Configuring the storage and return flow processes of reusable packaging for battery cells

A design science study of a global battery cell manufacturer

Master Thesis for M.Sc. in Mechanical Engineering

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Lund, May 2023

ABSTRACT

Title: Configuring the storage and return flow processes of reusable packaging for battery cells: A design science study of a global battery cell manufacturer

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Problem Description: As reusable packaging is becoming increasingly popular, the already existing warehouses need to adapt their configuration, so they are able to receive the packaging in an efficient manner. Company Alpha is currently facing the problem of incorporating the reverse flow of reusable packaging, and there is currently no concept for the return flow of empty cleaned packaging and where they should be stored internally.

Purpose: The purpose of this thesis is to design the return flow processes of reusable packaging from a third-party cleaning facility to Company Alpha and to define how and where the cleaned packaging should be stored once arrived at Company Alpha.

Objectives: Three research objectives were formulated to fulfil the purpose. The first one was to "*Describe the current layout of the outbound area at Company Alpha and identify the already existing processes in this area*". The second one was to "*Identify what processes that are of interest in the return flow of the packaging, and the contextual factors that may impact the configuration of the storage area*". The last one was to "*design the return flow processes when the packaging has arrived from the Third-Party Cleaning Facility at Company Alpha and the storage of the returned packaging*".

Methodology: The thesis follows a design science research strategy as it aims to solve a practical problem. An analytical framework was created from a literature review containing theories within warehouse configuration, warehouse contextual factors and process mapping. The analytical framework was tested by conducting a single case study at Company Alpha and their return flow of reusable packaging. Data was collected through interviews, observations, and secondary company data. The data was analysed with the help of the analytical framework, and the use of process maps helped to analyse the flows.

Findings: 12 propositions were found, which were used together to formulate the recommendations for the return flow processes, receive and put-away and storage. Additionally, the location for storing the empty packaging and how this area should be configured considering the contextual factors were designed and recommended to the company. The company is struggling with having enough space and while the recommendations provided will help, the company needs to investigate further solutions.

Conclusion: The analytical framework created in this thesis was validated by applying it to Company Alpha, and the proposals it generated were applicable at the company, and they provided value. The process mapping facilitated the analysis of the flows and processes, and the analysis of the contextual factors moulded the configuration so the reverse flow could be incorporated without disturbing the already existing processes at Company Alpha. The propositions helped to configure the storage for the reusable bins and defined the return flow processes. Thus, the purpose of the thesis has been fulfilled.

Keywords: Reusable Packaging, Warehouse Configuration, Warehouse Contextual Factors, Process Mapping, Design Study

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ABBREVIATIONS

3PCF = Third-party cleaning facility

ASRS = Automated Storage Retrieval System

Bin = The reusable packaging used by the case company Alpha

EPAL2 = Euro Pallet 2, a standardized pallet with the dimensions 1000x1200 mm

ERP = Enterprise Resource Planning

SIOP = Sales, Inventory and Operations Planning

SKU = Stock Keeping Unit

TecSa = Technical cleanliness

WCS = Warehouse Control System

WMS = Warehouse Management System

1. INTRODUCTION

1.1 Background

For many years, the supply chain has traditionally been viewed as a forward chain, a linear process linking the supplier to the end customer. However, this process is undergoing a significant change. Over the past two decades, the concept of a reverse supply chain has become more widely discussed in both academia and industry (Larsen 2017). The reverse supply chain has the opposite function to the traditional supply chain in that it focuses on activities from the customer to the supplier (Larsen & Jacobsen, 2016; Guide Jr & van Wassenhove, 2002). This development and change of perspective can be explained by increasing raw material prices, which creates an incentive for more reuse of already purchased material in an attempt to reduce costs, and the fact that companies are trying to be more aware of their impact on the environment by reusing material (Larsen 2017; Guide Jr & van Wassenhove, 2002). One common attempt at reusing material is by using reusable packaging.

While there are benefits of having reusable packaging, such as cost and resource saving, it is not an ensured factor for success. In order to successfully use reusable packaging and reap the associated benefits, a reverse supply chain process must be in place and the activities involved must be clearly defined (Pålsson, 2018). Handling the return of goods can be considered one of the most difficult and time-consuming operations for many warehouses to manage in a satisfactory manner (Kembro, Danielsson & Smajli, 2017).

Managing the reverse supply chain can be quite complex as it creates new points of contact and the processes associated with the reverse flow need to be aligned with the already existing activities carried out in the warehouse (Guide Jr & van Wassenhove, 2002). Kembro and Norrman (2021) discuss the importance of matching the warehouse configurations with the warehouse contextual factors in order to improve warehouse performance. Warehouse configuration includes aspects such as warehouse operations, resources and design. The contextual factors can be described as the context in which the warehouse operates and are harder to change in the short term. It is important that the warehouse configuration is adapted to handling both the reverse flow and forwards flow, creating a harmonised environment. If the reverse flow is added to an already up and running warehouse, the configuration of that warehouse needs to change, since the context has changed.

As one of the main reasons for using reusable packaging is to reduce costs and material use, it is important that the warehouse configuration is adapted so that the warehouse is able to receive, and handle, returned goods efficiently in order to reap the benefits of using reusable packaging. This thesis will focus on a case company, who are facing the challenge of incorporating the reverse flow of reusable packaging with its current warehouse configuration.

1.2 Case Company

The case company was founded in 2016 with the mission to build the world's greenest battery to enable the European transition to renewable energy. Since then, the company has grown to having over 4000 employees, gone through several investment rounds, and has grown into having a global presence. The first factory is located in Sweden, where construction started in 2019, and in 2021 the first lithium-ion battery cell was constructed in the factory. The company is continuously growing, and the goal for 2030 is to have an annual battery cell output of 150 GWh and to have a 90% reduction in cell CO_2 footprint compared to the 2021 industry average. To exemplify how much energy this is, 150 GWh corresponds to the yearly energy consumption of 7,500 normal-sized houses in Sweden (The Swedish Consumer Energy Markets Bureau, 2022). From here on, the case company will be called *Company Alpha.*

1.3 Problem Formulation

Like many other players in the automotive industry, Company Alpha uses reusable packaging to pack its lithium-ion battery cells for shipment to customers. There are many requirements when it comes to the packaging of battery cells. Not only does the company have to comply with industry standards. They also have very strict cleanliness requirements from their customers, which means that the packaging needs to be thoroughly cleaned before it can be reused. If Company Alpha fails to meet these cleanliness requirements, there is a risk of the cell being contaminated which can lead to them short-circuiting. Additionally, Company Alpha would be heavily fined by the customers since these would have to stop production if Company Alpha fails to deliver. The cleaning process is carried out by a third-party cleaning facility, which will be called 3PCF from now on, and once the packaging has been cleaned it is returned to Company Alpha.

When designing the outbound area at Company Alpha, there was little knowledge of how many cells would be handled there in the future. This has led to the area being too small to handle the volumes when the company starts its mass production of cells. The return flow of reusable packaging was another aspect that was overlooked, which has led to there being limited space and capacity to handle these volumes. Up to this point, the outbound area has had the capacity to meet the demand of the current processes. As production and customer demand increases, and the process of receiving cleaned packaging will begin, the area as it is today will not have the capacity to handle the return flow of the cleaned packaging. The cleaned packaging also has constraints since it cannot be handled or stored however due to cleanliness requirements.

There is currently no concept for the return flow of empty cleaned packaging in place. The processes for handling the return flow of the cleaned packaging and how the cleaned packaging should be stored at Company Alpha need to be determined.

1.4 Purpose

The purpose of this thesis is to design the return flow processes of reusable packaging from a third-party cleaning facility to Company Alpha and to define how and where the cleaned packaging should be stored once arrived at Company Alpha.

See Figure 1 for a visualisation of the part of the reverse supply chain of reusable packaging the thesis will focus on.

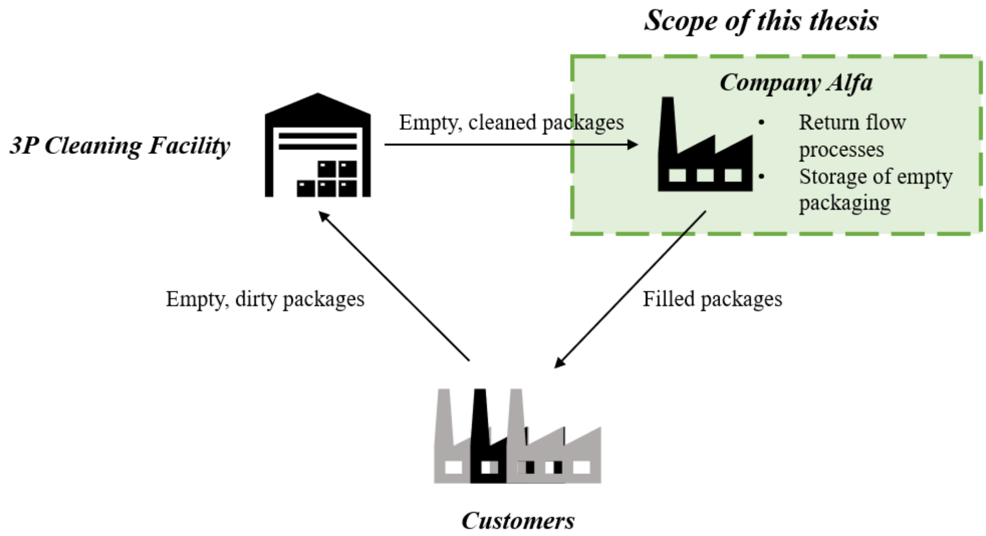


Figure 1: Visualisation of the part of the reverse supply chain of reusable packaging the thesis will focus on.

1.5 Research Objectives

To fulfil the purpose of the thesis and to provide the case company with a solution that explains the return flow processes and storage of cleaned packaging, three research objectives have been created. The research objectives are as follows:

1. *Describe the current layout of the outbound area at Company Alpha and identify the already existing processes in this area.*

   The deliverable of this research objective is to describe Company Alpha's outbound area as it is today to understand the current situation and already existing processes within the outbound area. This is relevant as it determines the capacity for handling and storing the returned cleaned packaging. Data will be collected through on-site observations, interviews with company representatives, and secondary data.

2. *Identify what processes that are of interest in the return flow of the packaging, and the contextual factors that may impact the configuration of the storage area.*

   This research objective aims to identify the requirements for handling and storage of the cleaned packaging and how these affect the processes that need to be carried out, and what activities they should include. Additionally, it aims to identify the future volumes that will be handled in the cleaning facility and outbound area, which will be needed to design efficient return flow processes and space allocation, as this combined with the characteristics of the packaging and the existing space at Company Alpha can be seen as a constraint. Data will be collected through interviews and secondary company information.

3. *Design the return flow processes when the packaging has arrived from the Third-Party Cleaning Facility at Company Alpha and the storage of the returned packaging.*

   The deliverables of this research objective will be maps describing the return flow processes, including the activities needed and the physical movements of the reusable packaging. In addition, a solution for how and where the cleaned reusable packaging should be stored at Company Alpha will be presented.

The deliverables are highly dependent on the outcome of the three research objectives and will be based on what has been discovered from these in combination with relevant literature. See Figure 2 for a summary of the research objectives and deliverables for the thesis.

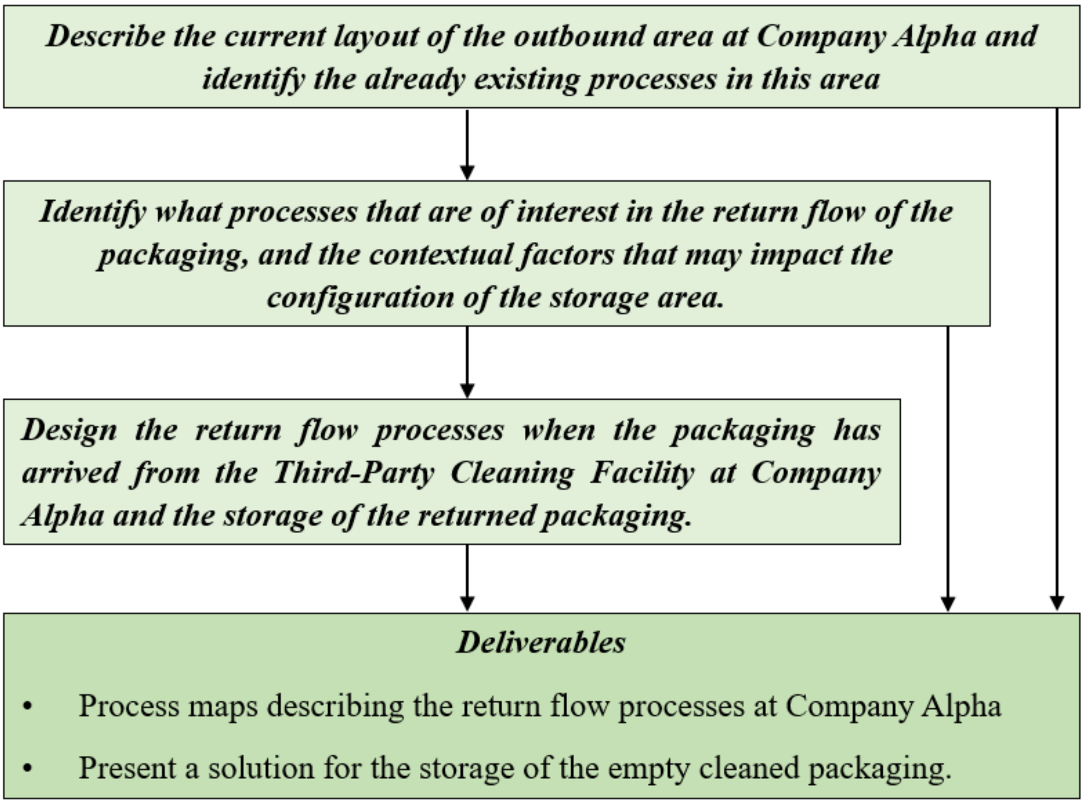


Figure 2: Research objectives and deliverables of the thesis.

1.6 Delimitations

The scope of this project will be limited to only focus on the return flow processes that need to be performed once the packaging arrives at Company Alpha. The thesis will not discuss the return flow from the customers to the third-party cleaning facility. Functions that are affected by the return flow of cleaned packaging will be considered, but not explored at a deeper level. See Figure 3 for a visualisation of the scope of the thesis.

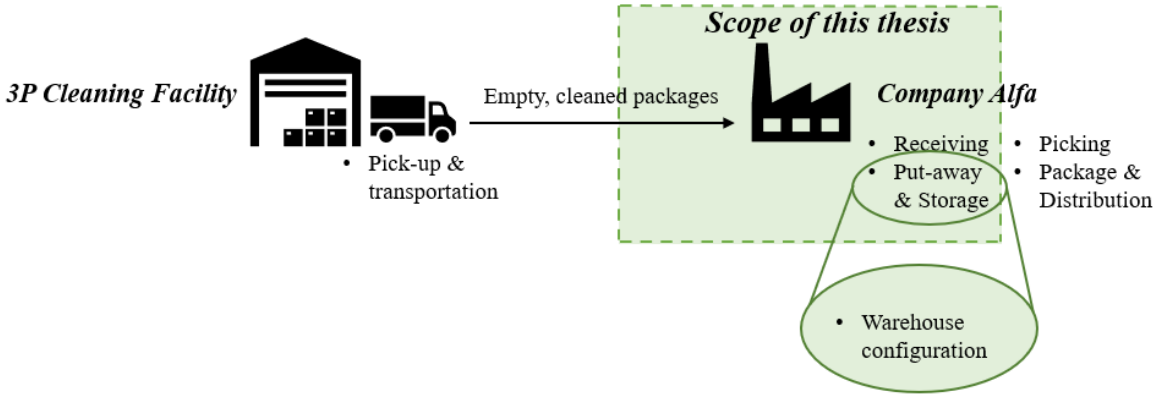


Figure 3: Visualisation of the focus and delimitations of this thesis

1.7 Disposition

This thesis consists of seven chapters. The first chapter is the introduction, which provides the background of the research topic, a brief introduction to the case company, the problem description, the purpose, and the research objectives. The scope and delimitations are also presented in this chapter. The following chapter is the methodology chapter, which aims to present and motivate the chosen research strategy used in this thesis, as well as to present the data collection and analysis methods. Quality in terms of reliability and validity is also discussed in this chapter.

The third chapter is the frame of reference, which presents previous research relevant to the research objectives. It includes theories linked to the return flow processes, such as pick-up and transportation, and inbound warehouse operations. In addition, it covers theories regarding warehouse configuration, physical layout, and contextual factors, which culminate in the analytical framework. The analytical framework gives an overview of the entire process for fulfilling the purpose of the thesis.

The next chapter contains the empirical findings, which include the current state of the outbound area, the activities it holds, and the criteria from the company's perspective regarding the processes and the storage. The fifth chapter presents the analysis carried out by the analytical framework being applied. The analysis is discussed, and it presents the return flow processes and solutions for the storage of the cleaned packaging. The following chapter focuses on the applicability of the proposed return flow processes and the solution for storage at the case company, which is evaluated with the help of a workshop with the case company.

The final chapter concludes the thesis by firstly discussing whether the purpose and research objectives have been fulfilled, secondly discussing the contribution of the thesis, and finally discussing the limitations of the thesis and suggesting areas for future research.

A summary of the contents and disposition of the thesis can be found in Figure 4 below.

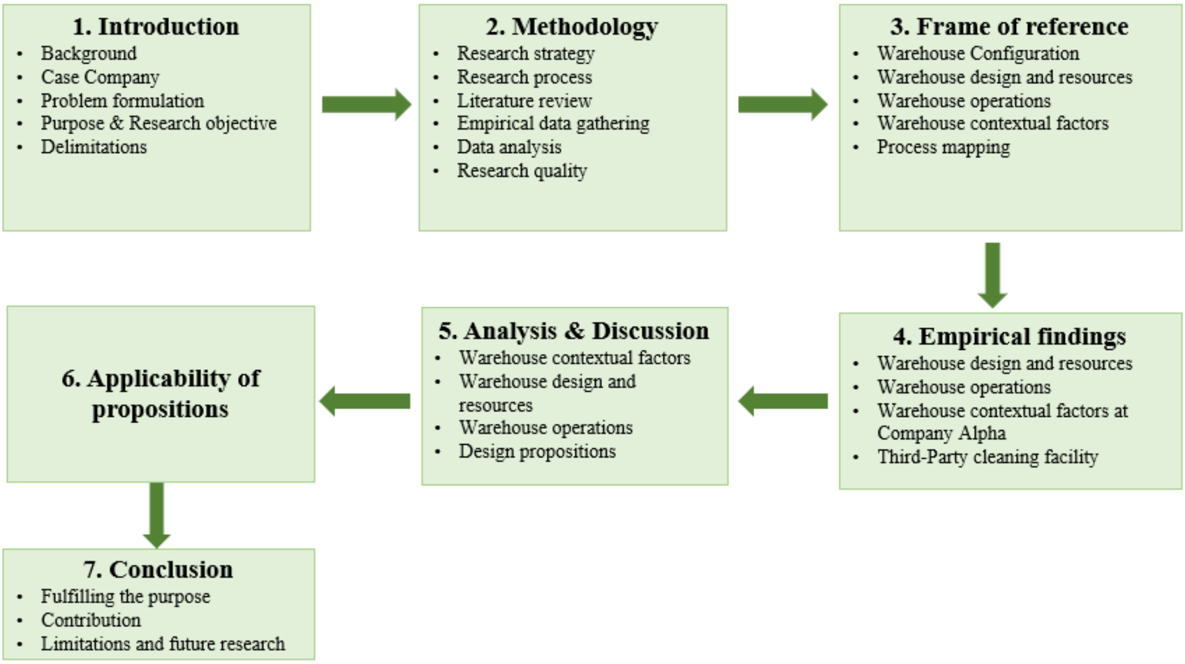


Figure 4: Disposition of the thesis

2. METHODOLOGY

The aim of this chapter is to present and discuss the methodology that has been used to fulfil the purpose of the study. The first part of the methodology chapter describes the research design, which includes selecting a research strategy and presenting the research process. Moving forward, the methods for data collection are presented, which are divided into a literary review and empirical data collection. The data collection chapter is followed by a description of how the data has been analysed. Lastly, the research quality is discussed. See Figure 5 for the structure of the methodology chapter.

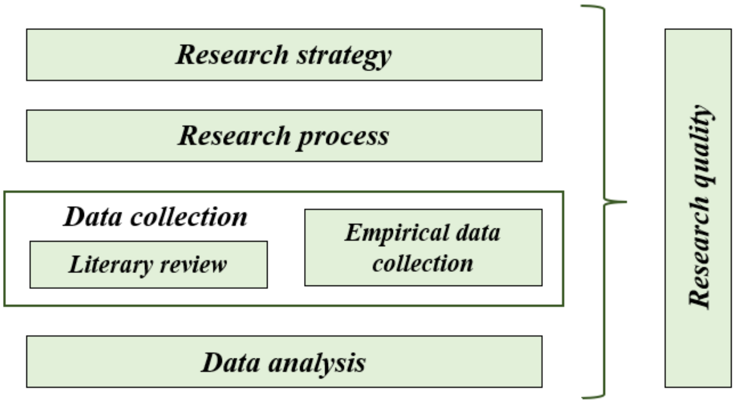


Figure 5: The structure of the methodology chapter

2.1 Research Strategy

When choosing a research strategy, there are different ways to approach the pre-defined research objectives and purpose of the study. The nature of the research objectives determines what strategy to pursue. Lukka (2003) presents a matrix that one can use to find the research strategy, which has two determining factors. The first factor is whether the study is theoretical or empirical, and the second is if the research objectives are descriptive or normative. The research objectives of this master thesis are defined as empirical as they require both data collection and the use of own observations. The first research objectives focus on describing the current state; hence it can be regarded as descriptive. The following two research objectives can be considered to be normative, as their aim is a specific goal and to identify specific factors. Considering these factors, the study is placed in the Lukka matrix as seen in Figure 6.

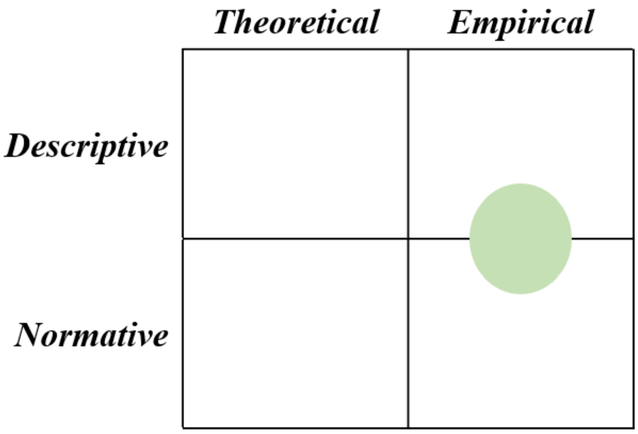


Figure 6: Visualisation of the Lukka matrix (2003) and the placement of this study represented by the green circle.

From the placement seen in Figure 6, Lukka (2003) presents two suitable strategies to pursue, either a case study or a design science study. To identify which strategy to choose, the differences between these strategies must first be defined. According to Yin (2009), a case study should be used when the research objectives aim to answer questions such as "how" and "why" a social phenomenon works. Romme and Dimov (2021) state that a design study has its starting point in the problem that needs solving, rather than a phenomenon. From these descriptions, the most appropriate strategy to apply to this study is a design science study since its starting point is a practical problem at Company Alpha that needs solving, rather than a phenomenon being investigated. The thesis will investigate the current state, and the problem that needs solving, and present a solution for how this problem can be solved, which is in line with how Romme and Dimov (2021) explain the content of a design science study.

One of the main advantages of a design science strategy is that it focuses on exploring rather than explaining (Holmström, Ketokivi & Hameri, 2009) Additional advantages and disadvantages for a design science approach and this specific thesis is similar to those for a single case study since only one company is investigated. An advantage of only investigating one company is that deeper knowledge can be developed (Voss, Tsikriktsis, & Frohlich, 2002; Yin, 2009). However, there is an increased risk of being biased against the said company, and it can be harder to generalize the knowledge (Yin, 2009).

2.2 Research Process

The research process will be divided and presented into two subsequent steps. Firstly, the research process will be constructed. Secondly, the application of the research process will be presented.

2.2.1 Construction of research process

This thesis will use a combination of the research process described by Romme and Dimov (2021) and Peffers, Tuunanen, Rothenberger, and Chatterjee (2007). The two processes will be described more in detail in the following sections.

Romme and Dimov (2021), present a four-step research process, see Figure 7. The process consists of (1) framing, (2) creating, (3) validating, and (4) theorizing, where the first two steps belong to the design element, and the last two belong to the science element. Framing refers to exploring concepts that can help to discover and understand the problem and solution space. Creating involves the creation of artifacts and is connected to the framing step as there are iterations back and forward between these two. An artifact is a broader term for a solution that doesn't exist, but the creation of it can help solve a problem. Theorizing is about developing key concepts from the gained knowledge and making them generalizable as well as applicable to individual cases. Validating involves the evaluation of artifacts, meaning the investigation of the framing of the problem, the created artifacts and theory are valid (Romme & Dimov, 2021). According to Romme and Dimov (2021), there is no given starting point for a design science research, and one can move between the different steps as many times as necessary.

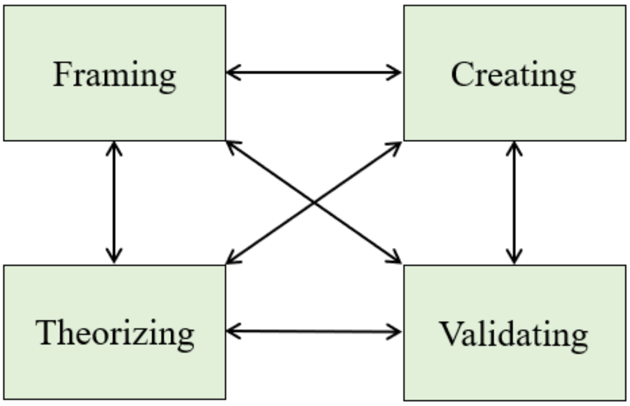


Figure 7: The research process as presented in Romme and Dimov (2021)

Peffers et al. (2007) present a six-step process of a design science research: (1) Problem identification and Motivation, (2) Define the objectives for a solution, (3) Design and development, (4) Demonstration, (5) Evaluation, and (6) Communication. When comparing the two research processes, it is clear that they have many similarities. Most of the activities in the research process presented by Peffers et al. (1007) can be linked to the activities in the process presented by Romme and Dimov (2021). A difference, however, is that the process presented by Peffers et al. (2007) is more straightforward, with a clearly defined order from the starting point to the ending point, and two additional steps are added. The steps are the first step of finding a practical problem to solve and motivating its relevance, and the last step of communicating the study to a relevant audience.

The differences and similarities in the two processes complement each other, where the process presented by Romme and Dimov (2021) has an operational management approach to the design science research process, defines the basic processes and is rather simple. Peffers et al. (2007) present a more concrete process that is aimed at researchers within information systems. Although that is not the scope of this thesis, the two research processes combined will result in a more extensive research process for the better and increase the validity of this thesis. Combining of the two processes gives us the research process used in this thesis. The research process and how the steps relate to this thesis are displayed in Figure 8.

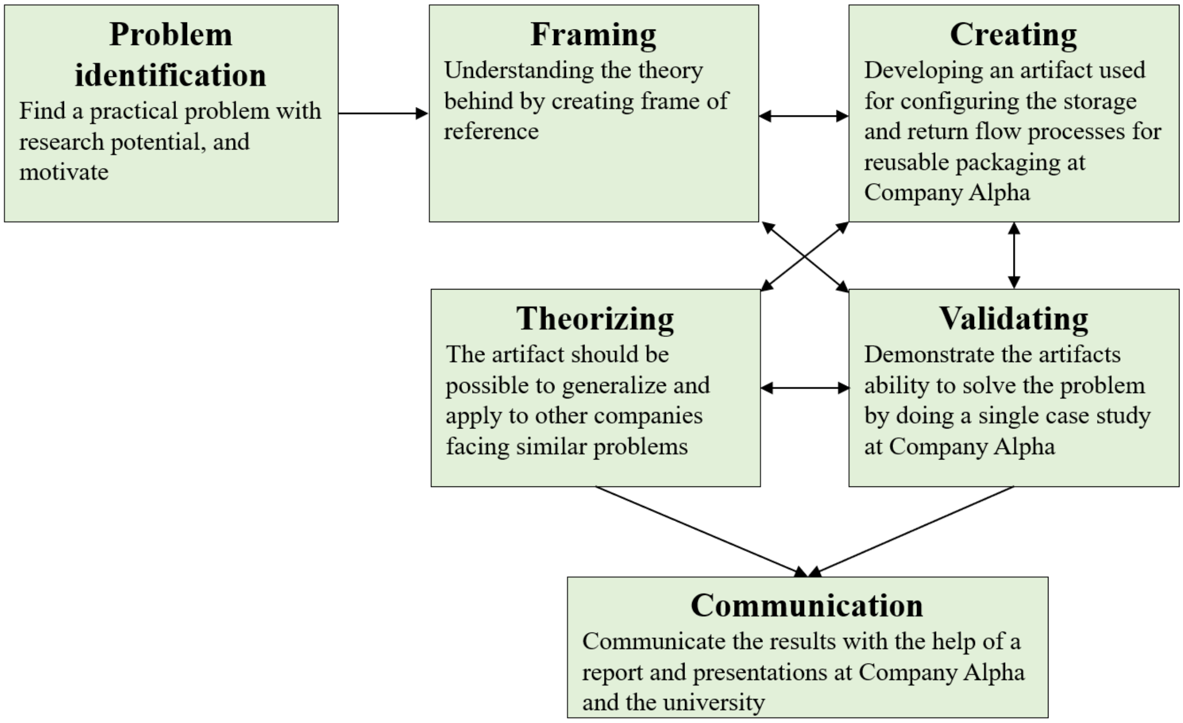


Figure 8:The research process used in this thesis, which is a combination between Romme and Dimov (2021) and Peffers et al. (2007)

2.2.2 Application of research process

The first step of the research process presented in Figure 8 is to find a practical relevant problem and to motivate the research topic. The practical problem that this thesis investigates is described in sub-chapter *1.3 Problem formulation*, together with a motivation of why the research topic is of relevance. The problem is that Company Alpha needs to define the return flow processes of reusable bins, determine how and where these should be stored, and how the flow can be incorporated into the already existing processes. As the use of reusable packaging is becoming increasingly popular, there must be ways of incorporating the return flow with the already existing warehouse processes. Although research has been made in this area to some extent, more is needed.

The next step in the research process is the iterative process described by Romme and Dimov (2021), which includes the processes of framing, creating, validating, and theorizing. The framing and creating activities often go hand in hand with many iterations back and forth and are referred to as the design stage of the process (Romme & Dimov, 2021). This design stage will frame the problem with the help of relevant theory and create the analytical framework for the thesis. The framing includes previous research on warehouse contextual factors, warehouse configuration, and process mapping, on which the analytical framework is built.

When a suitable framework is in place, the analytical framework is created. The analytical framework will act as the artifact of the thesis and is meant to act as a guide when collecting and analysing data in order to fulfil the research objectives. If the analytical framework is designed properly, the outcome when applying it will be propositions applicable to the case company. When creating propositions for a design science study, the CIMO structure described by Denyer, Tranfield, and van Aken (2008) is commonly used. According to Denyer et al. (2008), design propositions created following the CIMO structure contain information on what to do, and when to do it, to produce what effect and offer some understanding of why this happens.

CIMO stands for Context, Intervention, Mechanism, and Outcome, and its generic structure is described as "in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s) to deliver these Outcome(s)" (Denyer et al. 2008, pp. 395-396). Context is the surrounding factors that influence behaviour or choices. Interventions refer to the tools managers have at their disposal to influence behaviour, e.g., leadership style or performance management, and can be described as the key component of the design proposition. The Mechanism in certain contexts is triggered by the intervention. Finally, the outcome is the result of the intervention (Denyer et al. 2008). This approach exists in many different variations, and Romme and Dimov (2021) present a similar structure called CAMO, where the Intervention is replaced by Agency, which refers to the actors and their actions in a specific context. Romme and Dimov (2021) introduce a rewritten version, OCAM, which is more applicable to a design study, as it starts with the wanted outcome in the specific context. Applying this to the CIMO approach presented by Denver et al. (2008), the abbreviation OCIM is generated. The approach would be described as "to deliver these Outcome(s) in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s)", and is the approach used in this thesis.

When the framing and creating step is finalized, the steps of validating and theorizing can begin, which can be seen as the science stage of the model (Romme and Dimov, 2021). The process of validating is carried out in two steps. First, by applying the analytical framework to the real case scenario at Company Alpha the function is tested. When the analytical framework has been created it has to be demonstrated in a suitable context, and it needs to be evaluated and tested. As previously mentioned, the analytical framework acts as an artifact, and according to Hevner, March, Park, and Ram (2004), there are many ways to test an artifact. This study applies the artifact at Company Alpha with the aim to define the return flow processes and the configuration of how and where the empty packaging should be stored. Applying the analytical framework at Company Alpha facilitates the possibility to evaluate the performance of the analytical framework by understanding how the propositions are developed. This means, that even though the research strategy is a design science study, the analytical framework is tested and validated with the help of a single case study at Company Alpha, see sub-chapter *2.3 Research Design* for further elaboration on why. When applying the analytical framework, further knowledge of warehouse configuration and contextual factors, and how they affect each other, can be used for theorizing, hence contributing to knowledge within the field.

Additionally, the performance of the analytical framework is tested by presenting and discussing the propositions generated by the analytical framework in a workshop with Company Alpha. After the validity of the analytical framework is approved, the process of theorizing can begin. This step refers to the generalization of the gained knowledge and propositions created from applying the theoretical framework.

The final step of the research process is Peffers et al.'s (2007) step of communicating the knowledge gained from the study, both practical knowledge and the knowledge gained from the theorizing step.

2.3 Research Design

The research design needs to be determined and refers to the design of the study in detail. It can also be referred to as the process of demonstrating the analytical framework and includes the development of a plan for fulfilling the research objectives and purpose of the study. The research design is especially important for a design science study, as it is only a research strategy without any defined method for collecting data and data analysis. The data collection and data analysis can be conducted in many different ways, and this thesis will have a design science strategy with elements of a single case study for testing and validating the analytical framework. This subchapter will explain with motivating the choice of choosing case methodology study for testing the analytical framework, and further elaborate on the strength and weaknesses of applying case studies. Further, it will present how the case study can be conducted and how the research design will look for this thesis.

When choosing a research method to evaluate the artifact there are many different ways to go (Hevner et al. 2004). What method to use depends on three conditions: (1) the type of research questions, (2) if the study requires control of behavioural events, and (3) if the study focuses on contemporary events (Yin, 2009). This thesis focuses on analysing the outbound area at Company Alpha and investigates how the return flow of reusable packaging can be incorporated with the current process in the warehouse. Hence, it focuses on questions of how and why, it is in a contemporary setting, and the behaviour is hard to control. According to Yin (2009), answers like these means that the most suitable method for evaluating the artifact is a case study. This is further supported by the theory presented by Hevner et al. (2004), who mention that a case study is suitable to use when testing the artifact in a business context. As the artifact in this thesis is to be used in a business environment, it is suitable to test it at the case company.

