logistic center – Case study at ASSA ABLOY Opening Solutions Sweden AB

Master's thesis in Product and Process Development

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Abstract

Most organizations understand that in order to progress in a market that is dominated by competition, they must identify practices that can lead to improvements and obtaining competitive advantages. As a way to drive improvements, it has led to the link between layout planning and supply chain management receiving growing awareness. Due to modern facilities laying the foundation for organizations in order to achieve supply chain excellence and competitive advantages, layout planning is starting to play a more influential part for companies.

ASSA ABLOY Opening Solutions Sweden AB's (ASSA ABLOY OS) facility in Eskilstuna is currently in a transitional phase where they are planning on moving the current distribution center and certain warehouse operations to a third-party logistics solution in Gothenburg. In conjunction with this move, a smaller logistic center will be developed and operate instead. Unlike the distribution center that stores and manages several products related with opening solutions, whilst operating in a substantial area, the new logistic center will only store and manage components related with mechanical locks and cylinders, leading to the remaining operations operating in a significantly reduced area.

The purpose of this study was therefore to investigate how to develop an optimal layout design for a logistic center. The study will include identifying potential methods that can be used in order to identify existing wastes, improvement areas, as well as to developing a deeper understanding regarding how to design a layout. The aim of the study will lastly be to present recommendations and a suggestion for a future layout, based on scientific theories and empirical findings.

The Value Stream Mapping (VSM) method has been used in order to conduct a current state analysis, involving the identification of wastes that can be eliminated in the future layout, as well as improvement areas that can be implemented. Additionally, The Systematic Layout Planning (SLP) method has been used in order to develop a deeper understanding regarding the importance of closeness between the separate operations and workstations, which would feature within the future logistic center.

The application of SLP in the development of the new layout led to the forming of alternative layouts for the case company, were each layout consisting of a rearrangement of the operations and workflows, subsequently providing different advantages and disadvantages which could later be balanced against each other. Once evaluated based on which layout provided the finest distribution of its processes, it led to the development of an ultimate layout that provided the case company with maximized space utilization, improved flow of material, safer work environments, as well as opportunities for increased productivity. This was later presented to the case company.

Keywords: Layout Planning, Logistic center, Systematic Layout Planning, Value Stream Mapping, ASRS, AGV, AMR
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<td>Automated Guided Vehicle</td>
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<td>AMR</td>
<td>Autonomous Mobile Robot</td>
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<td>ASRS</td>
<td>Automatic Storage and Retrieval System</td>
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<td>ASSA ABLOY OS</td>
<td>ASSA ABLOY Opening Solutions Sweden AB</td>
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<tr>
<td>DC</td>
<td>Distribution center</td>
</tr>
<tr>
<td>FIFO</td>
<td>First-in-First-out</td>
</tr>
<tr>
<td>MTO</td>
<td>Make to order</td>
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<tr>
<td>MTS</td>
<td>Make to stock</td>
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<td>RFID</td>
<td>Radio Frequency Identification</td>
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Chapter 1
Introduction

This chapter presents a general overview of the study and the concept of layout design and planning. This is followed by problem formulation, purpose and research questions as well as limitations of the study.

1.1 Background

In a growing and globalized industry that is dominated by increasing competition as well as pressure from society, it is critical for companies to identify new and innovative approaches to implement for both the organization's survival as well as for achieving competitive advantages. Approaches that has been receiving growing awareness in recent times involves facility planning and improving an organization's supply chain management (Wlazlak and Johansson, 2014). Melo et al. (2009) and Dwijayanti et al. (2010) mentions that facility planning has been a popular topic for many years, however it is not until recent times that the process has been transformed from primarily considering science into a strategy that concerns how to obtain competitive advantages within a global marketplace. The link between facility planning and supply chain management has been identified as a critical aspect, due to modern facilities laying the foundation for organizations achieving supply chain excellence. For that reason, facility planning plays a vital role when it comes to obtaining both organizational effectiveness and competitive advantages.

The growth of organizations as well as global competition, has forced companies not only to relocate their plants and logistic centers, but also to redesign them for competitive and cost-efficient purposes (Lemoine and Skjoett-Larsen, 2004). Logistic and distribution centers involve and manages various logistic operations such as storage and deliveries of both raw materials and finished products, in order to support companies with meeting the supply and demand from the market. Proper planning of the logistic center can therefore provide numerous advantages such as safety improvement, efficient material flows, increased performance and storage capabilities (Langevin and Riopel, 2010). However, in order to obtain the previously mentioned advantages it is essential to conduct an analysis of the current state, in order to identify and develop a deeper understanding regarding the wastes that currently exist, as well as how they can be eliminated when redesigning a plant layout (AR and al-Ashraf, 2012; Brunt, 2000). A tool that can be used to conduct a current state analysis is the Lean management method known as Value-Stream Mapping (VSM). VSM provides companies with the possibilities to identify and eliminate waste in value streams, thereby creating leaner operations which consequently increases the productivity and efficiency of a given value stream (Brunt, 2000).

Although facility and layout planning offer numerous advantages is it much more easily said than implemented. When it comes to the actual development of a future layout, many organizations fail to plan and later on set up the designed layout due to various errors. One reason for that can be that not all aspects have been included in the planning of the layout (Hassan, 2002). There exist many elements and aspects that should be taken into
consideration when planning and designing future logistic centers. These aspects can include the following: space requirement, arrangement of functional areas, material flows, time, distance, flexibility and receiving-shipping zones. Therefore, it is crucial that all aspects are taken into consideration when planning and implementing efficient layouts (Khusna et al., 2010; Tompkins et al., 2010).

In addition to the several existing aspects that should be considered when designing a layout, there exist several methods related to plant layout design, such as Systematic Layout Planning (SLP), algorithms and arena simulation (Wiyaratn et al., 2013). However, SLP has proven to be a more efficient method due to it involves designing a layout based on the logical relationships between workplaces. Consequently, leading to workstations with high material flows and frequency of use are placed close to each other. Thus, establishing efficient material flows with minimized travel distances and least amount of material handling (Suhardini et al., 2017). Additionally, the method can utilize both qualitative and quantitative data during application, unlike a method like algorithms, which only can be based on quantitative input as well as being more complex (Eliud et al., 2018).

According to Brezovnik et al. (2015) as a consequence of many companies redesigning their plants as a driver for improvements, the integration of automatic systems and solutions are receiving growing awareness due to the benefits it can provide regarding to material handling. Today, automatic storage and retrieval systems (ASRS) are being demanded more than ever. This is due to increasing economic and logistic needs and the fact that more goods need to be stored. By implementing automated systems and solutions it can provide reduced labor costs, as the need for human workers can be eliminated. Subsequently it leads to eliminating occurrences of human errors, leading to increased safety within the workstation as well as increased productivity and precision as automated systems can work constantly without getting exhausted (Parab and Gore, 2018). Additionally, the implementation of ASRS leads to enhanced conditions for optimizing space that can be utilized for storage, due to the significant reduction in aisles needed for ASRS to operate within, compared to traditional manual systems involving a human worker (Soyaslan et al., 2012).

1.2 Purpose and research questions

Due to the ever-growing market and globalization, companies are forced to continuously identify new ways for achieving competitive advantages. In order to obtaining competitive advantage many organizations have been forced to look over their supply chains and logistics operations (Melo et al., 2009). This has led to numerous organizations relocating and redesigning their plants, as well as the rise of logistic centers within the industry. The relocating and redesigning of plants over the years, has led to facility planning playing an essential role in order to achieve supply chain excellence (Li, 2014). However, the planning procedures for new layouts have been regarded as a complex issue due to the numerous decision-making processes it includes (Hassan, 2002).

The overall purpose of this study will therefore be to investigate how to develop an optimal layout design for a logistic center. The study will include identifying potential methods that can be used in order to identify existing wastes, improvement areas, as well as to developing a deeper understanding regarding how to design a layout. The specific objective of the case study is to present recommendations and a suggestion for a future layout, based on scientific
theories and empirical findings. Three research questions have been formulated in order to accomplish the purpose of the study:

- What methods can be used in order to identify existing wastes and potential improvement areas within a current layout design?
- What factors and aspects can influence the design process for a future layout?
- In what way can the material handling be enhanced in a future layout design?

1.3 Limitations

This study aims to provide a methodology to understand the process of designing a layout for a warehouse with suggestions for a future state. This will be done through literature studies and a case study focusing on assessing the current state layout. However, the study does not include implementing the results of the study. The analysis of the current state will only focus on activities that related to the products: keys and cylinders. This is due to that only these two products will be featured in the new logistic center. In addition to only the two products being focused, the optimal location for the new logistics center will not be discussed, because it has been predetermined by the case company.
Chapter 2
Research Method

This chapter describes the research methods used in this study. The different approaches are described briefly, and the choices of the methods are explained. How the information has been collected and how it has been interpreted and analyzed is presented as well. To increase the quality and credibility of the study, a number of research techniques are used in the process of information gathering and analyzing, which are presented further in this chapter.

2.1 Research method

There exist several different ways to conduct a research process. Patel and Davidson (2011) mentions two different concepts that are related to conducting studies, deductive and inductive. Deductive reasoning is based on drawing conclusions that relies on existing and proven theories. It implies that there exists a logical consequence of individual phenomena that are based on current principles and proven theories. While inductive reasoning on the other hand, relies on discovering new conclusions that are independent from previous theories.

This study will be focusing on using a deductive methodology as it can be considered most suitable, since the aim of the study involves developing a future layout by the application of an existing theory. In addition, the deductive method seems to be a more common concept when it comes to supply chain and logistics researches (Golici et al., 2005). This research study will involve examining and studying previous literature and a current factory in order to develop a deeper understanding regarding efficient facility planning, as well as improving an organization's supply chain management.

When conducting research, it is crucial to understand what to study and the aim with the research. By developing a deeper understanding of the chosen field, it can lead to a more valuable research (Yin, 2014). By conducting a case study that uses an exploratory approach, it can lead to exploring a specific research field by gathering information and data. By gathering information and conducting literature studies, a broader understanding regarding the specific field can be developed, as well as it can lead to achieving more valid conclusions and results (Patel and Davidson, 2011).

2.2 Research process

The case study was divided into three different steps in order to conduct the study in an efficient manner. The project initiated by developing a Gantt chart in order to be able to visualize and estimate the time frame of the project’s different parts. By planning and utilizing deadlines for when each part should be finalized, the researchers could ensure that the different parts would be completed, as well as to encourage a smooth flow of work.
The first step involved conducting a literature review that would result in developing a deeper understanding regarding what the study could involve, as well as the development of the studies theoretical framework, which was based on scientific theory.

The next step involved conducting visits at the case company in order to collect data and information that would lay the foundation of the empirical findings. Data was gathered by following the flow of materials, as well as by conducting interviews and observations. Once data was gathered, the mapping of the current state could take place, which would lead to understanding what operations, workstations and material flows that would feature in the future layout, as well as to be able to identify existing wastes that could be eliminated in the future layout design.

The third step involved the analysis of the current state, which led to identifying improvement areas for the future layout. These improvement areas could later be considered when applying the SLP method to understand how to place the different workstations within the future layout, in order to utilize space and creating organized workflows. In addition, suitable material handling systems for the future storage was evaluated.

Finally, the fourth step involving a more detailed design and potential future state was established, based on the analysis of the current state and evaluations regarding the future layout.

The Figure 2.1 is an illustration of the order of the different steps was carried out. In the following sections, a more detailed description of the steps is presented.

![Figure 2.1: Research process map.](image)

### 2.3 Data collection

Interviews, observations and literature studies has been used as the primary approaches for collecting and processing data. These approaches have provided the foundation for the empirical study (Hancock and Algozzine, 2006). The interviews and observations have been conducted with both the management and operators within different workstations at the case company where this study has taken place.
According to Christensen et al. (2016) data can either be categorized as primary or secondary data. Primary data are data that is collected from first-hand sources using methods such as, interviews, observations and surveys with primary sources. While secondary data is gathered from previous studies that has been done by other researchers for various purposes.

This research study has gathered both primary and secondary data in order to enhance the quality and validity of the study. By combining the data collection types, it can therefor provide opportunities for triangulation (Christensen et al., 2016). Triangulation regards gathering data from different sources that are integrated in order to develop one conclusion. Primary data and information have been collected through methods such as, interviews as well as observations from the company in order to carry out the value stream map. The secondary data on the other hand will be obtained through literature reviews.

### 2.3.1 Literature review

A literature review has been carried out with the aim to build a conceptual framework for the study as well as a foundation for the research design and research questions (Hancock and Algozzine, 2006). The objective with these gathered peer reviewed articles was that they could offer an embryo of ideas that could be used in order to not only understand the problem, but also to identify adaptable solutions that could be implemented on an operational level (Hancock and Algozzine, 2006; Bryman and Nilsson, 2018).

The literature that has been reviewed had to involve studies related to facility planning, supply chain management and logistics. Search engines that was used to find related articles was Google Scholar, Emerald Insight, Research Gate, Discovery and Scopus. The researchers used many different keywords, such as the following: facility planning, logistics center, distribution center, layout design, systematic layout planning, storage layout, lean and value stream mapping. A method known as snowball sampling was also used to gather related articles from articles that was regarded as very notable (Bryman and Nilsson, 2018). In order to enhance the validity and quality of the study, the literature could not exceed 20 years of age.

### 2.3.2 Interviews

According to Hancock and Algozzine (2006) interviews is a qualitative research method used for gathering information and data. The method involves gathering information through formulated questions being answered either by one or several interviewees. The method provides the interviewer with information and various point of views about a certain field or problem.

The researchers have conducted semi-structured interviews with both the warehouse manager, as well as the team leaders within each department within the distribution center. The reason semi-structured interviews were conducted, was due to the interviewee was provided the freedom and fortuity to formulate her questions however she wished (Yin, 2014). Depending on who was being interviewed, the researchers formulated a list of specific themes that was
aimed to be covered. In order to enhance validity, conducting semi-structured interviews and asking questions in an open way led to minimizing the possibility that the answer of the individual being interviewed to be influenced by the interviewers (Hancock and Algozzine, 2006). Nevertheless, the opportunity for supplementary questions always existed.

The interviews that was conducted with the warehouse manager concerned parameters regarding the future layout, as well as overall potential improvement areas. Team leaders within respective department within the distribution center was also chosen as interviewees due to their knowledge regarding the department they were involved in. These questions could involve the operations that take place, problems that usually occurs, as well as data regarding the process and lead times. In addition, personal opinions regarding improvement efforts was also asked so that the researches could obtain inspiration regarding the future layout. In order to increase reliability and validity some key questions were selected and asked to several regular employees within each department. During all the interviews notes were taken.

2.3.3 Observations

Observation is another qualitative research method that involves gathering information through observing various processes and activities that occur within a certain work area. By observing several regular employees within their workstation, the researcher could develop a deeper understanding of experiences and events they experience during a process (Patel and Davidson, 2011). Through observations the researcher could obtain an oversight of how the various processes were being conducted within their respective work area. As a result of the observations, the researches could follow the flow of a chosen product from the unloading process, to the shipping process. This led to identifying wastes and non-value-added activities that could be aimed to eliminate in order to increase efficiency regarding the flow of material.

2.4 Data analysis

The qualitative methods, such as interviews and observations led to the gathering of primary data. To ensure that these collected data was factual and accurate, the interviewees would have to review the collected data and confirm its credibility. This was conducted by applying a method known as, theoretical propositions, which involved comparing the gathered information with the reviewed literature. By doing this the researchers could enhance the reliability and validity of the study being conducted. Empirical findings including current state analysis of various processes was also confirmed with responsible personnel to ensure authenticity. Additionally, empirical findings were compared to previous literature studies in order to identify general factors, as well as solutions related to improvement of certain problems involving facility planning.
2.4.1 Value Stream Mapping

The application of Value Stream Mapping has been mostly based on (Rother and Shook, 2009). Rother and Shook (2009) describe that the method needs to initiate with constructing a current state map, one that has been performed numerous improvement areas can be identified in order to construct a potential future state. The development of the current state map was carried out by following the flow of materials from, where they enter the facility, to where they exist, as well as by conducting observations and interviews with the involved employees at the related workstations. No Value Stream Maps had previously been constructed at the case company, implying that the mapping of the current state was performed from scratch. Ensuring reliability is essential and can be done by making sure that the VSM resembles the reality as much as possible. This would lead to similar results if constructed by someone else.

