2018

Improving inbound goods operation

Bachelor thesis:

Name: F.F.J. Koster

Student number: s1681346

Study: IEM

Supervisors:

University of Twente: Dr. P.C. Schuur

Dr. B. Roorda

Preface

This report finalizes my time working on my bachelor thesis, for the study of Industrial Engineering and Management, at Company X. During the five month period, I have gained a lot of new insight into the application of theory in practice and had the pleasure of broadening my work experience in a friendly working environment. For this, I would like to thank multiple people for assisting me throughout the project and ensuring I could achieve the results I wanted.

First of all, I would like to thank my supervisor at Company X, who always found the time to give feedback and provide information, no matter how busy his own schedule was. Besides this, I would like to thank the logistics manager and the rest of the warehouse team for finding the time to make me feel at home at the production plant and providing me with the necessary information that makes up the foundation of this report.

Furthermore, I would like to thank Peter Schuur my supervisor at the University of Twente, for guiding me from start to finish in writing my thesis and providing helpful feedback on the academic aspect of the report.

Finally, I would like to thank all others that contributed to this report in any way.

Florian Koster, 2018

Summary

Company X is a production company that produces cleaning & hygiene products and filling/bottling for the professional market is carried out. The raw materials and packing required for production are stored in different warehouse sections on site, but a significant amount is outsourced to a third party each year, to cope with lack of space. At the beginning of this year, a new warehouse was constructed, increasing the available space and providing an incentive to improve the inbound logistic operation.

My assignment is to: "*deliver an advice for the sake of an improvement in the incoming goods stream, aimed at the packaging and raw materials (excluding bulk), that will help the warehouse team to carry out their operation in a more efficient manner.".*

To guide the research process required to find a solution to the given assignment, the following research question was formulated.

How can resources (people, space, and capital) be used more efficiently in inbound goods operation at Company X?

To find an answer to the question above, a series of steps were taken. Firstly, a problem cluster was used to find the core problem, and the stakeholders and the scope of the report were determined. Then, the current situation at Company X was explained in further detail, along with issues that arise because of it. After, we took a step back to conduct a literature research, finding possible solutions and tips that help create a fitting advice for the situation at hand. Ultimately, information gathered in the previous steps led to the formation of a set of short and long term options as well as some recommendations.

Advice for the short term is to implement the following changes:

- The mezzanine should be painted with fixed floor based storage aisles, on the basis of a dedicated storage policy, potentially creating 92 new pallet locations
- The cap hopper used for the 20 and 10L production lines should be moved to the mezzanine, to a location right above the input point, to cut travel distance and time
- A class-based storage policy based on an ABC analysis should be applied to the products stored in the packaging warehouse (pallets and labels) and should be accompanied by restrictions in the ERP system on pallet type, weight, and diameter & width for the labels

In the near future some larger investments to improve the efficiency of the warehouse operation can be carried out:

1. The locations of the vertical carrousel storage units should be reorganized to decrease travel distance and time, and to accommodate more space for pallet racking.
2. Besides, the racks used to store labels should be refurbished to have slanted boards to carry more labels. Labels will be stored vertically, instead of horizontally, creating more bins, and will be allocated according to weight, height, and their ABC classification.
3. Additional space for pallet racking will become available due to labels being moved to the refurbished locations, thus allowing for a reduction in pallet outsourcing.

Furthermore, there are some recommendations that fall slightly out of scope for this particular project, but might be beneficial to the company. Firstly, Company X should try to adjust container shipments from suppliers in China to meet ISPM-15 standards, to reduce the costs of handling. Secondly, an attempt could be made to scanning system, already used in the finished goods

warehouse to the rest of the warehouses, to simplify picking operations. Finally, implementation of visual triggers like instruction screens, color coding and LED guidance might aid in simplifying of warehouse processes.

Contents

1. Introduction

For my bachelor thesis in the study Industrial Engineering & Management, at the University of Twente, research was conducted at the production plant of Company x in the Netherlands. Ultimately the goal of the research was to make better use of resources within the incoming goods stream. This version contains all information deemed necessary to carry out the research, and thus may not sensor possible classified data. Therefore, any reader of this report should respect the classified nature of its content and treat it as such.