The strengths of a case study are described by Voss et al (2002) as (1) relevance, (2) understanding, and (3) exploratory, where relevance refers to the possibility to study the phenomenon in a natural setting. Understanding refers to how answering the question of why will result in a deeper understanding of the studied phenomena, and exploratory refers to the case approach being easy to use when the result is unknown.

Yin (2009) presents the following steps when conducting a case study; (1) define unit of analysis, (2) select case type, (3) design data collection protocol, (4) conduct case study, (5) compile data, (6) data analysis, and lastly (7) draw conclusions. With the starting point in the research process displayed in Figure 8, the validation step is now modified with inspiration from Yin (2009) and Kembro and Norrman (2020) in order to display the actions included in this step. By doing so, the research process is more defined and transparent which increases the reliability of the study. The modified research process is presented in Figure 9.

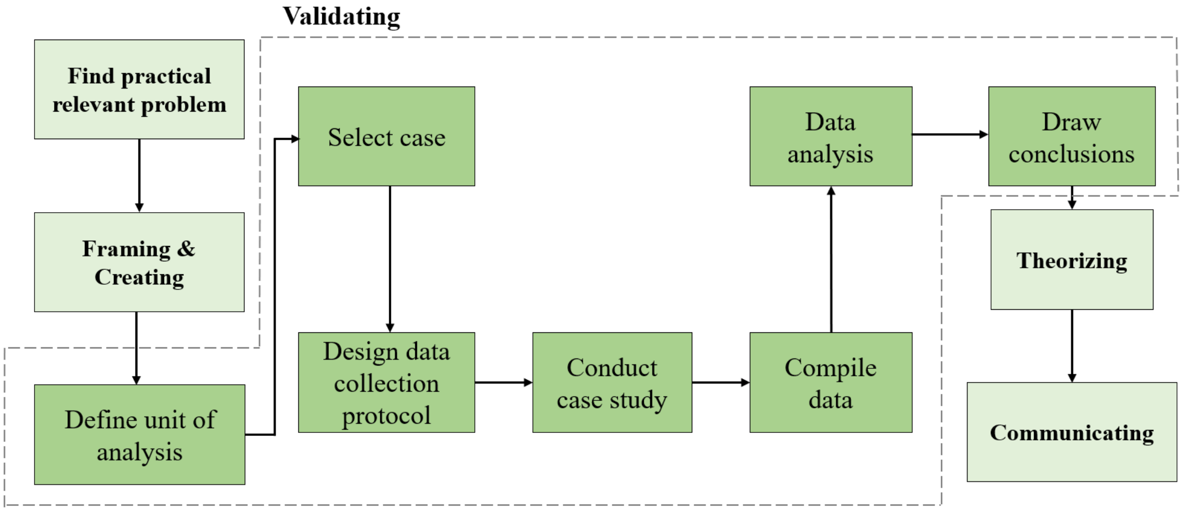


Figure 9: Modified version of the research process used in the thesis, with the validation step more defined. Inspired by Kembro and Norrman (2020) and Yin (2009)

The first step of the validating process is to define the unit of analysis which is what should be studied (Yin, 2009). Keeping in mind that the analytical framework should generate propositions regarding the configuration of the storage of empty packaging and the return flow processes connected to these, the unit of analysis is warehouse configuration, warehouse contextual factors, and process maps. The following step is to select a case. According to Voss et al. (2002), there are four types that can be chosen: (1) single case, (2) multiple cases, (3) retrospective cases, and (4) longitudinal cases. Since this thesis has a design science research strategy as it is studying a problem at Company Alpha, the analytical framework should naturally be applied at Company Alpha, hence a single case study is applied. Voss et al (2002) explain that a benefit of single cases is that they provide great in-depth knowledge. Disadvantages include that it may be harder to generalize and biases against the single case company (Voss, 2002).

After the case is selected, the data collection protocol should be designed, which is based on the analytical framework. When the design of the data collection protocol is designed, the case study can begin, which means that the analytical framework is applied to Company Alpha, which generates the propositions. These propositions are then tested by presenting these to company representatives from Company Alpha in a workshop setting. See Table 1 for information regarding the workshop.

Table 1: Information regarding the workshop with Company Alpha to test the applicability of the generated propositions

Participants	***Agenda***	***Date***	***Duration***
Senior Planning & Logistics Developer	Present the generated proposition and test their applicability at Company Alpha	2023-05-12	1 hour

Originally, the workshop was to be held with two additional participants from the company, but due to organisational changes, this was not possible. Having more participants would have been beneficial, as this would have opened up for a broader discussion with more perspectives. However, the Senior Planning and Logistics Developer has great insight into the project and deep knowledge of the company, which makes his thoughts and perspective valuable and deemed enough for testing the applicability of the propositions.

Data has been collected throughout the validating step with the help of the data collection protocol and analytical framework. The collected data is used to draw conclusions about the unit of analysis, which is the last step of the validation step. This conclusion is then used in the design science step of theorizing.

2.4 Data Collection

This study has used several methods to collect data, which can be seen in Figure 10. The analytical framework is based on data that is collected through a literary review, and it determines what data should be collected. The data collection explains how the data should be collected from the case company, and the data is later analysed with the help of the analytical framework. The output of the data analysis is the propositions for Company Alpha regarding the configurations of storage and the return flow processes.

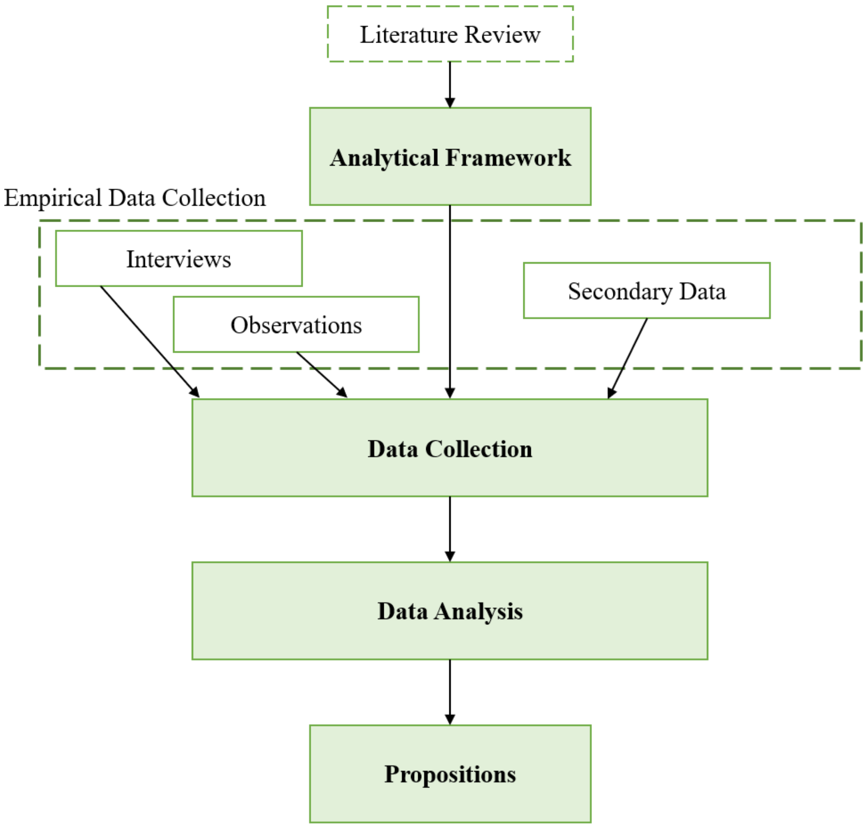


Figure 10: Data collection methods used in this thesis

2.4.1 Literature review

In order to build a foundation on which the framing and analytical framework can be created, it is of great importance to conduct a literature review (Hevner et al, 2004; Romme & Dimov, 2021). In accordance, Rowley and Slack (2004) mean that the purpose of conducting a literature review is to gain knowledge and understanding regarding the subject to be researched. Rowley and Slack (2004) further present that conducting a literature review can be useful when identifying research purpose and objectives, gaining knowledge about the current theoretical concepts, and gaining knowledge to be able to analyse the empirical framework.

Rowley and Slack's (2004) message about the importance of conducting a literature review has highly affected the way the literature review has been carried out in this thesis. The literature review has been conducted with the purpose of developing a knowledge base regarding the problem, gaining theoretical knowledge to facilitate the creation of the analytical framework, and identifying the gaps this thesis aims to fill.

To find relevant literature the databases LUBsearch and Google Scholar, where the strategy was to identify relevant key terms for the scope of the thesis. Examples of key terms used: warehouse configuration, warehouse operations, process mapping, return flow, and performance measurements. By adding the term literature review to the keyword, literature studies regarding the topic were found from which other sources could be identified with the help of cross-referencing. The literature in the literary review varies from books to articles in academic journals.

Sources have been prioritised after the number they have been referenced, in advantage for the ones referenced the most. Time has also been a deciding factor when selecting sources, where the studies published most recently have been prioritized. This is to ensure the relevance of the study in favour of the quality of the thesis. The literature review is the foundation of the theories presented in the analytical framework, which are warehouse configuration, warehouse contextual factors, and process mapping. Most of the presented theories will be used when conducting the analysis of the case company. The theory that is not used for the analysis is still relevant as it creates an understanding of the topic as a whole.

2.4.2 Empirical data gathering

Empirical data can be collected in many different ways, such as interviews, questionnaires, direct observations, and content analysis of documents, among others (Voss et al, 2002). In order to decide which data collection method to use, four important aspects to consider are (1) accessibility, (2) limitations in time and money, (3) if historical or current events should be evaluated, and (4) if a deeper or a broad result is sought after. Both Voss et al. (2002) and Näslund, Kale, and Paulraj. (2010) underline the principle of triangulation when collecting data, which refers to the use of different methods to study the same phenomenon. Näslund et al. (2010) emphasize that the use of multiple data sources may lead to discoveries that may not have been made if only using one data source. Further, Voss et al (2002) state that the reliability of data will be increased by using multiple data sources.

When collecting data, there are often two types of data that are being collected, qualitative and quantitative. Qualitative data can be described as softer data that usually is used to explain events and experiences. Methods commonly used to collect qualitative data are interviews and observations. Qualitative data is open for interpretation, both from the one collecting the data and the one presenting the information. Quantitative data is described as hard data, such as numbers and key performance indicators. This kind of data is often collected with the help of questionnaires, secondary data from the studied company, and observations.

This thesis will use both qualitative and quantitative data, which is not an uncommon approach in operation management research (Yin, 2014). In accordance with the literature, a combination of different methods of collecting data will be used, namely interviews, observations, and secondary data. In addition, the data collection methods need to be adapted according to the needed data for each research question. In order to fulfil the research objectives, it is important to understand what kind of data is needed, which in turn affects the data collection method or methods to use. The first research objective has a descriptive nature, where both qualitative and quantitative data are needed to understand the current state. This data will be collected through a combination of interviews, observations, and secondary data. The second and third research objectives are the results of applying the analytical framework, why the data for these are collected through discussions with internal stakeholders from Company Alpha

2.4.3 Interviews

Interviews play an important role as a source of information, and some of the effectiveness of the interview tends to depend on the skills of the interviewer (Yin, 2014; Voss et al, 2002). According to Yin (2009), a good interviewer should (1) be able to ask good questions and interpret the answers, (2) be a good listener and not be trapped by preconceptions, (3) be flexible and adaptable, (4) have a firm grasp of the issues being studied, and (5) be unbiased. These are all factors that have been considered when conducting the interviews in this study.

Interviews are often divided into three different types: structured interviews, semi-structured interviews, and unstructured interviews (Denscombe, 2010). The type of interview used depends on the wanted outcome of the interview. Structured interviews can be likened to a questionnaire, where the questions follow a fixed, pre-determined structure and the researcher has high control over the questions being asked. When conducting a structured interview, there is no room for additional questions that may come to mind during the interview. For this reason, structured interviews were not used in this thesis. Unstructured interviews can be likened to a conversation, where the focus is on the respondent's free-flowing thoughts. Unstructured interviews were used at the beginning of this thesis, as this is a good way to gain a broad understanding of the Company and the problem being studied. It can also help in understanding what questions that should be asked at a later stage. Semi-structured could be seen as a combination of the two, where the questions are pre-determined but there is room for follow-up questions and flexibility (Denscombe, 2010). Hence, semi-structured interviews can be adapted to the respondents' answers, making it possible to discover aspects outside of the initial questions. Semi-structured interviews have been heavily used in this thesis, as it allows for further investigation of aspects discovered in the interview which were not intended but still interesting. Before conducting the interviews, an interview guide was created, which can be found in the appendices. The interview guide was based on the theory of warehouse configuration presented by Kembro and Norrman (2021). See Table 2 for an overview of the conducted interviews for this thesis.

Table 2: Conducted interviews with key stakeholders.

Role	***Date***	***Purpose***	***Interview type***
Planning and Logistics developer	Weekly meetings from January 2023 – March 2023	Initial introduction to the subject. Gain insight into the current processes, product characteristics, and requirements.	Unstructured and semi-structured
Internal Logistics Developer	2023-03-22	Gain insight into the layout of the outbound area and the inbound warehouse operations	Semi-structured
Material Flow Automation Engineer	2023-03-24 2023-04-12	Responsible for the packaging machine in which the cleaned packaging is used. Gain an understanding of the packaging machine.	Unstructured
Purchasing Manager	2023-03-24	Responsible for negotiating the agreement with the third-party cleaning facility. Can give insight into what has been agreed on, what they can offer etc.	Semi-structured
Senior Planning & Logistics Developer	Weekly meetings from April 2023 – May 2023	Information regarding future volumes, number of SKUs, and material flow.	Semi-structured and unstructured
Lead Packaging Engineer	2023-03-28	Information about product characteristics, storing, and handling requirements.	Semi-structured

2.4.4 Observations

Observations are a common approach to collecting data and are usually divided into two types: (1) systematic observations, and (2) participant observations (Denscombe, 2010). Systematic observations are observations where the observer doesn't intervene and should blend into the background and focus on quantitative data. Participant observations include the researcher participating in the observed situation and its focus is on qualitative data. Voss et al. (2002) mention a third type of observation, the direct observation. Direct observation refers to data being collected through observations of processes or meetings, and the analysis of the data can be more or less structured (Voss et al. 2002).

For this thesis, direct observations have been used, with different levels of structure. The collected data build the foundation of the current state of the warehouse and the current processes taking place in the warehouse. The less structured observations allowed for observing the processes in their natural setting, while the more structured observation intend to provide data where it is missing.

Observations are beneficial as they provide first-hand information, and present events as they are, and not what respondents in an interview think of the event (Denscombe, 2010). However, observations are subject to the observer effect, meaning that "people are likely to alter their behaviour when they become aware that they are being observed" (Denscombe, 2010, pp. 69). There is also an issue of perception, meaning that the observer's own biases can alter the way the observed subject is being interpreted (Denscombe, 2010). Since the study is conducted by one person, there is a risk that the observations are subjective to the eyes of the author, why the collected data from the observation has been discussed with company representatives as an attempt to validate the collected data. See Table 3 for the conducted observations.

Table 3: Conducted observations.

Purpose	***Date***	***Additional Attendees***
First on-site visit to get a view of the outbound area	2023-01-11	Planning & Logistics Developer; Material Flow Automation Engineer
Walk-through of the area, following the process of receiving the manually cleaned bins. See the surrounding outside area.	2023-04-19	Internal Logistic Developer

2.4.5 Secondary data

Due to the limitations in time, this thesis has used secondary data, which can be defined as data that already has been collected with the main purpose of being used elsewhere. Although primary data is usually preferred, there are cases where secondary data is more suitable. The secondary data collected is internal company data, such as documents, illustrations, drawings, and raw data. The collected data have been used to map processes, layouts, future volumes, and requirements regarding the packaging. The calculations regarding volumes have been made from the SIOP numbers released in March 2023, where SIOP stands for *Sales, Inventory, and Operations Planning.* The data describing future volumes are for the period 2023-2030 and have been analysed with the help of Excel.

2.5 Data analysis

After the data has been collected, it needs to be analysed. This process usually includes activities such as categorising, examining, tabulating, and testing the evidence (Yin, 2009). To increase the validity of the collected data, it is important to (1) include all important information, even though it is contradictory and not displays the wanted result, (2) present alternative solutions when presenting the final recommendations, (3) only analyse data that is relevant to the purpose of the research, and (4) clarify that the author is familiar with the researched subject (Yin, 2009).

Depending on if the collected data is quantitative or qualitative, there are different methods how to analyse the data. However, Denscombe presents a five-step approach that can be applied to both types, which can be seen in Table 4.

Table 4: How to analyse quantitative and qualitative data in each analysing stage (Denscombe, 2010)

Analysing stage	***Quantitative data***	***Qualitative data***
Data preparation	Coding of data and categorising.	Cataloguing the interviews or observations
Initial exploration	Evaluate if any obvious trends	Identify if any reoccurring trends
Analysis of data	Further analyse of the data	Categorizing of notes and apply framework
Presentation & display of data	Present the results with the help of tables, figures, etc.	Present results in text
Validation of data	Check the results internally	Triangulate and follow-up observations and interviews

The quantitative data in this thesis is the future volumes of reusable packaging, which has been categorised and analysed with the help of Excel, and later displayed with the help of diagrams presented in the analysis chapter of the thesis. The data has been validated by presenting and discussing the numbers with the Senior Planning and Logistics Developer during one of the weekly meetings. It is important to note that the numbers presented in this thesis are not real volumes, as this is confidential company information. The numbers have been altered with the help of a dummy.

The qualitative data from interviews and observations have been compiled in a document, and the data has been catalogued so that all data regarding for example the warehouse operations are in the same place in the document. This layout makes it easy to see if there is any contradictory information and to identify trends. Additionally, the data have been analysed with the help of process mapping to create a visual understanding of where processes are needed. The results of the data are presented in the empirical chapter of the thesis and have been validated throughout the thesis during weekly meetings.

2.6 Research Quality

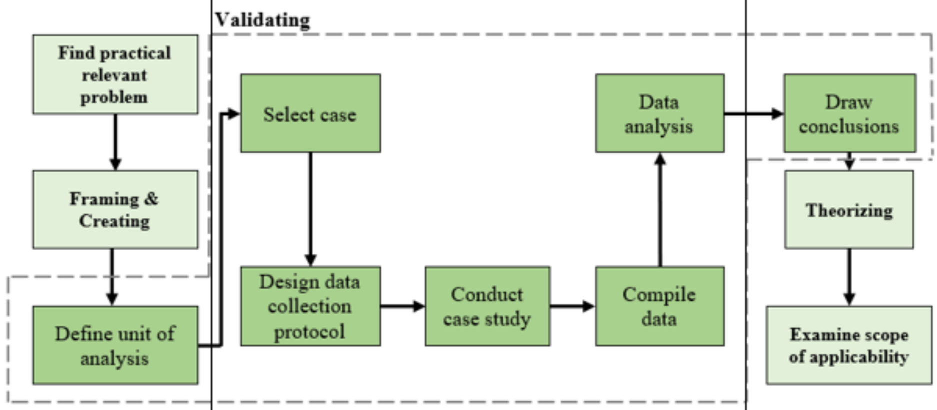
Research quality is always important, but according to Yin (2014), it is even more important when conducting a study focusing on a company problem, due to the risk of biases occurring. When ensuring research quality, two crucial concepts to consider are reliability and validity (Bryman, Bell & Harley, 2022; Näslund et al, 2010).

Validity refers to the accuracy of the results of the study, and what they are presenting is connected to reality. Reliability refers to the conduction of the study, and if repeated the same results would be achieved. In order to obtain high research quality, the study must be both valid and reliable. It is not enough if the study is valid but not reliable or vice versa (Bryman, Bell & Harley, 2022). Four criteria commonly used when evaluating research quality in operational research are presented in Table 5.

Table 5: Definitions of the four criteria commonly used when evaluating research quality (Bryman, Bell & Harley, 2022; Yin, 2014; Gibbert et al, 2008, Voss et al 2002)

Parameter	***Definition***
Construct validity	If the chosen measurements are appropriate and able to measure the studied phenomena
Internal validity	If the conditions found lead to the conclusion, or if the conclusion is pure coincidental
External validity	If it is possible to generalize the conclusions. Can other companies learn from the outcome of the thesis?
Reliability	Can the study be repeated with the same outcome?

To ensure research quality there is a need for a strategy how to achieve this, and even with a strategy in place, the researchers must always be critical of the study's quality (Kembro & Norrman, 2020; Näslund et al, 2010; Voss, Tsikriktsis, & Frohlich, 2002). The strategies for securing research quality used in this thesis have been inspired by Kembro and Norrman (2020), Näslund et al (2010), and Voss et al (2002). Figure 11 presents the chosen strategies, and where in the research process the strategies are applied.



Construct validity	• Use multiple sources of evidence • Explain key terminology	• Use multiple sources when collecting data • Explain key terminology	• Present preliminary finds for company representatives
Internal validity	• Structured approach. Presenting literary findings in tables and figures.	• Multiple sources regarding the same phenomenon • Findings displayed in tables and figures	• Conclusions summarized in tables and figures
External validity	• Rigid theoretical foundation	• Clear description of case company and their situation	• The use of theory and empirical findings when drawing conclusions
Reliability	• Use standardised interview protocol • Clearly described processes	• Observations and interviews are well documented with the help of case study database	

Figure 11: Strategies used in the thesis to ensure research quality. Layout and methods inspired by Kembro and Norrman (2020), Näslund et al (2010), and Voss et al (2002)

3. FRAME OF REFERENCE

The aim of this chapter is to build a theoretical foundation from which the analytical framework can be built. This chapter will discuss theories within warehousing and aspects to consider when designing a warehouse, or a space within a warehouse. The aim is to provide theory that can be used when determining when and how to store the incoming empty cleaned packaging at Company Alpha. The warehousing theory will also discuss warehouse operations, which is especially important to understand when it comes to designing and determining the return flow processes for the empty cleaned bins. In general, the return flow can be divided into two parts, the pick-up and transportation of the packaging, and the inbound processes once the packaging arrives at Company Alpha. In order to provide the physical flow of reusable packaging and identify the necessary processes and how they should be performed, the tool of process mapping and process design can be used. See Figure 12 for an overview of the disposition of the chapter.

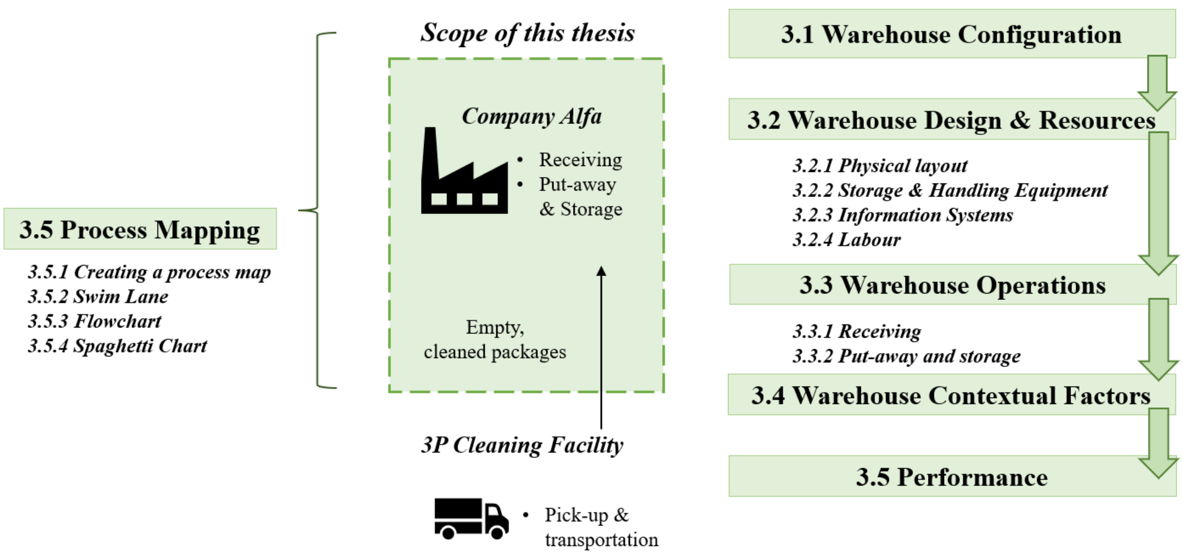


Figure 12: An overview of the disposition of the frame of reference chapter

3.1 Warehouse Configuration

Warehouse configuration refers to the combination of operations, design aspects and resources (Kembro & Norrman, 2021). Operations are the common warehouse operations such as receiving, put-away and storage, picking and sorting, and packing and shipping (Kembro & Norrman, 2021; Bartholdi III & Hackman, 2019). For the operations to be managed effectively and efficiently, a number of design aspects and resources need to be considered, such as the physical layout, automation and information system, storage and handling equipment, and labour and activities (Kembro & Norrman, 2021).

Rouwenhorst, Reuter, Stockrahm, van Houtum, Mantel, and Zijm (2000) take a similar approach and argue that processes, resources, and organisation are all aspects that need considering when designing a warehouse. The processes refer to the warehouse operations, resources include equipment and manpower required to operate the warehouse, such as storage systems, trucks, and information systems. Lastly, the organization refers to all the planning and control procedures used to run the warehouse, including picking and storage policies. Further, Gu et al. (2010) emphasize that the aspects that affect the design decision are highly connected, and all aspects need to be considered when making decisions. Additional factors to consider include the type and nature of products that are being stored in the warehouse, the frequency of the product movement, the storage conditions required, and the types of material handling equipment needed (Rouwenhorst et al., 2000; Gu et al., 2010).

Additionally, when designing a warehouse, or part of a warehouse, it is important to consider the goals, functions, and characteristics of the warehouse to ensure an efficient and effective operation. It is essential to consider the already existing processes within the warehouse and make sure that all the activities have the space required and don't act as a bottleneck for other processes. In addition, it is important to consider any future growth expectations of the company (Rouwenhorst et al., 2000; Gu et al., 2010).

Kembro and Norrman (2021) present a contingency approach to warehouse configuration, emphasising the importance to match the warehouse configuration to the contextual factors, see Figure 13. They argue that when not having a contingency approach, there is a risk that the contextual factors will be disregarded.

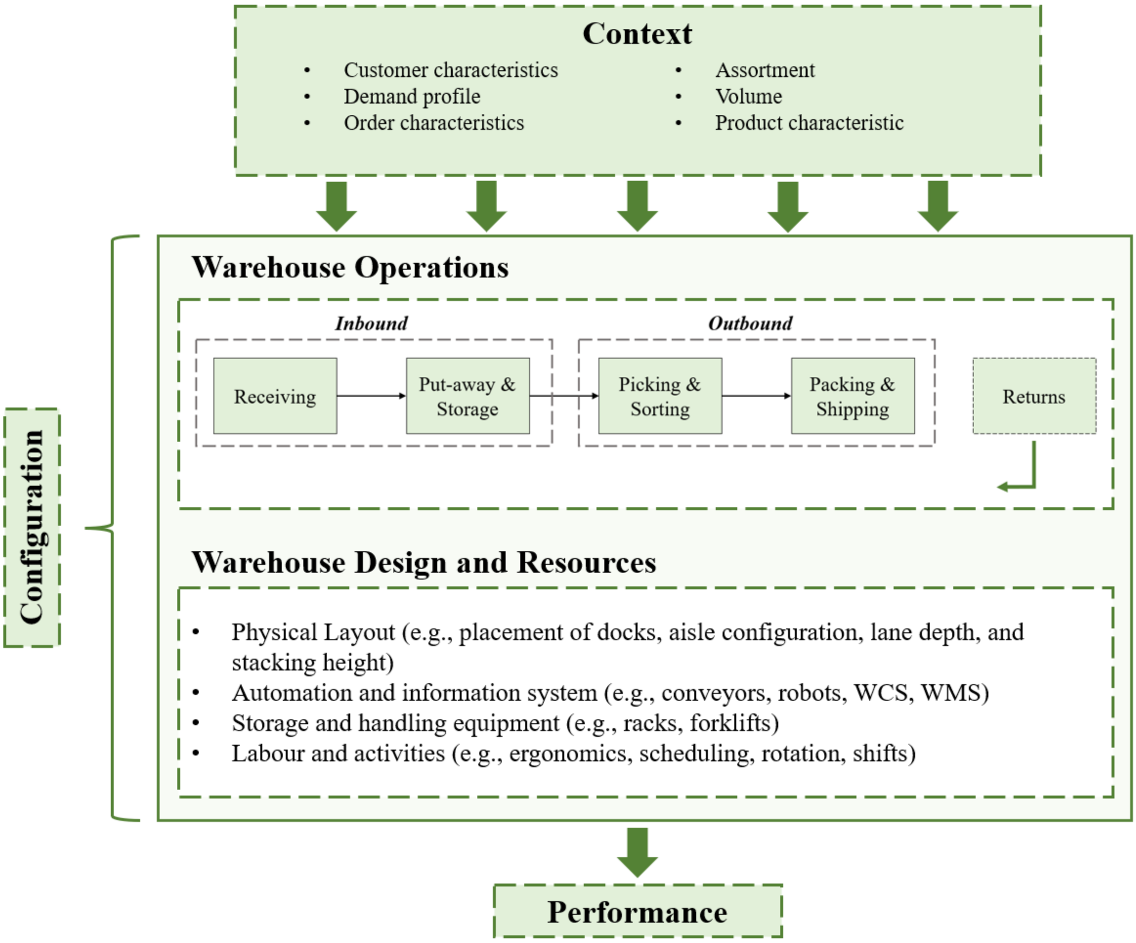


Figure 13: Conceptual contingency approach for warehouse configuration developed by Kembro and Norrman (2020) displaying that the match between context and configuration influences performance.

3.2 Warehouse Design and Resources

As seen in Figure 13, the warehouse design and resources are a part of the warehouse configurations which need to be matched with the contextual factors (Kembro & Norrman, 2021). This chapter will present these aspects one by one, more in detail.

3.2.1 Physical layout

Efficient warehouse operations require careful consideration of the physical layout, storage location, and resource allocation (Gu et al., 2007; Bartholdi III and Hackman, 2019). In the planning phase, the layout of the warehouse is a critical aspect to consider, as it largely determines the performance of the warehouse (Rouwenhorst et al., 2000). Designing the layout involves several components, such as determining the number of aisles, their dimensions and orientation, the location of input and output, estimating space requirements, and more (Hassan, 2002). Making decisions about the layout is complex and involves trade-offs (Rouwenhorst et al., 2000; Hassan, 2002).

Three areas to consider when designing the physical layout are space utilization, aisle configuration, and the location of receiving and shipping (Bartholdi III & Hackman, 2019). Space utilization is a critical factor to consider, where the goal is to maximize the number of pallet positions per square meter of floor space, thereby reducing the cost per pallet location. This can be achieved by using vertical space through pallet racks or stacking pallets on top of each other (Bartholdi III & Hackman, 2019).

A conventional and cost-effective storage solution is the block stacking storage system, which relies on effective space utilization for optimal performance (Derhami, Smith & Gue, 2017). Block stacking storage is commonly used in manufacturing systems where pallets containing *Stock Keeping Units,* or SKUs, are stored in a warehouse at fixed production rates. This unit load storage system involves stacking pallets of SKUs on top of each other in lanes on the warehouse floor. The maximum stacking height is determined by various factors, including pallet conditions and heights, load weights, safety limits, and clearance height of the warehouse (Derhami et al, 2017). Unlike other storage systems, block stacking does not require any racking or specialized storage facility and can be implemented in any warehouse with adequate floor space. This makes it a low-cost storage option, but it can be challenging to manage in terms of space planning (Derhami et al, 2017).Table 6 provides an overview of different storage methods and their respective pros and cons for utilizing space efficiently.

Table 6: Storage methods to utilize warehouse space (Bartholdi III & Hackman, 2019; Derhami et al., 2017)

Storage method	***Pros***	***Cons***
Block stacking storage	Cheap. Pallets can be stacked. Easily implemented. Requires no racking equipment.	Heavy or fragile items cannot be stacked. Can be hard to manage in terms of space planning.
Pallet racks	Use vertical space more efficiently. Can store heavy or fragile items. Easier to store and retrieve. Safer.	Cost. More of an effort to implement.

Another critical factor to consider is aisle configuration since it impacts the space needed, warehouse operations, and material handling. Aisle configurations include the number and length of aisles, the existence of cross-aisles, and the number of storage blocks (de Koster, Le-Duc & Roodbergen, 2007). The number of aisles highly affects space utilisation, as the more aisles used, the fewer SKUs can be stored in the area. On the other hand, having many aisles reduces the risk of congestion. Depending on the goal of the warehouse, trade-offs must be made (de Koster et. al, 1997; Bartholdi III & Hackman, 2019).

The location of the receiving and shipping docks is another important decision when designing the layout. The two most common configurations are flow-through and U-flow (Bartholdi III & Hackman, 2019; Hassan, 2002; Huertas et al., 2007). The flow-through configuration has the receiving and shipping docks located on opposite sides, reducing congestion, and making many positions equally convenient. On the other hand, the U-flow configuration has the docks located on the same side, creating flexibility for the usage of the docks and their equipment, and is suitable for warehouses with few SKUs accounting for a large portion of the picks (Huertas et al., 2007). See Figure 14 for a visualisation of the layouts previously described.

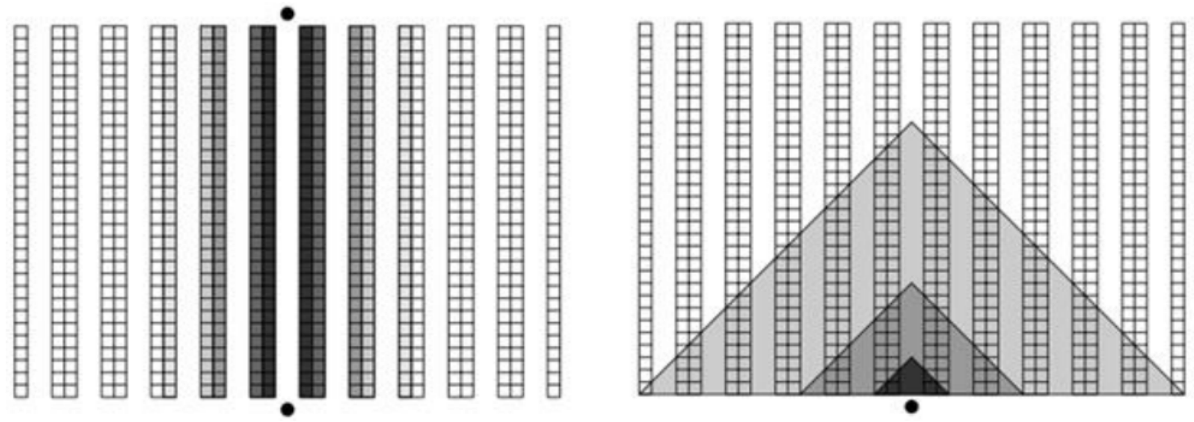


Figure 14: Flow-through layout (left) & U-flow layout (right). The darker the area, the more convenient location. (Bartholdi III & Hackman, 2019)

By carefully considering the previously presented factors, warehouses can optimize their layout and storage to improve capacity, throughput, and service levels. The layout also determines the allocation of resources such as space, labour, and equipment to meet these objectives (Gu et al., 2007). See Table 7 for a summary of the areas to consider.