2.4.2 Systematic Layout Planning

The SLP method was used as guideline for the development of the future layout. When conducting the literature review, the method was identified as the most optimal method to use for designing the future layout, based on its basic and efficient steps. It presented a framework that consist of a set of phases and a pattern of procedures for identifying, rating and visualizing the operations and areas involved in a layout. The method was primarily based on (Tompkins et al., 2010). By conducting a thorough initial research regarding the operations and flow of material that exist in the current state, the method could be used for developing a deeper understanding regarding how to place the workstations in the future layout, so that efficient and organized workflows and material flows could be established.

2.4.3 Visual Components

Visual Components is a 3D simulation software that was used in order to develop the alternative block layouts in 3D. The utilization of a 3D simulation software provided with a more realistic design, which subsequently would be easier to describe and communicate to the management at ASSA ABLOY OS. Additionally, it allowed the researchers to calculate the distances between the workstations and departments for the future state map, by using the distance-time-speed formula:

\textbf{Equation 2.1: Distance, Time, Speed formula}

\[
D = T \times S
\]

\[
D = \text{Distance}
\]

\[
T = \text{Time}
\]

\[
S = \text{Speed}
\]
2.5 Quality of research

Choosing what kind of strategies that should be implemented in the research process in order to obtain validity and reliability is essential when conducting a research study (Williamson, 2002). The researchers choose to use the triangulation method to ensure that the study can be valid and reliable. Triangulation implies the utilization of multiple theories and data sources to researching a question (Heale and Forbes, 2013). The researchers used different data collection techniques when collecting data at the case company, such as observations and interviews, which additionally was compared to secondary data obtained by the literature reviews. This enabled the utilization of triangulation in the research which could ultimately increasing the validity and reliability of the study.

When discussing validity, it can be divided into two different aspects, internal validity and external validity. Internal validity is about testing the coherence between the theoretical and the empirical data. Whilst external validity means that the results can be generalized and can be applied for other case companies (Ejvegård, 2009). Therefore, the utilization of triangulation proved to be very efficient as it could enhance the studies internal and external validity by utilizing different sources of evidence, interviews, observations and documents.

According to Ejvegård (2009) reliability on the other hand, implies that the measurements are made correctly and that the same results can be achieved by other researchers using the same methods. If the criteria for reliability are not met, the researcher might receive unreliable results, which makes reliability a significant matter.

The reliability was enhanced by describing and clarifying how the study would be conducted, which the research process section described. When the description of the current state was conducted, the interviews and observations that the map was based on, was done with both employees at the respective workstations, as well as with team leaders at the respective department. By conducting semi-structured interviews, the researchers could formulate the questions in an open way, which led to minimizing the possibility that the answer of the individual being interviewed to be influenced by the interviewers. These questions were asked to several in order to obtain accurate data.
This chapter will include and cover the presentation of the theoretical findings that are related to the study. Concepts such as logistic center, facility planning and Systematic Layout Planning and Lean will be described and explained in order to provide the reader with a broader understanding of the concepts being covered within the study. The chapter starts with describing what a logistic center is, since the main purpose of the study is to design a layout for a future logistic center, it is essential to know what a logistic center is and what operations that are carried out within. Therefore, theories describing facility and layout planning will be presented together with Systematic Layout Planning, due to the development of the future layout design will be constructed by the application of this method. Finally, the Lean philosophy and value stream map will be described due to the current state analysis that will take place at the case company.

3.1 Logistic center

Logistic center is a modern phenomenon that appeared more than 30 years ago. During this time, the perception of logistics has changed and there have been a number of significant changes involving how things are being produced, stored and moved (Rimiene and Grundey, 2007). Rimiene and Grundey (2007) and Jarzemskis (2007) explains that logistic center is a center in a specific area were various logistic operations such as, transportation, storage, and handling of goods are carried out of various operators on a commercial basis. It can involve both national and international handling of goods.

According to Rimiene and Grundey (2007) logistic centers have over the years extended the list of activities being conducted within the center, as it has transformed from only providing traditional activities such as receiving, storing and shipping of goods during the earlier days, until today were value added activities such as labeling, assembly, semi-manufacturing and customizing have been added to the list.

Logistic centers are often confused with distribution centers as they conduct similar activities and due to their identical similarities from the outside. However, it is their inner workings that differentiate the two (Rimiene and Grundey, 2007). A distribution centers does not precisely function in the same way that a logistic center does. Distribution centers emphasizes on rapid intake and distribution of finished goods, compared to traditional warehouses and logistic centers that are more suited for long term storage of a variety of goods, such as both components and finished goods (Mircetic et al., 2014).
3.1.1 Facility planning

Facility planning has according to Tompkins et al. (2010) a crucial part for organizations to achieve supply chain excellence. This is due to the reason that future manufacturing systems need to be able to handle customized product in a rapid and cost-efficient manner. When discussing facility planning, it regards the design, layout, workers, machines and activities of a system within a work area. The layout of the facility is what determines the flow of goods and support services in a facility for minimizing overall production and transportation time, while at the same time maximizing flexibility and the turnover of work-in process (WIP) (Dwijayanti et al., 2010).

Kulkarni et al. (2015) mentions that facility planning regards a broad area of work, due to the numerous activities that take place when it comes to facility planning. Figure 3.1 describes the different concepts and activities that are related with facility planning. According to Kulkarni et al. (2015) facility planning can be classified into different concepts, which include the following:

- **Plant location**: Location of the facility is placed in an area that takes into account and is connected to customers, suppliers and other facilities which it interfaces with. The decision regarding the location of the facility is generally one of the first steps when it comes to facility planning.
- **Structural design**: Regards the buildings and utilities of the plant.
- **Layout Design**: In order to maximize productivity and efficiency a broad understanding of the vital plays in the facility must be developed. When discussing design, it involves the placement of workstations and arrangement of operations and activities. The design of the layout is what determines the achievement of with minimizing general production times, while at the same time maximizing flexibility.
- **Handling System Design**: Regards the management of materials, personnel, information and equipment within a layout.
Tompkins et al. (2010) explains that the main goals with facility planning involves the following:

- **Increased Return on Assets (ROA):** Is achieved by maximizing inventory turns and continuous improvements, while at the same time minimizing obsolete inventory.

- **Improved customer satisfaction:** Involves the understanding of value-added activities that can benefit customers. This is conducted through the striving for high quality and flexibility in order to provide with high value products and the capacity to meet ever-changing requirements.

- **Reduced costs:** Continuously identifying approaches to lower down costs that impact the total delivered-to-customer cost. Costs that have major impact to name a few are: transportation costs, inventory costs, packaging costs and overall logistics costs.

- **An integrated supply chain:** By developing enhanced partnerships with suppliers in order to enhance the organizations ability to satisfy their ultimate customers.
### 3.1.2 Warehouse management

The warehouse has vital part to play when it comes to impacting an organization's aspiration for supply chain efficiency. A warehouse's main mission is to effectively store and distribute goods to the next step in the supply chain. If a warehouse fails to process orders effectively and in a rapid pace, then these factors will hinder the organization's supply chain efforts (Ramaa et al., 2012). There are many aspects that play a significant role in making warehouse operations more effective. Information technology and physical distribution are two aspects that are very central, while at the same time being associated with each other. This is due to the simple reason that even the best information system will be of little use if the physical systems necessary to distribute the goods are either outdated or misapplied (Tompkins et al., 2010).

Even though a warehouse's main mission is to store and distribute goods in an effective manner, there are still numerous of other activities that occur within the warehouse. The modern warehouse has experienced an evolution of processes being conducted compared to traditional warehouses that only focused on activities related to purely storage and distribution (Muther and Hales, 2015). Modern warehouses today have seen an increased number of processes and activities being conducted, which can include improving order picking, utilizing cross-docking, increasing productivity, utilizing space and increasing value-added services. Combinations of these activities can today be found at modern warehouses. Their role has extended to include services that improve the overall operations which eventually will lead to improved customer satisfaction and supply chain management. The Figure 3.2 presents a list of activities that can be identified in most of the warehouses today. Between these activities, direct putaway can be conducted, which implies stocking goods directly to an active or reserve storage location (Tompkins et al., 2010).

![Figure 3.2: Typical warehouse functions and flows. Modified from Tompkins et al. (2010).](image-url)
3.2 Layout planning

According to Tompkins et al. (2010) and Kovacs and Kot (2017) a number of different procedures for facility layout planning have been developed through the years. The reason for this has been to provide project managers with a broader understanding when it comes to developing layout alternatives. Layout planning involves the placement and arrangement of workstations, equipment, goods and personnel in the interest of reducing overall movement, material flow, time, as well as workforce. By taking these considerations into account it provides the opportunity to create a more efficient, convenient and safer work environment.

When discussing procedures for layout planning the procedures can usually be classified into two categories: construction type and improvement type (Tompkins et al., 2010). Methods involving construction layout procedures regards developing a completely new layout from “nothing”, while improvement layout procedures involve seeking and identifying improvements in a current layout (Muther and Hales, 2015).

3.2.1 Systematic layout planning

Systematic layout planning (SLP) is a procedure developed by Richard Muther that is used for facility layout planning. The SLP framework is presented in the Figure 3.3 and is based on the correlation of the input data and the understanding of the activities regarding the value flow of these data. The framework emphasizes a rapid pace of material flows at a cost-efficient operational level, as well as minimized material handling (Tompkins et al., 2010; Suhardini et al., 2017). The framework as presented in the Figure 3.3 consist of several steps that can provide a broader understanding of the relationship activities regarding the flow of material and space optimization. Therefor the framework can be used as guideline for project manager when developing both constructional and improvement layouts (Tompkins et al., 2010; Muther and Hales, 2015). The steps within the Figure 3.3 is described separately in the following section.
Input Data and Activities

The initial proceedings concerning SPL involves gathering and analyzing data to which the layout will be covering. Data usually consist of five base elements which underlie most of the calculations needed for layout planning. The five base elements regard the following (Tompkins et al., 2010; Muther and Hales, 2015):

- **Product (Material)**: Regards what kind of goods the company handle and base their business upon.
- **Quantity (Volume)**: Regards the quantity of goods, orders and contracts processed by the company.

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**Figure 3.3**: The systematic layout planning. Modified from Tompkins et al. (2010).
• **Routing (Process sequence):** Regards the identification and development of operations sequences and process requirements.

• **Supporting Services:** Regards the identification of utilities, activities and functions that must be provided in the area to be laid out. Supporting services can include maintenance, receiving dock, as well as cafeterias.

• **Time:** Regards various operating times for the goods, as well as when the planned layout should be operational.

The five base elements provide as mentioned a broader understanding when planning layouts by calculating and understanding the correlation between the flow of materials, physical equipment required, as well as space requirements (Tompkins et al., 2010; Muther and Hales, 2015).

**Step 1: Flow of material**

The flow of material is the most central aspect within a layout. By considering the sequence and intensity of material movement when planning a layout, it can lead to attaining an efficient flow through the area involved that consequently can lead to reduced material handling efforts and costs (Shah and Joshi, 2013). Before deciding a location where the layout will be based, the planner must have an idea of what the layout should look like. By analyzing the flow of materials and identifying service relationships the planner can combine the two in the form of an activity relationship chart, which later on can be converted into a picture that describes the arrangement of workstations, equipment and material (Muther and Hales, 2015).

**Step 2: Activity Relationships**

Activity relationships together with the flow of materials are the two basic procedures that determines the desired closeness of various workstations, activities or functions to each other. Activity relationships regards the analysis of all the activities conducted within a certain area, using relationship charts (Yang et al., 2000). Analysis of activity relationships provide a systematic way of relating service activities to one another, as well as integrating them in a process. When analysis of the activities relationships using various charts have been carried out, the following step that take place involves diagraming the information gathered (Suhardinl et al., 2017; Tompkins et al., 2010).

<table>
<thead>
<tr>
<th>Value</th>
<th>Closeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Absolutely necessary</td>
</tr>
<tr>
<td>E</td>
<td>Especially important</td>
</tr>
<tr>
<td>I</td>
<td>Important</td>
</tr>
<tr>
<td>O</td>
<td>Ordinary closeness okay</td>
</tr>
<tr>
<td>U</td>
<td>Unimportant</td>
</tr>
<tr>
<td>X</td>
<td>Undesirable</td>
</tr>
</tbody>
</table>

**Table 3.1:** Closeness Relationship Values. Modified from Tompkins et al. (2010).
Step 3: Relationship diagram

When it comes to diagramming there exist numerous techniques available to use. The general sequence however involves working from the charted information and developing it into a visual diagram that is based on the calculations and analysis of the gathered data. By using the charted information, the visual diagram can later on arrange the activities geographically by showing the sequence of activities and the importance of the closeness of each activity to each other (Yang et al., 2000). The diagram can therefore be described as an essential layout but won’t be operational until it is adjusted to accommodate any modifying considerations. The relationship diagram later on provides the foundation for the development of the space relationship diagram, which is the following step (Muther and Hales, 2015).
Step 4: Space requirements

When the charting and diagramming of the relationships have been conducted, it is time for projecting the space required in the future facility. Space requirements is considered as one of the most difficult determinations when it comes to facility planning. This is due to the existing uncertainties such as, physical machinery and equipment, which impacts the projecting of true space requirements for the future (Naqvi et al., 2016). However, when projecting space requirements there exist five approaches that are available for use. These five approaches include the following: Calculation, converting, space standards, roughed-out layout, ratio trend and projection. Although being conducted differently they usually tend to check each other in order to give more credence to each other. When the space requirements have been determined they will eventually be balanced against the space that will be available in the future (Tompkins et al., 2010).

Step 5: Space Available

One of the most significant factors that influences the layout planning regards space limitations. Therefore, it is essential for the planner to be innovative enough to understand what to compromise and balance when it comes to the determined space requirements versus the actual space available. That is what this step covers, understanding how to balance space requirements against space available (Tompkins et al., 2010). Many planners have in previous layout projects solved this problem by making a single percentage reduction for all areas involved. This solution has however viewed as ineffective due to the reason that is has been identified as more effective to make the required reductions in areas where the least hurt to total company operation will result. By rating each area based on importance for the company’s operations, a deeper understanding regarding which areas can afford to be reduced (Muther and Hales, 2015).
Step 6: Space relationship diagram

The Space relationship diagram incorporates the results from balancing the space requirement against the space available and serves as a guideline for identifying further adjustments (Muther and Hales, 2015). The space relationship diagram is what eventually the layout becomes after having gone through modifications of several considerations and their practical limitations (Matusek, 2012; Karandikar et al., 2017).

![Space relationship diagram](image)

Figure 3.6: Space relationship diagram according to Tompkins et al. (2010).

Step 7: Modifying consideration

As mentioned previously the space relationship diagram can be seen as the eventual layout but won't be operational until a variety of modifications and practical limitations have been adjusted. This step involves the identification of potential modifying considerations as well solutions to these considerations. Some of the most common modifying considerations are the following (Karandikar et al., 2017):

- Handling methods.
- Storage facilities and equipment.
- Personnel requirements. Building features.
Some of these mentioned considerations may require broad analysis and adjustment time, while some on the other hand may be negligible.

**Step 8: Practical limitations**

While modifying considerations are accessible for adjustments and decisions, practical limitations however, impose constrains on the procedures for the layout planning (Tompkins et al., 2010). Practical limitations can include constraints such as physical characteristics of a location and available investment money. The latter also includes the question of cost savings and by that reason being one of the most important limitations (Muther and Hales, 2015).