In chapter 1: introduction, the build-up to my research is described in detail as well as the background of the assignment. In 1.1 Company X's operations are briefly described, as well as the department the research focused on. Continuing in 1.2, the different aspects of the problem that fueled the research are investigated. This is followed by a brief breakdown of the stakeholders of the project and their involvement in 1.3. Ultimately, the narrowed down scope is laid out in 1.4, followed by the intended deliverables in 1.5, and ultimately 1.6 lays out the research approach.

1.1 Background

Company X offers multiple solutions, by using an approach that combines products & services to improve the operational efficiency of their customers. At the plant, cleaning & hygiene products are produced and filling/bottling for the professional market is carried out.

The improvement project will focus on inbound logistics. The aim is to provide the inbound warehouse team an advice that will help them to carry out their operations in a more efficient manner.

1.2 Problem identification

1.2.1 Motivation

The factory is challenged to reduce costs by improving the operating efficiency. This external motivation is a reason to take certain processes under the loop (e.g. outsourcing of storage). Another driver of motivation comes internally from observing and overhearing employees talk about problems within these processes (e.g. unnecessary distance travelled during order picking). At the end of 2017, a new warehouse was completed for the storage of ADR goods (e.g. flammable, corrosive, etc.) which spurred the question whether it is possible to make better use of available capacity. Furthermore, the complaints regarding the processes only started popping up recently, that in combination with the new warehouse only spurred the search for a solution since that moment.

1.2.2 Assignment

The assignment presented to me before the start of my research was as follows;

The goal of the assignment is to deliver an advice for the sake of an improvement in the incoming goods stream. The scope of the assignment will be aimed at the packaging and raw materials (excluding bulk). The focus will be on: optimal warehouse layout -> minimizing distances and time, overflow locations, ABC classification, goods restrictions (ADR and PGS15), and rework locations. The important stakeholders for the assignment are; support team (raw material warehouse), call-off team, and management team.

1.2.3 Problem cluster

After reading through the one-page outline of the assignment (provided by my supervisor at Company X), I sat down multiple times with some of the stakeholders at the company. During this meeting, they got the chance to mention any issues they believed to be relevant to the current situation. To get a clearer overview for myself, I first divided all the information into a table (appendix A.1) into five categories: materials, labels, mezzanine, support team warehouse, and overall. Then I noted down all the problems that are occurring into a list (appendix A.2). From this list, I then started to work out a problem cluster to identify the core problems, as seen below, which is followed by a more detailed description of each of the problems found in the cluster.