Table 7: Summary of the three areas to consider regarding physical layout.

Configuration area	***Methods***	***Benefits***
Space utilisation	Floor storage	Cheap
	Rack storage	Increase volume utilisation
Location of Receiving & Shipping	Flow-through	Many locations with good accessibility
	U-Flow	Few locations with great accessibility
Aisle configuration	Many aisles	Less congestion
	Few aisles	Higher space utilisation

3.2.2 Storage and Handling Equipment

A warehouse can have many different types of equipment, depending on the context of the warehouse (Bartholdi III & Hackman, 2019). Typically, the equipment can be divided into two major groups, storage equipment and handling equipment. Bartholdi III & Hackman (2019) emphasizes that the use of the right equipment can reduce labour costs and increase storage utilization. Storage equipment can be used to improve space utilization in a warehouse, by for example storing SKUs on the height. One of the most common storage equipment is pallet racks, which are used for bulk storage and support full-case picking. Rack storage also allows the possibility to access loads on each level while utilizing the height of the warehouse. See Table 8 for the most common types of rack storage considered in this thesis.

Table 8: The most common types of rack storage (Bartholdi III & Hackman, 2019).

Storage equipment	***Description***
Single-deep rack	Stores pallets one deep. Each SKU can be retrieved from any level and location of the rack. It requires relatively more aisle space.
Double-deep rack	Stores pallets two deep, achieved by placing two single-deep racks behind one another. It is recommended to store the same SKU in each lane to avoid double handling. Requires less aisle space, but specialized handling equipment to reach.

Handling equipment supports the vertical and horizontal movement of the SKUs within the warehouse. It is crucial that the handling equipment is in line with the choice of storage equipment, meaning the handling equipment needs to be able to use in combination with the storage equipment. Usually when using rack storage, lift trucks are needed to access SKUs that are stored higher up in the rack (Bartholdi III & Hackman). Table 9 summarizes the common types of handling equipment.

Table 9: Common types of handling equipment (Bartholdi III & Hackman, 2019).

Handling equipment	***Description***
Pallet jack	Manual tool used for moving goods horizontally
Counterbalance truck	The standard truck version. All-around lift truck that has both sit-down and stand-up versions.
Reach lift truck	Has a reach mechanism that enables forks to extend to put-away and retrieve pallets.
Double-reach lift truck	Similar to the reach lift truck, but the forks can extend even further. Useful when having double-deep racks.

3.2.3 Information systems

When talking about information systems, what usually comes to mind is the term ERP, which stands for *Enterprise Resource Planning* and is one of the most common information systems. An ERP system is often used by many different departments throughout an entire organization, and the system is designed to manage and integrate all aspects of a business, e.g., finance, human resources, and supply chain management (O'Leary, 2012). The main purpose of having an ERP system is to *"process an organisation's transactions and facilitate integrated and real-time planning, production and customer response"* (O´Leary, 2012, p.27). ERP systems can also manage warehouse operations; however, it is not their primary function.

When managing warehouse operations, it is beneficial to use a *Warehouse Management System*, WMS, which is an information system that supports aspects such as inventory management, storage locations, and workforce (Bartholdi III & Hackman, 2019). According to Bartholdi III and Hackman (2019), a WMS should at least track all arriving goods and all goods shipped out. However, the majority of WMSs also have a stock locator system, which makes it possible to manage the inventory of storage locations as well as the inventory of products. A well-functioning WMS should track every location an SKU can be on a detailed level, whether it is in a pallet rack or on the forks of a forklift (Bartholdi III & Hackman, 2019). Bartholdi III and Hackman (2019) emphasize that the core of a WMS is a database of SKUs and a stock locator system to facilitate the management of both SKUs and inventory storage locations.

3.2.4 Labour

An important resource that needs considering has an impact on the warehouse configuration is the employees and labour. Labour is important as it is a significant part of the costs, but also because it is a necessity for the activities to be performed. The workload in the warehouse changes with the demand, and not having adapted the number of employees and workforce scheduling accordingly will result in an unbalanced workload as well as the turnover (De Leeuw & Wiers, 2015; Dewi & Septiana, 2015).

When planning manpower, there are four different strategies that can be chosen (1) flexible contracts, (2) flexible planning, (3) job rotation, and (4) workload balancing (De Leeuw & Wiers, 2015). Flexible contracts refer to using flexible and temporary workers who have a specified timeframe of their contracts. Flexible planning means that workers with fixed contracts work in a flexible manner based on the number of working hours and free days stated in the contract. The third strategy, job rotation, is when the employees shift between different tasks and operations in a systematic manner. For this strategy to work, the employees need to be capable to carry out various tasks which results in a more varied workload. The last strategy presented is workload balancing, which refers to planning the workload and distributing the work shifts between busy and calm days to vary the workload (De Leeuw & Wiers, 2015).

3.3 Warehouse operations

According to Bartholdi III and Hackman (2019, p 3), warehouses can be described as “the points in the supply chain where the product pauses, however briefly, and is touched”. Warehouse operations include: (1) receiving, (2) put-away and storage, (3) picking, and (4) packing and distribution (Bartholdi III & Hackman, 2019; Gu, Goetschalckx & McGinnis, 2007). These operations can be divided into inbound and outbound processes, where receiving and put-away and storage are inbound processes, and picking, packing and distributions are outbound processes. For this thesis, only the inbound operations, receiving and put-away and storage, will be considered. These processes are taking place at Company Alpha’s outbound area, see Figure 15.

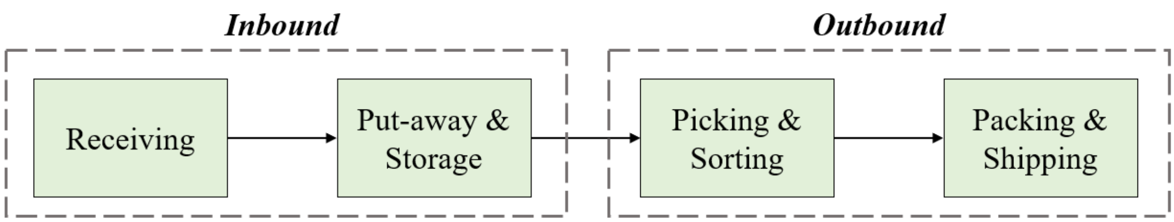


Figure 15: Warehouse operations (Bartholdi III & Hackman, 2019; Gu et al., 2007).

A general rule for warehouse operations and how they interact is that the material should flow as continuously as possible through these steps to avoid double handling (Bartholdi III & Hackman, 2019).

To make warehouse operations effective and efficient, multiple design aspects and resources must be considered, including physical layout, storage and handling equipment, information systems and labour management. (Kembro, Norrman & Eriksson, 2018)

3.3.1 Receiving

The process of receiving often begins with a notification of the arrival of goods at the warehouse, and it is the first step in the inbound warehouse operations. The warehouse can then schedule the receipt and align the arrival of goods with other activities in the warehouse. Typically, warehouses schedule a specific time slot for trucks to arrive, i.e., 30-minute windows (Bartholdi III & Hackman, 2019; Gu et al. 2007).

When the product has arrived and has been unloaded, it is often staged for put-away, where common activities are scanning to register the products' arrival and inspections for deviations (Bartholdi III & Hackman, 2019). The process of inspecting the arriving goods is important, as it may have an impact on the other warehouse operations by risking stocking the bay area. The arriving goods are often transported in pallet loads and are in some cases repacked into other storage units before being ready for put-away (Bartholdi III & Hackman, 2019; Rouwenhourst et al. 2000).

In order to ensure an efficient receiving process, it is important that the time for when the goods can arrive is clearly defined, and that the goods are loaded in a way that makes it possible to unload the goods efficient.

3.3.2 Put-away and storage

To be able to put away the received goods, it must be clearly defined where the goods should be stored, and what storage policy should be used. It is important to choose the storage policy carefully as this determines how quickly the SKUs can be retrieved at a later stage. The storing policy should make the picking process as efficient as possible, with little to no room for errors (Bartholdi III & Hackman, 2019).

When choosing a storage policy there are two primary principles that can be used: dedicated and shared storage (Derhami, Smith & Gue, 2017; Bartholdi III & Hackman, 2019). When applying a dedicated storage policy, lanes, or locations, are dedicated to a specific SKU, where only designated SKUs are allowed to be stored. On the contrary, when applying a shared storage policy, locations are not dedicated to a specific SKU, and any available location can be used to store any SKU (Derhami et al., 2017).

There are benefits and disadvantages of the two policies. The shared storage policy utilises space more efficiently than the dedicated policy. However, it can lead to less efficient picking since the storage locations for SKUs change over time, and it makes the put-away process more time-consuming (Derhami et al., 2017; Bartholdi III & Hackman, 2019). By having dedicated storage, the workers have the possibility to learn the layout which facilitates more efficient picking and can reduce the risk of picking the wrong SKUs. On the downside, dedicated storage lowers space utilization as there is a risk of having empty storage locations (Bartholdi III & Hackman, 2019).

The shared storage policy is often used in warehouses that deal with a large number of SKUs and limited space. The dedicated storage policy is suitable when the demand of material is relatively even and a stable mix of SKUs, meaning that the number of different SKUs is fairly even over time. (Derhami et al., 2017; Olhager, 2018)

An additional policy that can be used is a forward picking area, which is a separate picking area in the warehouse. This area is usually relatively small, and SKUs that are demanded frequently are placed there in small quantities to facilitate easy and fast picking. The benefits of having a forward picking area are the traveling when picking is reduced, and popular SKUs are placed in convenient places. However, this requires more planning and space for SKUs ready for replenishment. The replenishment will have to be more frequent, leading to additional movement in the warehouse (Bartholdi III & Hackman, 2019). A summary of the different storage policies presented in this sub-chapter can be seen in Table 10. There are of course other storage policies apart from the ones presented in this sub-chapter, such as family grouping and class-based storage, but as they are not relevant to the thesis, they will not be presented further.

Table 10: Summary of different storage policies (Derhami et al., 2017; Bartholdi III & Hackman, 2019).

Storage policy	***Meaning***
Shared storage	SKUs are allocated randomly which requires less space, enabling higher space utilisation.
Dedicated storage	Different SKUs all have a predetermined location. Requires more space
Forward picking area	Smaller quantities of fast-moving SKUs are stored within a smaller area, which is replenished from a reserve.

3.4 Warehouse contextual factors

The previous chapters have discussed the different configuration aspects that need to be considered when configuring a warehouse. In recent years, the concept of tailoring the warehouse configuration to its contextual factors has become increasingly popular in literature, and the contextual factors can include both the internal and external environment (Kembro & Norrman, 2021). In warehousing, the environment refers to the operation environment, which can be challenging to change in the short term (Faber, de Koster, Smidts, 2013). As stated by Kembro and Norrman (2021), comprehending the context within which the warehouse operates is crucial since diverse contextual factors must be considered while designing the warehouse configuration.

One important contextual factor to consider is the purpose, or the goal of the warehouse (Kembro, Norrman & Eriksson, 2018). For example, if the goal is to store as many SKUs, as possible, the target of the warehouse design is to maximize space utilisation. If the goal is to be flexible and responsive in the flow of products, the target is instead to maximize the accessibility of the SKUs. It is not uncommon that these goals are contradictory, and it is not possible to achieve the goals without making trade-offs (Gu et al., 2010). The warehouse goals should be determined in the initial steps of the design process, and later used for evaluation of the performance of the design to see if the goal is fulfilled (Gu et al., 2010).

Additionally, it is important to understand the functions and characteristics of the warehouse. Rouwenhorst et al. (2000) identify two main types of warehouses: distribution and production warehouses. Distribution warehouses serve the customer, and typically have a higher assortment of SKUs, in order to fulfil a large number of customer orders, which in turn makes the picking process both costly and complex. Consequently, the primary goal for a distribution warehouse is to maximize throughput. Production warehouses serve the production and store SKUs related to the manufacturing or assembly process. Examples of SKUs stored in a production warehouse are raw materials, work in progress, and finished parts that are used in these processes. Often, these warehouses require a high storage capacity due to longer storage period of SKUs (Rouwenhorst et al., 2000; Gu, Goetschalckx & McGinnis, 2010)

Another aspect to consider is where in the supply chain the warehouse is positioned and kinds of flows it handles, as the forward and reverse flow of products have different requirements on warehouse capabilities. Often when handling the reverse flow, the warehouse facility must be able to handle both the distribution of finished goods while also being able to handle the return flow processes, which may require additional resources compared to the forward flow (Dowlatshahi, 2012; Richey, Genchev & Daugherty, 2005). However, by utilising already existing warehouse capabilities, the effectiveness of the return flow can be improved (Dowlathsahi, 2012).

On a more detailed level, the contextual factors can include product characteristics, supply chain design, and financial and operational factors (da Cunha Reis, de Souza, da Costa, Stender, Vieria & Pizzolato, 2017; Bartholdi III & Hackman, 2019). Two categories discussed by Faber et al (2013) are task complexity and market dynamic. Task complexity refers to the number of SKUs, process diversity, and number of order lines. Market dynamic refers to unpredictability in demand and assortment changes. Other contextual factors are what can be described as market-related factors, such as customer characteristics, demand profile, order characteristics, assortment, volume, and product characteristics (Kembro & Norrman, 2021). See Table 11 for a summary of the different contextual factors.

Table 11: Examples of contextual factors (da Cunha Reis et al., 2017; Kembro & Norrman, 2020: Faber et al., 2013; Rouwenhorst et al. 2000).

Contextual factor	***Description***
Product Characteristics	Refers to the type of SKUs, their size, and if they have specific handling and storing requirements. This factor impacts the space needed and the choice of storage policy, among others.
Customer Characteristics	Refer to the number and types of customers.
Assortment	Refers to the number of SKUs and the introduction of new SKUs. Impacts the storage strategy
Demand Profile	Refers to the seasonality of demand and how often SKUs are picked. This factor affects storage strategies and labour required.
Volume Profile	Refers to the throughput of the warehouse and popular SKUs. Impacts the picking process.
Order Characteristics	Refers to the number of orders, number of pick-lines per order, and number of units per pick-line. Impacts the picking process

3.5 Performance

So far, the importance of matching the warehouse configuration to the contextual factors has been presented. As presented by Kembro and Norrman (2021), when matching the warehouse configuration with the contextual factors the warehouse performance may improve.

On a similar note, Donaldson (2001) presents that organisational decisions that are aligned with the contextual factors result in an increase in performance. If the organisational decisions were to be misaligned with the contextual factors, this would negatively impact the performance. Consequently, as the contextual factors change there is a chance that the organisational characteristics need to change accordingly to avoid any decrease in performance. Thus, the way you manage should change depending on the circumstances. This contingency approach has been increasingly discussed within warehouse theory, where the focus is on matching the warehouse configuration to the contextual factors in order to improve performance (Faber, de Koster & Smidts 2017; Kembro, Norrman & Eriksson, 2018). If the warehouse configuration is not matched with the contextual factors, this may contribute to a lower warehouse performance (Kembro & Norrman, 2020; Kembro, Norrman & Eriksson, 2018). Kembro and Norrman (2020) present that the contextual factors play a significant role in determining warehouse configurations as they create trade-off challenges among various configuration decisions, such as storage, processes, and resources, and how these can be combined.

An example of how contextual factors influence the warehouse configuration is presented by Rouwenhorst et al. (2000). They describe that the contextual factor product characteristic affects how the products are stored, which in turn influences what handling and storage equipment to use. All of which influence warehouse performance. Therefore, it is essential to understand the contextual factors to match the configurations accordingly but also to consider potential trade-offs.

It is important to measure the performance of the warehouse, which can be done with the help of *Key Performance Indicators*, KPIs (Bartholdi III & Hackman, 2019). KPIs are different measures that can be used for determining the performance of the warehouse, e.g., response time, operating costs, space utilisation, and picking accuracy. Continuous measurements of the warehouse productivity are needed in order to find where improvements can be made and make these improvements. However, it can be hard to know what KPI to use and how to measure them in an unbiased manner. For example, the KPI pick-lines per labour hour is biased because it depends on the type of unit. A guideline for choosing relevant KPIs is to apply the concept of SMART KPIs, which is an abbreviation meaning that KPIs should be *specific, measurable, attainable, realistic,* and *time sensitive* (Shahin & Mahbod, 2007).

3.6 Process Mapping

The concept of a process can be described in many different ways, but a common recurring description is the one from Davenport (1993, p. 5), who describes a process as *"a specific ordering of work activities across time and place, with a beginning, an end and clearly identified inputs and outputs: a structure for action"*. Dumas, La Rosa, Mendling, and Reijers (2018, p.6) define a process as *"a collection of inter-related events, activities and decision points that involve a number of actors and objects, and that collectively lead to an outcome that is of value to at least one customer"*. The definitions may vary, but the essence of them is the same, which Aguilar-Savén (2004, p. 133) describes as "*Processes are relationships between inputs and outputs using a series of activities, which add value to the inputs"*.

Ljungberg and Larsson (2012) describe a process with the help of five keywords, which they call *process components,* see Figure 16 for a visualisation of their description.

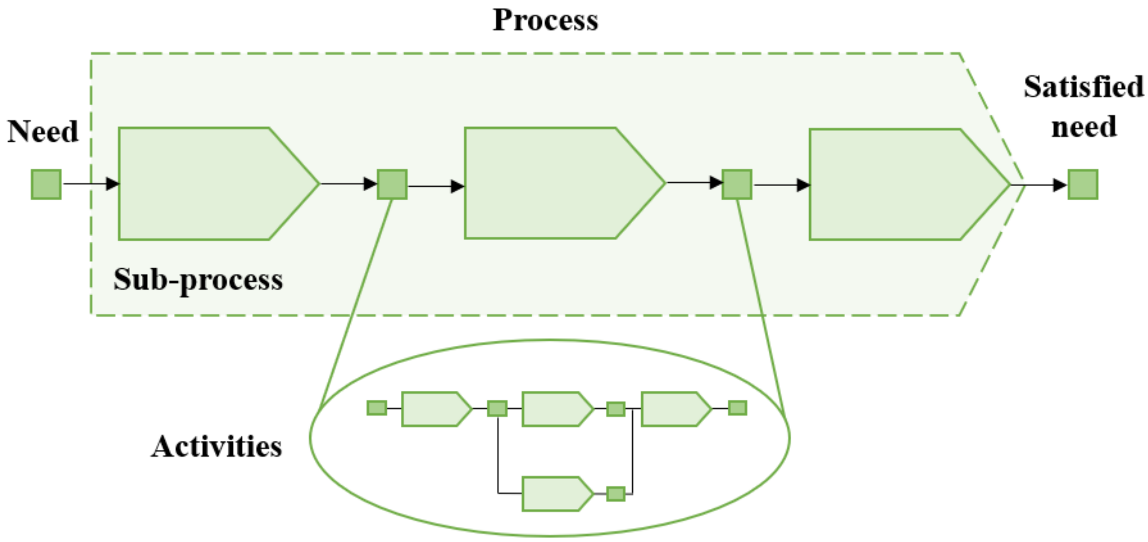


Figure 16: The components of a process presented by Ljungberg and Larsson (2012, p.204)

Process mapping can be described as a management tool used to describe every important step in a business process in order to identify the flows and find room for improvements. The tool was initially developed for maximizing performance and profit margin in manufacturing companies, but today process mapping is used in several industries and areas and is commonly used in business process management (Ornat & Moorefield, 2019). Process mapping makes it easier to develop, monitor and control processes to achieve the expected outcome, as it provides a simplified overview of the activities and their relationship. It can also be used as a basis to identify the logically correct way of working (Ornat & Moorefield, 2019). A process map can for example include processes, activities, workflow, material flow etc. (Hunt, 1996).

The beneficial outcomes when using process mapping are many (Kalman, 2002), where a few examples are:

- The workflow can be simplified, by eliminating unnecessary controls and transportation.
- As a result of eliminated or reduced queuing and controls, the cycle time can be reduced.
- The quality improves and variability is reduced, due to fewer steps which in turn leads to a lower risk of errors. In this way, process mapping can eliminate sources of error.
- The communication and cooperation between different functional departments within the business increases.
- Reduce costs by eliminating unnecessary tasks that are not value-adding.

For a supply chain to reach its full potential and to be as efficient and effective as possible, it is important the material flow of the supply chain is integrated with the supporting processes (Childerhouse & Towill, 2003). Hence, to ensure that the supply chain reaches its full potential process mapping can be a beneficial tool to identify gaps and potential problem areas in certain processes (Gardner & Cooper, 2003; Wichmann, Brintrup, Baker, Woodall & McFarlane, 2020). The tool of process mapping will be used to identify where in the return flow the processes and activities need to be performed. Factors that going to be included in the map are the physical flow of products, and the processes performed.

3.6.1 Creating a process map

Ornat and Moorfield (2019) present five steps for a systematic approach to process mapping. The five steps are: (1) define the process and its extent, (2) collect information about the process, (3) create an "as-is map", (4) analyse the "as-is map" in order to identify possible improvements, and (5) Create a "should-be map".

The first step refers to understanding the process that is supposed to be mapped, the reason why the process is being mapped, and its strategic impact. In order to decide the extent of the process it's important to determine where the process starts and where it ends (Ornat & Moorefeld, 2019).

The second step is about collecting information about the process in order to identify the activities and possible documents involved in the process that is needed at a later stage when creating the "as-is map". In this stage, it is important to work closely with the people involved in the process to get a sense of how it actually works in reality (Ornat & Moorefield, 2019).

After the information is collected, the "as-is map" can be created. The purpose of this map is to act as a visual presentation of the current process, where it should be easy to follow the logic behind every step of the process (Ornat & Moorefield, 2019).

The fourth step is to analyse the "as-is map" and identify potential improvements in the process. Usually, ideas of improvements come up when creating the "as-is map", and this step is a possibility to investigate these potential improvements further (Ornat & Moorefield, 2019).

Lastly, a "should-be map" can be created, where all of the improvements have been considered and evaluated. The ones that seem feasible are included in the "should-be map" as improvement recommendations (Ornat & Moorefield, 2019).

There are several tools that can be used when mapping a process, and which tool to use all depends on what it is that is being investigated, whether it is an information flow, material flow, etc. One thing most of the tools have in common is the usage of shapes to demonstrate the characteristic of activity in the process, see Figure 17.

Figure 17: Symbols commonly used for different activities in a process map (Ornat & Moorefield, 2019)

The following sub-chapters will discuss three of the common tools used, *Swim Lane Diagrams*, *Flow charts,* and *Spaghetti diagrams.*

3.6.2 Swim lane diagram

A swim lane diagram is a process map that separates the process steps between the different departments or individuals that are involved in the different steps (Ezeonwumelu, Kalu & Johnson, 2016). It shows which group or department that is performing each step in a process, and demonstrates where handoffs occur, which are the weakest links in the process. According to Ezeonwumelu et al. (2016), swim lanes are suitable when processes are being displayed on different levels of detail and can be used both for displaying processes on a general level to the most detailed level.

Swim lane diagrams can be a big help when it comes to improving the processes, as they can help identify bottlenecks and who is responsible for them. See Figure 18 for an example of a swim lane diagram.

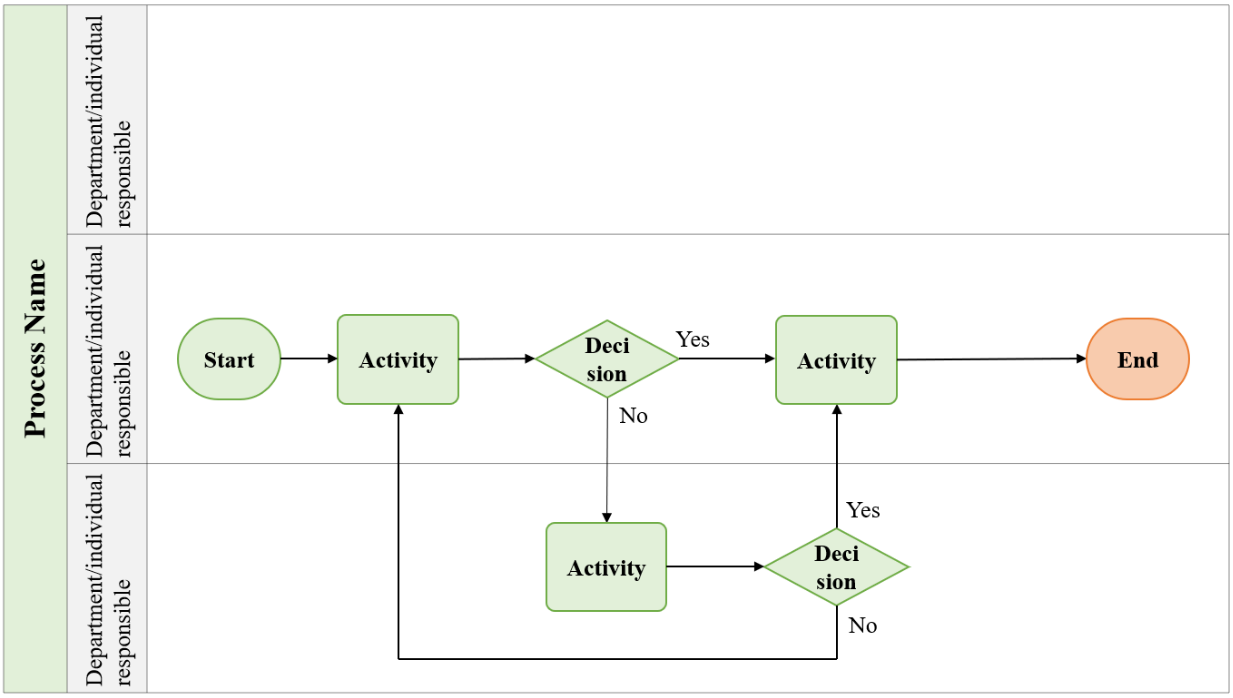


Figure 18: Example of swim lane diagram, modified from Ezeonwumelu et al. (2016)

3.6.3 Flow chart

A flow chart can be described as a graphic representation describing process-related information such as activities, information flows, and material flows (Aguilar-Savén, 2004). It is an easy and flexible tool that is easy to adapt to what it should display. Flow charts are suitable when processes are to be described in sequences and when specific areas are to be analysed in order to solve a problem at a later stage (Aguilar-Savén, 2004). Flow charts are not equally as useful when it comes to dividing activities between different individuals or departments. Additionally, they do not separate the main activities from side activities. The main advantage of using flow charts is that they can be used to quickly identify bottlenecks and handle processes that need describing with a high level of detail (Aguilar-Savén, 2004). See Figure 19 for an example of a flow chart.

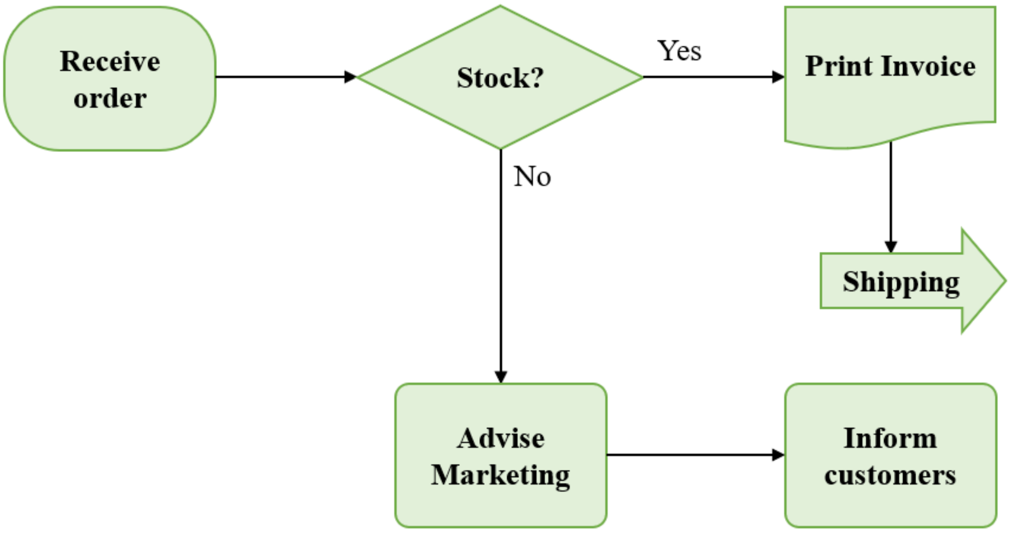


Figure 19: Example of flow chart adapted from Aguilar-Savén (2004, p. 134)

3.6.4 Spaghetti Diagram

Spaghetti diagrams is a tool used for visual representation of the physical movement of an object, material flow, or employee through a process or system (Pyzdek, 2021; Senderska, Mareš and Václav, 2017). The reason for its name is that the movements are represented by lines, which often end up looking like a tangled mess of spaghetti noodles. The system it moves through can be a production area, warehouse, or part of any building (Senderska et al., 2017).

Spaghetti diagrams can be used in manufacturing, logistics, or any other industry where processes are involved. The diagram can be used to identify movements that don't add value, bottlenecks, and areas where improvements can be made. By analysing the movements of resources such as workers and materials with the help of spaghetti diagrams the productivity can be increased (Pyzdek, 2021). One of the key benefits of spaghetti diagrams is the fact that they provide a visual representation of a process that can increase the understanding of the workflow, which in turn can be used for making informed decisions about the process (Pyzdek, 2021).

When creating a spaghetti diagram, the physical movement of a material or employee is drawn as a line, either by using pen and paper or software. The lines can then be labelled with information about the movement, such as the time it takes, the distance travelled, or the number of times the movement is repeated, which in turn helps to gain insight into the process and identify areas for improvement (Pyzdek, 2021; Senderska et al., 2017). See Figure 20 for an example of a spaghetti diagram.

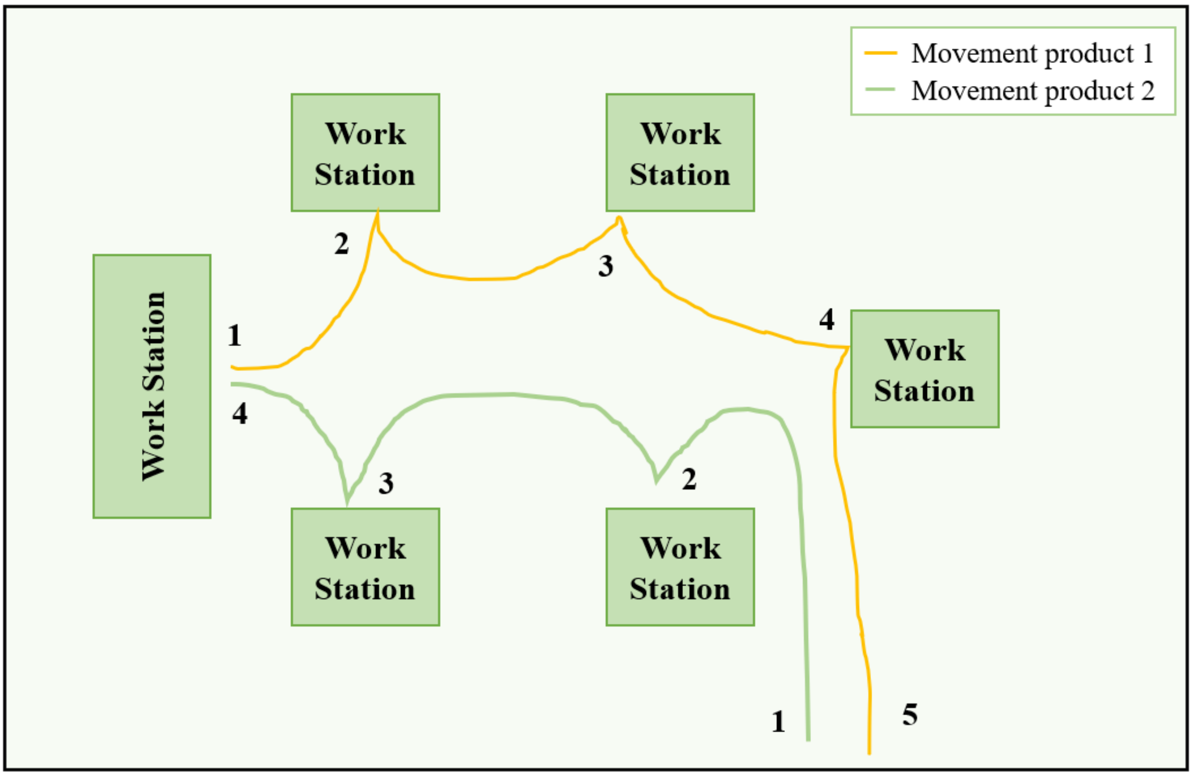


Figure 20: Example of a Spaghetti diagram. The lines represent the movement, and the numbers represent the sequence.

3.7 Analytical Framework

From the frame of reference an analytical framework is created. The analytical framework acts as a support and guidance when collecting data, analysing the data, from which a proposed solution to Company Alpha will be made. The analytical framework can be seen in Figure 21.