**Step 9: Develop layout alternatives**

When adjusting the space relationship diagram under the influence of different modifying considerations and practical limitations, it leads to the development of several alternative block layout plans (Muther and Hales, 2015). Including more appropriate personnel that can be assigned with developing their own layout using the space relationship diagram as their target, can be effective approach for developing alternative layouts (Eliud et al., 2018).

![Figure 3.7: Alternative block layout according to Tompkins et al. (2010).](image)

**Step 10: Evaluation**

This step involves the screening and selection of alternative layouts. This is conducted by an evaluation procedure that objectively highlights the values of each alternative layout. The difficulties regarding the evaluation of the layouts can be simplified using the following methods (Muther and Hales, 2015):

- Balancing advantages against disadvantages.
- Factor analysis rating.
- Cost comparison and justification.

After the evaluation procedure and approval, the chosen alternative becomes the layout plan.
There exist numerous factors and aspects to consider when evaluating a potential layout design. Factors to consider when evaluating a potential layout can be the following (Arunyanart and Pruekthaisong, 2018; Besbes et al., 2017):

- **Flexibility**: A good layout can be easily modified to meet changing in circumstances.
- **Safety**: Concerns both personnel and working environments are safe from danger in the workplace.
- **Utilization**: Regards the utilization of the floor space and resources, such as personnel and equipment.
- **Distance**: The distances between workstations.

### 3.2.2 Storage layout

SPL presents a number of different methods and models to use when balancing storage layouts. Before proceeding with the layout planning, the planner must determine the specific objectives of a storage layout. The objectives of a storage layout are in general the following (Tompkins et al., 2010; Liu, 2004):

- To use space efficiently.
- Providing most efficient material handling.
- Providing the most economical capability for storage in relation to costs of equipment, use of space, damage to material, personnel, and operational safety.
- To provide maximum flexibility in order to meet the ever-changing customer demands.

According to Tompkins et al. (2010) and Liu (2004) these objectives are similar to the overall facility layout, although they emphasize good “housekeeping” activities. The Figure 3.8 presented different methods and models available for optimizing storage layout. The focus on minimizing picking time and distance of movements by analyzing where the placement of different goods can be most beneficial. The analysis and calculation are based on determining the popularity of the goods and therefore placing close to the entrance, as well as to each other. Hence, placing less popular goods in the rear of the facility. This can therefore lead to providing the opportunity to reducing travel distances and time.
Figure 3.8: The impact of storage depth on travel distances. Modified from Tompkins et al. (2010).

The Figure 3.9 illustrates how to storage materials depending on their popularity. Materials that enter and leave a storage area from different points will be received and shipped in the same quantity, therefore the most popular items should be connected to the most directed route between the entrance and departure points. In summary the figure is based on positioning materials depending on their receiving and shipping ratio (Tompkins et al., 2010).
3.2.3 Receiving and shipping space planning

The design of receiving and shipping space layout regards a different set of factors and steps than the design of storage layout. Factor and steps that are required to determine the space requirement for receiving and shipping areas include the following (Tompkins et al., 2010):

- Determining what is to be received.
- Determine the number and type of docks.
- Determine the space requirements for the receiving and shipping area within the facility.

Developing a deeper understanding regarding the mentioned steps above, leads to simplifying the planning procedures, something that is crucial for any processes in order to prevent the occurrences of errors.

The receiving and shipping department area which inside require space allocations for the following (Tompkins et al., 2010):

- **Receiving hold area**: An area to place rejected deliveries that are awaiting return to the vendor. The size of this area depends on the likelihood of deliveries to be rejected.
- **Recycling and trash disposal**: Processing these orders tends to generate a huge amount of waste materials. Space must be allocated within the receiving area for the disposal and recycling of these items.
• **Pallet and packaging material**: Due to the likeliness of goods arriving unpalletized or on disposable pallets, there must therefore exist palletizing material.

• **Material handling equipment maneuvering**: The area for these maneuverings usually concerns the backside of the receiving area and the beginning of the storage area. Factors that determine the space required depends on the material handling equipment.

When the receiving and shipping layout have been planned, it will be integrated with safe flows from the truck waiting areas. The truck waiting areas need to be big enough to handle the maximum number of truck deliveries per day.

### 3.3 Lean

Lean is a systematic ideology originating from the Toyota Production System. The essence behind the concept of lean is maximizing customer value and competitiveness through minimizing waste (Muda) and streamlining a company's main processes. The philosophy has due to the numerous positive impacts it can provide become adopted across various industries and many organizations (Atti, 2019). The concept of lean includes continuously improving work processes, purposes and people, while at same time encouraging sharing responsibility and leadership within the organization. However, before integrating methods and tools that involve lean management, a culture that emphasizes the concept of lean must be integrated and accepted by all within the organization (Chahal and Narwal, 2017).

#### 3.3.1 Value stream mapping

Value stream mapping is a lean method that was introduced by the Toyota Motor Company. The method is based on mapping all the activities related to a specific product or service within a company, from raw material to customer (Forno et al., 2014). The method categorizes all activities into three groups: value adding activities, non-value adding activities and necessary non-value adding activities. Value adding activities can for instance include machining and assembly operations, while non-value adding activities can include transportation and storage. Reduction in non-value-adding activities can therefore lead to reduced cycle times and work-in-process inventories (Rother and Shook, 2009).

By charting all these activities and processes that take place within the company, the method provides a deeper understanding regarding the value flow that take place, as well as providing a broader oversight regarding the identification of non-value activities that can be eliminated (Rother and Shook, 2009). The method has since its introduction become a fundamental method when it comes to lean management. This is due to its positive capabilities regarding waste reduction and continuous process improvement (Forno et al., 2014; Rother and Shook, 2009).
3.3.1.1 Current state map

According to Rother and Shook (2009), in order to identify potential improvements that can be implemented in the future state, an analysis of the current state must be conducted. A current state analysis that charts all the value flows within an organization will provide a broader oversight of non-value-added activities that can be eliminated. When analyzing and charting these value flows, one can use a number of icons and symbols when developing the value stream map. The Figure 3.10 includes the different symbols and the description of these symbols.

![Material Flow Icons](image)

**Figure 3.10**: Value stream mapping icons. Modified from Rother and Shook (2009).

3.3.1.2 Future state

When the current state analysis has been conducted, one can identify potential improvements areas for the identified wastes, which later on can be implemented in the future state map. According to Rother and Shook (2009) there are certain guidelines that can be followed and used when developing the future state map. These are the following guidelines:

- Calculating times such as cycle, process and lead times.
- Developing a continuous flow.
- Determining the distances for the material movements.
- Determine what process improvements that will be necessary for the value stream to flow as the future state design specifies.
3.4 Lean automation

Lean automation is a concept that has been developed due to the introduction of industry 4.0 (Kolberg and Zühlke, 2015). The concept is based on the combination of automated technologies with lean production. This combination has in recent times proved to be very beneficial for companies as it can lead to obtaining several advantages. By automating repeating and value-adding tasks, benefits such as the following can be obtained: reduced cost in operation, efficient processes related to both production and material handling, safer work environments and increased productivity overall (Groover, 2015; Cruz Di Palma and Basaldúa, 2009; Spah et al., 2009).

Due to the advantages that have been provided by the integration of industry 4.0 technologies, it has led to many companies automating their storage and material handling systems (ASRS) (Yamazaki et al., 2017). Subsequently it has led to the rise and further development of innovative technologies that can be integrated with ASRS, such as Automated Guided Vehicles (AGV), Autonomous Mobile Robots (AMR), as well as larger integration of Radio-frequency identification (RFID) systems and Pick/Put-to-light systems (Martienz-Barbera and Herrero-Perez, 2010; Petrov et al., 2019; Piasecki, 2005).

3.4.1 Automated Storage and Retrieval System

Traditionally, goods are moved around the storage systems by manual workers using various material handling equipment, such as forklifts, to retrieve and store goods within the warehouse. The introduction of automated guided vehicles and robots has therefore revolutionized the processes regarding the material handling process within the storage.

With the implementation of AGVs and AMRs within the storage system, following advantages can be achieved:

- **Increased Safety**: AGVs lead to a heavily reduction of human errors, thus preventing the occurrences of accidents caused by human errors, such as exhaustion. Subsequently leading to a safer work environment where damages occurring to humans and goods are reduced. By utilizing sensors, lasers and cameras the driverless vehicles use designated paths in order to prevent collisions (Damacharla et al., 2018).

- **Reduced Costs**: Implementing AGVs leads to reducing the need of labour, consequently leading to reduced labour costs. Compared to human labour, AGVs can work nonstop and on demand, thus increasing productivity by disregarding factors such as exhaustion among workers, as well as training for new employees. Additionally, other costs such as electricity bills can be reduced as these AGVs not needing lighting to operate, thus also taking environmental aspects into account (Gothwal and Raj, 2018; Grandviewresearch.com, 2019).

- **Increased productivity and precision**: As AGVs can work nonstop and on demand, they can work at a consistent speed with no disregards to human factors such as exhaustion. This leads to a consistent and efficient material handling process which is less prone to errors (Gothwal and Raj, 2018).
3.4.2 Automated Guided Vehicle

AGVs (Automated Guided Vehicle) are used for transporting goods in production and in warehouses. There are different systems for guidance in the plant and the most common are wire guidance, inertial guidance and laser guidance (Liotine, 2019). Wire guidance directs the AGV with wires installed in the floor and inertial guidance is supported by gyroscopes and magnets to determine the location of the AGV. Laser guidance requires laser transmitters and receivers to navigate through the warehouse by following reflective markings located strategically (Vivaldini et al., 2010).

An AGV, such as an automated forklift, can similar to a manual forklift pick any different sized pallet and transport it anywhere throughout the warehouse. The AGV linked to a wireless network which is integrated with the warehouse management system, thus enabling the integration of multiple automated forklifts. The truck uses safety sensors to slow down or stop in order to prevent collisions. Thus, allowing for a mixed operation with both manual tracks and pedestrians (Vivaldini et al., 2010; Liotine, 2019).

3.4.3 Autonomous Mobile Robot

An Autonomous Mobile Robot (AMR) is used for the same purpose as an AGV, but the technology behind it works differently. Unlike AGVs, that follows markings to navigate, an AMR uses sensors to register its surroundings (Liaqat et al., 2019). The AMR outlines its own map of the plant by gathering information as it moves through the warehouse. It optimizes its route automatically and can be reprogrammed according to different purposes (Abdulmajeed and Mansoor, 2014).

According to Abdulmajeed and Mansoor (2014) an AMR uses sensors to outline its own map of the warehouse while navigating through the storage area. By gathering information as it moves it can avoid obstacles and identify the quickest route the location. Due to their significant abilities regarding flexibility and responsiveness during navigation, they can conduct the goods-to-person fulfilment more efficiently and quicker. AMRs are usually integrated with a certain mobile rack that can be easily picked underneath. Due to the AMRs being able to operate on very small pathways and navigate even under these mobile racks, it provides an increased utilization of storage space (Boysen et al., 2017).

When an order gets scanned, these AMRs work as collective and retrieve all mobile racks the order concerns simultaneously to either the putaway or picking station. In many cases, all items within an order can be placed in the same mobile rack, leading to very efficient processing of ingoing and outgoing orders. The integration of these robots causes the elimination of big forklifts that take up a lot of space within the storage area (Liang et al., 2015).
3.4.4 RFID

RFID, which stands for Radio Frequency Identification, is a technology based on radio waves that are used to identify objects from distances between a couple of inches to hundreds of feet. The technology uses Auto-ID which automatically identifies the object in question (Valero et al., 2015). The RFID technology is thus able to automatically capture data which in order increases the efficiency of the system. Tags are used in order to successfully identify each object and this is done with the help of a reader that scans the tag. Each tag has a specific code stored within it and is attached to a specific object thus making each object uniquely identifiable. As the reader scans the tag on a specific object, it receives information through the code in order to receive information about the object (Chechi et al., 2012).

3.4.5 Picking system

Warehouse picking managers usually aspire to maintain a high volume of picking within as short of a time window as possible. This type of workflow has been impacted in recent times as customers nowadays seem to change their orders more frequently (Andriolo et al., 2016). The traditional way to handle warehouse picking is to perform it manually, which is unfortunately highly impacted by various human factors such as probable human errors and processing time for orders which need to be reduced in order to improve the efficiency of the system in place (Wu et al., 2015). According to Andriolo et al. (2016) and Wu et al. (2015) there is one way of doing this is by implementing a Pick-to-Light system in which order pickers press a button by an occupied bin after picking up an item from said bin. This action turns the light for the bin off which helps the order picker to know that the bin is empty.
Chapter 4
Empirical Findings

This chapter presents the empirical findings from the case study. The chapter begins with a description regarding the case company and the problem that lays the foundation of the thesis. Later, the current layout is presented with a description regarding the operations that take place and the relationships between these processes. Lastly, the chapter concludes with a value stream description of the current state, as well as a description of the problems identified within the facility.

4.1 Case company

ASSA ABLOY Opening Solutions Sweden AB (ASSA ABLOY OS) was founded in 1994 and is today a global leader when it comes producing and providing access solutions. They offer a variety of products and services related to openings, such as locks, doors, gates and automatic entrance solutions. Today, the company has approximately 350 employees in Eskilstuna and has operations all over Scandinavia.

With a comprehensive approach that involves the flow of people, goods and vehicles, ASSA ABLOY OS creates safe and reliable access and entrance solutions that are based on balancing cost, quality and sustainability. These products are used every day and can be found in both private homes and among warehouses. The company's strategic goal and vision involves leading the trend towards the worlds most innovative and well-designed access solutions.

Due to the rise of prosperity, continues urbanization, as well technological developments, the demand for innovative and sustainable opening solutions have seen an enormous growth over the years. A constant flow of new, innovative and sustainable products, as well as local acquisitions, has therefore been the main driver for ASSA ABLOY OS economic growth and position as one of the global leaders when it comes to access solutions. (ASSA ABLOY, 2018)
4.2 Problem background

ASSA ABLOY OS’s facility in Eskilstuna is currently in a transitional phase where they are planning on moving the current distribution center and certain warehouse operations to a third-party logistics solution in Gothenburg. The current distribution center stores and manages all kind of lock and security related products, such as mechanical and electronic locks, security and fire doors. As a consequence of the move that will take place, it will lead to the relocation of several operations, personnel and goods to a third-party logistics solution in Gothenburg. This will result in a significant reduction regarding the management of goods within the future facility.

In conjunction with this move, it provides the company with the conditions to properly start the project for the construction of the new Scandinavian cylinder factory that will take place in the remaining area. This new Scandinavian cylinder factory that will be located in Eskilstuna will be responsible for the production and distribution of mechanical locks in the Scandinavian region. Along with this project, a future logistic center which only will store and handle goods that will be featured in the future cylinder factory, will be constructed as well. These goods will involve mechanical locks and other cylinder components, therefore all other goods that the current distribution center handles will be moved to Gothenburg.

As the company strives to build a state-of-the-art cylinder factory with a strong focus on flexibility, short lead times and high quality. The aim of this study will therefore be to design and develop a potential layout for the future logistic center, which can be integrated on an operational level with the future facility. However, before conducting the development of the future logistic center, the study will carry out a current state analysis of the distribution center, in order to develop a deeper understanding regarding the operations and flow of materials that will be relevant within the future logistic center. Additionally, by conducting a current state analysis, the researchers can identify waste that can be eliminated within the future logistic center.