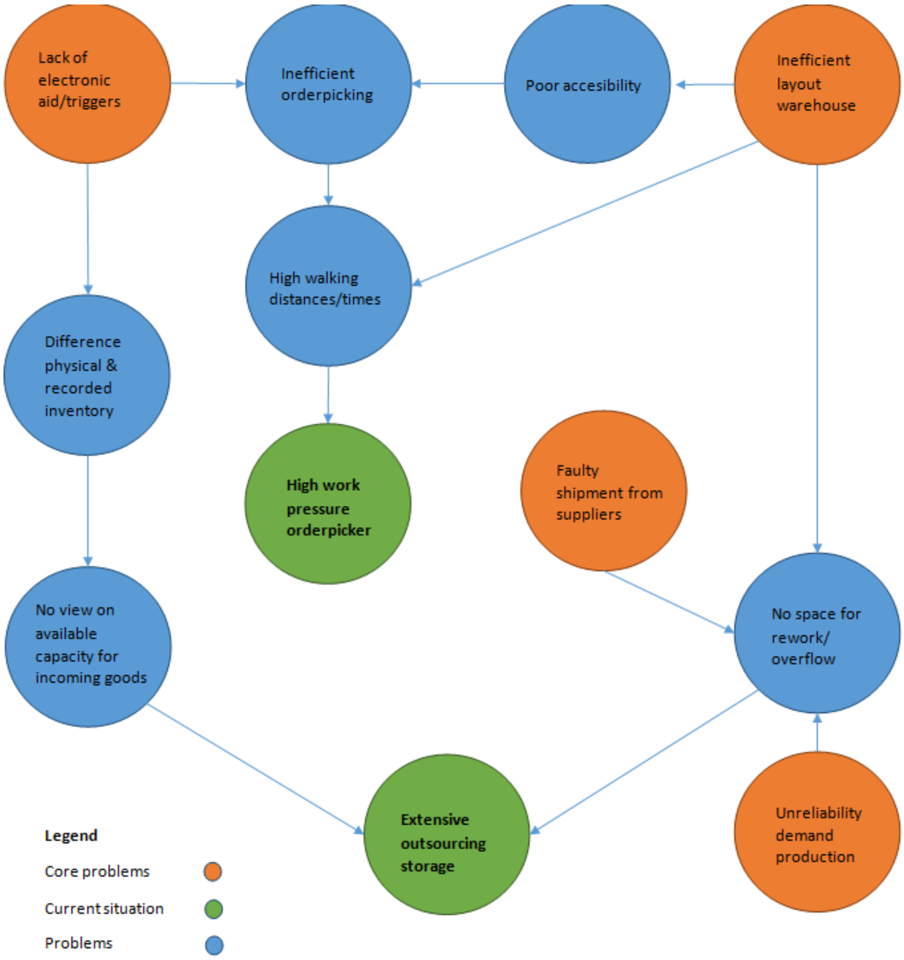

Figure 1.2.a: Problem cluster

Lack of electronic aid/triggers
Within the warehouse information and real-time updates are missing that give employees insight into product stock or the progress of certain processes/work.

Difference physical & recorded inventory
Without the use of electronic aid, there is often an unclear view of how much stock is present in the warehouse, leading to new orders being placed, when they might be unnecessary in the near future. This might also lead to the build-up of certain product stocks taking up excess capacity in the warehouse.

No view on available capacity for incoming goods
Due to the lack of electronic aid & triggers and the unclear view of the stock, it is very difficult for the warehouse team to keep track of the available capacity when new goods are delivered.

Inefficient order picking
The order picking process summarized has the following steps; (1) Filling order received, (2) Order form printed, (3) Pick list print, (4) Administrative confirmation in ERP system. The inefficiency is a result of not using electronic tools which contain the required information, but instead having to

print multiple forms to get an overview of what is needed. Another factor that plays a role is the accessibility of certain products in the labels storage.

Long walking distances/times

This problem is a result of both the inefficiency in the order picking process and in the layout of the warehouse. This leads to warehouse personnel moving over large distances during their workdays when picking their orders.

Inefficient layout warehouse

No real logic is used for the placement of goods in the warehouse, and in some cases, pallets are simply placed in a spot where there was still leftover space. This means that the available capacity for storage is not used in an efficient manner.

Poor accessibility

An issue that arises due to the inefficient layout is that certain products are difficult to access. This comes to light in the label storage, where the labels are placed on shelves that must be accessed with small ladders, to which the employee then carries the product down the ladder. Not very efficient and strenuous on the employee, as some frequently used labels might be on the top shelf and can weigh up to 5-10kg per roll.

No space for rework & overflow

In the current layout, no space has been reserved for any rework that should be done or overflow from production. Quite often faulty shipments of packaging are delivered by suppliers that are placed somewhere until they are returned. Another issue is the fluctuation in the output of the production lines, that can cause an overflow of materials. Besides not having space to cope with these issues there is also no room for any products that need rework (e.g. wrong labels or packaging).

Faulty shipments from suppliers

Due to deviating quality products delivered by suppliers, often products need to be returned. This can be faulty packaging (e.g. damaged bottles or caps) or can simply be a wrong shipment (wrong size or a different type of packaging than ordered).

Unreliability in demand from production

Stoppages and batch changes (e.g. to meet an important customer order) lead to unreliability in the demand from the production department for raw materials and packaging.

High work pressure order picker

High walking distances and times lead to high work pressure for the order picker, as they make 'unnecessary' long routes when retrieving the required materials. Again, fueled by the inefficiency in the layout in addition to them putting strain on their bodies when picking orders from the label storage.

Outsourcing storage

Causes for the excessive amounts of outsourced storage come from the lack of space for rework/overflow and the lack of insight in the available capacity for incoming goods. When a production batch needs to be reworked and there is no space available to store it until there is time for the rework activity, then it is stored at a third-party warehouse. The same applies to excess materials or packaging when there is not enough available capacity to store it. Resulting from this are high costs made even though the capacity could be at hand if things were done differently.