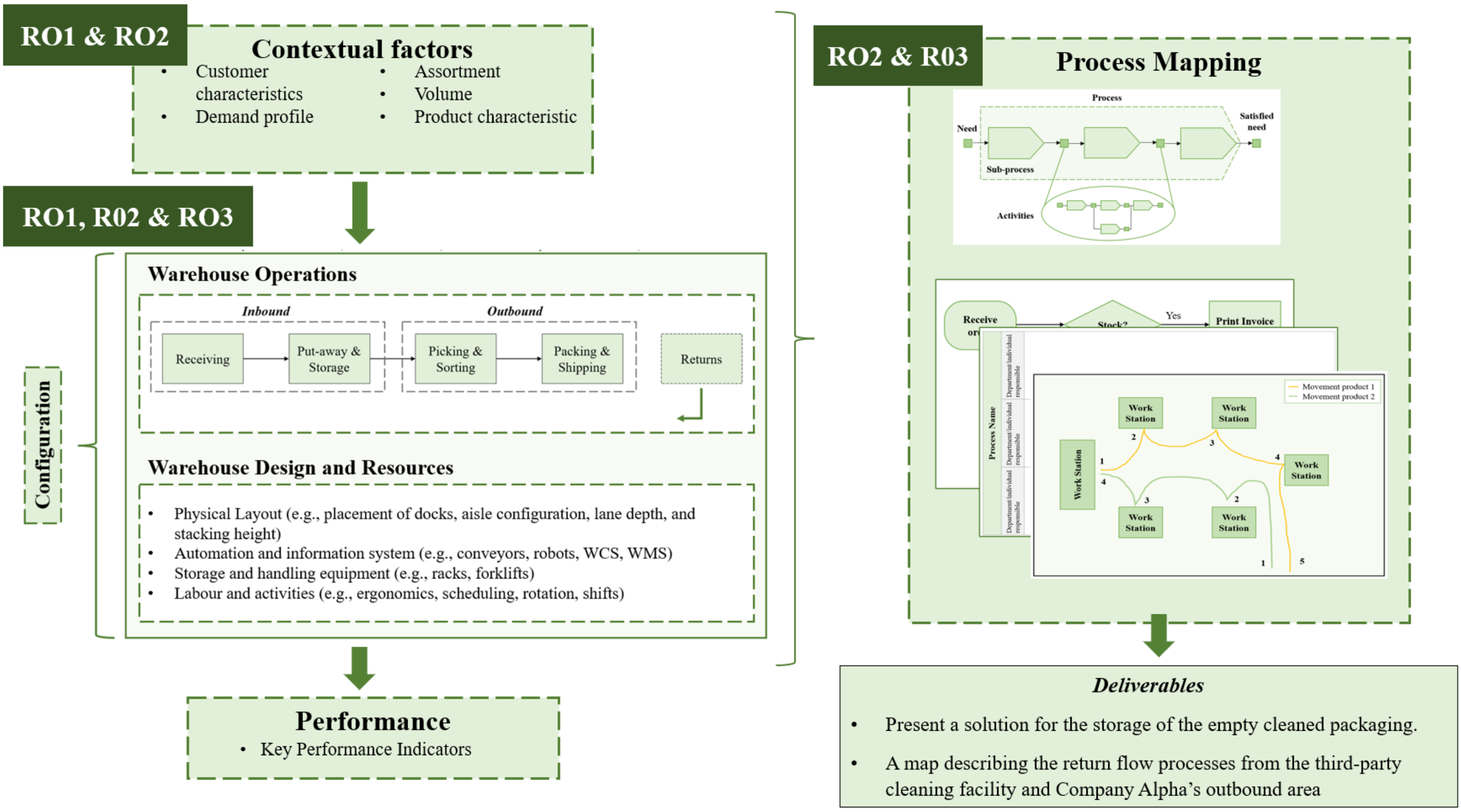


Figure 21: Analytical framework

The first research objective is to describe the current state of the warehouse, in terms of warehouse contextual factors and warehouse configuration. In order to create an understanding of these aspects at Company Alpha, theory within the areas is needed, which can be found in Chapter 3. The second research objective refers to identifying the processes needed for the return flow as well as the requirements for storing and handling the packaging. The theory needed for this is yet again theory within warehouse configuration and contextual factors. The data which has been collected for the first research objective will be used for various process maps, such as an "as is map", in order to create a better understanding of how the contextual factors and warehouse configuration is matched today, and how the new contextual factors can be incorporated to this.

The last research objective is to present a solution for the storage of the empty cleaned packaging and a map describing the return flow processes of the packaging at Company Alpha. In order to create these propositions, the outcome from research objectives one and two will be combined and analysed with the help of further process mapping and warehouse configuration theory. From the warehouse configuration and contextual factors at Company Alpha, potential KPIs will be identified and suggested as performance measurements for the future when applying the propositions in reality.

4. EMPIRICAL FINDINGS

This chapter aims to provide information from Company Alpha that has been discovered through interviews, observations, and internal company material. The findings will be used to create an “as-is map” presenting the current processes and material flows taking place in the outbound area. The chapter will go through the current warehouse configuration and the contextual factors that have been identified at Company Alpha with the aim to create an understanding of the environment in which Company Alpha Operates. The collected data will be used at a later stage when designing the area where the cleaned packaging will be stored. Table 12 presents the people that have been interviewed and contributed to the data collection with insightful information.

Table 12: Overview of the people that have been interviewed.

Title	***Contribution***
Internal Logistics Developer	Current layout and processes at Company Alpha
Planning & Logistics Developer	How they want the process to work and what the 3PCF can provide. Information about the packaging line and its capacity.
Senior Planning & Logistics Developer	Forecasted volumes of the packaging. Information about current processes.
Purchasing Manager	Information about the contract with the 3PCF
Lead Packaging Engineer	Information regarding the product characteristics.
Production Planner	Information regarding packaging planning
Material Flow Automation Engineer	Information regarding ASRS capacity and Packaging Line capacity and requirements

4.1 Warehouse Design and Resources

The following chapter will discuss the warehouse design and resources as they are at Company Alpha currently. The aim of this information is to create an understanding of the current environment and the resources available.

4.1.1 Physical Layout

The outbound area at Company Alpha today consists of a loading area with two loading docks, and a packaging line, where finished cells get put into the reusable packaging to then be put away in an *automated storage and retrieval system*, ASRS. See Figure 22 for the physical layout. The area is relatively small considering the number of various processes that are performed in the area. The processes carried out in this area include packing the cells in reusable bins and the subsequent outbound activities all the way to the shipping of the finished goods to the customers. The packaged bins are stored in the ASRS until it is time for them to be shipped.

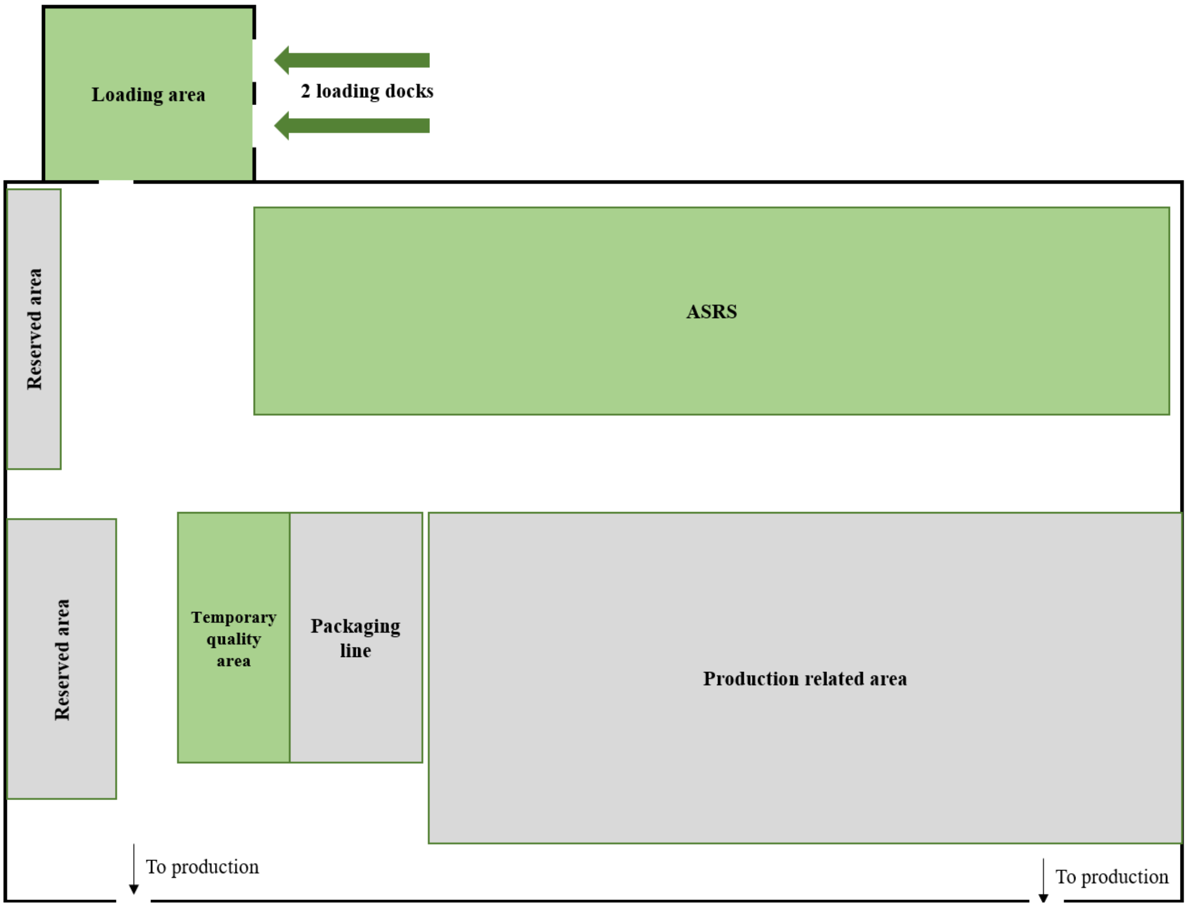


Figure 22: The current layout of Company Alpha's outbound area

The loading area is meant for staging finished goods and preparing them for shipment, but this area is also used for storing disposable packaging material, for example, cardboard boxes. These types of materials are not allowed to store in the bigger area where the packaging line is located, since they can collect dust and have fibres that may contaminate the cells and the bins during the packaging process.

As seen in Figure 22, the loading area only has two loading docks, and according to the Planning and Logistics Developer, the area itself is relatively small considering the future volumes that are going to be handled there. The number of docks and the space of the loading area is considered a bottleneck, and when the number of shipments increases, the loading docks will act as a huge constraint and shipments will not be able to be dispatched as planned. For this reason, Company Alpha is considering expanding the loading area, making it bigger to facilitate more staging as well as adding two additional loading docks, increasing the total amount to four loading docks. According to the Planning & Logistics Developer, this expansion is essential for the company in order to have a continuous outbound flow of finished goods and avoid congestion. The extension would also mean an additional opening between the outbound area and the loading area in order to improve the flow between the two areas. See Figure 23 for the potential extension of the loading area, including the extra opening between the loading area and the outbound area.

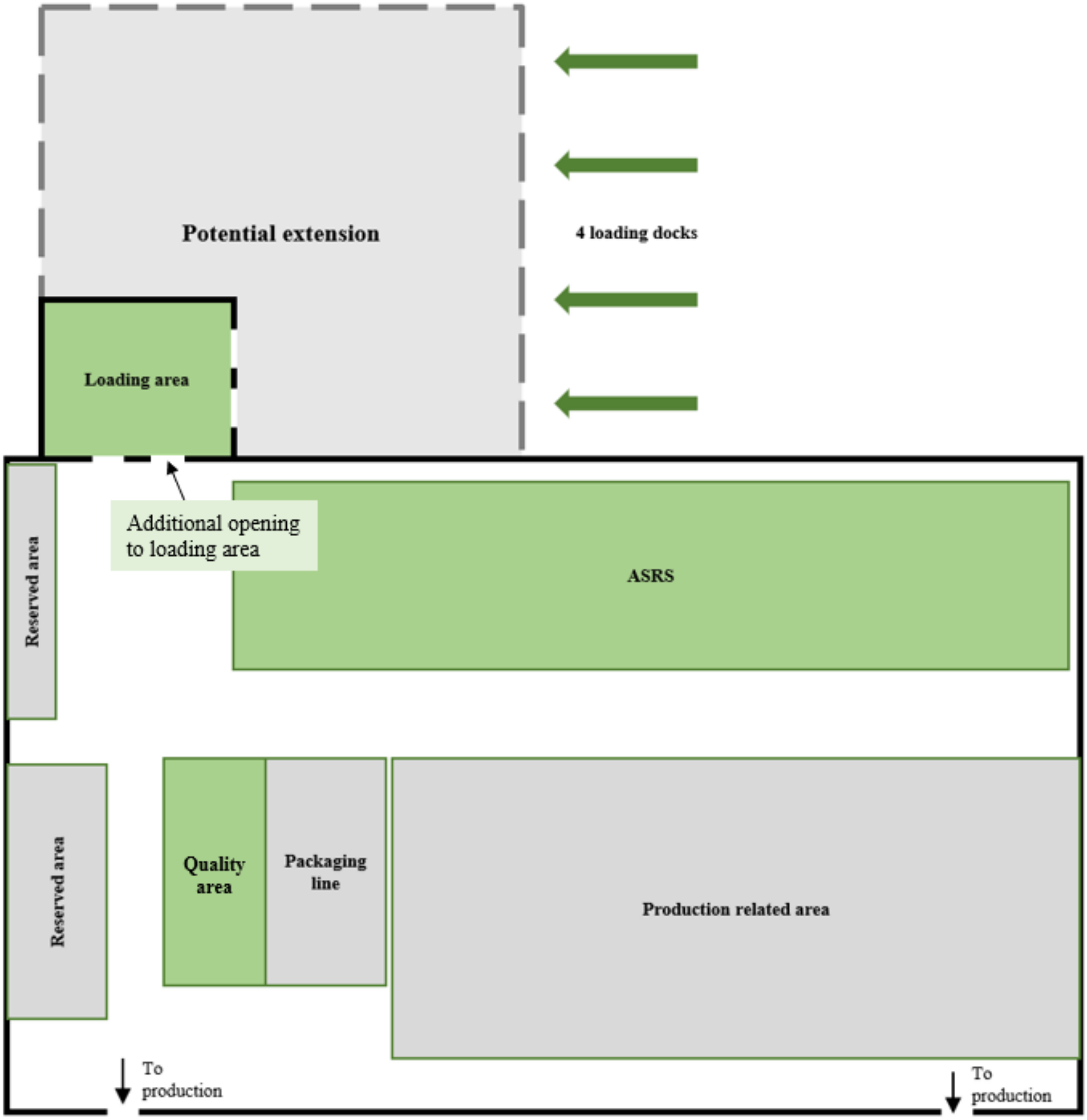


Figure 23: Physical layout of Company Alpha's outbound area, including the potential extension of the loading area.

As mentioned in the problem description of the thesis, Company Alpha will soon start to receive high volumes of empty, cleaned bins, but it is not yet determined where these should be stored. According to the Internal Logistic Developer, there is only one space available. This space is located right next to the packaging and is currently used as a quality area, see Figure 23 above. Currently, the area only consists of a tent and a couple of benches, which are easily removed since they are not fastened to the floor in any way. The dimension of the area is approximately 20x10 meters, with a floor area of 200 square meters. The Internal Logistic Developer continues that if there is an extension in the future, there would be a possibility to store the empty bins here. However, how much space that would be available is not determined, as the loading area mainly is for the outbound processes. The extension is only in the discussion phase for now, and it is estimated to take 18 months from construction start before it is ready for use. This vision is not shared with other company representatives. The Senior Planning and

Logistics Developer states that the loading area should not be used for storing the empty bins, as this is not clean enough, and it would compromise the cleanliness of the bins. He continues that the ASRS would be a possible location to store the bins as well.

4.1.2 Information system

Company Alpha has an ERP system that is currently developing, and they also have a WMS, however, these two systems are not fully incorporated with each other, and the development of the different software is continuously ongoing.

In the outbound area, the WMS is the system that is used the most. It holds information on storage locations in the ASRS, if they are occupied or not, what type of bin that is stored in a specific location in the ASRS, the number of bins in stock, and volumes of the different SKUs. The system also holds information regarding each SKU and item-ID, so that when scanning a bin, the item-ID will appear on the scanner and show what bin type it is. Other than this, the WMS is not that developed yet. The only storage locations it has information about in the outbound area are the ones in the ASRS. However, it is possible to add locations if necessary.

4.1.3 Equipment & Employees

The existing equipment in the area are two electric forklifts, which have a capacity of 1.6 tons and a maximum reach height of 7.87 m, see Table 13. They also have regular pallet jacks that are suitable for lower levels and moving goods horizontally. Additional equipment is handheld scanners, which are used when scanning goods upon arrival. These scanners have a display that shows what kind of bin it is when it is scanned.

Table 13: Forklift characteristics

	Number of forklifts	***Capacity***	***Maximum reach height***	***Total width***	***Working aisle width***
Electrical forklift	2	1.6 ton	7870 m	1099 mm	3269 mm

Regarding storage equipment, the area has an ASRS with limited space, and the rest is floor space. The ASRS has 5760 locations in total, and considering a wanted space utilization of 85%, this would mean 4896 storage locations. The ASRS operates at a slow pace, with an in- and outfeed of forty pallets per hour. See Table 14 for the ASRS characteristics.

Table 14: Characteristics of the ASRS

	Number of storage locations (100% utilisation)	***Number of storage locations (85% utilisation)***	***Operating speed***
ASRS	5760	4896	80 bins/hour

The slow operating pace has led to a discussion whether the empty bins should be stored in the ASRS or not. According to the Internal Logistics Developer, the empty bins can be stored in the ASRS for now, but as soon as production ramps up and the volumes increase there will no longer be room for the empty bins in the ASRS. The Senior Planning & Logistics developer agrees that there is space in the ASRS for now, but also believes that it is possible to store empty bins in the ASRS in the future. However, that would mean less space for finished goods, and a trade-off would have to be made. On the other hand, according to another Planning &

Logistics developer, the ASRS should not be used as storage for the empty bins, due to the slow operating pace and wanting to prioritize the storing and outfeed of finished goods.

Regarding the employees at Company Alpha, they currently work in three shifts, and the plan is to keep it like this in the future as well. The company did not provide how many operators that are currently working in the outbound area, and not what the plan is for the future. The employees at the 3PCF work two shifts from Monday to Friday.

4.2 Warehouse Operations

The processes in the area that already are carried out in the outbound area at Company Alpha can be seen in Figure 24. The outbound process starts when the finished goods are outfeed from the ASRS and prepared for shipping. The bins are moved to the loading area for pre-staging and inspection before they are picked up. The customers are responsible for the pick-up, and they can arrive whenever between 6.00 and 16.00.

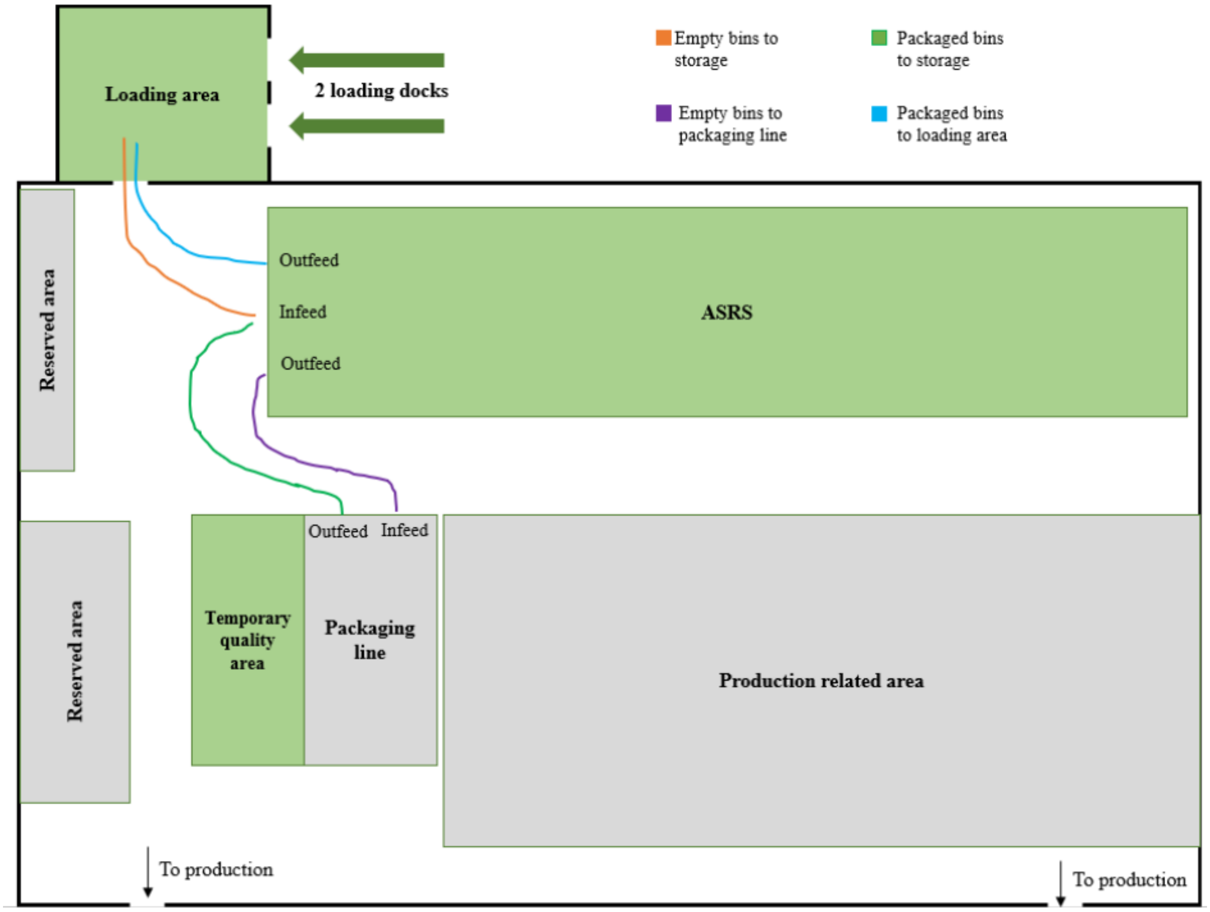


Figure 24: Visualisation of the movements connected to the operations in the outbound area at Company Alpha

Apart from the outbound activities, there are also some inbound activities in the area, where material related to production arrives in cardboard pallets. When the pallet arrives, it is scanned so the inventory is updated in the WMS system, and then they need to be repacked into plastic trays. The reason for this is that they are going to be stored in the ASRS where it is not possible to store cardboard pallets. Also, it is not allowed to store any cardboard in the production area since this may cause shedding of fibres and dust, compromising the cleanliness level of the area.

Another process is that the company has started a trial with receiving bins that have been manually cleaned, which are on a much smaller scale than the automatic cleaning process that will be carried out in the future, which is the one that this thesis focuses on. However, the process of transporting these bins and handling them once they arrive at the company can be investigated and used as an inspiration for the bins that are automatically cleaned. The processes will be described further in detail below.

4.2.1 Receiving

The receiving process begins when the goods arrive at Company Alpha since they are responsible for the pick-up. Once the 3PCF has a full truckload of cleaned bins, Company Alpha can collect the bins, as long as it is within the working hours of the 3PCF.

The bins are transported in full truckloads containing 72 bins and are transported in stacks of three. The bins are wrapped in plastic in order to maintain the cleanliness level of the bins. When the bins arrive at Company Alpha, the first step is to unload the bins. This is done in accordance with the handling recommendations in the packaging manual, by first unloading one bin on the top layer of the stack, and then the two below can be unloaded together. The unloading is done by one operator, who uses one of the electric forklifts. The unloading process of a full truckload of 72 takes approximately 30 minutes for one person.

After the bins have been unloaded, they are staged in the loading area, where the plastic wrap is removed from the bins. According to the Internal Logistics Developer, there are no inspections carried out on the bins. Instead, they are directly scanned with a handheld scanner, adding the bins as in stock in the WMS, and ready for put away. The bins that are manually cleaned are all of the same bin type, why it is not important to sort the bins.

According to the Senior Planning and Logistics Developer, the process of receiving the automatically cleaned bins should include similar activities. However, the bins will not be wrapped in plastic, as this is a waste of resources. The bins need to be covered in something in order to maintain the cleanliness, and one suggestion, for now, is to use reusable plastic hoods that can be used to cover the bins. However, this is a discussion that is currently ongoing at the company, and nothing is determined yet. In addition, the Senior Planning and Logistic Developer also want to add an inspection as part of the receiving process, in order to see whether any bins have been damaged during transit, even though it is only a 10-minute drive from the 3PCF to Company Alpha.

4.2.2 Put-away and Storage

After the bins have been scanned and their status have been updated in the WMS, it is time to put away the bins. This process is carried out with an electrical forklift, where the bins are picked one by one and driven to the ASRS. The bins get fed into the ASRS, which automatically scans the bins once again, updating their exact location in the WMS, and puts them away in a pallet location that is available. It is only possible to feed the ASRS with one bin at a time, and its capacity is 80 bins per hour, meaning that it takes approximately 45 seconds to enter one bin into the ASRS.

The storage policy used in the ASRS is shared storage, since everything is automatised and the system keeps track of what SKU is stored where. This is more space efficient and increases the space utilisation.

It is not clear whether the ASRS will be used as storage for the empty bins that have been automatically cleaned, meaning that additional steps may have to be added for the process of putting away and storage of the bins that have been automatically cleaned. Depending on where they will be stored, it has to be determined whether a shared or dedicated storage policy should be used, and how they should be stored.

In order to decide how the bins should be stored it is important to consider the next step after the bin has been stored. According to the Planning and Logistics Developer, the bins are feeding the packaging line after they have been stored. According to the Material Flow Automation Engineer, the bins need to be fed into the packaging line from the long side of the bin in order for the packaging line to function. However, which long side is not yet determined. The Senior Planning and Logistics Developer continues that there needs to be a standard where the bins are fed into the packaging line consequently from the same side. The reason for this is that it should be possible to know the orientation of the cells without having to open the lid of the bin. This is a factor that needs to be considered when putting away the bins, as this affects how the bins are picked.

4.2.3 Summary of the warehouse operations

Figure 25 below visualises the material flow and movements related to receiving and put-away and storage of the bins that have been manually cleaned. This figure shows where the activity takes place at a current state and plays an important role in understanding where in the outbound area most of the activities are performed.

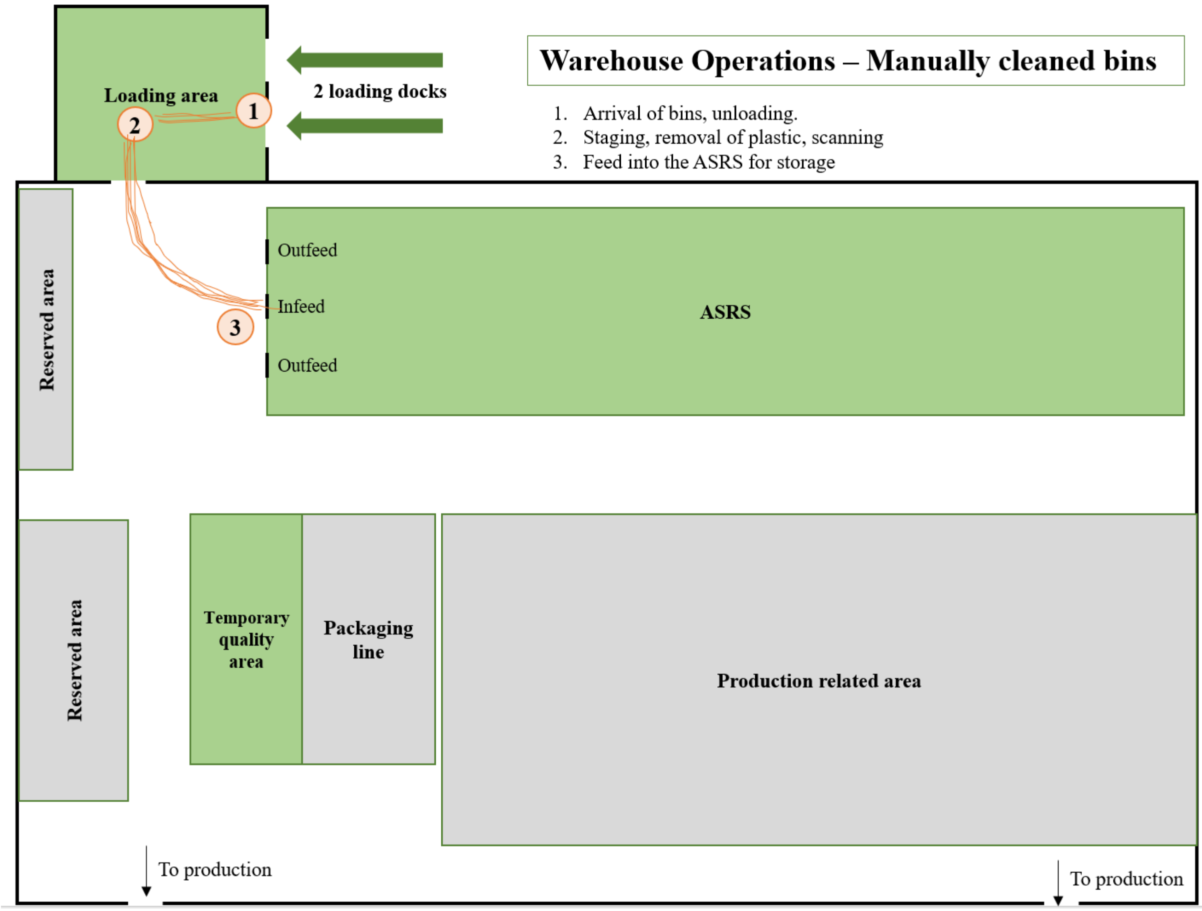


Figure 25: Spaghetti chart visualising the material flow and movements of the bin, and where the processes are carried out.

The flowchart below, see figure 26, visualises the activities that are included in the process of receiving and put-away and storage of the bins that have been manually cleaned, as it is now. It also shows the handling time per activity and bin, which is 86 seconds, or 1 minute and 26 seconds.

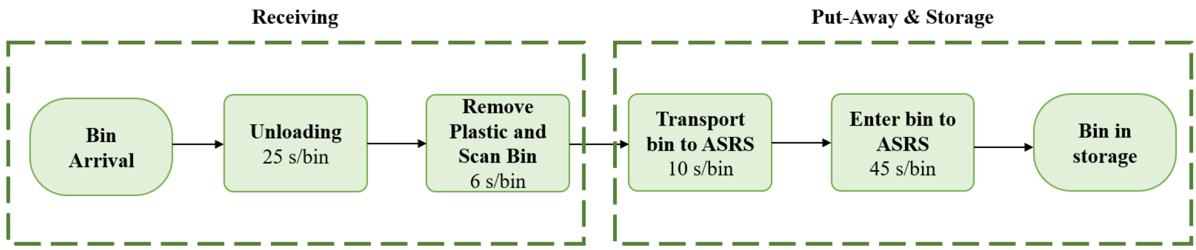


Figure 26: Flowchart describing the sequence of the activities performed and the time it takes per bin

4.3 Warehouse Contextual Factors at Company Alpha

This chapter will describe Company Alpha and the outbound area as it is today. Contextual factors such as the product characteristics, demand profile, and the assortment will be presented in this chapter, in order to create an overview of the current state of Company Alpha's outbound area, and the current contextual factors.

4.3.1 Product characteristics

The product characteristics are factors such as size, weight, and if they have specific handling and storing requirements. For the product that is considered in this thesis, the handling and storing requirements play a big role, hence this will be presented in a sub-chapter on its own. All of the information below has been collected from internal material provided by the Lead Packaging Engineer, as well as complementary interviews with the Lead Packaging Engineer, the Senior Planning & Logistics Developer, and the Internal Logistics Developer.

The product is a reusable plastic bin with a lid and inner layers with different inserts depending on what customer it is for. The bin is used to pack finished cells and ship them to customers. The dimension of the bin is the same as a regular euro pallet 2, *EPAL 2*, which is a standard commonly used within the automotive industry. The dimensions of the bin without the lid are 1200x1000x750 mm (LxWxH). Dimensions of the bin including the lid are 1213x1013x778 the lid and the weight of an empty bin including the lid and inner layers is approximately 92 kg. Due to some nesting features in the design, the stacking height of the bin with the lid is 760 mm: a 2+1 stack of bins is calculated as 760+760+778 = 2298mm. See Table 15 for a summary of the product characteristics.

Table 15: Summary of product characteristics

Characteristic	***Value***
Length (no lid/with lid)	1200/1213 mm
Width (no lid/with lid)	1000/1013 mm
Height (no lid/with lid)	750/778 mm
Weight (empty bin + lid + inner layers)	92 kg
Number of SKUs	6

Visually, the bins are identical from the outside, but the insides are adapted to different cell types, which is why it is crucial to prevent any mix up of the bins. When they arrive from the 3PCF, they are only labelled with a dangerous goods label and two QR code plates, which are a permanent part of the bin. The QR codes hold information regarding the item-ID connected to the bin. The different bin types have a unique item-ID, meaning that when scanning the QR code, the bin type is displayed, which is an additional way to separate the bins. The dangerous goods label is approximately 10x10 cm and has a coloured background where the different bin types have a unique colour. Visually, these colours are the only thing that separates the bins from the outside. See Figure 27 for a simplified image of the bin.

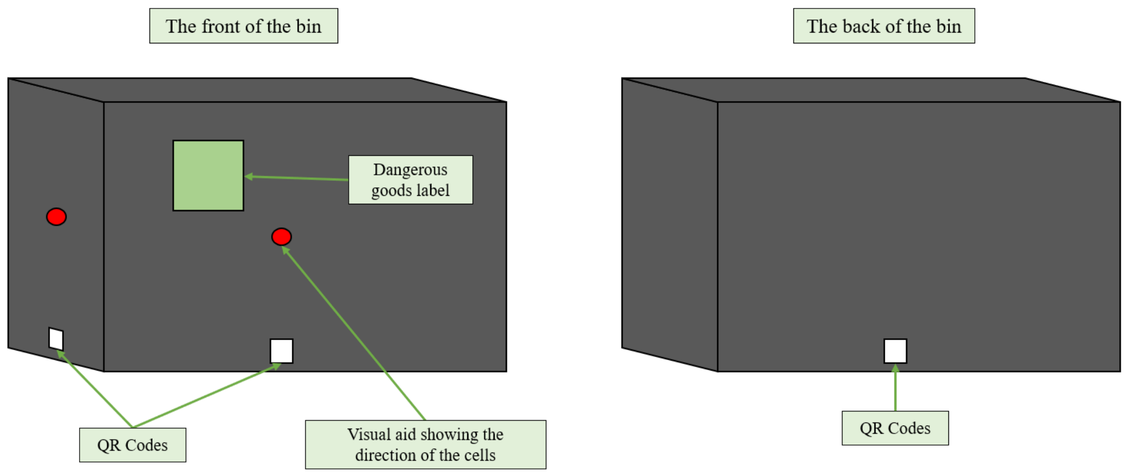


Figure 27: Simplified image of the reusable bin

4.3.2 Cleanliness requirements

The cleanliness requirements are mostly focused on the cleanliness of the cells, and not directly on the packaging that holds the cells. The requirements are that the cleanliness should follow TecSa and VDA 19 requirements and recommendations. TecSa stands for Technical Cleanliness and is a standard commonly used in the automotive industry. VDA 19 is a European standard for inspection of technical cleanliness focusing on particulate contamination of functionally relevant automotive components.

The focus of these standards is the size of the particles on the automotive components, which in this case are the battery cells. This indirect also puts certain requirements on the packaging. In the guidelines, it is stated that the layer of packaging that is in contact with the components must meet the same cleanliness requirements as the components. Connected to the packaging, this refers to the inside of the packaging since this is the only part that is in contact with the cells. The rest of the requirements connected to cleanliness and how to handle the packaging accordingly refer to when the cells are packaged in the bins, which is not of interest in this thesis.

4.3.3 Handling and storage requirements

The bins are stackable and can be stacked three units during transport, and six units when storing. It is not recommended to stack bins outside of the recommended guidelines, since this can damage the bins. When loading the bins in a transport unit it is important that they are loaded in a way that rear unloading can be performed. A total of 72 bins fit in a 28-ton truck. When loading the bins, it is recommended to first load one bin, and then stack two additional bins on top of the first bin, since there is a risk of damaging the bins if trying to load three bins stacked at the same time. Consequently, the same goes for when unloading the bins.

The bin can only be stored indoors, and it has to be stored in dry environments at an ambient temperature between 18-25 °C. The reason for this is that it is hard to ensure the proper cleanliness requirements if stored in other conditions than this. In order to maintain the desired cleanliness level, it is stated that the lid should only be opened in an appropriate environment with appropriate tools and workwear.

4.3.4 Customer Characteristics & Assortment

Customer characteristics refer to the number of customers and the type of customer. From the outbound area that this thesis focuses on, Company Alpha will handle the demand for six different customers. Each customer has similar cleanliness requirements, but they have their own specific bin type, which are the SKUs handled in the outbound area. Consequently, the number of SKUs is equal to the number of customers, namely six.