Unlike the current distribution center that operates on an area corresponding to approximately 16000 m², the future logistic center will only operate on an area involving 1580 m². Subsequently, leading to the remaining operations being conducted within a heavily reduced area. Therefore, the design process for the future layout will focus on aspects such as space utilization, travel distances and efficient material handling, in order to develop an efficient plant layout that consist of organized workflows.
4.2.1 Criteria and parameters for the future logistic center

Due to the case company being in the initial phase of the project, there existed some uncertainties regarding future criteria and parameters. For example, future capacity regarding deliveries and storage capacity have yet not been established. These uncertainties have therefore been critical indicators that have influenced the decision-making process regarding the most optimal layout for the future logistic center. The researchers were therefore given freedom and independence regarding the design of the future layout. However, a list of parameters, operations and departments that would be included in the new layout was provided by the case company and based on the current layout. This included the following:

- Dimensions for the future layout: Total area of 1580 m².
- Departments and workstations: Unloading/loading area, receiving area, storage area, quality department and shipping area.
- Estimated personnel need: 15 employees total.
- Storage capacity for 1500 pallets.
- Estimated future daily deliveries (ingoing and outgoing): ten pallets each for ingoing and outgoing
- Areas and offices for respective departments: receiving, quality and shipping.
- Offices would consist of 3 x 3 m dimensions in order to fit two people.
- Coffee room for truck drivers outside.
- Aspects to consider: Flexibility, storage capacity, space utilization, safety, organized flows and potential automated solutions.

4.3 Current state

4.3.1 Layout description

The current distribution center that will be studied is located in Eskilstuna and consist of an area of 16000 m². The major part of the facility is dedicated to the storage areas that consist of five-level pallet racking systems that provides a storage capacity of 8000 EU Pallets. The other parts of the facility include departments such as: receiving area, quality area and order picking area to name a few. The Figure 4.1 illustrate the layout of the facility, as well highlights the locations and sizes of the several departments that lays the foundation of the facility. The area that is not interesting for the study has been covered over with lines. Figure 4.2 illustrates where the future logistic center will be placed and operated.
The Figure 4.3 illustrates the space requirements for the several operations and departments that take place within the warehouse. Information regarding each section and department within the studied area was provided by the case company. The current space the operations required could easily be converted to percentage units by using basic mathematical calculations. By converting required space for the current operations into percentage units, it could simplify the estimation of space required for respective operation within the future layout based on the space available.
4.3.2 Description of the current operations

The operations that today take place within the studied area in the warehouse are the following:

- **Receiving**: Initially involves unloading the goods from the truck and placing them on the receiving area. Every pallet has its own receipt that consist of documentation of the order. When the goods have been unloaded from the truck, responsible employees' control that the delivered goods are identified within the system by scanning the receipts. When scanning the receipts, the system informs if the goods shall be transferred to the put-away area or to inspection and quality. Sometimes it can occur that wrong orders have been delivered, these won't be identified within the system and will be placed in the investigation area. Once placed in the investigation area, the
purchasing department will be informed and henceforth handle the issue. If the goods are identified within the system, they are later on transferred to the put-away area.

- **Inspection and quality**: The selection of goods that needs to be transferred to the inspection and quality department is determined beforehand. Certain goods that are heavily regulated are marked within the system and transferred to quality before being transferred to the put-away area. Now and again some goods are selected randomly for inspection. This is done to enhance quality and prevent the liability of defected goods being transported to the storage and later on to the customer.

- **Putaway**: Putaway is the process that involves the transporting of the goods to the warehouse storage. Once the goods have been transferred to the put-away area, they are ready to be transferred to the storage. Put-away employee scans the pallet label and gets informed where to place the pallet within the warehouse storage. When the pallet has been placed the employee informs the system that pallet is placed in the correct spot. The employee later on repeats the process until all pallets have been transported to their correct spot.

- **Storage**: Storage is the physical containment of goods (raw materials and components) while it is awaiting a customer order. The storage consists of both fixed places where some specific goods are always stored at, as well as variable places where varying goods are stored at.

- **Production (won't be covered in the study)**: The company uses a combination of both push- and pull strategies, this is done through the conduction of methods such as: make to stock (MTS) and make to order (MTO). The MTS method relies on manufacturing goods based on demand forecasts. Accurate forecasts are therefore vital due to it can lead to preventing excess inventory and opportunity loss due to stockout. The MTS method can be considered as a push-strategy. The MTO method on the other can be considered as a pull-strategy, as it is dependent on manufacturing after receiving customer orders. The forecasts will therefore prevent excess inventory and Goods, such as raw materials and components are transferred to the production when a customer order has been developed. The employees within the production department handles the transportation of goods from the storage to the production department.

- **DC-storage**: Finished products that emerges from the production department are transferred to DC-storage. DC-storage is the physical containment of finished products.

- **DC-pack**: A department that consist of a storage and assembly stations for components related to products that will be relocated to Gothenburg, such as safety doors. This department will not remain in the future layout.

- **Order picking and packing**: Employee gets informed regarding customer order from the warehouse management system. The customer order consists of information such as: item number, lines, location, weight and quantity. The employee uses the information to remove the identified items from the storage to meet the customer order. The picked items are later on packed in an appropriate shipping container with
the packing list. The shipping container get measured in height and weight and later on wrapped and sent to the shipping area.

- **Shipping**: Once the container has been placed in the shipping area, shipping documents including address label and bill of lading are prepared. Finally, the containers get loaded into the delivery truck.

All these operations, except DC-pack and DC storage, will remain in the future logistic center. However, they will be operated within the heavily reduced area due to the reduction regarding future goods management. The reason they will be moved is due to the operations that take place within the DC-pack and DC-storage won’t be relevant for the future logistic center, due to the relocation of goods that are being handled at those areas.

### 4.3.3 Goods handling

This section will focus on identifying the customers and suppliers related to the Eskilstuna facility, as well has how the goods been handled within the warehouse.

Due to ASSA ABLOY OS being a global player, they have several customers and suppliers. These customers and suppliers are either external or internal. The Figure 4.4 illustrates ASSA ABLOY OS’s largest internal and external customers, as well as suppliers. As can be obtained from the Figure 4.4, most of the companies that ASSA ABLY OS conduct businesses with involves internal customers and suppliers. When working with internal customers and suppliers, it can lead to smoother communication and cooperation regarding strategies that aim to improve and increase quality. The reason for this is that the internal partners can prosper themselves due to the developments the main company conducts.

![Diagram of Internal Suppliers, Internal Customers, and External Customers](image)

**Figure 4.4**: ASSA ABLOY Opening Solutions Sweden AB’s customers and suppliers.
ASSA ABLOY OS receive eight delivery trucks per day from their suppliers. From these eight delivery trucks, 30 pallets are usually unloaded using a manual forklift. The unloading of goods is conducted at the dock, which only consist of one input gate. All goods that is delivered from the suppliers must be palletized on EU pallets (if nothing else is agreed) and with wooden frames when needed. These EU pallets consist of a dimension: 1.2m x 0.8m x 0.144m and can handle a maximum weight of 600 kg. The pallets can either consist of single parts or mixed parts. The maximum height for a full-size pallet and number of frames applies for both pallets, they are respectively 0.53 m and two pieces. When it comes to mixed part number pallets it is important that same orders are kept together, heavy boxes in the bottom of the pallet and that the orders are separated with a top sheet.

Same thing applies for the transportation of goods within the facility. Once the orders have been received, they are transported to the storage. All goods distribution is carried out by forklift-drivers, which receives information through a screen regarding where to pick and deliver the material. The facility has a storage capacity that consist of 8000 pallet spots, 2000 shelf positions and uses a five-level pallet racking system to store its goods. If the goods are transported and handled roughly, the goods should be protected with a pallet top that can stabilize the pallet, as well as plastic wrapping.

Once orders have been picked and packed, they will be transported to the shipping area. Approximately 50 pallets per day leaves the shipping area, leading to six delivery trucks being received and loaded daily. The loading stations, compared to the unloading station at the dock, consist of two output gates, enabling two outgoing trucks to be loaded simultaneously. Additionally, the loading of output goods into the delivery trucks, compared with the unloading of input goods, is that the truck driver handles the loading of goods into the truck. Direct deliveries from the facility to the customers rarely take place as most of the deliveries are delivered to two different terminals, one located in Västerås and operated by Schenker, while the other located and operated by DHL in Folkesta, Eskilstuna. At the terminals the orders get sorted and later on delivered to their respective customer.

4.3.4 Mapping of current state

During the study, several interviews was conducted with different personnel within the facility in order to identify current wastes that could be eliminated. A value stream map was therefore developed in order to obtain a deeper understanding regarding how the value stream is constructed within the facility, by conducting interviews as well as a walkthrough along the flow, the authors managed to identify problems that occurred, as well as potential bottlenecks. The Figure 4.5 illustrates the current state.

Figure 4.5 and Figure 4.6 describing the current state map is presented in the following section, starting with (1) value stream map, (2) flowchart and (3) process data for different processes.
4.3.4.1 Current state map

Figure 4.5 represents the current state map and describes all the process conducted within the current state, starting from unloading to storage and from storage to customer. The data that is presented in the current state map is based on the activities that are presented in the flowchart, which is presented in the following section.

- Left part of figure 4.5: describes the supplier information.
- Right part of figure 4.5: describes the transportation information to customer.
- Upper part of figure 4.5: describes the information flow.
- Lower part of figure 4.5: describes the operations that are conducted in order.

![Current State Map](image)

**Figure 4.5**: Current state map.

4.3.4.2 Flowchart

Figure 4.6 presents a flowchart of the activities for processing incoming and outgoing orders within the warehouse. It describes the activities step-by-step, the distance from one process to the following, as well as which employees that are conducting the activities. In addition, the time for respective activity, as well as the lead time for each process. The calculations regarding the lead times can be found in the following section named process data.
4.3.4.3 Process data

The following calculations shows the times of interest such as cycle time, process time and lead time for each process. The data that the calculations are based on are gathered through interviews and observations of the employees within respective workstation. These calculated times have been presented in the value stream map.

- **Unloading**

The company usually receive 30 pallets a day. At the unloading area there are two employees who are responsible for the unloading of goods from the daily eight trucks. Before unloading the goods, the staff controls that the orders are correct together with the chauffeur by comparing them to the shipping documents. Once conducted, the chauffeur will show were the goods are placed in the truck so they can be unloaded. This process takes approximately 20 minutes for each truck. Each pallet takes three minutes to unload and transport to the receiving area.
The following calculations are used to calculate the lead time for two employees to conduct the process:

**Table 4.1: Activities for unloading.**

<table>
<thead>
<tr>
<th>Activities</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control each truck</td>
<td>20 min</td>
</tr>
<tr>
<td>Unload one pallet from truck</td>
<td>40 sec</td>
</tr>
<tr>
<td>Placing one pallet at dock</td>
<td>110 sec</td>
</tr>
<tr>
<td>Travel time to receiving area</td>
<td>30 sec</td>
</tr>
</tbody>
</table>

\[
Pallets \text{ each truck} = \frac{30 \text{ pallets}}{8 \text{ trucks}} = 3.75 \text{ pallets}
\]

\[
Cycle \text{ time (unload each pallet)} = 40 \text{ sec} + 110 \text{ sec} + 30 \text{ sec} = 180 \text{ sec} = 3 \text{ min}
\]

\[
Cycle \text{ time (each truck)} = (3.75 \text{ pallets} \times 3 \text{ min}) + (20 \text{ min control}) = 31.25 \text{ min}
\]

\[
Process \text{ time (eight trucks)} = 31.25 \text{ min (CT) \times 8 trucks} = 250 \text{ min}
\]

\[
Lead \text{ time} = \frac{250 \text{ min}}{2 \text{ employees}} = 125 \text{ min}
\]

- **Receiving**

Once the pallets have been unloaded, they will be transported to the receiving area. A total of 30 pallets are transferred to the receiving area per day. At the receiving station there are three employees who work with the registration of the goods into the WMS. The incoming pallets consist of ten articles each, where each article consist of ten boxes. In addition to registering the goods, they are also responsible with sorting two articles together in one pallet. Leading to one pallet consisting of two articles and a total of 20 boxes.

Once all articles have been sorted on pallets, they can be moved to the putaway or quality area. It takes approximately 40 minutes for each employee to register and sort all the articles that are contained in one pallet. Once they are done with registering and sorting all goods, usually five pallets will be transported to quality and the remaining 145 pallets will be moved to the putaway area during one complete workday.

The following calculations are used to calculate the lead time for three employees to conduct the process:
Table 4.2: Activities for receiving.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control shipping document</td>
<td>4 min</td>
</tr>
<tr>
<td>Sort and impact if the quantity is correct</td>
<td>20 min</td>
</tr>
<tr>
<td>Registering goods in WMS</td>
<td>15 min</td>
</tr>
<tr>
<td>Place pallet at putaway area</td>
<td>1 min</td>
</tr>
</tbody>
</table>

Cycle time (one pallet) = 4 min + 20 min + 15 min + 1 min = 40 min

Process time (30 pallet) = 40 min (CT) × 30 pallets = 1200 min

Lead time = \( \frac{1200 \text{ min}}{3 \text{ employees}} \) = 400 min

- **Quality**

Ten articles are usually quality marked within the WSM, leading to five pallets needing to be transported to the quality department for inspection before being stored. Two employees are based at the quality department and conducts the inspection of goods. Each pallet needs 120 minutes to be processed. Once inspected they are transported to the putaway area.

The following calculations are used to calculate the lead time for two employees to conduct the process:

Cycle time (one pallet) = 120 min

Process time (five pallets) = 120 min (CT) × 5 pallets = 600 min

Lead time = \( \frac{600 \text{ min}}{2 \text{ employees}} \) = 300 min

- **Putaway**

Once the goods have been transported to the putaway area, a total of 150 pallets will be transported to the putaway area during one complete workday. At the putaway area there are four employees who operate. Each pallet takes 15 minutes to process. This implies driving to two different locations within the storage, manually placing ten boxes at respective location and driving back to the putaway process. This process repeats until all articles at the putaway area have been stored. Depending on where the spot location is, as well as which level the article spot is placed in, it will influence the process time.

The following calculations are used to calculate the lead time for four employees to conduct the process:
Table 4.3: Activities for putaway.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan articles</td>
<td>20 sec</td>
</tr>
<tr>
<td>Travel time</td>
<td>12.7 min</td>
</tr>
<tr>
<td>Placing 20 boxes</td>
<td>2 min</td>
</tr>
</tbody>
</table>

Cycle time (one pallet) = 20 sec + 762 sec + 120 sec = 902 sec = 15 min

Process time (150 pallets) = 15 min (CT) × 150 pallets = 2250 min

Lead time = \( \frac{2250 \text{ min}}{4 \text{ employees}} \) = 562.5 min

- Picking and Packing

The amount of lines and quantities that can exist within an order differs significantly between order to order. Additionally, factors such as where the articles are located within the storage area and in what level in the pallet racking system, they are placed in affects the cycle time for one line to be picked. By choosing a random employee to observe, we estimated the cycle time for one line to be five minutes. This involved selecting a line, driving to the location of the line, picking it, driving to the packing station and conducting the shipping activities.

The order pickers pick approximately 600 lines daily together. In this area there are eight employees who is working to pick the daily demand. The orders that are picked consist of completely varied lines. One order can consist of lines ranging from 1-200. Once the employees complete an order, they must pack it and place it on either a pallet or in the car parcel-system, depending on orders size and weight. If the order weighs more than 20 kg, its packed on a pallet, if it's less than 20 kg its placed in the car parcel-system.

The following calculations are used to calculate the lead time for eight employees to conduct the process:

Table 4.4: Activities for picking and packing.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to select line</td>
<td>10 sec</td>
</tr>
<tr>
<td>Travel time</td>
<td>80 sec</td>
</tr>
<tr>
<td>Picking</td>
<td>30 sec</td>
</tr>
<tr>
<td>Packing</td>
<td>1 min</td>
</tr>
<tr>
<td>Shipping</td>
<td>2 min</td>
</tr>
</tbody>
</table>
Cycle time (one line) = 10 sec + 80 sec + 30 sec + 60 sec + 120 sec = 300 sec = 5 min

Process time (600 lines) = 5 min (CT) × 600 Lines = 3000 min

Lead time = \( \frac{3000 \text{ min}}{8 \text{ employees}} \) = 375 min

- **Shipping**

These 600 lines usually converts into 50 pallets needing to be shipped to customers. In shipping area there is two employees who is working on printing items list, invoice and addressing to the pallets. Each pallet takes five minutes.