1.2.4 Choice of the core problem

Within the problem cluster, different colors can be seen, with their meaning defined in the legend. The current situation at the company is that the work pressure of the order pickers is too high and there is too much outsourcing of storage. For clarification purposes, these are combined to the following situation; *inefficient use of resources*.

At Company X, the inefficient use of resources comprises of multiple aspects; space, people, and capital. Hence, leading to the following research question:

How can resources (people, space, and capital) be used more efficiently in inbound goods at Company X?

First, for space, this means that the warehouse capacity available is not used logically, leading to overcrowding in some areas and empty lots in other places. Besides this, in the case of backorders or other problems, external third-party warehouses must be used to store these materials. For the people, this mostly comes down to high work pressure on some employees, caused by high walking distances and times. Finally, capital is used inefficiently because of the outsourcing of storage, which is a substantial expense.

The prospective core problems don't have any more incoming arrows (causes coming from other problems), only outgoing. The first step towards picking the core problem from these four candidates is looking at my influence on them. This quickly led to two problems falling out of reach: (1) faulty shipment from suppliers, and (2) unreliability in demand from production. The problem of faulty shipments from suppliers was something outside of the scope of the assignment and is something that requires some forms of incoming quality control and eventual critical changes to new suppliers. These are the kind of decisions that are beyond my sphere of influence, as Company X might already have these suppliers for years, and faulty shipments occur partly by chance. Unreliability in the number of raw materials and packaging required by the production line is also a problem that falls out of scope. Tackling this problem could require changes to machines, large scale investments, changes in personnel etc. Based on this realization I decided to not focus on these leaving the inefficient layout of the warehouse and the lack of electronic aid/triggers.

The decision remaining is which of the two has a more significant impact on the current situation at Company x (inefficient use of resources). In terms of the impact, the layout of the warehouse has the most effect on subsequent problems, as can be seen in the problem cluster (6 issues resulting from it) and is thus a major factor in the current situation at Company X. This does not mean that a lack of electronic aid and triggers throughout the company does not play a role. However, based on brief personal observation, meetings with different representatives and the problem cluster I believe that tackling this issue will not have the same impact. Therefore, the core problem tackled is the inefficient layout of the warehouse, and if time suffices there might be an opportunity later in the process, to have a brief look at how visual triggers might benefit the overall situation.

1.3 Stakeholders

Throughout the course of the research, but also for the outcome, there will be multiple parties involved in terms of influence, decision making, and provision of information/data. These parties known as stakeholders are actors that have an interest or stake in the development of a technology but don't necessarily possess the influence to steer the development (van der Poel & Royakkers, 2011, p.142). Thus, it is important to know who these people are and how they can be involved in the process.

First, Company X is a major stakeholder as they are the ones that formulated the assignment and are in a way sponsoring my time spent researching at the plant. Particularly my supervisor is the one that has an influence on the outcome of my research as he decides if it will be implemented and if it meets their expectations/standards. Therefore, it is important to keep my supervisor in the loop of my progress, and thus by having regular meetings, this is achieved. Once a week I will have a short milestone meeting with him to get some feedback on the work done so far, as well as to keep track of my progress.

The warehouse managers are the ones that will ultimately be implementing the outcome of my research and will be working with it on a day to day basis. Besides this, they are also a good source of information on what goes on within the warehouse. Therefore, including them in the decision-making process to the furthest possible can be of great added value.

Part of the assignment was to have a look at the large distances travelled in the warehouse by employees, more specifically by the order pickers who collect all the supplies needed to run a batch on one of the many production lines. Thus, as part of the research, I will look into their troubles and try to find a solution that benefits them.

Finally, a stakeholder of the project could be the external storage Company Y that currently makes large sums of money from keeping stock for Company X. By making the warehouse more efficient, this need could be reduced, and thus also their business. A gradual implementation that keeps the relationship in good condition, could help ease the reduction of outsourced storage.