The contextual factor assortment refers to the number of SKUs and whether new SKUs are introduced. According to the SIOP numbers and the Senior Planning and Logistics Developer, the number of SKUs will remain the same over the time period investigated, and after this time period as well, meaning that no new SKU will be introduced or removed. However, the volumes of each SKU vary from year to year, hence the most popular SKU varies consequently. The assortment of SKUs and the respective percentage of the total volume can be seen in Figure 28.

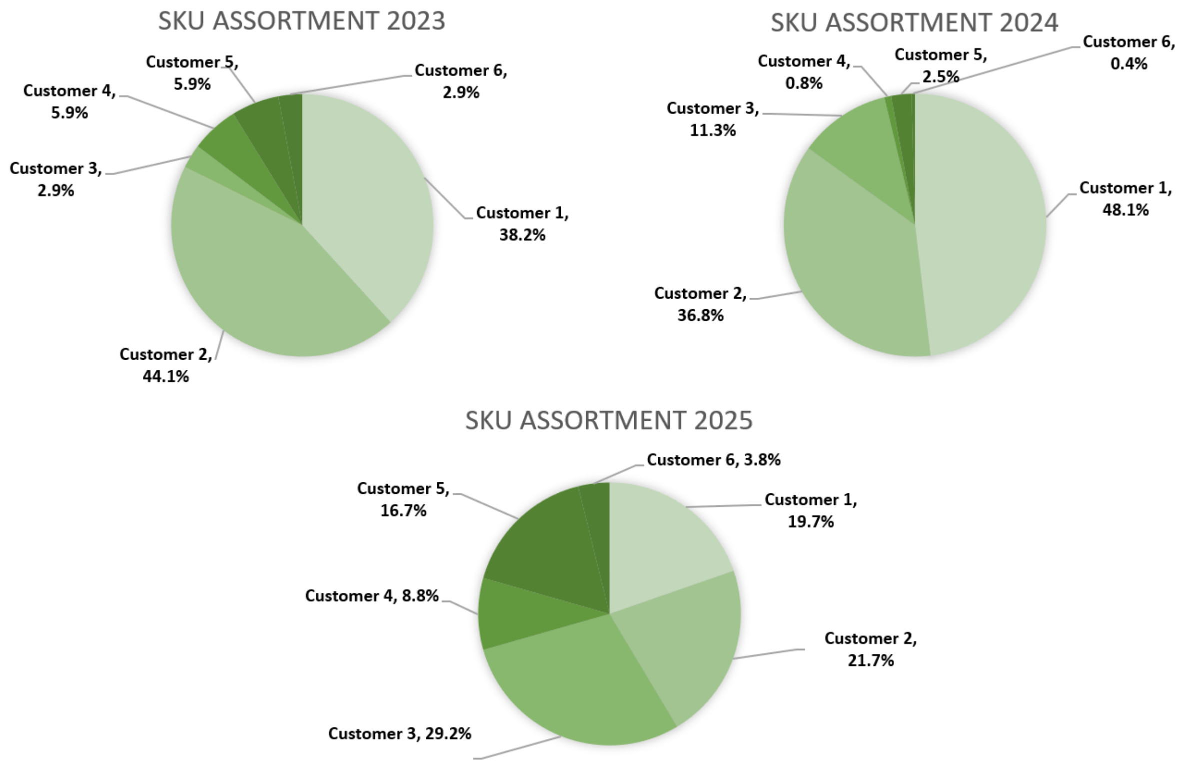


Figure 28: SKU assortment for 2023, 2024, and 2024.

4.3.5 Volume profile

The contextual factor volume profile refers to the throughput of the warehouse and the popular SKUs. The popular SKUs have already been presented in the previous sub-chapter regarding the assortment and can be seen in Figure 30. This sub-chapter will present the forecasted volumes, both in total and per SKU, divided over the years 2023, 2024, and 2025. There are numbers available all the way to 2030, but according to the Senior Planning and Logistics Developer, these volumes will be handled by more warehouses than just the one this thesis is focusing on, but the amount the different warehouses are going to handle is not determined yet, why only volumes for 2023 to 2025 will be considered. It is important to keep in mind that the numbers are only forecasted and may change in the future. However, the volumes are based on contracted volumes for each customer, so the biggest risk is not that the volumes may increase but that the timeframe change when the cells are to be delivered.

The forecasted volumes are based on the SIOP numbers that were released in March 2023. As previously mentioned, the volumes vary depending on the year and customer. The forecasted volume of bins has been calculated from the number of cells that are being produced for each customer, and these volumes are contracted with each customer. The bin demand directly correlates to the number of cleaned bins that need to be handled in the return flow to Company Alpha, since it is assumed that no new bins need to be purchased. The volumes of bins that will be handled at Company Alpha can be seen in Table 16 and Figure 29, which show the forecasted volumes from 2023 to 2025.

Table 16: Bin demand per day for 2023 to 2025

Customer	***2023***	***2024***	***2025***
Customer 1	26	230	174
Customer 2	30	176	192
Customer 3	2	54	258
Customer 4	4	4	78
Customer 5	4	12	148
Customer 6	2	2	34
Total	68	478	884

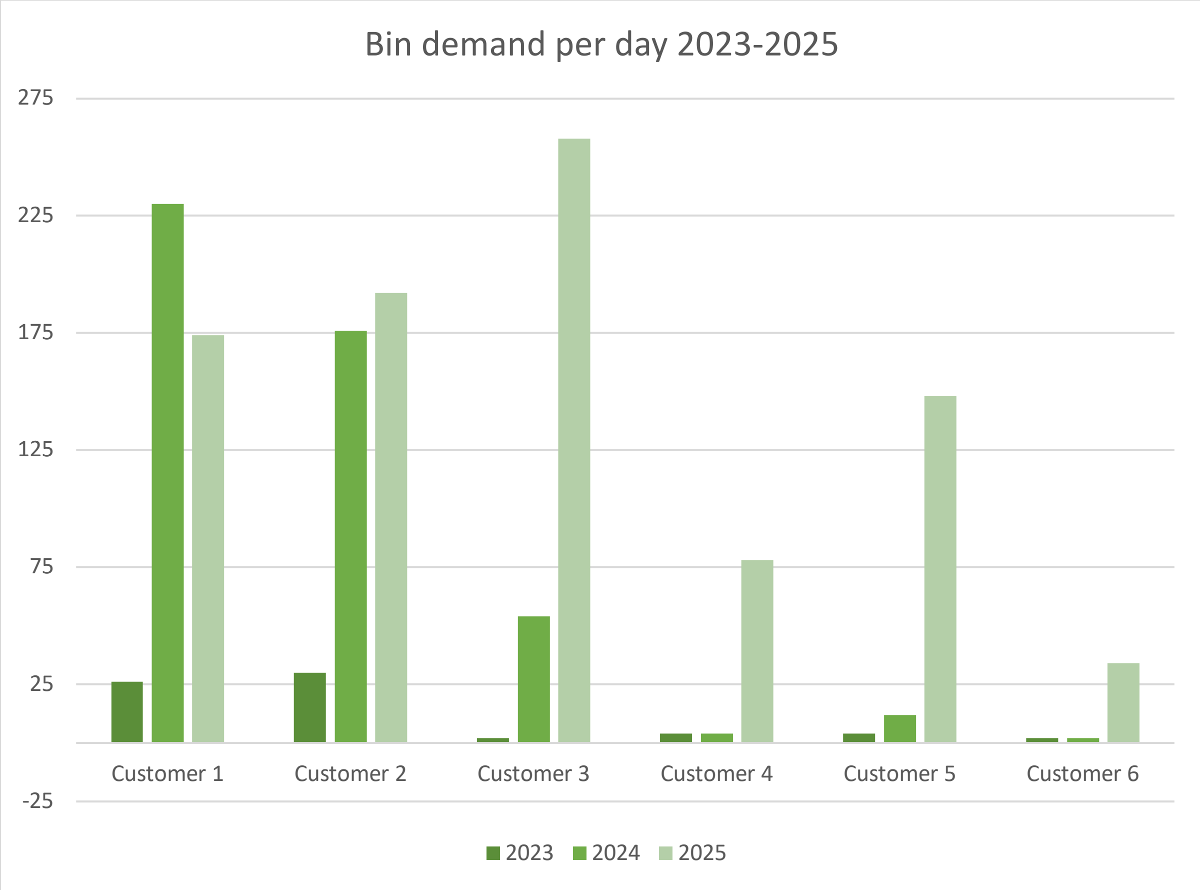


Figure 29: Bin demand per day for 2023 to 2025

4.3.6 Demand profile

The demand profile refers to seasonality and how often SKUs are picked. According to the Planning and Logistics Developer, the empty bins are feeding the packing line, meaning the next step in their journey after being stored is to enter the packaging line to be filled with cells.

How often the bins will be picked depends on the capacity of the packaging line and when the different bin types are being packaged. According to the production planner, there is currently no schedule for when each bin type is to be packaged, and no plan for how this is to be done in the future. Hence, it has to be assumed that one bin type is packaged at a time, but that it is possible that all bin types are needed every day. The capacity of the packaging line refers to the cells it can handle per min. Since the number of cells varies between the different bin types, the number of bins the packaging line can handle per hour depends on the bin type. Due to confidentiality reasons, the capacity of the packaging line will not be disclosed in the thesis, but it has been used to calculate the capacity connected to each bin type, which is presented in chapter *5. Analysis and Discussion.*

4.4 Performance

From the interviews with the company representatives, it is clear that there has not yet determined what KPIs to use and how they should measure the performance of the return flow of the bins and the performance in total. They are currently keeping track of the space utilization of the ASRS, but this is the only KPI that is considered for now. Regarding this, the goal is to have a space utilisation of 85% in order to be able to handle occasional fluctuations in volume.

Since the return flow of the bins that have been automatically cleaned has not started yet, there are no KPIs connected to this. However, one aspect that they mentioned as an interesting factor to keep track of was the handling time per bin, as this affects the whole flow.

4.5 Third-Party Cleaning Facility

The contract with the 3PCF is yet to be finalized, but the assumptions are that they, apart from cleaning the bins, will act as a third-party warehouse and that the bins will be cleaned upon arrival at the 3PCF and then stored at their facility until Company Alpha needs the bins. The 3PCF is located approximately 7km from Company Alpha, which is equal to a 10 min drive.

The 3PCF will be staffed by the external company, and they will work in two shifts, Monday to Friday, meaning that they only can deliver the bins during these hours. The Senior Planning and Logistics Developer further points out that the packaging line is planned to run 24 hours a day, hence there needs to be bins in stock during the weekend. Since the 3PCF only can deliver during weekdays, they will be responsible for making sure that they have cleaned packaging in stock and ready when Company Alpha needs them. Company Alpha will then be responsible for the pick-up and transportation from the 3PCF to Company Alpha.

5. ANALYSIS & DISCUSSION

The following chapter will include an analysis of the data presented in the previous chapter and discuss the study and the conducted analysis. The data analysis and discussion will have its base in the frame of reference and the empirical findings. The aim is, by applying the presented theory regarding warehouse configuration and warehouse contextual factors to the empirical data, to find a solution to how the empty bins can be stored internally. The tool of process mapping is intended to provide information regarding the current flows and processes in the outbound area, as well as being used to design the return flow processes of the automatically cleaned bins.

This thesis focuses on the return flow of reusable packaging and where and how these should be stored internally at Company Alpha. More specifically, it aims to design the processes and storage location that are needed for the return flow to run smoothly, be incorporated with the already existing activities in the outbound area, and meet all of the additional requirements regarding cleanliness, storing and handling. In order to design these, it is important to first define the process and what activities it should include.

In order to create a visual understanding of where processes are needed, we use process mapping. When creating a process map, one should start with collecting the data needed and then creating an "as-is map", which is used to build an understanding of how the processes are, as is (Ornat & Moorefield, 2019). The collected data is presented in the empirical chapter, and it is this data that is used to create the process maps. In Figure 30, a version of a flow chart describing the different processes and the order they have in the return flow process, and how these interact with each other. The figure visualises that the processes of receiving and put-away and storage are sub-process in what is called the return flow processes in this thesis. It further visualises that the subprocesses can be divided into activities that will be performed in order to reach the wanted outcome of the process. The subprocesses will be described further in the following chapter.

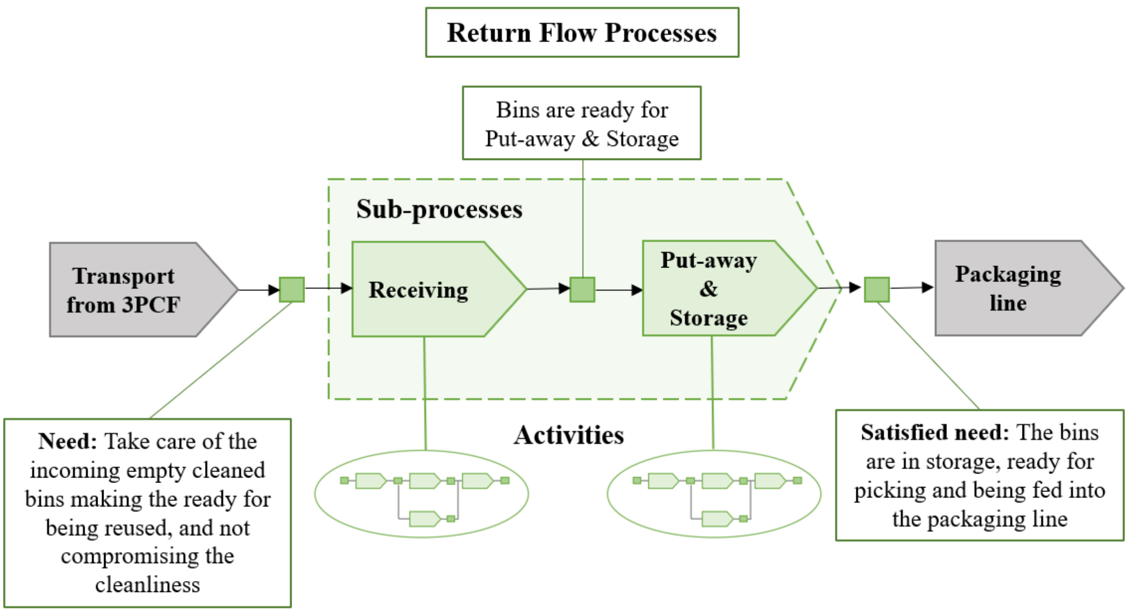


Figure 30: Visualisation of the return flow processes, the sub-processes it includes, the order they are carried out and the adjacent processes.

In addition to the return flow processes, the goal of this thesis is also to present a solution for the storage of the empty cleaned bins. For this, theory within warehouse configuration and warehouse contextual factors will be used. The analysis will start with an analysis of the contextual factors, and later continue into an analysis and discussion of how the warehouse configuration can be matched with the contextual factors.

5.1 Warehouse contextual factors

According to Kembro & Norrman (2020), it is crucial to know the goal of the warehouse in order to create a design and configuration that will work to meet these goals. It is further emphasised that the warehouse configuration needs to be matched to the contextual factors in order to improve the warehouse performance and to apply a contingency approach and change the configuration as the context changes.

The warehouse contextual factors of Company Alpha were presented in Chapter 4.3, where the main factors presented were product characteristics, customer characteristics, assortment, demand profile, and volume profile. The contextual factors are all related in such that they influence each other.

Based on the contextual factors presented in the empirical chapter, as well as the rest of the empirical findings and the frame of reference, the warehouse configuration can be analysed, and a suggestion of how and where the bins should be stored, as well as the return flow processes can be presented.

The current warehouse configuration at Company Alpha is not adapted for the increasing volume of returned empty bins. As of now, the empty bins that are arriving at Company Alpha are being manually cleaned by the 3PCF and are only arriving in small volumes. In order to match the configuration to the contextual factors, the changes in these need to be investigated.

5.1.1 Warehouse goals

As the theory clearly states, when designing a warehouse, or part of a warehouse, step one is to understand what kind of warehouse it is, a distribution or production warehouse, as this affects the goals of the warehouse (Gu et al., 2010; Rouwenhorst et al., 2000). Applying this to Company Alpha, the warehouse as a whole can be seen as a distribution warehouse, as its main function is to store finished goods and distribute these to Company Alpha's customers. Looking at the return flow of bins and storage of these, the storage area can also be considered to have a distribution focus. The reason for this is that the empty bins are feeding the packaging line but is not part of the production. In this case, the packaging line can be seen as the "customer" the storage area is supposed to serve, and the demand is depending on how often the packaging line is in use and packages cells into bins. Rouwenhorst et al. (2000) state that a distribution area often aims to maximize the throughput, which can be applied at Company Alpha, as the packaging line should not have to wait for bins since that may act as a bottleneck.

It is also important to consider where in the supply chain the warehouse is positioned and what kind of flow it handles (Dowlatshahi, 2012). Company Alpha will handle both a forward flow when distributing finished goods to customers, and a reverse flow when receiving the empty, cleaned bins, meaning that these have to be adapted to each other, so they affect the respective processes. As the space at Company Alpha already is limited, and having to share the space with other processes, the storage of the empty bins should maximise the space utilisation.

As previously stated, the empty bins feed the packaging line, meaning that they will be picked up from where they are stored and entered into the packaging line, where they are filled with cells. Since there are different bin types being handled it is crucial to store the empty bins in a way that prevents any mix-up or faulty picking. If there were to be a mix-up, and the wrong bin type is entered into the packaging line, there is a risk that both the cells, the packaging line, and the bin gets damaged, leading to high costs.

Concluding what has been discussed, it is clear that the storage of the empty cleaned bins should serve three main purposes: (1) maximise space utilization, (2) feed the packaging line in an efficient way preventing any mix-up, and (3) maintain the required cleanliness level of the bins.

5.1.2 Product Characteristics

According to theory regarding contextual factors, the product characteristics affect the space needed to store the SKUs as well as the choice of storage policy (Kembro & Norrman, 2020; da Cunha Reis et al., 2017; Faber et al. 2013). The product characteristics for the reusable bins are presented in Chapter 4.3.1.

From the dimensions presented in the empirical chapter, the floor area required for one bin can be calculated. One bin needs an area of approximately 1.23 square meters. The packaging manual stated that when being stored, a maximum of six bins can be stacked on top of each other, meaning that a maximum of six bins will require 1.23 square meters. The number of bins that can be stacked can also be considered as a constraint that may affect the storing method, as well as the equipment needed. Six bins stacked on top of each other is equal to a total height of 4.58 meters from the floor to the top bin, which would require a forklift that can reach at least 4.19 meters, in order to be able to reach and remove the top bin. See Figure 31 for a demonstration of how the minimum reach capacity was calculated.

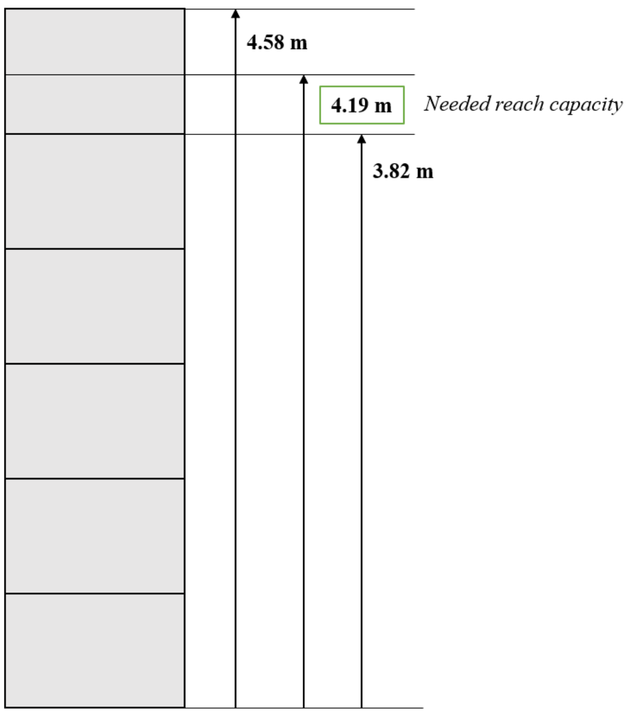


Figure 31: Visualisation of six bins stacked on top of each other and the respective heights and how much a forklift needs to be able to reach

Product characteristics also include the handling and storage requirements of the products. Connecting this to Company Alpha this refers to the handling and storage requirements of the bins. As mentioned in the empirical chapter, there are cleanliness requirements for the bins which have to be complied with. However, these requirements are only referring to the part of the packaging that is in direct contact with the cells, which is the inner layers of the packaging. When the bins arrive at Company Alpha, they have been thoroughly cleaned, so they meet the desired level of cleanliness, and the lids are closed. In order to maintain the cleanliness level of the inner layers of the bin, the lid should be kept on the bin the entire time until they are entered into the packaging line. The cleanliness requirements also have an impact on where the bins can be physically stored at Company Alpha.

5.1.3 Volume profile

As seen in the empirical chapter, the volumes that are being considered are the ones for 2023 to 2025. Figure 32 presents the total volume during this time period, and Figure 33 presents the volumes for each customer during the same period. As seen in Figure 32, the volumes are increasing quite significantly during this period. Between 2023 and 2024, the volume increases by 603%, and from 2024 to 2025 the increase is 85%. This trend is not the same when looking at the customers individually. Looking at Figure 33, it is seen that Customer 1 has its peak in demand during 2024. For Customers 2, 3, 4, 5, and 6, the demand increases over the years, where they take turns in having the highest demand.

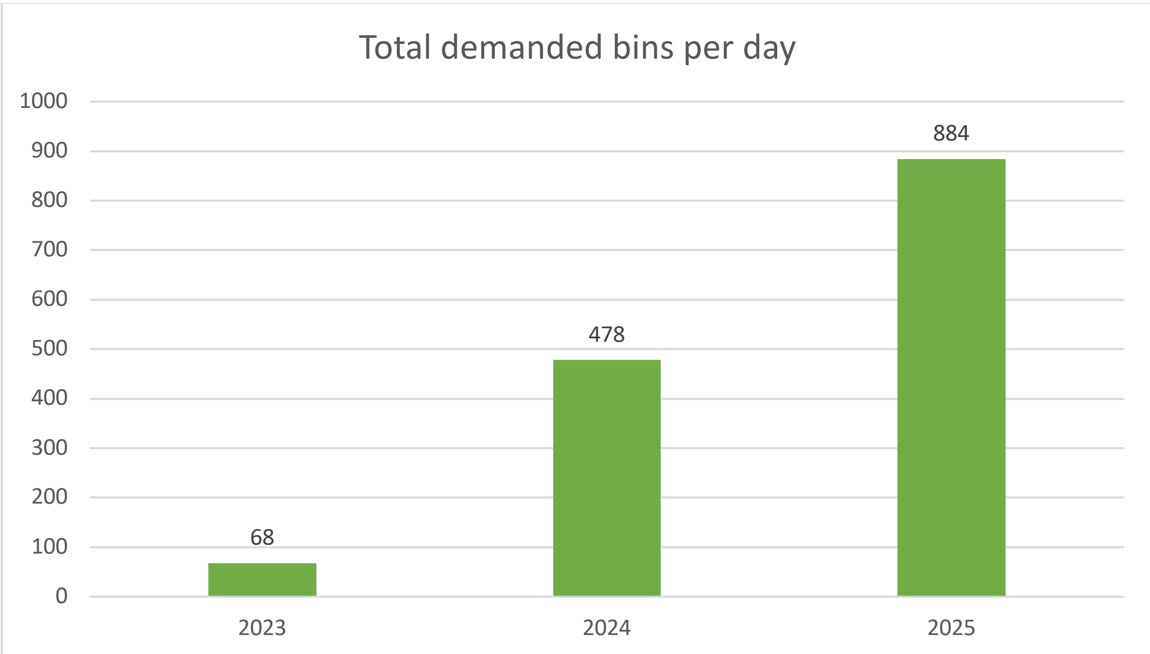


Figure 32: Total demand of bins per day for 2023 to 2025

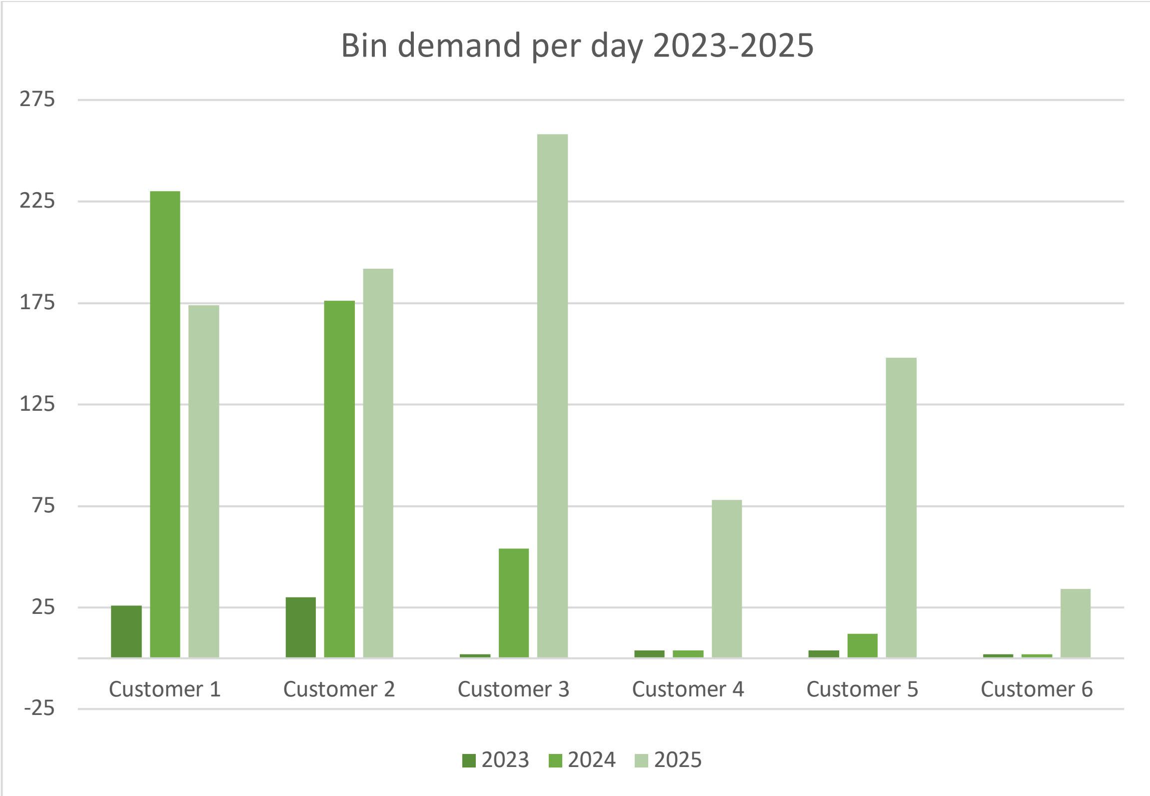


Figure 33: Bin demand per day for 2023 to 2025 for each customer

The number of bins demanded correlates with the space needed, as one bin will occupy one pallet location. Hence, the total demand of bins will be equal to the pallet locations needed. From the daily demand the floor space for each SKU and the number of pallet locations needed is calculated for 2023 to 2025, and the values can be seen in Table 17.

Table 17: Number of pallet locations and storage area required per day for 2023, 2024, 2025.

2023	***Bins/day***	***Pallet locations /day***	***Storage area required (m^2)***
Customer 1	26	26	6.14
Customer 2	30	30	6.14
Customer 3	2	2	1.23
Customer 4	4	4	1.23
Customer 5	4	4	1.23
Customer 6	2	2	1.23
Total	**68**	**68**	**17.29**
2024			
Customer 1	230	230	47.92
Customer 2	176	176	36.86
Customer 3	54	54	11.06
Customer 4	4	4	1.23
Customer 5	12	12	2.46
Customer 6	2	2	1.23
Total	**478**	**478**	**100.76**
2025			
Customer 1	174	174	35.63
Customer 2	192	192	39.32
Customer 3	258	258	52.84
Customer 4	78	78	15.97
Customer 5	148	148	30.72
Customer 6	34	34	7.37
Total	**884**	**884**	**181.86**

5.1.4 Assortment

While the total number of bins increases over this period, the demand for each customer varies, meaning that the volume for the different SKUs varies from year to year as well. Figure 34 displays the SKU assortment for each year and the share each customer represents of the total volume. From these figures we can see that Customer 2 has the highest demand in 2023, Customer 1 has the highest demand in 2024, and Customer 3 has the highest demand in 2025. We also see that even if some customers may have a low demand for some years, the number of SKUs remains the same over the years.

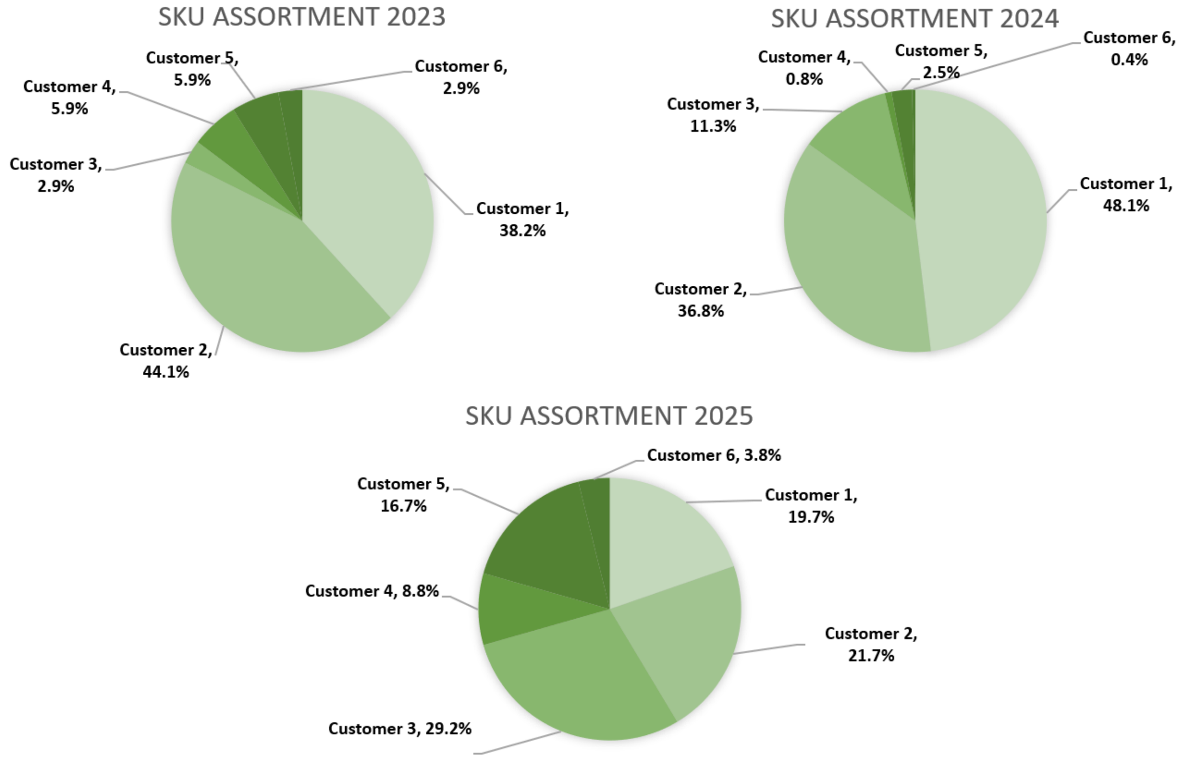


Figure 34: SKU assortment and the percentage of the total demand they make for 2023 to 2025

5.1.5 Demand profile

The demand profile refers to the seasonality of demand and how often the SKUs are picked (Kembro & Norrman, 2020). There is no seasonality in demand, as the volumes required are the same every day. As previously mentioned, the empty bins feed the packaging line, meaning that once they are picked, they are directly entered into the packaging line. Consequently, the capacity of the packaging corresponds to how often the bins are picked. From the capacity for each bin type, the time required to pack one bin and the total time required for the daily demand is calculated. See Table 18 for the time required.

Table 18: Overview of the time per bin and the time required to meet the demand for one day for 2023 to 2025

2023	***Bins/day***	***Time/bin (sec)***	***Time required daily bin demand (hrs)***
Customer 1	26	54	0.39
Customer 2	30	54	0.44
Customer 3	2	118	0.07
Customer 4	4	54	0.06
Customer 5	4	59	0.07
Customer 6	2	52	0.03
Total	**68**		**1.06**
2024			
Customer 1	230	54	3.44
Customer 2	176	54	2.63
Customer 3	54	118	1.76
Customer 4	4	54	0.06
Customer 5	12	59	0.20
Customer 6	2	52	0.02
Total	**478**		**8.12**
2025			
Customer 1	174	54	2.60
Customer 2	192	54	2.87
Customer 3	258	118	8.42
Customer 4	78	54	1.17
Customer 5	148	59	2.42
Customer 6	34	52	0.49
Total	**884**		**17.98**

The time required to package the daily bin demand assumes that there are no stops in the packaging line. This time is equal to the time it takes for the storage area with the daily demand of bins to be emptied. We see that in both 2023 and 2024, the time required for packaging is less than 16 hours, which is the number of hours worked when working two shifts. The time also indicates that in terms of space, it would be feasible to receive multiple shipments per day and restock the area directly when the goods arrive.

5.1.6 Summary contextual factors

The previous chapters have discussed the warehouse contextual factors of Company Alpha. If applying a contingency approach to warehouse configuration, the configuration should be matched to these contextual factors in order to improve warehouse performance (Kembro & Norrman, 2021). Table 19 presents a summary of the contextual factors presented and how they affect the warehouse configuration of Company Alpha.

Table 19: The contextual factors and how they affect the warehouse configuration

Contextual Factor	***Configuration it affects***
Product Characteristics	Physical layout in terms of space required to store one bin, and storage requirements. The handling requirement affects the warehouse operations of receiving and put-away.
Volume profile	The space required for each year. It also affects the receiving and put-away in terms of time required
Customer Characteristics & Assortment	The number of customers is the same as the number of SKUs. This, and the assortment, affects the storage policy and the configuration of the storage area.
Demand profile	How often the bins are picked and the picking process. Affects how often it is possible to restock the storage are.

5.2 Warehouse configuration

5.2.1 Physical layout

When deciding where the storage should be, it is important to consider its relation to where receiving and shipping is located (Bartholdi III & Hackman, 2019). When applying this to Company Alpha, we need to consider the relation to where the bins are received, and where the packaging line is located, since this is the step following after the bins have been put away for storage. In addition to the locations, it is important to consider the space utilisation and aisle configuration. Apart from this, the storage requirements for the bins need to be considered.

In Figure 35, the current movement in the outbound area is visualised with the help of a spaghetti diagram. A spaghetti diagram is useful when wanting to show or analyse a physical movement of an object, material flow, or employee through a process or system, and can be used to identify bottlenecks (Pyzdek, 2021; Senderska et al., 2017). By using a spaghetti chart to analyse the current processes taking place in the outbound area, areas where congestion may occur can be identified. This can then be used to see how the new return flow of empty bins can be incorporated with the already existing flows without increasing the risk of congestion or bottlenecks.