The following calculations are used to calculate the lead time for two employees to conduct the process:

\[
\text{Cycle time (one pallet)} = 5 \text{ min}
\]

\[
\text{Process time (50 pallets)} = 5 \text{ min (CT)} \times 50 \text{ pallets} = 250 \text{ min}
\]

\[
\text{Lead time} = \frac{250 \text{ min}}{2 \text{ employees}} = 125 \text{ min}
\]

### 4.4 Identified wastes

**Unloading:**

The current layout of the dock is ineffective and does not take utilization of space and distance into account when operated. This is due to the dock being old and previously developed for receiving train deliveries. Trains would drive in and out through the gateway and unloading of goods would be conducted on the side, directly to the dock. Today trucks drive in like the trains used to do but the unloading of goods cannot be conducted through the side. This is due to the absence of a secure interlocking systems that can provide safe loading directly from the dock. A forklift needs to drive down to the road where the truck drives in, in order to conduct the unloading of goods. This causes long travel distances and process times relating the movement of goods.

Due to the dock being previously used for train activities, some railways still remain and have not been fully covered. Therefore, the road that the trucks and forklift handle the goods on is very uneven and needs repairing, something that has never seriously been handled even after complaints received by employees. The rough and uneven road has caused goods being damaged, as pallets have fallen from the forklifts during unloading activities. Thus, it is crucial for the forklift-drivers to drive carefully in order to prevent goods from being damaged. In addition, this is causes longer transportation times when goods need to be transported to receiving.
There exist many problems related with the supplier that affect the productivity at the dock. Problems that can occur concern poor information flow with the supplier and can include problems such as: lack of information regarding incoming deliveries, missing delivery notes from trucks and unsorted goods within the trucks. When it comes to daily arriving trucks, there is no information distributed to the dock workers regarding the quantity of daily incoming trucks, when they will arrive, as well as what they contain. This poor information flow prevents the dock workers to prepare for incoming deliveries. Addition to this there exist no signaling or queuing system for incoming trucks. First truck in place gets unloaded first, even if a following incoming truck contains far less goods. This can cause unnecessary queues for the trucks due to the limitations regarding only being able to unload one truck at a time, as well as heated arguments with late and stressed truck drivers. Unsorted goods within the truck is another problem that occur. Arriving trucks usually tends to contain goods that are supposed to be distributed to another destination. Due to badly sorted and placed pallets within the truck, it regularly leads to dock workers needing to unload goods belonging to other companies before unloading their own goods. Besides causing longer process times relating to unloading activities, it also endangers other companies’ goods if they were to get damaged.

When it comes to problems relating to flawed delivery note and incorrect deliveries, they occur frequently. Many times, when orders have been purchased the supplier doesn't send an invoice to the purchasing department that can be used to create a transfer order within the WMS. This causes that goods that have arrived and not been documented within the system beforehand, won't be handled and will be placed in an investigation area. This can lead to unnecessary stops as certain goods are placed in waiting and investigation areas.

**Receiving:**

Several problems that was identified traced back to the supplier and included problems such as: flawed delivery notes, unsorted goods, incorrect deliveries. This caused problematic situations in shape of stops at the receiving area which consequently affected the following processes. It occurred several times that orders would be delivery with flawed delivery notes that included the supplier's order and item number. This information could not be identified within the system and personnel had to either follow a procedure to match make information received with the existing within the system or contact the purchasing department. These choices depended on if the employee had the knowledge to control the order information single-handedly or not. In worst case scenario, these orders could be received incorrectly and be transferred at the wrong spot in the storage, later on leading to wrong products being sent to the customer.

Incorrect deliveries concern wrong quantities, wrong orders and damaged goods. All these were transferred to the investigation area by the receiving personnel and information was given to the purchasing department. When unsorted goods would arrive, it would lead to longer inspection time and delay of goods being transported to the put-away area. Addition to these problems, all employees are not trained to perform the task that is needed at the receiving area. This would lead to situations where other employees outside the receiving area with less workload couldn't assist the receiving personnel when workload is high.

The receiving area was identified as the bottleneck within the flow of goods, due to the high frequent causing of stops and waiting lines that affected both operations that are operated
ahead of the receiving area, as well as subsequently. Due to receiving area being regarded as the bottleneck, it is vital to reduce the number of errors occurring at the receiving area.

**Quality:**
Problems related to the quality processes that can occur, usually concerns goods remaining in quarantine unnecessarily long. The time that goods can remain at quarantine varies from two hours to one week. The causes for the delays usually involve the continuous inbound of prioritized orders, the FIFO method does not dictate at the quality area.

When it comes to employees, the absence of daily goals involving goods handled is also a problem. The absence of daily goals tends to lead to notable variations regarding productivity among the employees at the quality area. The view of what can be regarded as a productive day varies from employee to employee.

**Putaway:**
Not many errors were identified within the putaway process. The majority of the ones that was identified was related to system errors. These errors could include problems such as server errors and the system experiencing slow updates regarding balance within the storage. IT problems such as these won't be covered within the study due to their complexity and irrelevance.

**Storage:**
Finding available spots within the storage can sometimes be tricky for employees. This is due to the fill rate usually exceeding over 90 percent. If the percentage of unavailable spots is high, it prohibits flexibility when it comes to the stocking and movement of goods. The reason for unavailable spots often exceeding 90 percent is due to low inventory rate and delivery accuracy from suppliers, as well as to customers.

**Picking:**
Like the putaway process, the majority of problems occurring within the picking and packing operations traced to system errors.

The pickers within ASSA ABLOY OS are trained to pick correctly so the right amount of articles leaves the shelf and that they later on pack the articles according to weight, so that those articles which weight the most are sorted at the bottom. However sometimes it can occur that pickers make coincidental errors. These errors can be traced back to the individual through a tracking system. This is usually monitored when someone does a mistake in order to learn and prevent the same individual from making the same mistake.

However, productivity among employees are not really monitored. The reason for this is due to the lack of internal daily picking goals. As the main goal with order picking is order fulfillment, there are many approaches that can be used to optimize order picking processes. By introducing a standard daily picking goal, it can enhance the productivity among the employers and keep them effective. Addition to this the internal goals can later on provide the warehouse manager of an overview of which employees who are not suited for picking.
General problems:
Something that has been identified as common is that the employees within the different work areas only are trained to conduct the activities that take place within their work area. For example, the employees that are based at the dock are not trained to conduct activities that are operated within the warehouse, such as receiving and picking orders. Therefore, when they don't have any trucks to unload goods of, they don't really have something to do and usually tend to take breaks. Due to employees not being trained to conduct tasks that take place outside their department, it leads to situations where employees with less workload are not assisting other departments with higher workload. This is something that is crucial as bottlenecks at the receiving area can occur due to high workload and low personnel. Addition to this the absence of daily goals for the employees caused notable variations among the employees' productivity.

Another problem was the easy access the truck drivers had throughout the warehouse, especially at the dock area. The reason for this is due to the warehouse not being isolated from the dock and no existing resting areas for the drivers. This is something that needs to be resolved in order to prevent unauthorized individuals to enter the warehouse.
Chapter 5
Analysis and Discussion

This chapter aims to address the analysis of three separate areas. Initially, the section will address the identified waste in the current distribution center and how they can be eliminated within the future logistic center, followed by the results of the SLP application and evaluation of a potential material handling system that can be integrated within the future layout. Presented analysis is based on theories described in the theoretical framework, as well as empirical findings that are obtained through interviews and observations.

5.1 Potential improvements

For decades, warehouse managers have continuously sought to adopt practices that can improve the operations that take place within their warehouse, as well as in order to achieving competitive advantages. Today's companies are in an environment where their customers continue to demand more and at the same time for a lower cost. This has led to the growth of many innovative ideas and technologies, which companies have exploited in order to increase productivity and staying ahead of competition.

Although several new practices have been proved to be very effective, many warehouses have been very slow with integrating new technologies into their warehouses. One of the reasons for this can be that warehouses have many inter-connected processes and systems. Therefore, by integrating a new technology it would need to be integrated into the entire system, something that can be proved to be very complex and as a consequence constrain warehouse managers. Subsequently, the utilization of outdated methods has preserved instead of being replaced by new and innovative technologies.

However, the most successful warehouse companies have proven to be the ones that have been able to quickly embrace and prosper of the rise of innovative technologies. Lean automation has proven to be a game changer in recent years, as it has led to increased integration of automation within warehouses.

Below follows a list of various practices ASSA ABLOY OS can seek to implement in order to obtain improvements and increase productivity:

Dock:
The unloading dock is where it all begins and therefore sets the pace for the rest of the warehouse. Therefore, it is essential that the unloading and loading processes are operated in an efficient manner. When not operated efficiently it can result in reduced productivity and potential accidents concerning humans, products or equipment damages. When discussing approaches relating to the dock, it will generally concern the objective to unload cargo safely and in an efficient manner.
As mentioned in the empirical findings, the biggest problem regarding the current dock concerns the current design of the dock. The current design causes unnecessary distances and inconsistent loading sequences. Thus, the need for a new more efficient design for the future layout is vital.

Instead of trucks driving in and conducting the unloading on the side like they do today, it would be more efficient if trucks could reverse back into the unloading area with an interlocking system. An interlocking system would enable docking directly from the truck into the unloading area, leading to a safer and more efficient docking process.

Additional to the vitality of a new design for the dock, there exist also some problems tracing to the supplier. Problems tracing to the supplier involved poor information flow, causing uncertainties regarding the timing of incoming trucks, as well as what they contain. By improving and developing better relations with the suppliers a truck tracking system can be implemented, enabling ASSA ABLOY OS to track their deliveries and prepare for daily deliveries in a more efficient manner. For this to be possible all trucks need to be tagged so they can be identified within the tracking system. Once tagged, an automatic identification system can be placed near the entrance to the truck area, therefore preventing unknown trucks from entering the premises. While inside the truck premises, incoming trucks will be directed to a truck waiting are, enabling employees inside the facility to dictate which truck to handle first depending on the schedule and on the volume of goods that are contained in respective truck. This can be done through a digital display that can be placed outside where it is easily visible for the truckers.

Enabling the ASSA ABLOY OS employees to dictate load sequencing instead of using a FIFO rule, it can reduce the occurrences of an overflow of trucks that have to wait longer then they must. With proper load sequencing trucks will drive in and be handled in a consistent pace. Establishing safe and ergonomic workstations at the docking area, can be conducted by making sure employees are welly trained to handle the required equipment at the docking area, as well as making sure that the area is well ventilated in order to prevent employees to inhale chemicals and experiencing health risks.

Receiving:
Due to the receiving process having the largest impact on every step of the downstream processes, it can be considered as the most important process within a warehouse. The reason for this is that downstream processes depends heavily on the accuracy rates in receiving. If a container, as mentioned in empirical findings, is improperly received it can affect the entire process, leading to loss of money, time and productivity.

Therefore, it is vital for companies such as ASSA ABLOY OS to identify new and innovative technology that can be implemented in order to enhance the productivity and efficiency within the receiving process. One policy regarding the receiving process that has seen growing awareness through the years regards the “one touch” mentality and involves reducing the number of touches as much as possible. This is due to the more times an item is handled as the same time more people are involved in the handling process, it tends to lead to longer process times, as well as higher risks regarding the occurrences of mistakes.

A larger embrace of automation within the receiving process has thus, been identified as an approach that can be utilized in order to integrate the one touch mentality and enhance
productivity. By automating processes such as the data collection process for incoming orders at the receiving area, the opportunity for human errors is significantly reduced, leading to reduced risks that orders will be received incorrectly. The automation of the data collection process can be conducted using Radio Frequency Identification technology (RFID), also known as automatic identification. The RFID technology consist of several components and uses barcode tags to automatically collect information from incoming shipments, which is later communicated via software to warehouse management system. Using RFID technology, it provides an innovative way for orders to be automatically scanned in larger volumes as well as at a higher speed. Furthermore, leading to reducing costs, streamlining processes and increasing accuracy at the receiving area.

However, for this to be possible it requires a devoted collaboration with suppliers as they as well need to use same systems and technologies in order to enable the software at the receiving area to collect the information and transfer it to the main system. The supplier also is responsible for placing the tags in an effective manner on the containers, so it enables the RFID system to collect the data from the pallets.

**Material handling process – Putaway and Picking:**
The material handling process is often a process that usually gets ignored by warehouse managers when identifying innovative ways to optimize the warehouse operations. This is due to the putaway and picking process commonly being constrained to the distance between the storage and these respective areas. However, one should not belittle the impact of the workstations and goods placement as it increases travel time, as well as the time concerning the picking and packing of goods once not stored in an optimal location. Therefore, it is essential to consider the placement of workstations and goods within the future layout in order to reduce travel distances and create more efficient flows.

In another sense, as modern supply chains are experiencing a larger shift towards automation, Automated Guided Vehicles (AGVs) have experienced a larger usage regarding material handling within the modern warehouse, concerning processes such as putaway and picking. These driverless vehicles such as forklifts and rack carrying robots use magnets, sensors, lasers and cameras in order to program themselves onto their designated paths. This is something ASSA ABLOY OS could consider as todays processes solely consisting of time-consuming manual labor. Based on Theoretical Framework 3.4.1, the implementation of AGVs can lead to obtaining the following advantages:

- **Increased Safety:** As the occurrences of human errors are significantly reduced, its leads to reduced occurrences of accidents. Therefore, leading to safer work environments (Damacharla et al., 2018).
- **Reduced Costs:** Reduces the need for manual labourers to conduct the material handling processes. AGVs don't need lighting to operate, leading to reduced electricity bills and a more environmentally friendly aspect (Gothwal and Raj, 2018; Grandviewresearch.com, 2019).
- **Increased productivity and precision:** AGVs can work nonstop and on demand, with no consideration for exhaustion. Additionally, the work in a consistent pace which is less prone to errors (Gothwal and Raj, 2018).
Storage:
Considering that storing goods cost, organizing the warehouse storage in order to optimize space due to limited space availability is essential for any warehouse. Traditionally, optimizing storage space have concerned the tracking of assets and conducting various analysis, such as ABC analysis to name an example, in order to identify efficient ways to store goods depending on their throughput rate (Tompkins et al., 2010).

This is something that is crucial and needs to be taken into account when designing the future storage, regardless if the storage and retrieval activities are conducted manually or automatically. Developing a deeper understanding regarding which products that leave the storage quickly and which stays unnecessary long, can lead to reducing the material handling time and storage costs. Goods placed depending on their throughput level is something that is considered within the current storage at ASSA ABLOY OS.

In addition, with placing goods within the storage depending on their throughput rate, the material handling activities related to the storage is something that should be automated due to the amount of repeated activities. By implementing an ASRS integrated with AGVs it can lead to the same advantages as mentioned with the material handling process.

5.2 SLP method

Once a thorough initial research concerning the current flows, procedures and activities that take place within the distribution center was conducted. The application of SLP in the development of the new layout could be initiated. Since the main reason of the study was design a potential layout that could be operated on an operational level, it involved finding the relationships between the workstations and operations in order to achieve smoother processing of ingoing and outgoing goods in the future logistic center.

The SLP method will be divided into three separate sections and include the following: activity relationship chart, activity relationship diagram and space relationship diagram. The aim is to design potential layouts that take into consideration space utilization, transportation distances and organized workflows.

5.2.1 Activity relationship chart

Once a flowchart illustrating the activities that take place within the warehouse was constructed, it provided a depiction of how the material flow looks like in the current state. This depiction could later be used to conduct an activity relationship chart and analyze the relationships between the respective departments and workstations.