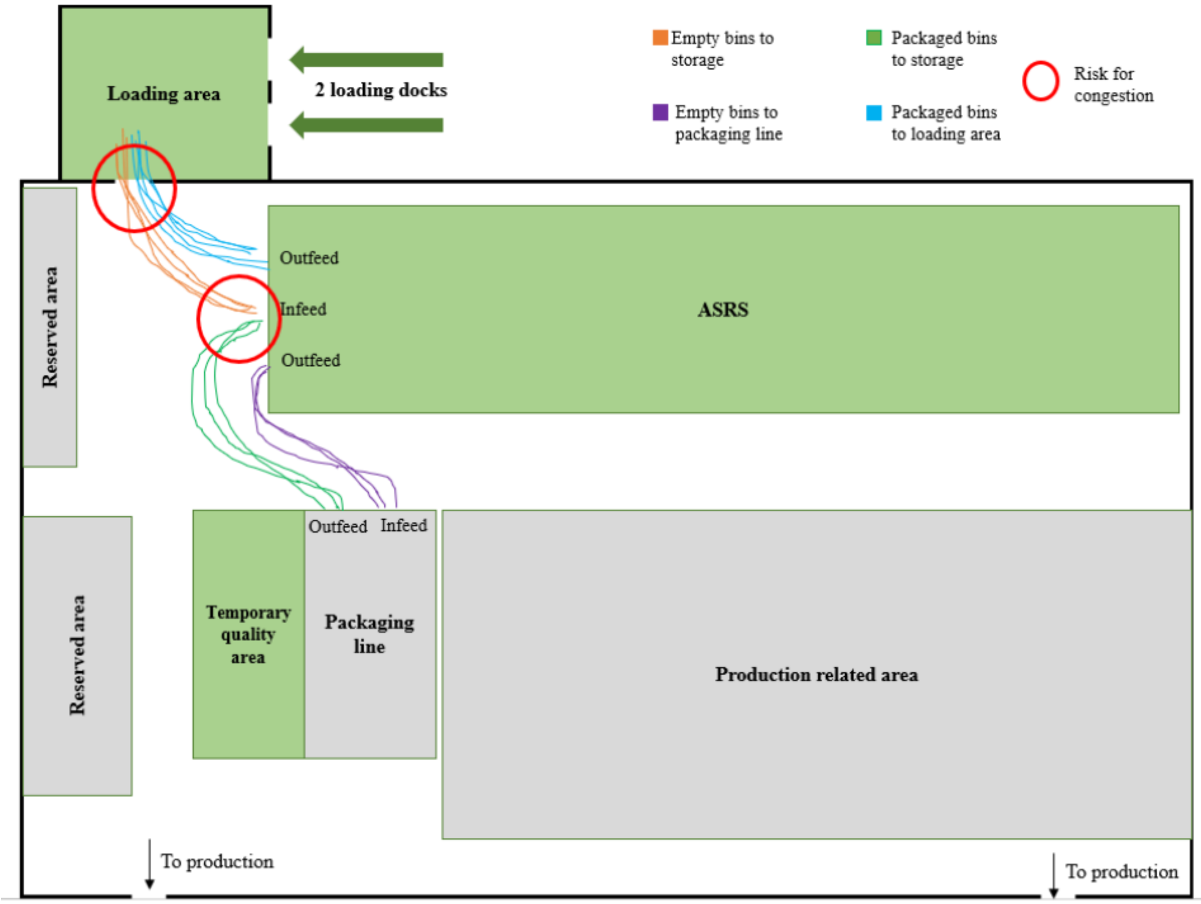


Figure 35: Spaghetti chart visualization of the current movements in the outbound area and where there is a risk of congestion.

In Figure 35, the outbound process of shipping finished goods and the current return flow process connected to the small volume of the bins that have been manually cleaned is visually represented with the different lines. We see that both the empty bins and the bins full of cells are stored in the ASRS. Although this location is close to both the location of receiving and the packaging line, it may not be the best location to store the empty bins in the future when the volume increases considering the rest of the flow. As seen in the figure, the majority of the movements take place either by the ASRS or the loading area, especially by the opening between the loading area and the outbound area. In order to facilitate continuous movements with unnecessary stops, it would be beneficial to spread out the activities in the area, so they are not at the same place.

As the Internal Logistics Developer stated, there is only one space available at the moment that would be a suitable location to store the bins, which is the space right next to the packaging line, see Figure 36.

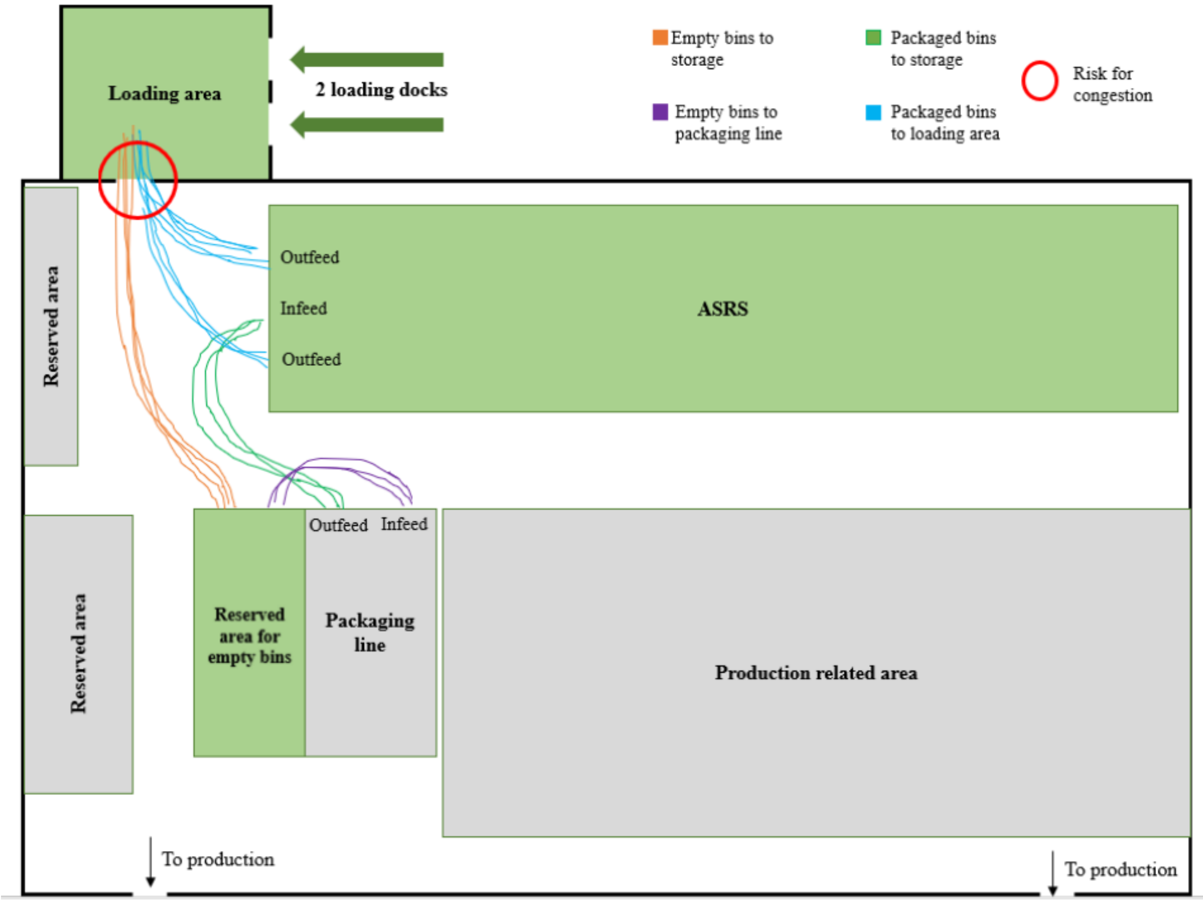


Figure 36: Overview of the reserved area for the empty bins in relation to where the bins are received and the packaging line, as well as the other activities in the warehouse.

The distance from where the bins are received to this space is approximately twice as long as the distance to the ASRS, and it is located right next to the packaging line. The figure shows how the flows would look if having the storage of the empty bins in this area instead of the ASRS. There would still be a lot of movement between the loading area and the outbound area, but not as much by the ASRS, since two activities would not be performed there anymore, the infeed and outfeed of empty bins. By not storing the empty bins in the ASRS, the capacity can be used to feed out finished goods and prepare them for shipment, feeding in packaged bins, and also leaving more room for storing finished goods. However, the new location would mean a couple of crossovers in the movements of the different flows. This could potentially lead to some congestion, but not necessarily, as it depends on when the activities are performed.

The company representatives all mentioned that there would be a potential extension, which would mean a bigger loading area, 2 additional loading docks, and one additional opening between the loading area and the outbound area. The bigger loading area would mean a significant increase in space available. However, considering the storage requirements and that the bins have to maintain a certain cleanliness level, it is not recommended to use this space to store the bins firsthand, since this area holds packing material such as cardboard and other disposable material. As there is a lot of movement in the loading area, whit loading docks opening and closing, this increases the risk of the area being too dirty to make a suitable storage location for the empty cleaned bins.

As mentioned, the extension would also mean an additional opening between the loading area and the outbound area, which would lead to a significant improvement in the flow. By having an additional opening, the two openings could be unidirectional, reducing the risk of congestion between the loading area and the outbound area. See Figure 37 for a visualisation of the flows when having two openings.

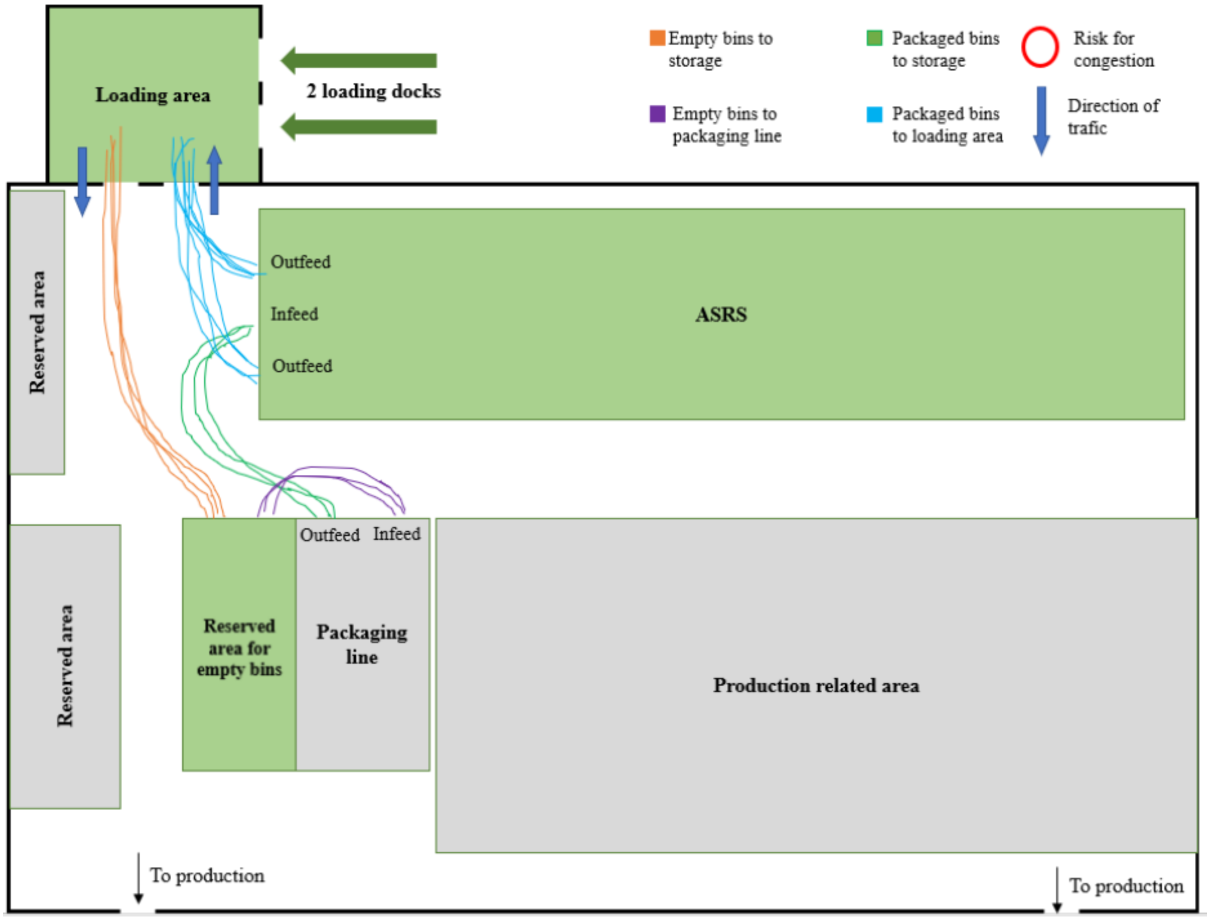


Figure 37: Visualisation of the movements and flows when having two openings between the loading area and the outbound area

From the figure above, and the previous discussion, a conclusion can be drawn the area provided by the company is suitable for storing the empty bins considering the distance from where the bins are received and the packaging line, as well as the storing conditions.

Proposition 1: *The empty bins should be stored in the storage area located next to the packaging line.*

An assumption from Company Alpha is that space is one of the biggest constraints, meaning that the storage principle must be space efficient. As previously stated, Company Alpha has a designated space for storing the empty bins, which is approximately 200 m^2, and the maximum number of bins that can be stored in this area is 960 bins. This number has been calculated by dividing the floor area available with the area of the bin with the lid, and then multiplying by six, since six bins can be stacked while in storage. See Equation 1 for the formula used.

$$Maximum\ storage\ capacity = (Floor\ area\ availible / Bin\ area\ with\ lid) * 6$$

Equation 1: Formula used to calculate the maximum storage capacity.

When calculating the needed space, it is important to consider when the bins will arrive at Company Alpha. The employees in the outbound area at Company Alpha work three shifts, meaning that the area is staffed around the clock. However, the 3PCF is only staffed two shifts from Monday to Friday, hence the bins can only be dispatched from them during these hours. Since Company Alpha works around the clock, as well as the packaging machine, there need to be enough bins in stock during the weekend to cover the demand for three days, Saturday, Sunday, and Monday. See Figure 38 for the storage capacity needed during the weekdays, weekends and the storage capacity available in the storage area provided by the company.

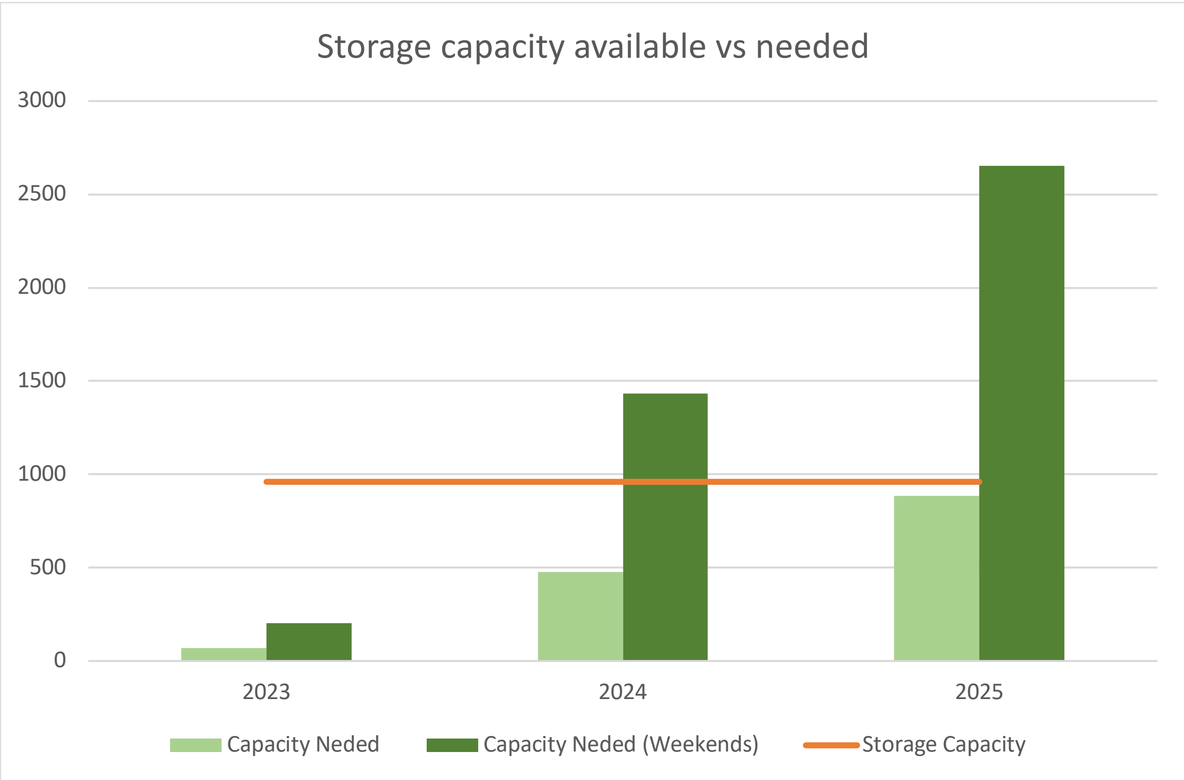


Figure 38: Relation between the needed storage capacity and the available storage capacity for 2023 to 2025

As seen in Figure 38, the assumption that space is one of the biggest constraints appears to be somewhat correct. From the figure the conclusion can be drawn that the space is enough for the weekdays in 2023, 2024, and 2025. However, the space is not enough for the weekends in 2024 and 2025. Hence the configuration of the storage must be space efficient. Looking at 2024, we see that even with a volume increase of 50.2% there would still be enough space for the daily demand of bins. For 2025, this number is only 7.9%, meaning that if for example volumes for 2024 get delayed increasing the volumes in 2025, there is a risk that the storage area would not be able to cover even the daily demand of bins.

Looking at the different storage methods presented in the frame of reference, the principles that are space efficient are floor storage or pallet racks (Bartholdi III & Hackman, 2019). Derhami et al. (2017) present a form of floor storage, called a block stacking storage system, which relies on effective space utilisation. Block stacking storage involves stacking pallets on top of each other on the warehouse floor and is suitable for SKUs that are unit loads (Derhami et al., 2017). Connecting this to Company Alpha, the SKUs handled are unit loads and the bins are stackable, making block stacking storage a possible storage method to consider.

While block stacking storage is cheap, with little to no investment cost, and easy to implement, the space can be hard to manage in terms of space planning (Bartholdi III & Hackman, 2019; Derhami et al., 2017). A con when having block stacking storage is also the stackability of the bins, meaning that no more than 6 bins can be stored vertically since this is the maximum that the bin can handle. If pallet racks are used, it is possible to store more than 6 bins vertically, since every bin is stored on an individual rack. The only constraint here is the ceiling height and the reach capacity of the forklift.

Apart from the storage method, it is also important to consider the aisle configuration (Hassan, 2002; Bartholdi III & Hackman, 2019). There are different ways to go, depending on what the goal of the storage area is. As previously mentioned, the goal of the area is to maximise space utilisation while keeping the different bins separated and sorted. If only focusing on space utilisation, theory says that fewer aisles are a beneficial approach when wanting to maximise the space utilisation. However, by not using aisles, there is an increased risk of congestion and longer travel distances (Hassan, 2002; Bartholdi III & Hackman, 2019). Whether aisles are needed depends on the number of SKUs and how they are getting picked, which essentially is one of the main factors to consider when choosing a storage method and aisle configuration. In Company Alpha's case, the bins should be picked from the long side of the bins, as this is the way they are entered into the packaging line at a later stage. The number of SKUs is relatively low, with only six SKUs to consider. As long as the layout of the storage area is designed in a way that facilitates the picking of all SKUs whenever, aisles are not necessary, and would in this case only take up space that would be needed for storage instead. Hence, aisles will not be considered when analysing whether block stacking storage is a suitable solution for Company Alpha.

Starting off with the calculations for block stacking storage with no aisles. Figure 39 visualises two potential layouts when using block stacking storage without any aisles. Each rectangle represents six bins, as this is the maximum number that can be stacked. The rectangles will from now be referred to as floor locations, where one floor location fits six bins vertically. In the layout to the left, the bins are stored in an 8x20 pattern, resulting in 160 floor locations and 960 pallet locations. The layout to the right has a storing pattern of 9x17 bins, resulting in 153 floor locations and a total of 918 pallet locations. In this layout, the bins have been rotated 90°. Even though there are differences in the number of pallet locations, both layouts have enough pallet locations to meet the demand for bins stored during the weekdays.

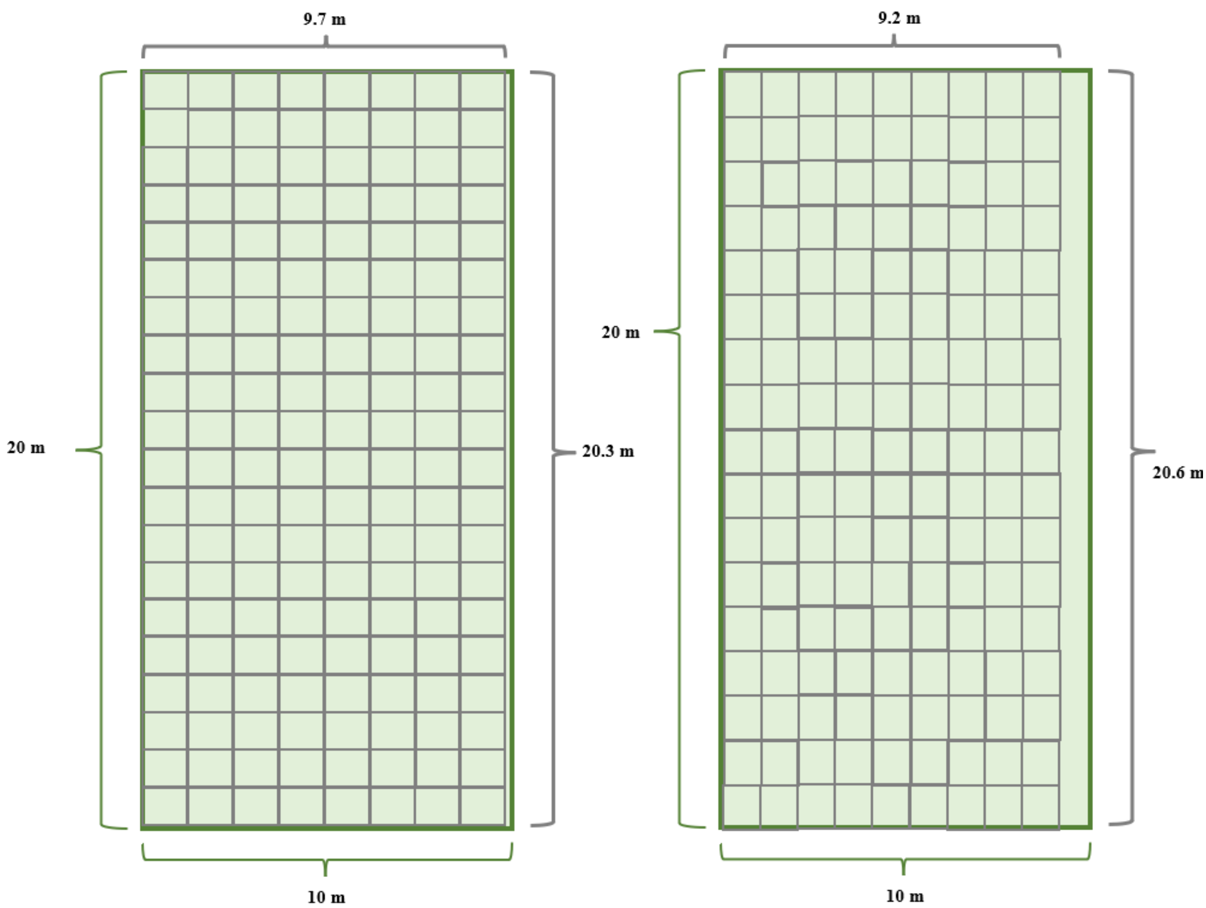


Figure 39: Potential layout of the pallet locations using block stacking storage with no aisles. The layout to the left has the long side of the bin facing the short side of the storage area. In the layout to the right, the bins are turned 90°

What is important to consider when choosing the layout is the purpose the area serves. In this case, the bins are to be picked and inserted into the packaging machine. The aspects that are important to consider here are what way the bin should be inserted into the packaging machine and how to make sure that the right bin type is picked. In order to prevent double handling, the bin should be picked so that the same side is facing the operator both when picking and feeding the packaging machine. It is already known that the bin needs to be fed into the packaging machine from the long side, but which long side is not determined. It is only important that a standard is formed, and the bin is fed into the packaging machine consequently from the same side. Apart from this, it is also crucial that the correct bin type is fed into the packaging line since the inner layers in the bins are adapted to the different cell types. If the wrong bin is inserted, there is a risk that the bins or the packaging machine breaks, or that the customers get the wrong cells, all of which may have expensive consequences.

Even though the company has expressed that they would prefer block stacking storage, as this is the cheapest alternative and could be implemented relatively fast, it would be interesting to have an alternative to compare with. This alternative would be pallet racks. The area that was to be used is still the same as when having block stacking storage. When having pallet racks, it is necessary to have aisles, and the aisle would have to be 3.3 meters wide since this is the working aisle width for the forklifts used at Company Alpha. Applying this at Company Alpha and the space provided would mean one of the layouts displayed in Figure 40.

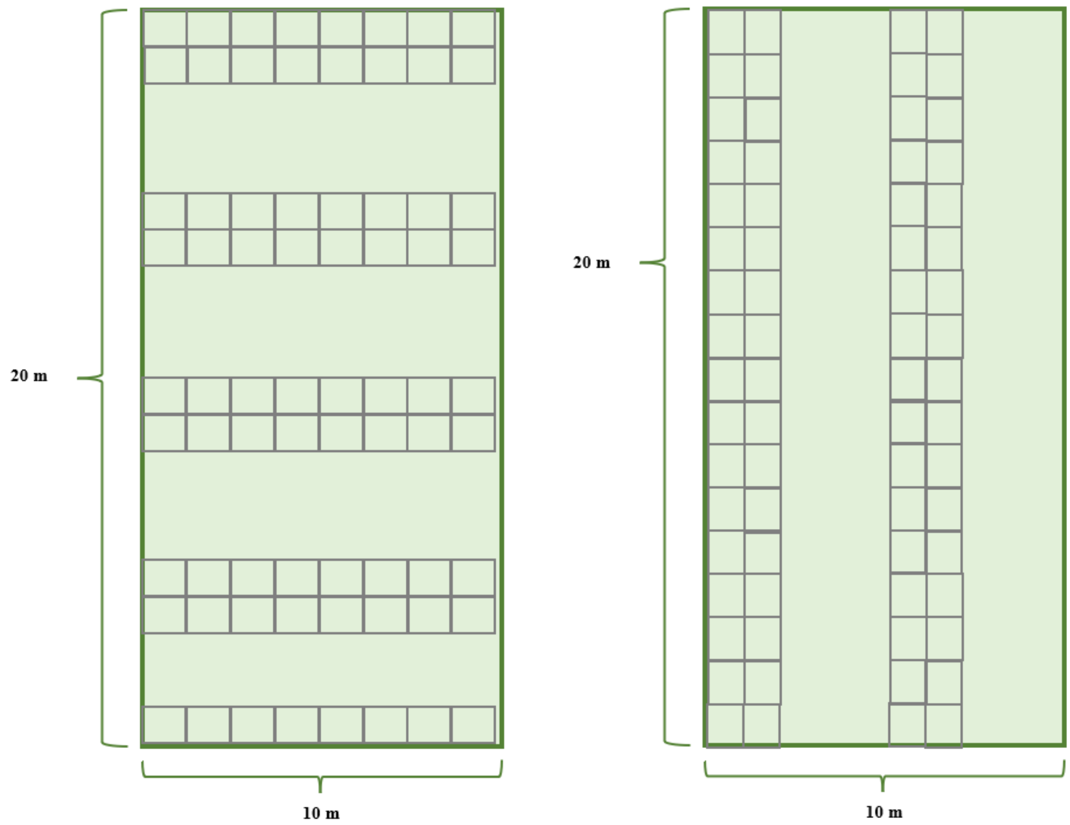


Figure 40: Visualisation of potential layout with pallet racks

Since the maximum height of the forklift is approximately 7.9 m this means that you can store eight bins vertically assuming a 10 cm gap and a 10 cm shelf between the bins. This would mean that it is possible to store two additional bins on the height when using pallet racks. However, the added space on the height does not make up for the pallet locations lost when adding the aisles. The layout to the left in Figure 40 has 432 pallet locations, and the layout to the right has 408 pallet locations. This is 45.0% and 44.4% respectively compared to when having floor storage without any aisles. If using any of the layouts presented in Figure 40, the space would not be enough for the weekday demand in 2024 or 2025. The company has expressed that space is one of the most important factors, and the solution that offers the most pallet locations is the one that is going to be preferred.

Proposition 2: *Use block storage as this offers the most pallet locations, is easily implemented and requires little to no investment cost. The configuration with an 8x20 floor location offers the most pallet locations and should be considered.*

Even if the area will not have any aisles, the configuration is still important, and theory within aisle configuration can be used. Huertas et al. (2007) present aisles configurations, where the SKUs that are most popular should be located in the most convenient locations. According to Bartholdi III and Hackman (2019), the SKU that is most popular should be stored in a beneficial location which is close to the packaging line, since this reduces the distance travelled and the time it takes. Since the packaging line is to the right of the area where the bins can be stored, when looking at the layout from above, the bins should be stored according to one of the suggestions in Figure 41 below, where the darkest colour represents the most popular SKU, and the lighter the colour gets, the less popular the SKU is.

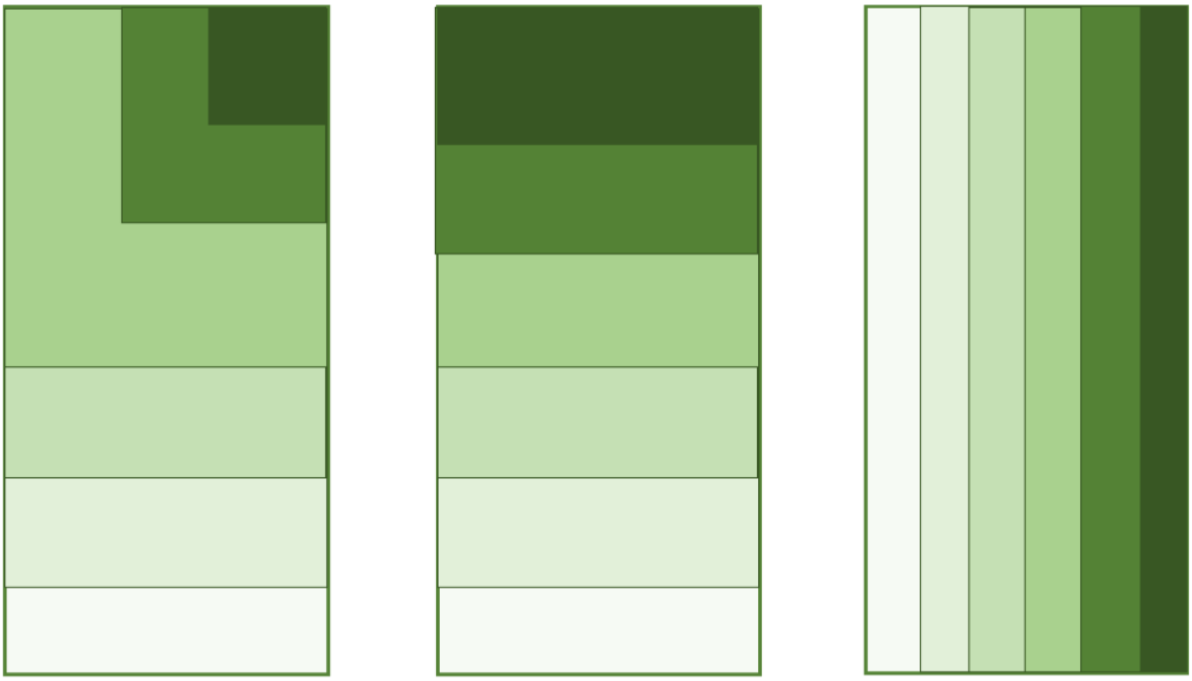


Figure 41: Configuration proposals, where the darkest colour represents the most popular SKU, and the lighter the colour the less popular the SKU.

As there currently doesn’t exist a schedule for when the different bin types should be packed, the storage solution must consider that all bin types must be easily accessible at all times. This means the layout shown to the left in Figure 41 is not an option. The layout in the middle and the one to the right could be potential layouts, depending on the direction of the bin and from where it is picked.

In order to analyse which layout is the best, the spaghetti chart can be used again to see how the different layouts will affect the rest of the flows in the area, and how they compare to each other, see Figure 42.

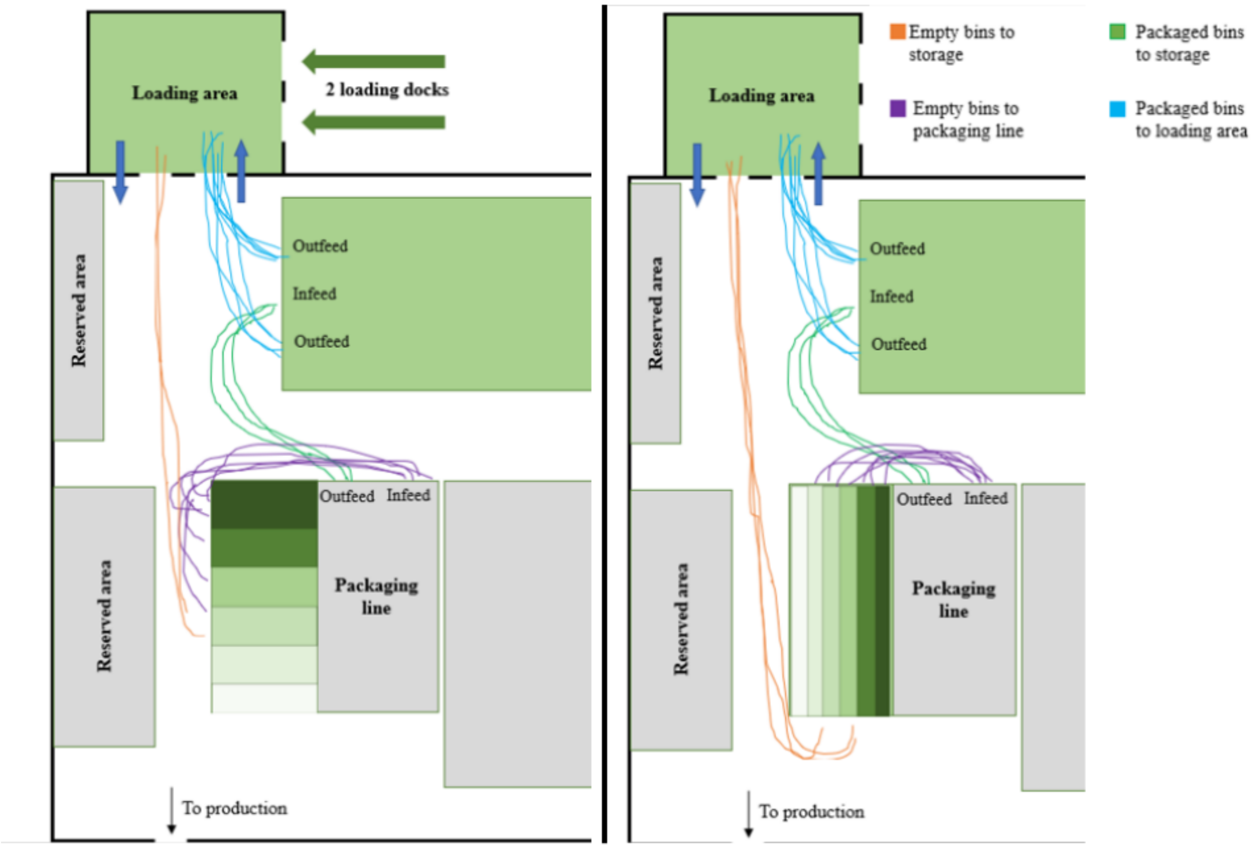


Figure 42: Spaghetti chart comparing two different layouts of the area for storing the bins.

Looking at the different flows in the figure, one thing that becomes obvious is the using the layout to the left, most of the activity connected to the storage area takes place on the left side of the area, and there is no natural way of restocking the area without interfering with the movement of the bin to the packaging line. The bins would also have to be picked from the short side for all bins to be accessible, which would lead to double handling as the bins have to be entered from the long side into the packaging line. Looking at the area to the left, there is a natural way of restocking the area without interfering with the picking of the bins, and their paths will never cross. Looking at Figure 42 below, it can be argued that the layout to the right is the layout that should be used.

Proposition 3: *The most popular SKU should be stored closest to the packaging line, in lanes, as seen to the right in Figure 42.*

Now when the layout is determined on a bigger scale, it is time to go into the details and investigate the storage policies, whether it should be shared or dedicated storage. According to theory, there are advantages and disadvantages with both policies. For example, shared storage uses space more efficiently, but can lead to less efficient order picking. Dedicated storage does not use space as efficiently, but it gives the employees a chance to learn where the SKUs are stored, leading to a reduced risk of picking errors (Derhami et al., 2017; Bartholdi III & Hackman, 2019).

From the forecasted demand that has been presented previously, the needed floor locations can be calculated. This is done by dividing the demand for each customer by six, as this is the number of bins that can be stacked on top of each other and rounding the number up. The floor locations needed for each customer can be seen in Table 20.

Table 20: Floor locations needed during weekdays and weekends

Floor locations needed	***2023***	***2024***	***2025***
Customer 1	5	39	29
Customer 2	4	30	32
Customer 3	1	9	43
Customer 4	1	1	13
Customer 5	1	2	25
Customer 6	1	1	6
Total	**14**	**82**	**148**
Floor locations weekend	**2023**	**2024**	**2025**
Customer 1	13	115	87
Customer 2	15	88	96
Customer 3	1	27	129
Customer 4	2	2	39
Customer 5	2	6	74
Customer 6	1	1	17
Total	**34**	**239**	**442**

The numbers presented above are equal to the floor storage needed when applying a dedicated storage policy, and the number of pallet locations that are occupied or not allowed for storage of another bin type, is calculated by multiplying each floor location with 6. When using shared storage, it is allowed to store different bin types on top of each other, and in that way using the space more efficiently. The number of pallet locations that are occupied when applying a shared storage policy is the same as the total demand of bins. See Table 21 for a comparison of the two storage policies.

Table 21: Summary of the occupied pallet locations comparing dedicated vs shared storage.

Pallet locations weekdays	***2023***	***2024***	***2025***
Pallet locations dedicated storage	84	492	888
Pallet locations shared storage	68	478	884
Pallet locations weekends	***2023***	***2024***	***2025***
Pallet locations dedicated storage	204	1434	2652
Pallet locations shared storage	204	1434	2652

Looking at the numbers, it is clear that shared storage is more space efficient than applying a dedicated storage policy at least during the weekdays, and the biggest difference is when the total demand is low. We can see that the larger the volumes are, the less difference in the occupied pallet locations. Considering that the storage area will not have aisles and that it is important that the right bin type is getting picked and entered into the packaging machine, a dedicated storage policy is the most suitable to use, and dedicated lanes should be used to the extent possible in order to keep all the SKUs accessible at all times. Already in 2024, we see that it is hard to keep one lane for each SKU since each lane only has 120 pallet locations. What is important here is to keep the SKUs together, making sure that every SKU is accessible, and not storing different bin types in the same stack. According to the theory, while dedicated storage requires more space, it also gives the operators the possibility to learn where the different SKUs are located, making the picking go faster and reducing the risk of picking the wrong bin.

Proposition 4: *Apply a dedicated storage policy, with dedicated lanes for each SKU to the extent possible.*

Combining the four propositions presented, we get the layout of the storage area presented in Figure 43. In the figure, we see that the bins should be stored in the area next to the packaging line. It should have block stacking storage with no aisles and the layout of 8 columns and 20 rows, creating space for 960 bins to be stored in this area. The storage policy should be dedicated lanes to the extent possible, and the most popular SKU should be located closest to the packaging line.

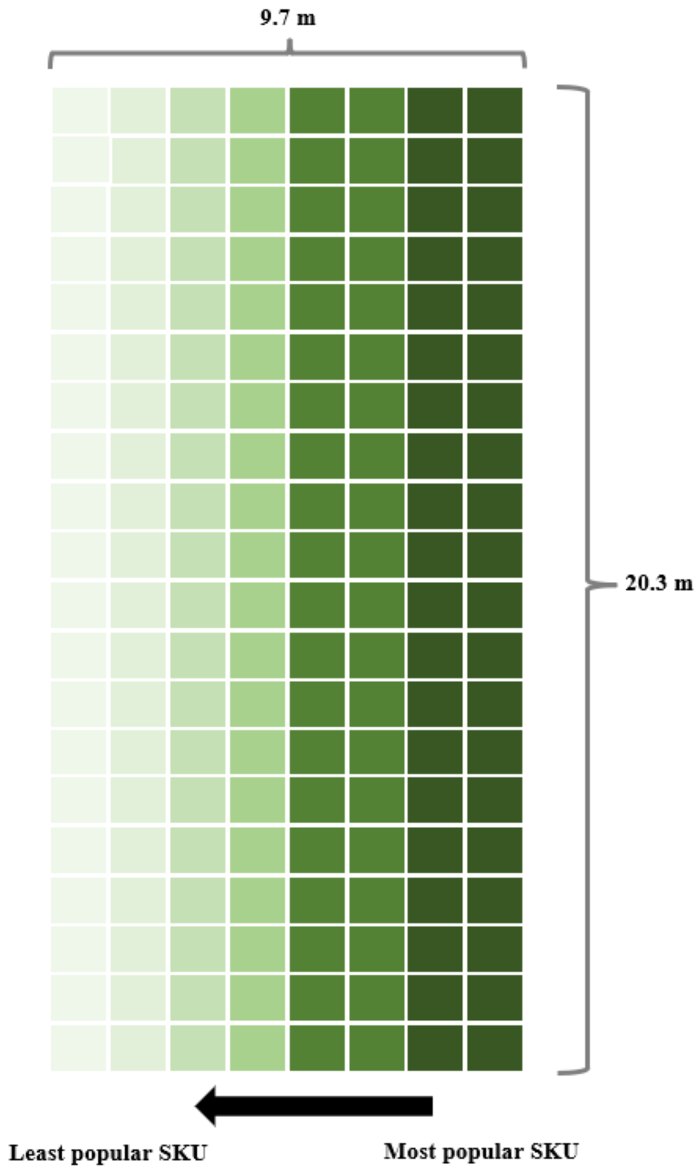


Figure 43: Proposal for the layout of the storage area

5.2.2 Storage & handling equipment

Bartholdi III and Hackman (2019) divides equipment commonly used in the warehouse into storage equipment and handling equipment, and that the right use of equipment can both reduce labour cost and increase storage utilisation. Looking at Company Alpha, the handling equipment they currently have in the outbound area is a pallet jack, and two electrical forklifts. The storage equipment is only the ASRS.

Starting off with the handling equipment, the outbound area is currently equipped with two electrical forklifts and a pallet jack. It is important that the handling equipment is in line with the storage equipment so that they can be used together (Bartholdi III & Hackman, 2019). If Company Alpha chooses to have block stacking storage, the handling equipment needs to be able to transport the goods horizontally, from the location of receiving to the storage area. Apart from this, the equipment must also be able to reach the top bin, as the bins are stacked on top of each other vertically. As calculated in *5.1.2 Product Characteristics,* the forklift will have to reach at least 4.2 meters. The reach height of the forklift that Company Alpha has is 7872 mm, approximately 7.9 m which is more than enough to reach the bin that is stacked the highest. In addition to the reach capacity, the forklift must also be able to go down the lanes of the block stacking storage to retrieve the bins. The total width of the forklift is 1099 mm or approximately 1.1 mm. The width of a bin with lid is 1213 mm or approximately 1.2 m. If having block stacking storage with no aisles, this would leave 5 cm on each side of the forklift if going into one of the aisles. However, there will be some extra space next between the staged bins and the packaging line since the bins will not be stacked so that they touch the packaging line. If starting from the right and then going down lane by lane this would increase the operating space each time, making it easier and easier to access each bin. Considering this, and the fact that there is some additional space between the storage area and the packaging line, the space is deemed as enough for a skilled forklift driver.

Looking at the requirements the block stacking storage puts on the equipment, it is deemed that the current equipment that Company Alpha has meets these requirements. However, it can be argued that two forklifts may not be enough. The majority of the activities in the outbound area requires a forklift with a lifting capacity, which a pallet jack does not have. By only having two forklifts, only two activities can be performed at the same time.

The storage equipment can be used to increase the space utilisation in the warehouse by storing goods on the height (Bartholdi III & Hackman, 2019). In Company Alpha's case, it has already been discussed that using pallet racks would not mean a higher space utilisation. This may be explained by many different factors. For starters, the bins that are being stored are already stackable, so they can be stored vertically without needing pallet racks. Continuing, as there is limited space for where the bins can be stored, there are only so many racks that would fit in this small area, and there would have to be aisles between the racks so that the bins are accessible. In order to increase the space utilisation when using pallet racks, more bins would need to be stored on the height and the aisles would have to be narrower. Apart from investing in new storage equipment, Company Alpha would also have to invest in new handling equipment that has a higher reach capacity and doesn't require wide aisles.

Continuing with the storage equipment that currently exists in the outbound area they have an ASRS. As stated in the empirical chapter, there are some conflicting opinions on whether empty bins should be stored in the ASRS or not. On one side, the ASRS operates at a slow pace and must prioritise the outfeed of the finished goods that are shipped to the customers. On the other side, the storage area that has been dedicated to the bins will not be enough for the volumes over the weekends in 2024 and 2025. As there is space in the ASRS, it could be a possibility to store the bins that do not fit in the storage area in the ASRS, and then restock the area when more bins are needed.

Proposition 5: *Use the ASRS as storage during the weekends for the bins that do not fit in the storage area. The storage area will then be restocked from the ASRS when new bins are needed.*

5.2.3 Information system

One of the most common information systems used is an ERP system, which is a system that is often used by many different departments within a company in order to manage and integrate all aspects of the business (O'Leary, 2012). Often these systems are integrated with the WMS in order to integrate the business aspects with the actual warehouse operations (O'Leary, 2012). According to Bartholdi III and Hackman (2019), a warehouse management system is beneficial to use when managing a warehouse, as it supports aspects such as inventory management, storage locations and workforce. They continue that a WMS should at the minimum track all arriving goods and all goods shipped out. A well-functioning WMS, however, should track every location a SKU can be on (Bartholdi III & Hackman, 2019). The WMS at Company Alpha is not considered an advanced system, as it is currently not used that frequently and it is not yet fully integrated with the ERP system that the company use. Similar to what Bartholdi III & Hackman (2019) describe as the minimum requirement of a WMS, Company Alpha uses the system for tracking incoming goods and outgoing goods. It would be beneficial for Company Alpha to update the WMS and add both steps in the process and physical locations. so that it is possible to track the bins, where they are in the handling process, and where they are physically. Even though it is not possible to add the exact pallet location in the WMS when the bins are stored on the floor, it is still beneficial to add the location in order to keep track of where the bins are located, whether they are in the ASRS or the storage area, and to keep track on the volumes in the storage area.

Proposition 6: *Add storage area as location and steps in handling process in WMS, to keep track of where the bins are stored internally.*

5.3 Warehouse Operations

Once we have the physical layout and the warehouse design in place the next step is to look at the warehouse operations. The warehouse operations that will be analysed are the process of receiving and put-away and storage. It is important that these processes are defined and adapted to the storage in order to have a continuous flow of material. According to Bartholdi III and Hackman (2019), a general rule for warehouse operations and how they interact is that the material should flow as continuously as possible and avoid any form of double handling. Kembro, Norrman, and Eriksson (2018) continue that when designing efficient and effective warehouse operations, aspects such as physical layout, storage and handling equipment and information systems must be considered. This is all true in Company Alpha's case, but it is equally important to also look at the requirements of the products that the return flow will handle. It is important that the processes are performed in a way that maintains the cleanliness level of the bins and accordingly with the handling and storage requirements presented in the empirical chapter. One important note is that the bins must not be opened at any time during the warehouse operations since this may compromise the cleanliness of the bin.

5.3.1 Receiving

The receiving process often start with a notification of the arrival of the goods, and the warehouse can schedule a timeslot for when the goods can arrive in order to align this with the other processes in the warehouse (Bartholdi III & Hackman, 2019; Gu et al., 2007). For Company Alpha, the arrival of the bins needs to be aligned with the outbound warehouse operations. As Company Alpha only has two loading docks which are used for shipping out the finished goods, the time when the bins can arrive needs to be adapted to this, so the loading docks are not occupied. The outbound goods at Company Alpha are shipped out between 8.00 and 16.00. The employees at Company Alpha works 3 shifts, meaning that they can receive the goods whenever from an employee perspective. However, the employees at the 3PCF only work two shifts Monday to Friday, 06.00-22.00. Consequently, the bins will have to be picked up during the working hours at the 3PCF. Since the loading docks at Company Alpha are occupied between 08.00 and 16.00, the bins should arrive at company alpha at 17.00 at the earliest, giving room for potential delays in the shipping of the finished goods.

Proposition 7: *Receive the empty cleaned bins at 17.00 at the earliest since there are no outbound shipments after 16.00, and the loading docks are unoccupied.*

After the bins have arrived, they need to be unloaded. We have the forecasted bin volumes for 2023 to 2025 from earlier. Combining these with the information that it takes approximately 30 minutes for one employee to unload a full truckload, and that it fits 72 bins in one full truck, we get the number that can be seen in Table 22.

Table 22: Numbers of trucks per day, the total unloading time per day, and unloading time per bin

	2023	***2024***	***2025***
Bin demand per day	68	478	884
Bin demand weekend	204	1434	2652
Trucks needed per day	0.94	6.64	12.28
Trucks needed weekend	2.83	19.92	36.83
Trucks handled per day	1	7	13
Trucks handled weekend	3	20	37
Total unloading time per day	0.47 hours	3.32 hours	6.14 hours
Total unloading time weekend	1.42 hours	9.96 hours	18.42 hours
Time to unload per bin	25 seconds	25 seconds	25 seconds

As seen in the table, the bin demand is not equal to an exact number of full truckloads, meaning that if only sending the exact demand, there will be one truck per day that is less than a truckload. Shipping less than truckloads increases the cost of shipment per bin since the last shipment will be transporting mostly air. To avoid this, let's investigate how many bins that would arrive if sending full truck loads and how this would affect the handling time and bin volume, see Table 23.

Table 23: Bin volumes and unloading time if only receiving full truckloads.

	2023	***2024***	***2025***
Full truckloads per day	1	7	13
Full truckloads weekend	3	20	37
Number of bins received per day	72	504	936
Number of bins received weekend	216	1440	2664
Total unloading time per day	0.5 hours	2 hours	3.5 hours
Total unloading time weekend	1 hour	5 hours	9.5 hours

As seen in the table above, the difference in the volumes when sending the exact number of demanded bins versus full truckloads is not that big. The lowest difference is during weekends in 2023, with a difference of only four bins. The highest difference is during weekdays in 2025 with a difference of 52 bins. While shipping full truckloads would mean cost savings and having a bit of safety stock in-house, this would also mean that the storage capacity will not be enough during the weekdays anymore. Hence, for now, it is recommended to only receive the exact volume of the bin demand. Looking at the unloading time, the difference is not that significant. Keep in mind that the time is adapted for one person unloading. If both docks are used, and 1 operator is unloading a truck, the total unloading time would reduce the time needed with 50%

Proposition 8: *Ship the exact volumes, resulting in less than truckloads since space is a constraint.*

When the bins are cleaned at the cleaning facility, they are cleaned so that they meet the cleanliness requirements. Thereafter they need to be transported to Company Alpha in a way that maintains the cleanliness level of the bin. As the requirement states, it is only the part of the bins that are in contact with the cells that needs to meet the TecSa requirements, but it is important that the entire bin is handled with care and that precautions are taken to minimize the risk of cross-contamination. If the outside of the bin gets dirty, it is a high risk that the insides get dirty when the lid is taken off the bin, which then will contaminate the cells. Due to this, the bins will arrive with some sort of protection covering them. This protection will probably be a reusable plastic hood, but nothing is determined yet. Once the bins arrive, they need to be unloaded, which will be done by one operator.

After the bins have been unloaded, they should be staged in the loading area, which is in line with theory presented by Bartholdi III and Hackman (2019), and the return flow of the bins that have been manually cleaned. Unlike the return flow of the manually cleaned bins, there will now be different bin types that are being received. When staging these bins, it is important to try and sort these as much as possible, so that they are stacked and standing together with the same bin type and ready for put away, as this ensures an efficient put-away process (Bartholdi III & Hackman, 2019). Once the bins have been staged the protection is removed from the bins. Right after this step, the bins are counted and inspected. As the number of bins that are being received is the exact number needed, it is important to count the bins upon arrival to make sure that the right amount has been received, and if not, the shift manager should be contacted, who in turn should contact the 3PCF and arrange for the shipment of the bins that are missing. The same goes for inspecting the bins. If a bin is damaged or is covered with dirt or dust, the shift manager should be contacted who should make the final decision whether the bin can be used or not. If no inspection is made of the arriving goods, there is a risk of delays and congestion, which may affect the other warehouse operations (Bartholdi III & Hackman, 2019; Rouwenhourst et al. 2000).

Once the counting and inspection of the bins are conducted, it is time to scan the bin in order to update their status in the WMS. Additionally, it is important to know what bin type that is being handled. One way would be to open the lid, but that would compromise the cleanliness of the bin, and it is stated in the packaging manual that the lid should only be opened in the right environment. Instead, the bin type can be identified by either looking at the dangerous goods label or scanning the bins. Since the bins are to be scanned anyways, the operator should pay attention to the display of the scanner when scanning the bin and identify the bin this way. Even if the bin type can be identified by the colour of the dangerous goods label, the scanner is a more secure method, as there is a risk that the dangerous goods labels have been mixed up. Optimally, the bins are loaded in a way that makes it possible to unload the bins in an efficient way and that they are already sorted when the unloading begins. But there is always a risk of mix-up as the bins are so similar from the outside, why an extra step of scanning and sorting the bins when they are staged is added. Once the bins are sorted after bin type, scanned into the WMS, and counted, the bins are ready to be put-away.

Proposition 9: *See the proposed receiving process of the empty cleaned bins in Figure 44.*

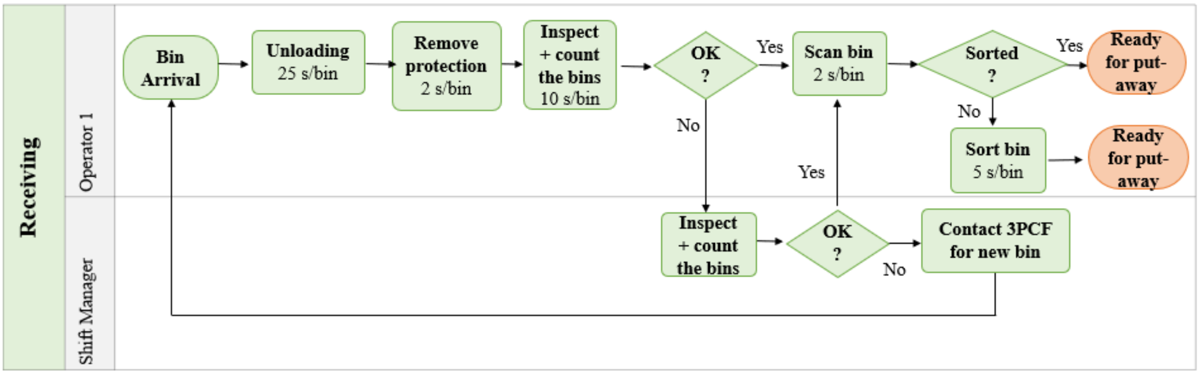


Figure 44: Proposal for the receiving process

The suggested receiving process is in line with warehouse theory, as common activities after the goods have been staged are to scan the arrival of the goods, to inspect the goods and to look for any deviations (Bartholdi III & Hackman, 2019).

5.3.2 Put-away and Storage

Once the bins have been properly received and scanned into the WMS, they are ready for put-away and storage. Moving into this process, the bins should already be staged in the loading area and sorted so the different bin types are separated from each other. The bins should be put away one by one, as transporting more than one bin will obstruct the visibility of the operator driving the forklift. The order of putting away the bins should be working one bin type at a time in order to prevent mixing up the bins. In line with Bartholdi III and Hackman's (2019) view of what makes a well-performing WMS, the bins should be scanned when they are picked up from the loading area, to update the WMS that the put-away process has begun.

In order to have an efficient put-away process, it is important that the location where the goods should be stored is determined and clearly defined (Bartholdi III & Hackman, 2019). As already stated, the bins should be stored in the storage area next to the packaging line. However, this space is not enough for the weekend demand during 2024 and 2025. During these periods, the bins that don't fit in the storage area will have to be stored elsewhere. As the layout is today, the only space where these can be stored is in the ASRS. The area that is prioritised to restock first should be the storage area, and then the ASRS is used when the storage area is full. The reason for choosing the storage area as the prioritised area can be explained by the flow described in chapter *5.2.1 Physical Layout*, and by the time difference in putting away and retrieving the bins from the storage area compared to the ASRS. Due to the capacity of the ASRS, the time for putting away and retrieving the bins from the ASRS is in total 100 seconds per bin. Comparing this to the time it takes to put away and retrieve the bins from the storage area, which is approximately 35 seconds, it is clear the storage area is the faster, and thus the most efficient option.

Proposition 10: *The storage area should be the prioritised area, and the ASRS are used for the bins that don't fit in the storage area during the weekends.*

For the warehouse operations to be efficient, it is important to consider the whole process, how the different activities within the processes relate to each other and try to reduce any form of double handling (Bartholdi III & Hackman (2019). In order to prevent double handling of the bins, it is important to consider from what direction the bins should be staged in the storage area as this affects from which direction the bins should be picked up in the loading area. It has already been stated that the bins should be stored so that the dangerous goods label is facing the operator when picking the bins for the packaging line. As the storage area is restocked from the back, this means that the dangerous goods label should not be facing the operator when the bins are being picked up for put-away. That way, when the operator puts the bin down, the dangerous goods label will face the operator that picks up the bin and enters it into the packaging line in the next step. Once the bin has been put down it should be scanned so that the location is updated in the WMS, and that the put-away process is done, and the bins are now in storage.

Proposition 11: *See the proposed put-away and storage process of the empty cleaned bins in Figure 45.*

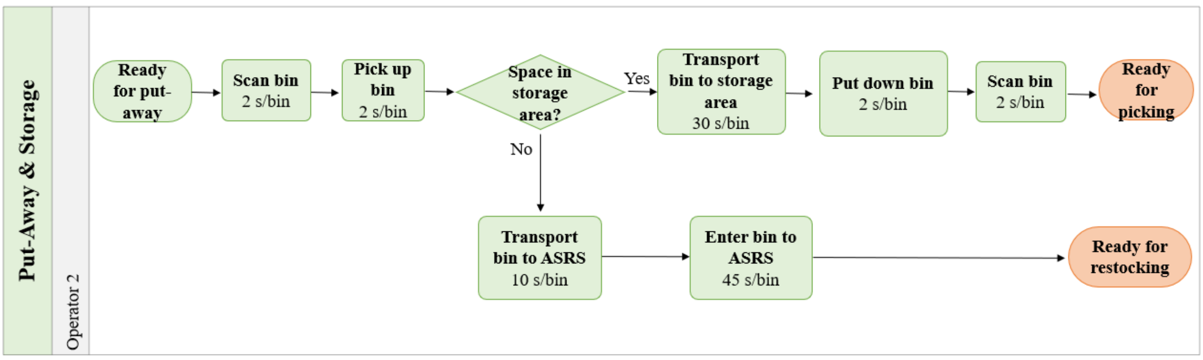


Figure 45: Proposal of the process of put-away and storage

5.4 Performance

As stated throughout the thesis, Kembro and Norrman (2021) emphasize that one has to match the warehouse configuration to the contextual factors in order to improve warehouse performance. Consequently, if failing to do so, the performance will be lacking (Donaldson, 2001). Since the return flow of the automatically cleaned bins has not yet started, it is a challenge to measure the performance of the solutions provided. However, KPIs for measuring the performance can and should be selected before the return flow starts. By having clearly defined KPIs to measure the performance, the chance of actually improving the performance increases, since they present where the improvements can be made (Shahin & Mahbod, 2007). In accordance with theory presented by Shahin & Mahbod (2007), the KPIs selected should be SMART, meaning that they should be *specific, measurable, attainable, realistic,* and *time sensitive.*

The KPIs for the return flow processes and the storage of the empty clean bins should stem from the goals of what Company Alpha wants to obtain with the processes and storage solution. Starting off with the return flow processes, these are supposed to be as time efficient as possible, since they occupy loading docks and staging area in the loading area that is needed for other activities as well. KPIs that can be used to measure this is the *unloading time per bin*, *time of receiving per the bin,* and *time of put-away per bin*. These KPIs are all specific, as they refer to the activities in the previously defined processes. They are measurable since it is time that is being measured, which is not subjective. Whether they are attainable and realistic depends on what the goal is, how much Company Alpha want to reduce these numbers. This is something that has to be further investigated when the return flow has begun. By clearly defining how often these KPIs should be measured, and compared to previous results, the KPIs are time specific. A suggestion is to measure the KPIs every day and to make a summary of the measurements at the end of each month to then compare the values to the months previously to identify trends. The analysis can also be done with the help of the swim lane diagrams presented in the previous chapters, as these kinds of maps can help to identify bottlenecks, and the activities within the processes that are the most time consuming (Kalman, 2002; Ezeonwumelu et al. (2016).

Regarding the storage solution, the goals are to maximize space utilisation, feed the packing line efficiently, and to maintain the cleanliness level. The first goal of maximising the space utilisation is easily measured by simply using *space utilisation* as a KPI. The goal of feeding the packaging line efficiently can be measured by different factors. Firstly, it is important that the right bin type is entered into the packaging line, hence the KPI of *picking accuracy* would make a good measure to identify how many bins that are picked incorrectly. The goal is to have a picking accuracy of 100%, meaning that the right bin is picked and entered into the picking line at all times. Another factor that facilitates the efficient feeding of the packaging line is how long the packaging line needs to wait for the new bin to be entered once it is ready to receive a new bin. This KPI can be called *waiting for bin*. Regarding the cleanliness level, this goal is rather a requirement for where the bins can be stored, hence no KPI will be applied to this goal connected to the specific storage area.

Proposal 12: *KPIs to use in the future connected to the return flow processes and storage area in order to measure the performance and to identify rooms for improvement should be unloading time per bin, time of receiving per bin, time of put-away per bin, space utilisation, picking accuracy, and waiting for bin.*

5.5 Design Propositions

The propositions presented in the previous chapters will now be presented and adapted to the volumes that Company Alpha is facing in 2023, 2024, and 2025. The propositions are presented in Table 24, and it is described if the proposition is affecting the storage solution or the return flow process.

Table 24: Summary of propositions and the area they affect

Number	***Proposition***	***Configuration affected***
1	The empty bins should be stored in the storage area located next to the packaging line.	Physical Layout
2	Use block storage as this offers the most pallet locations, is easily implemented and requires little to no investment cost. The configuration with 8x20 floor location offers the most pallet locations and should be considered.	Physical Layout
3	The most popular SKU should be stored closest to the packaging line, in lanes	Physical Layout
4	Apply a dedicated storage policy, with dedicated lanes for each SKU to the extent possible.	Physical Layout, Put-away Process
5	Use the ASRS as storage during the weekends for the bins that does not fit in the storage area. The storage area will then be restocked from the ASRS when new bins are needed.	Storage Equipment, Put-away Process
6	Add storage area as location and steps in handling process in WMS, to keep track of where the bins are stored internally.	Information system
7	Receive the empty cleaned bins at 17.00 at the earliest since there are no outbound shipments after 16.00, and the loading docks are unoccupied.	Receiving Process
8	Ship the exact volumes, resulting in less than truckloads since space is a constraint.	Receiving process,
9	*Picture of receiving process (Figure 44)*	Receiving process, Equipment
10	The storage area should be the prioritised area, and the ASRS are used for the bins that don't fit in the storage area during the weekends.	Put-away process
11	*Picture of put-away process (Figure 45)*	Put-away process, Equipment
12	KPIs to use in the future connected to the return flow processes and storage area in order to measure the performance and to identify rooms for improvement should be unloading time per bin, time of receiving per bin, time of put-away per bin, space utilisation, picking accuracy, and waiting for bin.	How to measure the performance

Starting off with the storage solution for 2023, 2024 and 2025. Due to the difference in volume, layouts have been made for each year individually. In Figure 46 below, the layout for the storage in 2023 is presented. The area applies a dedicated storage policy, where each SKU has its own line. The SKU that is the most popular is located closest to the packaging line, and the further away the SKU is located, the less popular it is, which is in line with theory presented by Bartholdi III and Hackman (2019) and Derhami et al (2017). Since the area has eight lanes, and there are only six SKUs, the two most popular SKUs are given two lanes each. In 2023, the demand for weekdays and weekends both will fit in the storage area, why the all the bins can be stored in the storage area at all times. The space utilisation for this solution is 7% during weekdays and 21% during weekends.

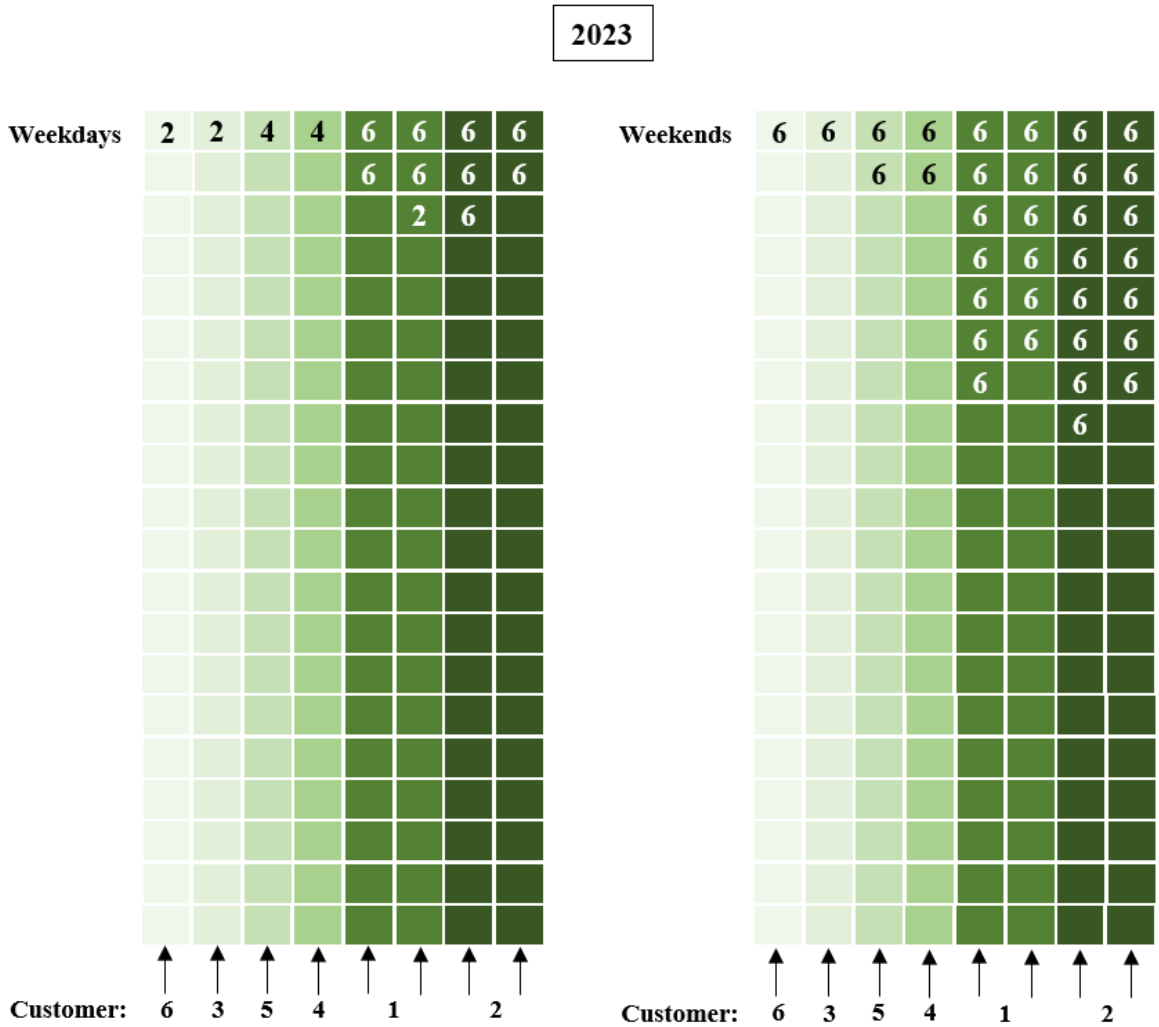


Figure 46: Proposed storage solution for 2023, the numbers refer to how many bins that are stacked in the area.

Continuing with the storage solution for 2024, which can be seen in Figure 47. Similar to the layout for 2023, each SKU has its own lane, except for the two most popular SKUs, which have two lanes each. Once again, the SKU that is most popular is located the closest to the packaging line. However, in 2024, the demand during the weekend does not fit in the storage area. Hence, some of the bins will have to be stored in the ASRS and restock the area when needed. However, due to the low operating rate of the ASRS, we want to store as many bins in the storage area as possible. Looking at the layout for the weekends in Figure 47, we see that Customers 6, 4 and 5 have the entire demand for the weekend in the storage area. The original lines for Customers 3, 2 and 1 are stacked to the maximum, however, it is not enough to store the entire demand of bins. After this, the space behind Customers 6, 4 and 5 is filled with the most popular SKU, in this case the SKU for Customer 1. There is some space between the different SKUs to prevent picking the wrong bin.