An activity relationship chart was constructed in order to develop a deeper understanding regarding the activities that take place and the relationships between them in the current state. The activity relationship chart in Figure 5.1 illustrates the relationships between the different workstations in the current state, hence illustrating how close they need to be to each other respectively. The assessments of grades have been rated based on the flowchart activities.
within the current facility. The grades that have been colored in red are the most important operations that require close distances between each other due to their high material flow and frequency of use. The blue colored grades describe that the distance between the operations are less important, while the black colored grades describes that the distance between the operations are completely unimportant.

![Diagram of Activity Relationship Chart]

**Figure 5.1:** Future activity relationship chart between the respective departments and workstations.

Once the analysis of the activity relationship chart was constructed, the most important relationships were identified. For example, one of the most important relationships is the distance between the unloading area and the receiving area. The reason for this is that once the goods have been unloaded from the truck, it is important that they are received and transferred to the putaway area as quick as possible. Therefore, it is vital that the distance between the unloading area and receiving area is as short as possible in order to save time and minimize the traveling distance of goods between these two areas. Less important relationships on the other hand, such as the distance between receiving to shipping, the distance between these departments isn't important due to the non-existing material flow and frequency of use.

Once the activity relationship chart was constructed, the charted data was used in order to conduct the analysis regarding the activity relationship diagram. As mentioned in Theoretical Framework 3.2, the activity relationship chart was conducted in order to illustrate the results from the activity relationship chart in a geographical manner, hence providing an idea of the future layout could be designed.


5.2.2 Activity relationship diagram

In this step the goal was to present the charted information in a geographical form that would aim to identify the best possible locations for the listed activities. This was carried out by focusing on reducing the number overlapping lines, which would potentially lead to prohibiting the occurrences of traffic and collisions within the future logistic center. When initiating the activity relationship diagram, it is crucial to identify and draw the most important connections between the stations, as these relationships lays the foundation for the potential layout. Thus, relationships between stations that are not as important can be placed last.

Each circle within the Figure 5.2 portrays a workstation inside the warehouse. As presented in the Figure 5.2, all circles are connected with at least one other circle, although the importance of their closeness is defined by the way the line is drawn. The placement of the circle is based on their relationship to the material flow within the layout. As the Figure 5.2 depicts, stations connected with the inbound flow are placed more to the right, stations connected with the outbound flow are placed on the left side, therefore stations connected with both flows such as storage is placed centrally in order to reduce the distances between connected stations, as well as prevent traffic and collisions. Although overlapping lines should be aimed to minimize, it unfortunately will occur some depending if the future layout will consist of one dock for both unloading and loading activities or two separate loading bays. However, it is crucial that these lines are not described as absolutely necessary, although lines described as ordinary closeness is more acceptable due to the low traffic they cause.

The activity relationship diagram provides a simplified overview regarding the importance of closeness between respective stations, which in turn can be used when designing the future operational layout. As a result of placing stations using the activity relationship diagram one can therefore reduce unnecessary distances, movements and overlapping workflows.
5.2.3 Space relationship diagram

As the current warehouse is going through a transitional phase involving moving to a smaller layout it is crucial to estimate the future space requirements so they can be adjusted with the actual space available.

Today’s operations are utilized within an area that consist 16000 m². Due to production and volume of goods handled being reduced, the operations concerning the inbound and outbound flows will be moved to a smaller area. This smaller area will consist of 1580 m². Therefore, in order for the activity relationship diagram to be constructed as an operational layout it is crucial to control that the space requirements are adjusted to the actual space availability. The addition of space requirements within the space relationship diagram is what essentially differentiate it from an activity relationship diagram.

When estimating the different space requirements for respective station, it is vital to also adjust suitable space requirements for the workers to operate between the stations. This is especially important between aisles within the storage area so lift trucks can freely operate, as well as at the unloading and shipping areas. The estimations regarding the future layout is based on the current space requirements, information provided by personnel within respective workstation, as well as on the dimensions for the future layout provided by the warehouse manager. By taking all these considerations into account we could provide estimated data as

Figure 5.2: Future activity relationship diagram provides an overview regarding the importance of closeness between respective stations.
listed below in the Figure 5.3 for each operation in the future layout. These values can change in the future depending on future production and personnel needed for the future layout.

Figure 5.3: Future space relationship diagram.

5.2.4 Alternative layouts

Once the system layout planning charts and diagrams were conducted, the actual layout design could initiate. Adopting and utilizing SLP as a foundation for designing a layout, it is essential to develop alternative block layouts that can be compared and analyzed, in order to identify the most optimal alternative. The alternative block layout would later be modeled in 3D using a software called Visual Components. The utilization of a 3D simulation software provided with a more realistic design, which subsequently would be easier to describe and communicate to the management at ASSA ABLOY OS.

Since the design of the actual layout was the main reason for the study, two alternative layouts were designed. Each alternative layout was examined by taking into consideration aspects such as space utilization, transport distances, material flow, safety and number of loading docks. The design process initiated with drawing the actual space available in order to fully understand how big the future area would be. Therefore, boundaries such as borders, walls and pillars of the facility was modeled according to the available dimensions. Once the boundaries had been established the placement of the different workstations could be placed according to the activity relationship chart and diagram.
The product flow within a warehouse is the essential factor that determines the overall productivity and efficiency of a facility. Due to the flow of products having such a huge impact it is crucial to evaluate the placement of the shipping and receiving area based on the available space, product throughput needs and available resources. This study has therefore presented two alternative layouts that takes all modifying considerations into aspect.

5.2.4.1 Layout 1

The first layout alternative Figure 5.4 was based on the determination of only using one loading dock and anticipating a low future demand. Due to one loading dock already existing at the allocated area, it was decided to keep it based on economic purposes, such as to avoid investing in a new loading dock located at a different location. By placing the loading dock at the left side of the building, it led to allocating the receiving and shipping area close to the loading dock based on the activity relationship chart. Due to both workstations depending on being allocated as close as possible to the loading dock, consequently caused them both to be placed close to each other, along with the remaining workstations and departments. By placing all workstations in such a close range to each other it led to obtaining several advantages, as well as disadvantages.

![Figure 5.4: 2D-materialflow of Layout 1.](image)

One advantage with the layout 1 is that due to all workstations being located at close range to each other, it would make it easier for workers with low workload being allocated to workstations with higher workload. Consequently, it would lead to less travel distances between departments and a higher utilization of resources such as personnel and material handling equipment. Additionally, the team leader has a better oversight of the several activities that are being conducted within the area, subsequently leading to communication being more efficient between departments.

Another advantage with the design of this layout is that by allocating all workstations and department to the left side of the building, it established better conditions for utilizing the space for the storage area, considering the boundaries that existed within the facility. Additionally, efficient picking paths can be arranged in order to reduce excessive travel times improve the material handling process within the storage.
Due to the receiving and shipping activities being conducted at the same dock, the need for duplicated supervision at the docking station would be eliminated. Therefore, the need for docking station personnel would be reduced as less workers are needed to conduct the unloading and loading activities.

However, by having all workstations and departments placed relatively close to each other, as well as having the same dock serving both receiving and shipping activities, it can lead to inefficiencies and mistakes. As can be obtained from the Figure 5.4, the make-up of this layout causes several overlapping workflows. This is something that should be avoided as overlapping workflows can lead to increased traffic and interactions between pedestrians and trucks. This can consequently affect the processing of goods in and goods out, as well as it can lead to insecure work environments due to increased chances for collisions and safety hazards to occur.

Another disadvantage with only using one dock for both receiving and shipping, is that it can create an overflow of trucks that have to wait around due to the restraint regarding only being capable to handle one truck at a time. This is something that can occur when trucks not arriving according to schedule. Therefore, incoming and outgoing trucks can bottleneck at the dock and cause delays that significantly can influence the production inside the warehouse, as well as deliveries to customers.

While inside the docking area, receiving and shipping activities overlap with each other and can therefore affect the processing of incoming and outgoing goods. Due to receiving being one of the most important process it is crucial that the receiving area is not too small. It is vital that no errors occur in the receiving process as they will affect all downstream processes as well. Having many trucks, pallets and workers all in one place can lead to disorganization, accidents and workers operating in tight spaces. For example, having the shipping activities being operated at such a close range can in some cases lead to outgoing orders being confused with incoming orders and accidentally getting transferred back in the storage.

When it comes to future growth, the overall set-up of this layout can turn into a restraint and hinder the future expansion if the market demand would increase. Due to the area being restricted to only being able to handle a certain amount of goods and traffic, it can therefore be very problematic to implement changes that would require allocating certain sections to another location in order to create space for the processing of ingoing and outgoing goods.

5.2.4.2 Layout 2

The second alternative layout Figure 5.5 was inspired by having two separate loading bays for the receiving and shipping area. By placing them on different sides of the facility it provides a smoother processing of ingoing and outgoing goods, leading to the overall flow of goods appearing as a U-flow design. In this layout receiving trucks pulls up to one side of the U where employees unload the goods and later transport it to the receiving and putaway area. While at the same time outbound activities are conducted simultaneously on the other side of the U.
Figure 5.5: 2D-material flow of Layout 2.

By separating the inbound and outbound activities, they could be more organize and avoid the occurrences of overlapping workflows. This compared to the first layout causes less traffic and safer work environments overall for the workers. As less trucks are operating at the same tight area it leads to reduced interactions between pedestrians and vehicles, thus leading to less collisions and accidents.

Additionally, it enables the warehouse to optimize truck unloading and loading as more than one truck can be handled at the same time, subsequently leading to improving the flow of inbound and outbound goods, as well as reducing the occurrences of an overflow of trucks waiting to be handled.

The receiving process in this layout is prioritized extra as it consists of more sufficient space to conduct the processing of inbound goods. The reasoning for this was to avoid congestion in the receiving area in order to reduce the occurrences of errors. No other activities overlap with the processes that are conducted in the receiving area, leading to less trucks, pallets and workers located in the area. The receiving area is therefore further organized and consist of more peaceful flows, eliminating the risk that outbound goods will be confused with inbound goods.

However, the price that comes with arranging the layout this way is sustained by reducing the storage capacity, as area related to the storage on the first layout is cleared in order to make up space for the inbound activities. In this layout the storage area is located centrally providing easily accessible paths to the putaway and picking/packing area. The storage was placed central so it could be equally close to both the putaway and pick/packing area accordingly to the SLP data, therefore reducing time consuming transportations between the storage and the respective areas. While inside the warehouse storage, goods are later stored depending on their throughput levels. Items with high throughput levels are stored closer to the docks in order to reduce the traveling distances for fast moving items.

But due to the inbound workstations being isolated from the outbound workstations, it leads to lesser communication between the departments and therefore reduced utilization of resources, such as personnel and material handling equipment. The team leader doesn’t have as clear oversight regarding the productivity and workload among the different departments,
thus increasing the need for another team leader in order to allocate personnel to different workstations depending on workload.

When it comes to potential growth, this layout can provide better circumstances for processing higher volumes of ingoing and outgoing goods. The reason for this is due to the capability of handling more than one truck at the same time, as well as more organized workflows leading to more efficient material handling processes. If demand would increase in the future, the processing of goods would not be conducted in tight and disorganized areas.

5.2.5 Multiple criteria decision-making framework

When it comes to evaluating alternative layouts in systematic layout planning, there exist numerous approaches to simplify the decision-making process. In order to identify the most optimal layout, a multiple criteria decision-making framework was formulated to simplify the decision-making process. The framework consisted of several indicators that was selected by the researchers, which were based on (Arunyanart and Pruekthaisong, 2018; Besbes et al., 2017) as well as provided by the case company. The following factors was selected:

- **Flexibility of the layout**: Regards the ease of rearranging the layout according to future changes or growth.
- **Storage capacity**: Regards the amount of goods that can be stored within the storage area.
- **Flow and movement effectiveness**: Regard the smoothness of workflows and reduction of traffic.
- **Utilization of resources**: Regards personnel and material handling equipment.
- **Safety**: Regards the interactions between vehicles and pedestrians.

5.2.6 Layout evaluation

The main aspect that have separated the two alternative layouts was the number of loading docks, which affected the placement of the receiving and shipping area, leading to completely different workflows within the warehouse. Capacity and traffic scheduling are important factors to take into consideration when determining the number of loading bays. Due to uncertainties regarding the future storage capacity and delivery frequencies it has influenced the decision-making process.

The Table 5.1 consist of a summarization of advantages and disadvantages regarding respective alternative layout.
Table 5.1: Evaluation between future alternative layouts.

<table>
<thead>
<tr>
<th></th>
<th>Layout 1</th>
<th>Layout 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>- Increased utilization of resources.</td>
<td>- Smoother processing of ingoing and outgoing goods.</td>
</tr>
<tr>
<td></td>
<td>- Lesser travel distances between departments.</td>
<td>- More organized workflows leading to less traffic, pallets and workers within an area.</td>
</tr>
<tr>
<td></td>
<td>- Better communication between departments and workstations.</td>
<td>- Reduced interactions between vehicles and pedestrians.</td>
</tr>
<tr>
<td></td>
<td>- Increased storage capacity.</td>
<td>- More flexible when it comes to future growth and changes.</td>
</tr>
<tr>
<td></td>
<td>- Better suited if future demand will be low.</td>
<td>- Optimized truck unloading and loading.</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>- Increased overlapping workflows and traffic.</td>
<td>- Lesser communication between departments.</td>
</tr>
<tr>
<td></td>
<td>- One loading dock can cause bottlenecks at the dock, affecting both inbound and outbound flows.</td>
<td>- Reduced utilization of resources.</td>
</tr>
<tr>
<td></td>
<td>- Increased congestion in a busy receiving area.</td>
<td>- Reduced storage capacity.</td>
</tr>
<tr>
<td></td>
<td>- The overall set-up of the layout can hinder future growth or changes.</td>
<td>- Increases the need for supervision.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Can lead to empty loading bays during the off-peak times.</td>
</tr>
</tbody>
</table>

When analyzing the different layouts according to the multiple criteria decision-making framework, the researchers concluded that layout 2 would suit the future logistic center in a more efficient manner.

The main factors that influenced the selection of layout 2 was based on the flexibility of the layout, workflows and a safer work environment. As mentioned earlier, the set-up of layout 2 provided with more organized workflows. This was due to the separation between the inbound and outbound activities, which consequently led to smoother processing of ingoing and outgoing goods. Something that is essential for the receiving process, as it can affect all the downstream processes if not conducted correctly. Making sure the receiving area has adequate space, not only for holding pallets, but for performing activities such as control and sorting for example, can lead to less congestion at the receiving area during busy periods, therefore reduced occurrences of errors. Additionally, it caused for less traffic as less trucks, pallets and workers was located at the same area. Consequently, leading to safer work environments due to the reduced interactions between trucks and pedestrians.
Utilizing resources and allocating personnel is important for the future logistic center. In order to enable conditions for personnel with low workload to assist personnel with high workload, it is crucial that every personnel have sufficient training and experience for each warehouse operation that is conducted within the warehouse. Thus, it can lead to increased personnel utilization and preventing variations regarding workloads among workstations. This is something that can be achieved by conducting cross training for employees. Cross training provides employees with learning new skills and increase their value to the warehouse. Subsequently, making it easier to allocate them based on workload. Depending on the future warehouse will have one leader for all departments or one team leader in respective workstation. It will be these individuals that will be responsible for the communication between the departments and the daily personnel relocations, as well as establishing daily goals for each department and employee.

Anticipating the future is something that can be difficult. Therefore, depending solely on forecasts can lead to devastating costs if the layout is not flexible enough for future changes. A layout set up must take into consideration future changes as future demand is something that can always change. When planning layouts, it is essential to optimize space in order to make sure all space is utilized. Paying for unused space is something that no warehouse managers want to do. However, not having extra available spaces during busy periods or if future demand would increase can be very costly. Making sure that the layout is therefore flexible enough to handle busy periods and future changes is something that makes the advantages with layout 2, outshine the advantages with layout 1.

5.3 Storage and material handling system

Now that the future layout (layout 2) has been established, the study will discuss what kind of material handling system would be most optimal for the future layouts putaway, storage and picking processes. In the current distribution center, goods are moved around the storage systems by manual workers using various material handling equipment, such as forklifts, to retrieve and store goods within the warehouse.

Two different scenarios, regarding three diverse material handling systems will be presented and analyzed before selecting the most superior system.

5.3.1 Scenario 1 – Automated Storage and Retrieval System (ASRS)

This scenario is based on an ASRS that uses a goods-to-person method. When orders arrive and get scanned at the putaway area, the central software will instruct unoccupied robots to transfer the correct portable units/pallets that the incoming orders will be placed into at the putaway station. While at the station, a put/pick to light technology will be installed and inform the employee in what shelf respective item will be placed. Compared to traditional putaway, the worker won’t have to move from his spot in order to store all items, therefore eliminating the time-consuming transporting that would be required to locate the spots of each items within the storage area. The robots will stand in line and await their turn, while the worker place each order in correct shelf until all orders have been replenished.
Simultaneously as one worker is conducting the putaway activities on the right side of the layout, another worker can conduct the picking activities on the left side of the layout. At the picking stations, similar activities will be conducted. A worker will select an order within the system leading to the central software instructing available robots to retrieve the correct pods that contain the items that the outgoing order consist of. Similar to the putaway station, a pick to light system will be installed and inform the worker using a laser, from what shelf and amount to pick. The worker will later scan and label respective order before placing them on an empty pallet, which will be transported the shipping area.

It will be crucial to implement ergonomic friendly stations for the workers at the putaway and picking/packing areas, in order to prevent workers from developing musculoskeletal injuries while they are picking items from the pods.

This automated storage and retrieval system (ASRS) involving automated vehicles can lead to obtaining numerous advantages, as well as disadvantages. The advantages with integrating these robots are they are not only more efficient, but they also take up less space. By eliminating the need for manual workers, it can lead to, eliminating human errors, reducing labour cost, safer work environments, increased accuracy and productivity (Khasasi et al., 2016).

However, with the implementation of ASRS comes disadvantages as well. One of the disadvantages with the implementation ASRS are that they require a large initial investment. The costs do not only consider the acquisition of the AGVs but the system and installation that these complex technologies require as well. Additionally, ASRS causes increased maintenance cost and in some cases occasional shutdowns. The company will therefore need to hire maintenance technicians instead of traditional warehouse workers, in order to conduct occasional repairs. Compared to the traditional warehouse workers, these employees require higher salaries and education. Having declared that, an ASRS is more beneficial for a long-term solution as the return on investment is achievable (Roodhergen and Vis, 2009).

Another disadvantage with ASRS is that are only suitable for repetitive activities, thus decreasing flexibility of operations. AGVs can't perform activities they are not programmed to conduct. In an ASRS, the receiving process has increased responsibility regarding processing of ingoing goods correctly as errors can be more problematic in an automated storage. This especially concerns the sorting and labelling of goods. For example, if goods are not clearly labelled, it can lead to difficulties for the robot to identify the label. Thus, causing error and the need for assistance.

An ASRS can be integrated with different kind of automated vehicles or robots. This study will present two alternatives and shortly discuss the pros and cons regarding respective system. Both will use the same concept regarding the handling of goods within the storage, known as goods-to-person fulfilment. However, respective robot can provide different benefits for the future storage system.
5.3.1.1 AMR vs. AGV

The main difference between AGVs and AMRs is the way of navigating and the racks they operate with. AMRs work rather independently and automatically compared to AGVs that require an adaption of the environment and can also easily be reprogrammed and adjusted to different requirements. Since an AGV follows pre-defined paths, there cannot be any obstacles in its way (Liotine, 2019). While an AMR can go around them and find new paths (Abdulmajeed and Mansoor, 2014). Due to their significant abilities regarding flexibility and responsiveness during navigation, they can conduct the goods-to-person fulfilment more efficiently and quicker within the future storage system.

However, due to these AMRs being limited to only handle certain customized racks and not being able to handle pallets, it limits them to a certain degree and hinders the utilization of height within the storage system. Another disadvantage with AMRs is that during occasional shutdowns, it will lead to complete shutdown as these robots not being able to be operated manually and other trucks not fitting within the storage area due to storage optimization.

When it comes to utilizing storage space, the AGVs can as any other forklifts, utilize the height of a storage area and therefore utilize the space in a completely different way, compared to AMRs. AGVs might take up more space then AMRs but they can operate on standard pallet racket systems consisting of several levels.

Another advantage with the automatic forklift is that they can be operated manually as well, therefore preventing complete shutdown if the central network is encountering errors. Additionally, the automated forklifts can easily be integrated with other operations within the warehouse. This is due to many operations involves the handling of pallets, such as the receiving and shipping operations.
5.3.2 Scenario 2 – Traditional manual retrieving and storage

Based on the current system, manual storage and retrieving system is the most conventional strategy when it comes to material handling. It involves a man “man-to-goods” process, where workers using machine operated vehicles such as forklift, move around the storage in order to locate goods for both putaway and picking activities.

As the introduction of lean automation has led to numerous companies embracing automated systems, many companies still use traditional manual due to numerous advantages. One of the main advantages is that they don't requires a large initial investment. Deciding to implement an automated system requires broad analysis involving the balancing of risks with rewards. When not done properly it can cause devastating costs for the company.

Another advantage is that human workers are considered more flexible compare to automated systems. In many cases automated systems are not feasible due to the lack of flexibility the operations require, such as the ability to jump between tasks. Unlike AGVs, human workers can cover for each other during busy periods or occasional of duty personnel. As long as the stand-in worker has the right training and experience. Additionally, if the operations in the warehouse tend not to be repetitive, chances are that they can be carried out more efficiently by human workers.

Disadvantages on the other hand, as earlier mentioned is that by integrating these robots, they are not only more efficient, but they also take up less space. Therefore, by eliminating the need for manual workers, it can lead to, eliminating human errors, reducing labor cost, safer work environments, increased accuracy and productivity.

5.3.3 Material handling evaluation

Evaluating what kind of material handling system to integrate within a warehouse requires a broad analysis involving the balancing of respective risks and rewards. Since this report involved designing the most optimal layout for ASSA ABLOY OS, it took into consideration what material handling system would be most superior for the layout. Indicators such as cost was not prioritized as the most cost efficient does not imply superiority.

The researches have concluded that an ASRS consisting of a mix of AGVs and AMRs, such as automated forklifts and Kiva robots, would be the most optimal solution. The main factors that influenced the conclusion was based on the ability to handle goods in an efficient and secure manner, along with the capabilities regarding future degree of automation within the warehouse.

By utilizing a goods-to-person fulfillment method instead of a person-to-goods method, time-consuming transportations would be eliminated leading to increased productivity and orders handled. Something that is essential as a warehouse productivity is what defines its potency.

Comparing and balancing the advantages with the disadvantages between the vehicles was complex. The researchers first leaned towards only integrating AGVs, such as automated forklifts. This was due to that they felt the advantages outshined the advantages provided by
an AMR. The reason the automated truck outshined the AMRs advantages was due the ability to be operated manually during occasional server shutdowns, as well as increased storage capacity due to the utilization of the warehouse's height. In addition, the automated forklifts consisted of features that enabled them to conduct operations throughout the warehouse and not only be limited to the storage area. Besides operating within the storage area, they would be able to transport goods throughout the warehouse, including to the production area. Subsequently, by utilizing different conveyors systems that can be interlocked with the delivery trucks, the automated forklifts would also be able to conduct the unloading and loading of goods, thereafter, transport them to pre-decided destination. Thus, increasing the amount of automated activities conducted within the warehouse.

However, when it to solely retrieving processes the AMRs seemed more efficient due to operating much quicker. Additionally, they seemed cheaper than modern automated forklifts when analyzing the current market, leading to obtaining more AMRs for the same cost of one automated forklift.

By integrating a mix of AMRs and AGVs and not only one kind, it can lead to a more utilization of storage space, as the automated forklifts can utilize the height of the warehouse and handle pallets as well. Therefore, the idea is that the storage will use the current pallet racking system which will lead to better use of space, as well as enabling the stocking of different goods. In addition, it will be cost saving as investments in new racking systems is avoided. The current racking systems consist of five levels, the idea is that the first level will only be suitable for portable units that the AMRs robots will operate with. Depending on the height of this portable unit, the height of the others level will be adjusted. Thus, the remaining levels will be suited for storing pallets, which the automated forklifts will handle.

However, with that concluded being determined, the implementation of an ASRS does not have to imply the discharging of manual workers. Instead of firing workers, they can be transferred from non-valued tasks, such as transporting material, to value added operations such as production or be trained to conduct the occasional maintenance and repairs required.
Chapter 6
Suggested Future State

Once the layout (layout 2) and material handling system (ASRS) had been selected, the layout was developed in a 3D simulation software. In this chapter, respective functional areas within the future layout will be presented and described more detailed, as well as how they differ from the functional areas in the current state. Lastly, a future flowchart describing the activities step-by-step will be presented and lay the foundation for the future state map. The 3D simulation of the layout can be found in Appendix A.

6.1 Functional areas and process data

The design of the new functional areas that will feature in the future layout, are based on the implementation of the evaluations regarding layout 2 integrated with an ASRS. The implementation of layout 2 and an ASRS will lead to the elimination or change for certain non-value-adding activities that exist in the current flowchart. The changed and remaining activities will establish the future flowchart, as well as cause different cycle and process times. This new flowchart consisting of new measured times will lay the foundation for the mapping involving the future state.

- **Unloading station**

The area where incoming trucks will be connected with an interlocking system. This will allow trucks to be unloaded directly and lead to reduced process time and transportation distances to the receiving area. Pallets will be unloaded manually with a forklift and later transported to the receiving area. The unloading station consist an area of 27 m². Therefore, it is sufficient enough for a forklift to operate its maneuverings in order to conduct the unloading of goods. Forklifts can easily drive into the truck, back out and place pallets that are awaiting to be transported to the receiving area.

Before the unloading begins, trucks will be placed in a truck waiting area. Operators at the dock will signal the truck driver through a digital display that will be placed outside once the truck can be unloaded. Therefore, enabling sequenced unloading operations. Additionally, the delivery documents will be quickly controlled as well before the unloading process starts. The area is also connected with a ramp, allowing the forklift to drive down to the driveway when needed. For instance, during the transportation of broken material to the recycle area, as well as during the rarely unloading processes regarding parcel trucks.

Compared to the current unloading process that operates on longer distances and an uneven ground, the implementation of an interlocking system leads to a reduced transportation distance and process time. The activity that will remain as it is, involves the inspection of incoming goods, and the time it takes to unload a pallet from a truck. Since the distance from unloading station to the receiving can be measured using the 3D software, as well as due to
knowing the average speed of a manual truck, the time it would take to unload one pallet, transport the pallet to the receiving area and drive back could be calculated as the following:

**Table 6.1**: Activities that will remain (unloading).

<table>
<thead>
<tr>
<th>Activities that will remain (Unloading)</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>20 min</td>
</tr>
<tr>
<td>Unload one pallet from truck</td>
<td>40 sec</td>
</tr>
</tbody>
</table>

\[ Travel\ time\ to\ receiving\ area = \frac{13\ meter}{1.39\ meter\ second} \approx 10\ sec \]

\[ Pallets\ each\ truck = \frac{10\ pallets}{2\ trucks} = 5\ pallets \]

\[ Cycle\ time\ (unload\ each\ pallet) = 40\ sec + (10\ sec \times 2) = 60\ sec = 1\ min \]

\[ Cycle\ time\ (each\ truck) = (5\ pallets \times 1\ min) + (20\ min\ control) = 25\ min \]

\[ Process\ time\ (two\ trucks) = 25\ min \times (CT) \times 2\ trucks = 50\ min \]

\[ Lead\ time = \frac{50\ min}{1\ employee} = 50\ min \]

- **Receiving area**

The receiving area will consist of 72 m². The aim was to make adequate space for the receiving area not only for holding inventory, but to conduct activities such as inspection, breaking down larger pallets, sort goods depending on where they need to be transported, and other receiving activities. The adequate space and preventing of overlapping workflows with the receiving activities, established conditions for the receiving activities to be processed smoothly, as well as to prohibit the occurrences of congestion during busy periods.

A RFID portal will be placed at the entry to the receiving area, enabling the ingoing order to eliminate manual time-consuming scanning. Using RFID technology, it provides an innovative way for orders to be automatically scanned in larger volumes as well as at a higher speed. When delivered to the receiving area, the orders will be quickly controlled and sorted depending on where they will be transferred. Once the RFID portal scan the orders, the warehouse management system will inform the human worker if the order is supposed to be transferred to the storage, quality, investigation or directly to production. The human worker will transport it to the location using a manual forklift.

By implementing an RFID system, the need for manually scanning and writing the article number within the computer will be eliminated from the current flowchart, which was measured at 15 minutes. However, some activities will still remain in the future flowchart.
Table 6.2: Activities that will remain (receiving).

<table>
<thead>
<tr>
<th>Activities that will remain (Receiving)</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control shipping document</td>
<td>4 minutes</td>
</tr>
<tr>
<td>Sort and inspect if the quantities are</td>
<td>20 minutes</td>
</tr>
<tr>
<td>correct</td>
<td></td>
</tr>
<tr>
<td>Place pallet at putaway area</td>
<td>1 minute</td>
</tr>
</tbody>
</table>

Travel time to putaway area = \[
\frac{10 \text{ meter}}{1.39 \text{ meter second}} \approx 8 \text{ sec} \approx 0.13 \text{ min}
\]

Cycle time (one pallet) = 4 min + 20 min + 1 min + (0.13 min × 2) = 25.26 min

Process time (ten pallets) = 25.26 min × 10 pallets = 252.6 min

\[
\text{Lead time} = \frac{252.6 \text{ min}}{2 \text{ employees}} = 126.3 \text{ min}
\]

- Quality

The quality process will look like it does in the current facility. The selection of goods that needs to be transferred to the inspection and quality department is determined beforehand. Certain goods that are heavily regulated are marked within the system and transferred to the quality department before being transferred to the put-away area. Now and again some goods are selected randomly for inspection. Once they have been inspected, they will be transported directly to the putaway area so that can be placed in the storage area.

The quality office where the inspection take place consist of an area involving 47 m². This required area has been based on the current area that exist in the current facility. We consider it to be to large due to that much less goods will be handled in the future layout. However, we still base the required area on the current state, although this area can be reduced to in order to allow more space for other operations. Pallets that are awaiting to be inspected can be placed either inside the department or outside next to the department wall. No changes regarding cycle time will be made.

Travel time to putaway area = \[
\frac{15 \text{ meter}}{1.39 \text{ meter second}} \approx 11 \text{ sec} \approx 0.18 \text{ min}
\]

Cycle time (one pallet) = 120 min + (0.18 min × 2) = 120.36 min

Process time (five pallets) = 120.36 min (CT) × 5 pallet = 601.8 min

\[
\text{Lead time} = \frac{601.8 \text{ min}}{2 \text{ employees}} = 300.9 \text{ min}
\]
• **Putaway**

Ingoing orders that are supposed to be transferred into the storage will be placed at the putaway area. When orders arrive and get scanned at the putaway area, the central software will instruct unoccupied AGVs and AMRs depending on the set-up of the order, to either retrieve a mobile rack that the ingoing articles will be placed into manually by the human worker, or transfer the complete pallet directly to a predetermined spot within the storage. When the human worker is needed to manually place certain articles in a mobile rack, a put-to-light system will inform in what place respective article will be placed. The putaway station can hold five pallets at the time. When workload is high, pallets can be stored at the receiving area while they are awaiting to be placed into the putaway area.

Due to the implementation of ASRS, it will lead to a goods-to-person process instead of a person-to-goods process. Consequently, it will eliminate the travel distances required for a human worker to drive to a location within the storage, place the goods at the right storage spot and finally to drive back to the putaway area in order to process a new pallet consisting of goods. The elimination of this activity that exist in the current flow chart, measured at 15 minutes, will affect the cycle time to process a pallet in the future state.