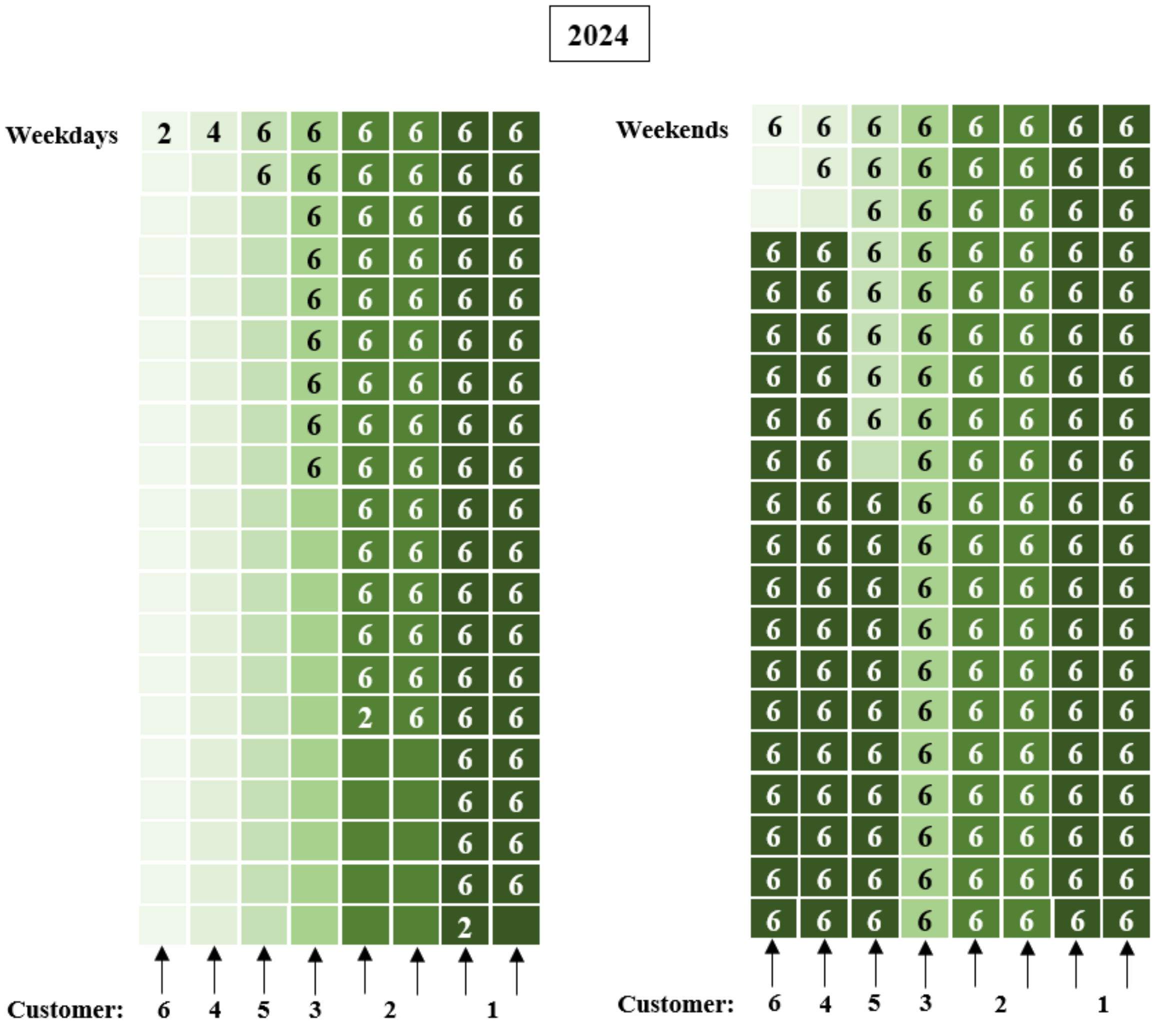


Figure 47: Proposed solution for storage during 2024

This way of storing would mean a storage utilisation of 50% during the weekdays, and 97.5% during the weekends. Table 25 provides a more detailed view of how many bins that is needed to be stored elsewhere. Considering the out feeding capacity of the ASRS, which is 80 bins per hour, out feeding 508 bins would take 6.35 hours. This time would be distributed during the weekend when the storage area would need to be restocked.

Table 25: Pallet locations weekend 2024

Weekend 2024	***Pallet locations needed***	***Pallet locations occupied***	***Bins in ASRS***
Customer 1	690	522	168
Customer 2	528	240	288
Customer 3	162	120	42
Customer 4	12	12	0
Customer 5	36	36	0
Customer 6	6	6	0
Total	**1434**	**936**	**508**

Continuing with the layout for 2025, which is presented in Figure 48. The layout follows the same approach as previously, with the most popular SKUs located closest to the packaging machine. The area has dedicated storage, and dedicated lanes to the extent possible. However, we see that there are five of the eight rows that are storing two different SKUs. It is important to note that while the lanes are somewhat shared, the stacks are still only containing the same SKU and the same SKU is stored together. If picking in a sequence starting in the upper right corner and continuing down the lane before moving to the next lane, it should not be possible to pick the wrong bin.

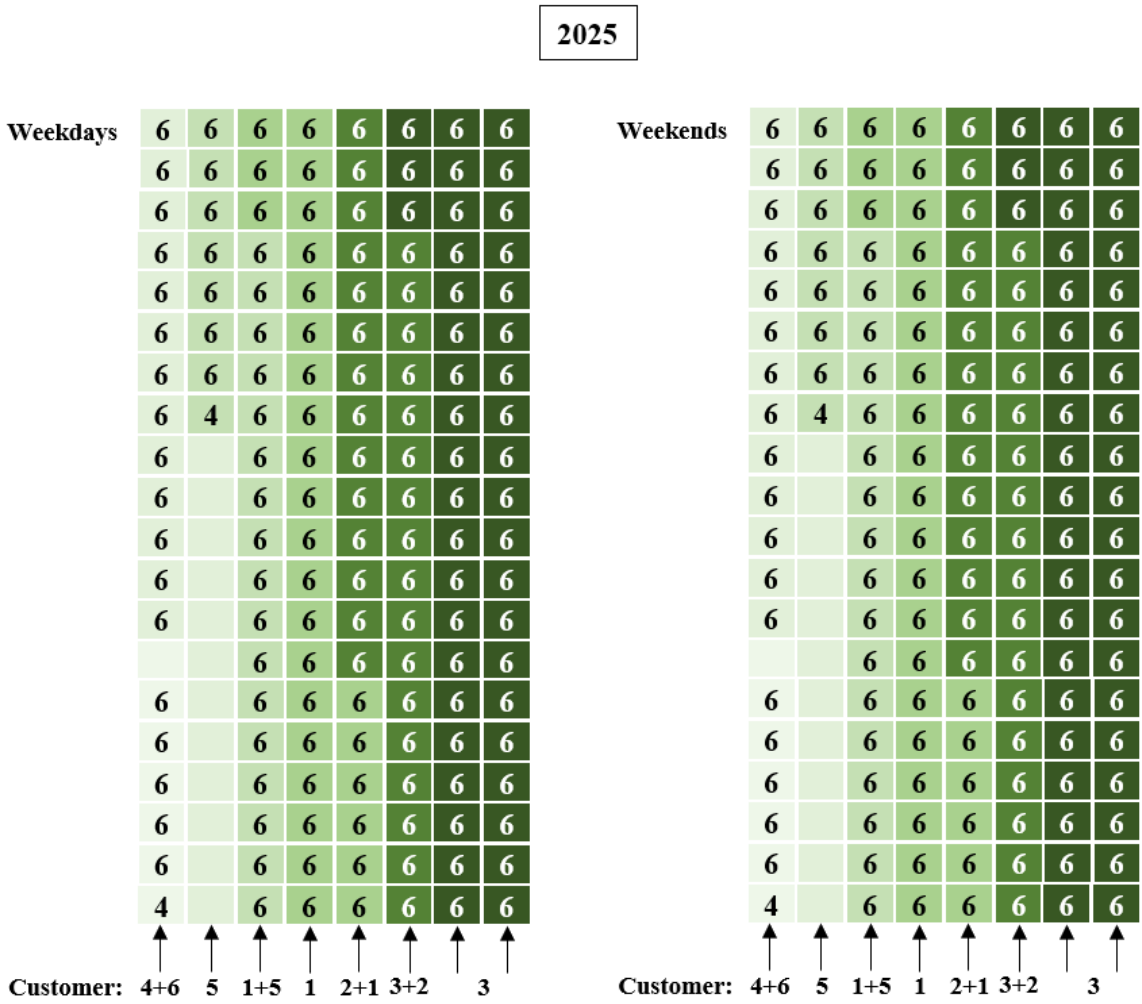


Figure 48: Proposed storage solution for 2025

An observant eye will notice that the layout for the weekdays and the weekends are identical. The reason for this is that during the weekdays the space utilisation already is at 92%, and there is little room left to store the bins for the weekend. Therefore, the recommended approach in 2025 is to store the demand for one day in the area, and the other bins have to be stored in the ASRS, and then the area will have to be restocked when needed. See Table 26 for the needed pallet locations during weekends in 2025, and how many bins that will have to be stored in the ASRS. With the ASRS capacity of feeding out 80 bins per hour, to outfeed the entire volume stored in the ASRS would equal 22.1 hours. The volume stored would cover a two-day demand, meaning that the time for out feeding the bins would equal 11.05 hours per day.

Table 26: Pallet locations weekend 2025

Weekend 2025	***Pallet locations needed***	***Pallet locations occupied***	***Bins in ASRS***
Customer 1	522	176	352
Customer 2	576	192	384
Customer 3	774	258	516
Customer 4	238	78	156
Customer 5	444	148	296
Customer 6	102	34	68
Total	**2652**	**884**	**1768**

Moving over to the return flow processes, receiving and put-away and storage. The processes are similar to the ones already carried out when receiving incoming goods, with some extra additions. In the process of receiving, the activities that have been added are the counting, inspection, and sorting of the bins. These are needed since we are receiving the exact number of bins, where there is no room for bins missing or being damaged. If this is the case, it needs to be discovered as soon as possible, so it can be arranged for shipment of new bins. In Figure 49, the proposed process of receiving can be studied more in detail.

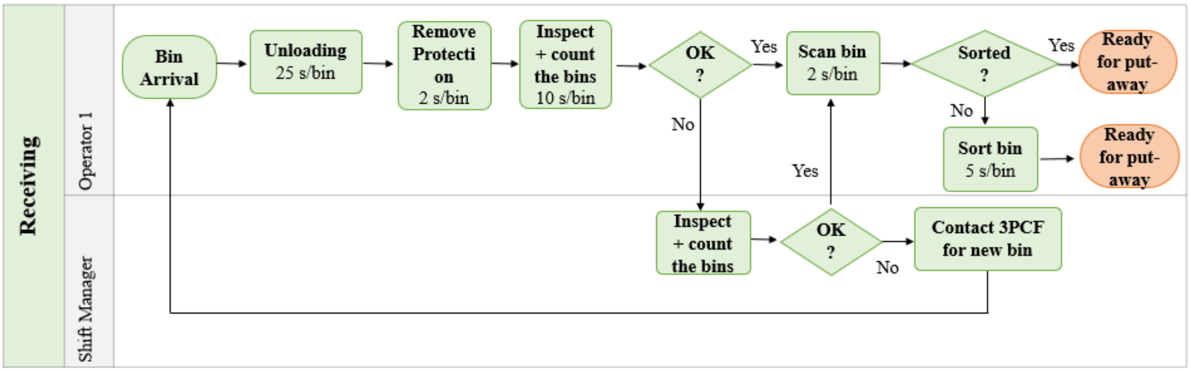


Figure 49: Proposed receiving process.

Regarding the put-away and storage, this process needs to be adapted to the storage where the bins are being put away to. See the proposed process of put-away and storage in Figure 50. The entire put-away time per bin equals 38 seconds per bin if there is space in the storage area and 59 seconds if stored in the ASRS.

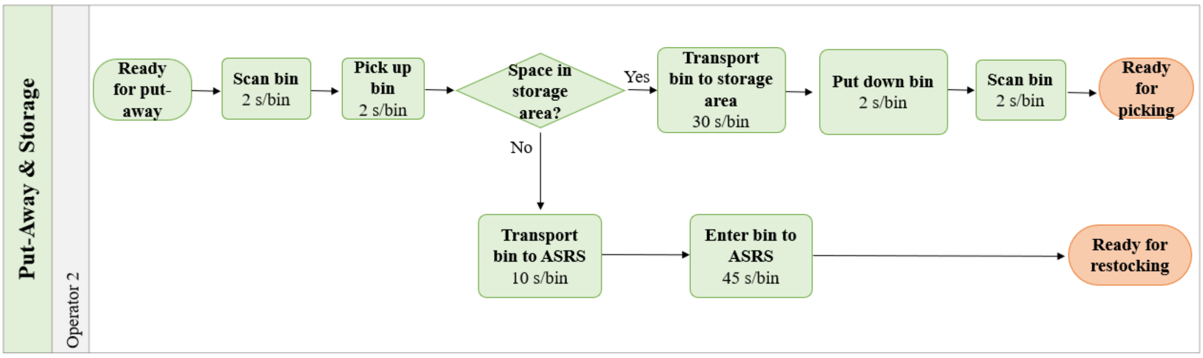


Figure 50: Proposed put-away and storage process

6. APPLICABILITY OF THE PROPOSITIONS

This chapter discusses the applicability of the proposed solution for storage and the designed processes, which has been presented and discussed with the Senior Planning and Logistics Developer at Company Alpha. The propositions were presented one by one, together with the reasons behind the propositions. After each proposition had been presented, there was room for questions, and a discussion was held regarding the respective proposition and its applicability.

The meeting was held the on 12th of May, and the participants were the author of the thesis and the Senior Planning and Logistics Developer. The reason for only having one company representative was due to organisational changes that have occurred during the duration of this project. Although the number of participants was low, the Senior Planning and Logistics Developer has deep knowledge of the project, the company, and the already existing processes in the outbound area, what is feasible and what is not feasible. Therefore, his knowledge was extremely valuable for the project and the proposed processes and the storage solution.

Before the different proposals were presented, the identified goals of the warehouse were presented, to make sure that the author was on the same page as the company, as the propositions all stem from the goals. The identified goals were (1) to maximise the space utilisation, (2) feed the packaging line in an efficient way, and (3) to maintain the required cleanliness level of the bins. The Senior Planning and Logistics Developer agreed that these goals were all of great importance and relevant for the storage area.

Proposition 1: *The empty bins should be stored in the storage area located next to the packaging line.*

The location of the storage area is applicable and easily implemented at Company Alpha. The area complies with the storing requirements for the bins, as it is inside, with the right temperatures and is considered to be clean enough to store the bins.

Proposition 2: *Use block stacking storage as this offers the most pallet locations, is easily implemented and requires little to no investment cost. The configuration with 8x20 floor location offers the most pallet locations and should be considered.*

The Senior Planning and Logistics Developer was positive to the proposal of having block stacking storage without aisles, having eight lanes with 20 bins deep. The fact that the solution was easily implemented, requiring little resources of time and cost was welcomed and appreciated. However, one concern was that the lanes would be too narrow for the forklift to operate in an efficient manner. After explaining that the storage area would be emptied lane by lane and that there was space to begin with between the packaging line and the storage area, the Senior Planning and Logistics Developer agreed that there would be sufficient space for the forklift to operate. A discussion was also had that a reduction of lanes from eight to seven would result in the possibility to store the bins further apart from each other, thus leaving more room for the forklift to operate. However, this would significantly reduce the number of pallet locations from 960 to 840. The reduced number would cover the weekday demand during 2023 and 2024, but not 2025.

Proposition 3: *The most popular SKU should be stored closest to the packaging line, in lanes.*

When discussing the fact that the most popular SKUs would be stored the closest to the packaging line, since this is in line with the theory and reduces the time and distance travelled, it was noted that the most popular SKU varies from year to year, meaning that the location of the different SKUs would change from year to year as well. The Senior Planning and Logistics Developer said that even if the solution is applicable, it might not be the best one since this may cause confusion for the operators when picking the bins if the location changes from year to year. He continued that it might be possible to keep the same order of the SKUs every year, since the total space is not that big and would not affect the total time significantly but help the operators to pick the right bin.

Proposition 4: *Apply a dedicated storage policy, with dedicated lanes for each SKU to the extent possible.*

The dedicated storage policy with dedicated lanes was applicable at the company and considered a good solution bearing in mind the limitations of the WMS and the use of block stacking storage. However, concerns were raised regarding the fact that some SKUs had to share lanes in 2025. However, this is unavoidable with the space available today using this configuration, this would be the only way to have room for the daily demand. The reasoning regarding this proposition was the same as for proposition 3. As operators often work after instinct and learn that each line is for one bin type only, there is an increased risk that the operator picks up the wrong bins. However, as the bins have a visual difference with the dangerous goods label, and the bins are scanned before the bins are picked up from the storage area, it should be able to avoid picking the wrong bin. Another solution that could be possible for the company to investigate further is if it is possible to mix the configuration, so that the lower volumes are staged and picked from the side instead of the front.

Proposition 5: *Use the ASRS as storage during the weekends for the bins that does not fit in the storage area. The storage area will then be restocked from the ASRS when new bins are needed.*

This proposition is only relevant during weekends in 2024 and 2025, as these are the periods where the demanded volumes don’t fit in the storage area. The Senior Planning and Logistic Developer agreed that this is the only space where the bins can be stored if they don’t fit in the storage area. After the time it would take to outfeed the bins that would have to be stored in the ASRS was demonstrated, he was sceptical to the proposition as it occupied a lot of the capacity of the ASRS. He continued that this could work as a solution for now, but that the company would have to investigate further if the capacity of the ASRS could be increased, and if the 3PCF could be available over the weekends.

Proposition 6: *Add storage area as location and steps in handling process in WMS, to keep track of where the bins are stored internally.*

Proposition 6 was something that the Senior Planning and Logistic Developer had thought about previously for other processes in the outbound area, and the fact that it would benefit the management of the warehouse and that if the company has invested in a WMS, they should also use it to its full extent.

Proposition 7: *Receive the empty cleaned bins at 17.00 at the earliest since there are no outbound shipments after 16.00, and the loading docks are unoccupied.*

When discussing the timeslot when the bins could be received at Company Alpha, questions were raised if there would be a possibility to receive empty bins more than one time per day, as this could help with the space limitations. For this to be a reality, the number of loading docks would have to increase. If the extension of the loading area becomes a reality, this is a solution that could be investigated. However, the time from construction start to when it is done is 18 months, and it is not yet certain that the extension will take place. The discussion also touched upon that it would be beneficial to be able to receive the bins every day since this would help with the lack of space. This would mean that the agreement with the 3PCF would have to be negotiated so that the bins are available during the weekends as well, which is not a change that can be done overnight.

Proposition 8: *Ship the exact volumes, resulting in less than truckloads since space is a constraint.*

The recommendation to ship exact volumes, leading to sometimes shipping air, was understandable from the Senior Planning and Logistics Developer considering the limited space available. However, he stated that it would be beneficial to look further into the shipping process of the bins, whether smaller trucks could be used, or is bins could be delivered more frequently which could lead to reducing the air being transported.

Proposition 9: *Picture of the receiving process.*

The receiving process is easy to implement at company Alpha, as it is similar to the one that they have today, adding an inspection of the bins. It was raised that the inspection of the bins would have to be defined on a deeper level how this should be done, but that this was outside the scope of the solution expected from this thesis. The inspection was a welcome addition, as the cleanliness of the bins is a crucial factor that must be kept track on.

Proposition 10: *The storage area should be the prioritised area, and the ASRS are used for the bins that don't fit in the storage area during the weekends.*

Considering the time, it would take to receive and put away the bins it was agreed that the storage area would be the prioritised area, and the ASRS would be used as a backup location for now when the space ran out at the storage area. However, as previously mentioned, the ASRS should be used as a solution for now, and Company Alpha should investigate alternative solutions.

Proposition 11: *Picture of the put-away process.*

The put-away process is applicable and would be easy to implement as the equipment needed is available at Company Alpha. For the process to for to its full extent, the WMS needs to be updated, which is possible according to the Senior Planning and Logistics Developer. By updating the WMS so that the location of the bin and where it is in the process are visible in the WMS, the return flow of the bins will be easier to manage.

Proposition 12: *KPIs to use in the future connected to the return flow processes and storage area in order to measure the performance and to identify rooms for improvement should be unloading time per bin, time of receiving per bin, time of put-away per bin, space utilisation, picking accuracy, and waiting for bin.*

The Senior Planning and Logistics Developer agreed that the KPIs had to be determined in advance before the return flow of the automatically cleaned bins begins and agreed that the proposed KPIs would make a good first step in starting to analyse the flows and performance of the storage solution.

The conclusion of the meeting was that the propositions were all applicable and deemed to be of value for Company Alpha, even if some of the propositions may not be as easily implemented in reality, such as keeping the bins apart when the SKUs change place over the years and that some SKUs need to share lane in order to fit in the area. The design for the storage area in 2023 is applicable and can be implemented as soon as the bins start to arrive at Company Alpha. Regarding the design of the storage area in 2024 and 2025 they are applicable, but they do have some constraints in SKUs having to share lanes, the SKUs changing lanes from the previous years, and the fact that the volumes over the weekends do not fit in the storage area. They are an option, but it would be beneficial for Company Alpha to start investigating alternative options as soon as possible so that when 2024 and 2025 come, a better or complementing solution might be in place.

7. CONCLUSION

This final chapter will summarize the study, where it first will revisit the purpose of the thesis and the supporting research objectives and discuss how these have been addressed. The following sub-chapter will discuss the contributions, both practical and theoretical. Lastly, the limitations and future research relates to the findings of the study will be presented. The limitations are presented to highlight the reliability and validity of the study.

7.1 Fulfilling the purpose

The purpose of this thesis was to design a storage solution for empty reusable packaging and design the return flow processes connected to the packaging internally at Company Alpha. In order to fulfil the purpose, a design science approach was used, as the study aims to solve a practical problem by designing a solution and contribute to both practice and theory. To fulfil the purpose of the thesis, three research objectives were created.

RO1: Describe the current layout of the outbound area at Company Alpha and identify the already existing processes in this area

This research objective was discussed in the empirical chapter, where the current layout of the outbound area was presented, as well as the already existing processes. The outcome of this research objective was used to understand what processes the return flow of the reusable bins would have to be incorporated with, as an understanding of the larger picture is needed for this. The data used for describing the layout and existing processes was collected through interviews with company representatives, and direct observations at Company Alpha's outbound area. The layout and processes were presented together in a spaghetti chart, which visualises the movements of the processes in the warehouse, thus connecting the layout with the processes. By presenting these together visually, a deeper knowledge of how they are connected and where the majority of the processes take place in the warehouse could be gained.

RO2: Identify what processes that are of interest of the return flow of the packaging, and the contextual factors that may impact the configuration of the storage area.

The second research objective was also discussed in the empirical chapter, with the help of process maps and data regarding the future volumes of the packaging at Company Alpha. Starting off with the identification of what processes that were of interest for the return flow, this data was mainly collected through interviews and observations. As the return flow is an inbound flow, the inbound processes of receiving and put-away and storage were of interest. The activities these processes would include were identified by both looking at similar processes taking place currently, which were discovered in RO1, by interviewing company representatives and looking in the packaging manual for handling requirements.

Continuing with the contextual factors that affected the configuration. It was discovered that these were very much in line with theory, as it was factors such as the product characteristic, volume profile, assortment, and demand profile. An additional factor that played a huge role in the configuration was the agreement with the 3PCF and the fact that they could not deliver the bins during the weekends. This highly impacted the space needed for storing the bins over the weekends. This agreement can be seen as an external contextual factor, and depending on how the contract is structured, it may be more or less difficult to change.

RO3: Design the return flow processes when the packaging has arrived from the Third-Party Cleaning Facility at Company Alpha and the storage of the returned packaging.

This research objective is discussed in the analysis and discussion chapter, where the outcome was 12 propositions, which together make the proposed return flow processes and storage solutions for the returned packaging at Company Alpha, presented at the end of the analysis and discussion chapter. The propositions and solutions were presented to Company Alpha, where it became clear that the propositions were applicable to Company Alpha, hence the analytical framework was useful.

When investigating the applicability of the propositions, it was concluded that the solution for 2023 could be implemented as soon as possible and would fulfil the company's needs in terms of space and handling. When the volumes increased moving into 2024 and 2025, the solution was applicable, however, it was lacking some of the key features from 2023, such as storing the SKUs in separate lanes and there not being enough space for the weekend demand of bins. Due to this, it is recommended that Company Alpha should start investigating alternative solutions for 2024 and 2025 as soon as possible. If nothing has changed until then, the solutions proposed in this thesis can be used.

As company Alpha is not starting from scratch, and that they have to incorporate the return flow and storage of empty bins with the already existing layout and processes in the outbound area, it is hard to create the optimal solutions from the beginning. Agreements of when the 3PCF had been negotiated before considering how this would affect the space required at Company Alpha. If the 3PCF would be open during the weekend as well, bins could be delivered every day, including Saturday and Sunday, and the space would not be a problem. The bins would all fit in the storage area provided by the company, meaning that no bins would have to be stored in the ASRS.

From the purpose and research objectives of the thesis, it is deemed that the purpose of the thesis has been fulfilled with the help of the research objectives.

7.2 Contribution

The study contributes to both practice and theory. In practice, it provides valuable insight for the company regarding the activities at Company Alpha, and the processes are mapped in a way that they have not been previously. The findings of the study highlight the lack of space that will occur during the weekends in 2024 and 2025, which is in less than 7 months away when this thesis is written. The thesis provides a simple short-term solution to how the lack of space can be handled that can be implemented quickly and can be used while investigating other solutions. Other options should be investigated further by the company as soon as possible, as time is of the essence. The study can also be used as input in the discussion if an extension of the outbound area should be considered, and that another opening between the loading area and outbound area would be beneficial. Additionally, the study provides process maps, which can be used continuously for improving the return flow process.

Regarding the theoretical contribution, the challenge with a study focusing on only one company is the fact that it can be harder to generalise the knowledge gained. However, the thesis can act as a receipt of how important it is to consider the purpose of the warehouse and the flow it is supposed to handle in the early planning stages of the warehouse. By not considering all the flows, and not adapting the warehouse configuration to the contextual factors from the beginning, it complicates the processes for the company when for example production ramps up as the flows are not adapted to each other. An additional contribution is that as reusable packaging is becoming increasingly popular, the need of a reverse supply chain will become a necessity. This thesis can be an inspiration for what factors that needs to be considered when incorporating the reverse flow.

7.3 Limitations and future research

To begin with, the timeframe of the thesis was 20 weeks, which has had an impact on how detailed the study has been. If the timeframe would have been longer it would have been possible and take part in the implementation of the propositions and test their applicability and how they perform. It would have allowed for an iterative process, where the analytical framework and the propositions could be revisited if the implementation did not work as intended. However, the propositions were thoroughly discussed with the case company to ensure their applicability.

Another limitation is that this thesis was written by a single author. By only being one author, it increases the risk of being biased or having a skewed perspective, since it is only one person collecting and analysing the data. However, the author has collaborated closely with company alpha throughout the project during weekly meetings to validate the collected data and the study as a whole. Additionally, the study has been discussed with the supervisor and opponents from the university as well, providing different perspectives to the study.

One limitation of this thesis is that it is only investigating one company. Even if it provided great depth of knowledge, it can be harder to generalize the results when only one company is investigated. It would be interesting to see whether the propositions would be similar if a multiple case study were conducted and applying the analytical frameworks to other companies. To start with, it would be interesting to apply the analytical framework to different companies in the same industry, and then to companies from different industries and analyse the generated proposition and if the industry has an impact.

The areas for future research connected to Company Alpha are numerous, and only imagination sets the boundaries. As Company Alpha is growing continuously there is always something to investigate. Examples of future research are optimising the return flow between the 3PCF and Company Alpha, how to call the volumes from the 3PCF, the restocking processes of the storage area, investigate whether this could be automated. In a year or two when the flows and processes have been performed multiple times, it would be interesting to revisit the processes and the process maps and try to improve the processes further.

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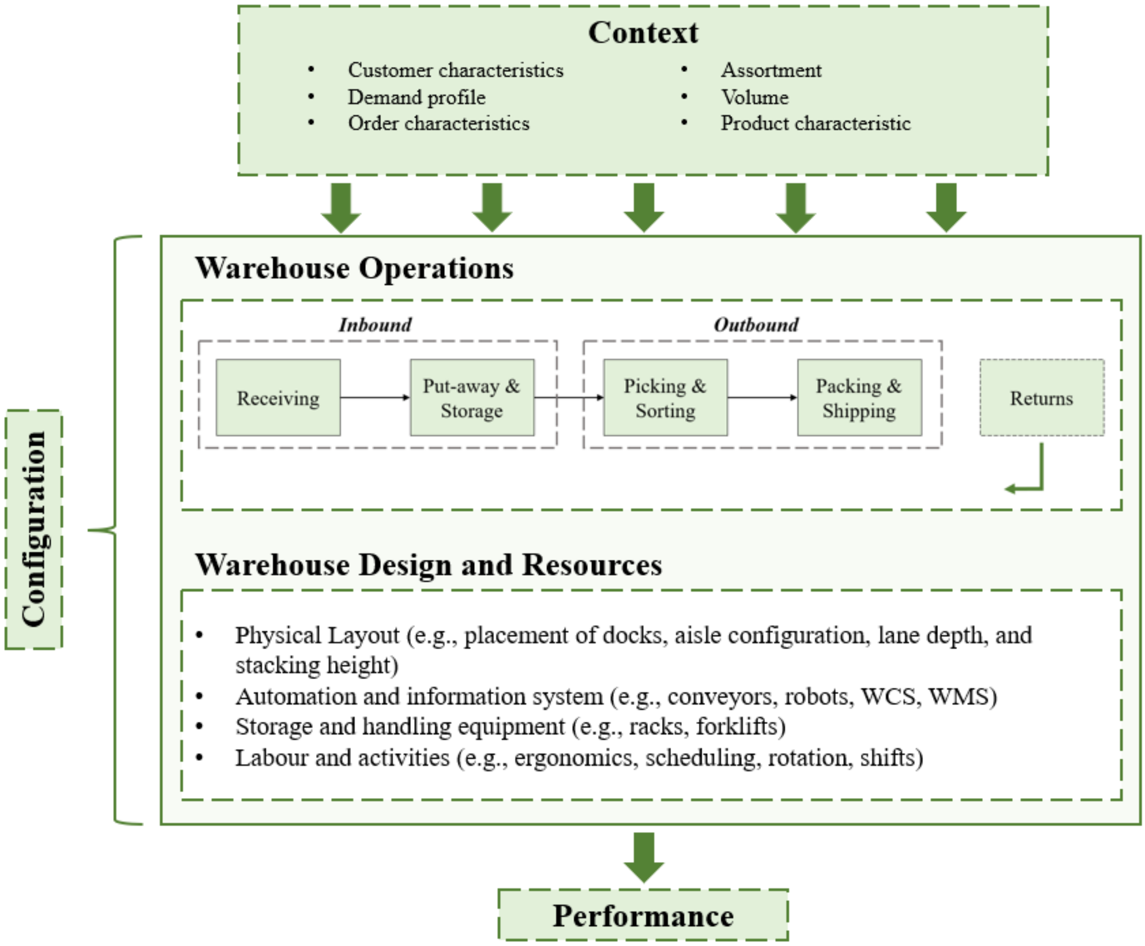
Interview guide

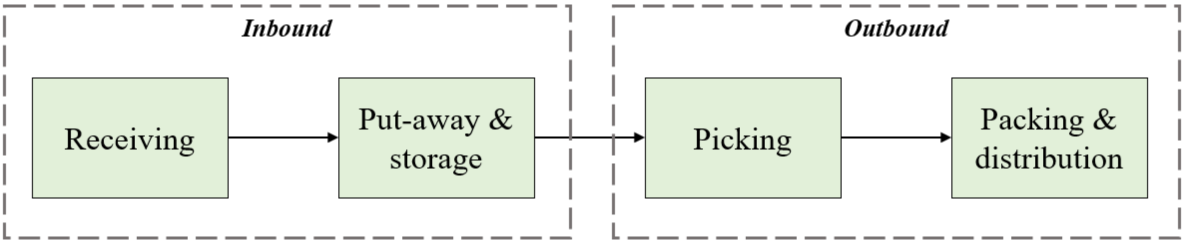
The interview guide has been created with the contingency approach to warehouse configuration presented by Kembro & Norrman (2021).



Warehousing Design and Resources

1. Can you give a general overview of what activities that are currently happening in the outbound area?
2. When is the outbound activities taking place?
3. What is the goal with the area where the bins are to be stored?
    a. Space efficient?
    b. Easy to keep bins apart?
4. What kind of equipment do you have today that can be used for transport and storing internally?
5. Are there any constraints with the area where bins cannot be stored?
6. How many loading docks are available?
    a. What times are these occupied?
7. What are the working times?
    a. At Company Alpha
    b. At the 3PCF

Warehouse operations



Receiving:

1. Who is responsible for the booking of the pick-up and transportation of the cleaned packaging?
2. What requirements are there on the transportation in terms of handling and cleanliness?
3. Have you thought of any way to control the cleanliness of the transportation?
4. How far away is the 3PCF from Company Alpha?
5. What's the time from ordering to receiving, meaning how fast are the packages delivered after an order has been placed?
6. When is the 3PCF available to ship the packaging? How many shifts do they have?
7. Do you have any processes of how you receive incoming goods today? If so, can you please describe them?
8. Do you have any communication with the third-party cleaning facility?
9. Timeslots: when do you have possibility to receive the empty packaging? Would a fixed timeslot be preferred?
10. When does the other activities, such as outbound activities, in the area take place?
11. How does the staffing look at the company? Are people working around the clock?
12. Do you have any inspection of goods upon arrival?
13. What kind of equipment do you have in the area, both for unloading and the put-away processes?
14. How long does it take to unload a Full-Truckload with empty packaging?
15. How many people does that require?
16. How would you prefer to receive the packaging?
17. What would you need from an inbound logistics perspective?
18. Are you using any sort of Warehouse management system today?

Put-away & Storage:

1. Do you already have an area in mind where the packaging should be stored?
2. Have you thought of any concept for storing yet?
    a. Racks vs floor storage? Why? Why not?
3. What is the next step after the packaging has been put away and stored? What function does it support?

Contextual Factors:

1. What is the goal with he storage area
2. What are the dimensions of the bins?
    a. Weight?

3. Stackability: How many can be stacked in transit vs in storage?
4. How many packages fit in a truck?
5. What are the cleanliness requirements?
    a. When transporting?
    b. When handling?
    c. When storing?
6. How many different SKUs are there? For cell types and customers.
7. Are the different SKUs easy to keep apart visually?
8. What kind of labels does the SKU have when it arrives at the company?
9. Any do's and don't's when handling and storing?

Related activities

1. When packaging the cells, is one cell type packaged at a time? I.e. one cell type per day or is it possible to package many different cell types per day?
2. How far in advance is the packaging process of the cell types determined?
3. What capacity does the packaging line have, meaning how many bins does is package per hours?
4. How many hours per day does the packaging line run?
5. From what side of the packaging is it fed into the packaging line