In the future state, the cycle time will only be based on the time it takes for a human worker to scan two articles by using a hand scanner, the time it takes for an AGV/AMR to retrieve a pallet or portable unit and the time it will take for the worker to place 20 boxes in the retrieved pallet/portable unit.

The calculation for the future cycle time to process one pallet that consist articles will be the following:

**Table 6.3**: Activities that will remain (putaway).

<table>
<thead>
<tr>
<th>Activities that will remain (Putaway)</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan articles</td>
<td>20 sec</td>
</tr>
<tr>
<td>Placing 20 boxes</td>
<td>2 min</td>
</tr>
</tbody>
</table>

\[
\text{Time for AGV to arrive at putaway station} = \frac{50 \text{ meters}}{1.39 \text{ meter seconds}} \approx 36 \text{ sec}
\]

\[
\text{Cycle time (one pallet)} = 20 \text{ sec} + 36 \text{ sec} + 120 \text{ sec} = 176 \text{ sec} = 2.93 \text{ min}
\]

\[
\text{Process time (50 pallets)} = 2.93 \text{ min} \times 50 \text{ pallets} = 146.5 \text{ min}
\]

\[
\text{Lead time} = \frac{146.5 \text{ min}}{1 \text{ employee}} = 146.5 \text{ min}
\]
• **Picking and packing**

Based on the setup of layout 2, simultaneously as one worker is conducting the putaway activities on the right side of the layout, another worker can conduct the picking activities on the left side of the layout. At the picking stations, similar activities will be conducted. A worker will select an order within the system leading to the central software instructing unoccupied forklifts to retrieve the correct mobile rack or pallet that contains the items that the outgoing order consist of. Similar to the putaway station, a pick-to-light system will be installed and inform the worker using a laser, from what container to pick. The picked items are later on packed in an appropriate shipping container with their respective packing list. The shipping container get measured in height and weight and later on wrapped and sent to the shipping area.

Similar to the putaway processes, the goods to person method will lead to the elimination of travel distances in order to pick articles. The cycle time to process one line will be based on the time it takes for a human worker to select a line, for the AGV/AMR to retrieve the pallet/pod which contains the article and for the worker to pick the right amount. Remaining activities is described in the table and need the same time as in the current flowchart. Calculation for the cycle time and lead time:

**Table 6.4: Activities that will remain (picking and packing).**

<table>
<thead>
<tr>
<th>Activities that will remain (Picking &amp; Packing)</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to select line</td>
<td>10 sec</td>
</tr>
<tr>
<td>Picking</td>
<td>30 sec</td>
</tr>
<tr>
<td>Packing</td>
<td>1 min</td>
</tr>
</tbody>
</table>

\[
Time \text{ for AGV to arrive at picking station} = \frac{50 \text{ meter}}{139 \text{ meter seconds}} \approx 36 \text{ sec}
\]

\[
Cycle \text{ time (one line)} = 10 \text{ sec} + 36 \text{ sec} + 30 \text{ sec} + 60 \text{ sec} = 136 \text{ sec} = 2.27 \text{ min}
\]

\[
Process \text{ time (200 lines)} = 2.27 \text{ min} \times 200 \text{ lines} = 454 \text{ min}
\]

\[
Lead \text{ time} = \frac{454 \text{ min}}{2 \text{ employees}} = 227 \text{ min}
\]

• **Storage**

The automated storage will consist of an area involving 908 m². The idea is that the storage will use the current pallet racking system which will lead to better use of space, as well as enabling the stocking of different goods. In addition, it will be cost saving as investments in new racking systems is avoided.

The current racking systems consist of five level, the idea is that the first level will only be suitable for portable units that the AMRs robots will operate with. Depending on the height of this portable unit, the height of the others level will be adjusted. The remaining levels will consist of pallet spots for the automated forklifts to operate with. The mix of AGVs and AMRs allows the storage area to be optimized in order to increase the storage capacity.
Which will lead to a storage capacity involving space for 361 pallets spots in the first level and to a total capacity of 1805 with all levels included. This has been installed together with optimized picking paths for the AGVs/AMRs in order to reduce excessive travel times and distances. The paths the robots will be guided through will have a vertical distance of 2.2 m, which allows two AGVs to operate side by side.

The storage will be gradually separated in two and aim to separate articles that will head to production, from articles that arrive from production which are intended to be shipped. Articles that will arrive from the production will be mostly stored on the left side depending on their throughput rate. In addition, items that are usually purchased together should be intended to be stored in the same portable unit. Same principal will be integrated for articles that will be stored for production. These will mostly be placed in the storage's right side close to the putaway area.

- **Shipping**

The shipping is the area where the pallets will be stored once they are ready to be shipped. This area consists of 30 m². At the shipping area the pallets will be wrapped with plastic and later stored awaiting to be loaded into the arriving trucks. Once the pallets have been placed in the shipping area, shipping documents including address label and bill of lading are prepared. At the shipping area a display will inform where each order will be placed, depending on which arriving truck the pallet will be loaded on. Instead of having the pallets placed on the ground and take up space while waiting for the arriving truck, they will be placed in a five-level racking system that is marked with numbers related to each arriving truck. Additionally, they will be sorted depending on the destination. If the outgoing truck has only one destination the sorting does not matter. However, if the truck has several stops on the route. Pallets will be sorted depending on what stop they will be unloaded at. Pallets which destination is at the routes last stop will be placed in the front, while pallets which stop is at the routes first destination will be placed last. By sorting and placing these pallets in order within the truck it can lead to more organized sorting which enables conditions for the customers to know what pallets belong to them. Therefore, preventing the unloading of wrong pallets.

Before the truck arrives, they will be removed from the racks and placed on the ground to reduce the time it takes to load them into the truck. Before the pallets get loaded in the delivery truck, they will pass a RFID portal, which will inform the WMS that the orders are leaving the warehouse. This information can additionally be sent to the customer as well. Similar to the current state, the truck driver will conduct the loading process.

The shipping process will be added with some extra activities compared to the current state. These activities involve, measuring the weight and dimensions of the pallets, wrap the pallets, and hand in the order documents to the office at the shipping area. The times for these activities are the same as in the current state. Therefore, leading to the cycle time for the processing of one pallet at the shipping area will be added with two minutes. Additionally, a significant reduction in orders will be featured in the future logistic center, leading to an estimation of ten pallets. The activity in table remains.
Table 6.5: Activities that will remain (shipping).

<table>
<thead>
<tr>
<th>Activities that will remain (Shipping)</th>
<th>Activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible constructs the shipping documents</td>
<td>5 min</td>
</tr>
</tbody>
</table>

*Shipping activities = 2 min*

\[
\text{Time travel from picking \\& packing area to shipping area} = \frac{20 \text{ meter}}{1.39 \text{ meter seconds}} \\
\approx 14.4 \text{ sec} \approx 0.24 \text{ min}
\]

\[
\text{Time travel to loading area} = \frac{13 \text{ meter}}{1.39 \text{ meter seconds}} \approx 9.4 \text{ sec} \approx 0.16 \text{ min}
\]

*Cycle time (one pallet) = 2 min + (0.24 min × 2) + 5 min + (0.16 × 2) = 7.8 min*

\[
\text{Process time (ten pallets) = 7.8 min} \times 10 \text{ pallets} = 78 \text{ min}
\]

\[
\text{Lead time} = \frac{78 \text{ min}}{2 \text{ employees}} = 39 \text{ min}
\]

- **Loading station**

Identical with the unloading station. Regards the area where outgoing trucks will be connected with an interlocking system. Just like in the current state, pallets will be loaded manually with a forklift into a truck by the truck driver. The area has sufficient space to hold inventory for arriving trucks. The area is also connected with a ramp, allowing the forklift to drive down to the driveway when needed to.

- **Coffee room**

A coffee room for the truck drivers was placed outside in order to prevent them from accessing within the warehouse. During unloading and loading processes, drivers can get inside for coffee. This room was something the case company was interested in implementing in the future layout. This area will consist of 9 m². However, this is something that the researcher does not recommend as it can lead to the delays if truck drivers are taking too long breaks.
6.2 Flowchart

Figure 6.1 and Figure 6.2 represents the future flowchart which is based on the implementation of layout 2 together with the other improvement areas such as, ASRS. It provides a description of how the activities are carried out step-by-step, as well as the time each activity takes. The implementation of the improvement areas described in Chapter 5, has caused for either the elimination or modification of certain non-value-added activities. For example, the implementation of an interlocking system at the unloading station has eliminated the travel distance that was required to be conducted within the current state. Additionally, the implementation of RFID systems, has eliminated the time-consuming manual scanning that was carried out in the current state.

However, some activities still remain, such as all the activities conducted at the quality department. Even if they are not considered as value adding, they are still necessary activities that needs to be conducted.

The data regarding activity times presented in this flowchart lays the foundation for the mapping of the future state. The design of layout 2 together with the improvement areas has led to obtaining new times regarding cycle and lead times.

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**Figure 6.1**: Flowchart illustrating the activities that take place from receiving to storage.
Figure 6.2: Flowchart illustrating the activities that take place from storage to shipping.
6.3 Future state map

Figure 6.3 represents the future state map and describes all the process conducted within the current state, starting from unloading to storage and from storage to customer. The data that is presented in the current state map is based on the activities that are presented in the flowchart. As can be obtained from the Figure 6.3, the implementation of layout 2 together with the improvement areas has led to achieving new and reduced cycle times.

- Left part of figure 6.3: describes the supplier information.
- Right part of figure 6.3: describes the transportation information to customer.
- Upper part of figure 6.3: describes the information flow.
- Lower part of figure 6.3: describes the operations that are conducted in order.

![Future State Map](image)

Figure 6.3: Future state map.
Chapter 7
Conclusions

This chapter will consist of the conclusion section of the study and link the findings with the purpose and research questions that the study is based on.

- What methods can be used in order to identify existing wastes and potential improvement areas within a current layout design?

Before redesigning a current layout or developing a new one from scratch, it is essential to examine the current layout design in order to identify wastes that can be eliminated within the future design, as well as identifying improvement areas that can be implemented in order to create leaner operations.

When conducting a current state analysis, VSM can prove to be an essential method concerning the identification of current problems and improvement areas. It provided the researchers with the opportunity to follow the flow in reality in order to develop a deeper understanding regarding the flow of materials and information within the current state, from the unloading of goods to shipping. When conducting the walkthrough, information such as, waste and non-value-added activities could be identified, along with various information that could be formulated within a map that visually displayed critical data regarding each process that is carried out. Once these waste and non-value-added activities was identified. The researcher could work towards identifying and developing improvements in order to prevent these issues from occurring within the new layout design. Therefore, potentially increasing customer value and efficiency of the given value streams. Additionally, leading to creating leaner operations which possibly could increase the productivity within the warehouse. Something that is essential within the lean concept as well as for plants overall.

Due to the lean management method being very useful when it comes to examining the existing flows, procedures and activities that take place within the warehouse, it proved to be very complementary for the use of SLP, due to the method requiring a thorough initial research on the operations that take place before being applied. The decision regarding the selection to apply SLP was therefore easy due to its effectiveness and results, when it comes to providing layout design guidelines in practice. As mentioned in the theoretical framework, SLP is an organized approach to conduct layout planning. It presents a framework that consist of a set of phases and a pattern of procedures for identifying, rating and visualizing the operations and areas involved in a layout. This proved to be very beneficial for the researchers due to the method providing a deeper understanding regarding the importance of closeness between the separate operations and workstations, which existed within the warehouse.
What factors and aspects can influence the design process for a future layout?

Most organizations understand that in order to progress in a market that is dominated by competition, they must identify practices that can lead to improvements and obtaining competitive advantages. As a way to drive improvements, it has led to the link between layout planning and supply chain management receiving more awareness. Due to modern facilities laying the foundation for organizations in order to achieve supply chain excellence and competitive advantages, layout planning is starting to play a more instrumental part for companies.

When it comes to planning and designing layouts, there exist several factors and aspects that should be taken into consideration. The main factors that influence the design process is the available space and the volume of goods requiring to be handled. Once these have been established aspects such as, the space requirement for the operations, arrangement of functional areas and activity relationships can be considered in order to enhance space utilization and creating efficient work and material flows.

It is therefore crucial that all aspects are taken into consideration when planning and implementing efficient layouts. With the application of SLP, which base its foundation on planning the layout based on the logical relationship between workplaces with high frequency are placed close to each other, the method proved to be very beneficial for the layout design process. Additionally, the application of SLP in the development of the new layout led to the forming of alternative layouts for the case company, were each layout consisting of a rearrangement of the operations and workflows, subsequently providing different advantages and disadvantages which could later be balanced against each other. Once evaluated based on which layout provided the finest distribution of its processes, it led to the development of a potential layout that provided the case company with maximized space utilization, improved flow of material, safer work environments, as well as opportunities for increased productivity.
In what way can the material handling be enhanced in a future layout design?

There exists an instrumental link between plant layout and material handling. Aspects regarding the determination and implementation of a material handling system is essential in the design of an effective plant layout. When using SLP as a guideline to design a layout, various departments and workstations should be placed so that the material handling can be minimized, the space requirements and material movements reduced, as well as bottlenecks and congestion being removed. This can be conducted by rating the closeness between each departments and workstations in order to understand where they could be placed. The application of an efficient material handling systems can therefore help developing an effective plant layout. Due to the objective of an efficient material handling being to minimize cost, while simultaneously minimizing delays when it comes to making the materials available at the point of use.

In addition to placing workstations close to each other in order to reduce material handling, identifying repeatable activities that can potentially be automated can prove to be very beneficial. Within a logistic center the workers available time is limited, therefore the time they spend within the warehouse should be aimed towards value-added activities as much as possible. Hence, it is crucial to reduce the time they spend on material handling activities due to material handling not adding any value within the value stream. This can be achievable by identifying and implementing automatic solutions, such as an ASRS. The implementation of an ASRS does not have to imply the discharging of manual workers. Instead of firing workers, they can be transferred from non-valued tasks, such as transporting material, to value added operations such as production or be trained to conduct the occasional maintenance and repairs required. Additionally, with the implementation of an ASRS which involves AGVs and AMRs, it can lead to more efficient material handling, as well as enabling further conditions for storage utilization.
Chapter 8 
Future Studies and Recommendations

Some fields within the study was not studied in more detail due to the time limit of the project, as well as due to certain uncertainties that existed before the study initiated. Uncertainties regarding future parameters such as production, storage capacity and deliveries affected the development and decision making regarding the most effective layout. Once these parameters have been established, the layout can be modified in order to accommodate the parameters more directly.

When it comes to the ASRS, further studies can be conducted regarding what kind of AGV or AMR would be most optimal for the future layout as well as if it would be feasible through a cost-efficient perspective. Since the study's aim was to design a layout for the future logistic center, the material handling system was only discussed in a simplified review in addition to the study's main aim. Aspects regarding future order picking and cost was not taken into consideration and discussed in a detailed manner. Same applies for identifying a potential VSM that can be integrated with the proposed automatic systems, such as AGVs, RFID system and pick-to-light system. With that mentioned, these systems as well needs to be studied further regarding how they be integrated within the workstations in order to increase productivity and develop more ergonomic workstations for the human workers. The integration of pick/put-to light system and e-Kanban systems could be studied in order to enhance the stations with the capability to processes several orders simultaneously.

Another interesting topic for future studies can regard how the AGVs can be integrated more with the warehouse's other operations, especially the unloading and loading activities, in order to increase the use of automation within the warehouse. One solution could involve the use of interlocking conveyors to the incoming and outgoing trucks, which could be integrated with the automatic forklifts. Thus, leading to the automated forklifts not only being limited within the storage but throughout the warehouse.
Chapter 9
References


Appendices A – Layout

C.1 3D-layout