1.4 Scope

As mentioned in 1.2.2 the management team at Company x wants me to improve the incoming goods stream to lower the costs of outsourcing and make the warehouse processes more efficient. For both, the packaging, as well as the raw materials, would mean going through more than 4000 SKU for my research and would require taking all four warehouses into account. Due to the amount of time available and the want to deliver a tangible product rather than multiple half-done attempts, we decided to narrow the focus of the research. The scope of the project will be on the packaging warehouse and the storage floor above the production area, and their corresponding problems that will be discussed in further detail in chapter 3.

1.5 Deliverables

At the end of the research conducted the following items will be handed to my supervisors.

- Advisory report (chapter 5 of thesis):
    - Short–term and long-term changes
    - Steps that need to be taken
- Additional advice and suggestions, that might fall out of scope (chapter 6)
- Excel files and databases, as well as any other materials used to gather data on KPIs

1.6 Approach

We decided to split the problem-solving approach into six phases, which contain corresponding research questions to guide data collection.

1.6.1 Phase 1: Mapping the current situation

1. What does the current layout of the warehouse look like?
2. What processes are carried out in the inbound warehouse and what steps do they consist of?
3. How do the employees feel about the current situation?
4. What are KPIs currently in place?

1.6.2 Phase 2: Employee Influences

5. What does an employee’s routing through the warehouse look like?
6. What are the average pick times for standard orders?

1.6.3 Phase 3: Quantitative data collection

7. How many times a week and in what quantity are labels and packaging ordered by the production lines?
8. What quantity of storage space is outsourced to third parties?
9. How many pallets of packaging are delivered each week?

1.6.4 Phase 4: Problems encountered

10. How many faulty shipments are delivered from suppliers each week?
11. To what extent is the order picking process influenced by the current warehouse situation?

1.6.5 Phase 5: Solution generation

12. In which way can products be classified into different groups to determine their locations in the warehouse?
13. What warehouse layouts are available in literature and how can they improve efficiency?
14. How can pick times and walking distances be reduced?
15. Which criteria can be used to determine an adequate solution?

1.6.6 Phase 6: Implementation

16. What steps need to be taken to successfully implement the chosen solution?

1.7 Report structure

The six phases mentioned earlier, are a guideline for gathering the required information, and not the structure of this report. The report itself is structured according to the IST-SOLL model (current situation, problems associated, and the sought-after new situation), with the stages filled in using information from the research questions. The structure is as follows:

- Chapter 1: General introduction to the research & problem identification
- Chapter 2: Current situation (IST, known warehousing KPI's and employee/management input)
- Chapter 3: Issues (IST, problems encountered through KPI analysis, observation, and research)
- Chapter 4: Literature (SOLL, finding guidelines in literature for a favorable new situation)
- Chapter 5: Solutions (SOLL, break-down of short & long-term changes to be made to create the wanted situation)
- Chapter 6 - 8: Concluding the research, apprise possible changes in the methodology, and mention of perceived changes out of scope that could be beneficial or require further investigation

In addition, all chapters will have a small short introduction and chapter 2-4 will also have a recap, to improve the readability and understanding of the report.

2 Current situation

In this chapter, the current situation at Company X will be described to have a base level from which to improve from. Paragraph 2.1 will start off with a description of the different types of storage units used in the warehouse. Next, paragraph 2.2 & 2.3 describes the two focus areas of this research in more detail, the packaging warehouse, and mezzanine respectively. Finally, paragraph 2.4 ends the chapter with a recap.

2.1 Storage units

There are many different types of storage units used to keep materials in the warehouse being IBC's, boxes, pallets, etc. However, since packaging materials are stored on pallets at Company X, this will be the focus of the assignment. There are three types of pallets in use, that will be highlighted below (for images refer to appendix A.3).

2.1.1 Euro Pallets

One of the most commonly used exchange pallets worldwide, with as much as 500 million currently in circulation, also known as EPAL (European Pallet Association) pallets. The pallets are 800mm wide, 1200mm long and 144mm high, and have an approximate weight of 25kg without load. There are many imitations to the official EPAL pallet that have the same dimensions.

2.1.2 Blok pallets

'Blok' pallets are an unofficial pallet size used in Europe which have the same dimensions as CHEP exchange pallets 1000mm wide and 1200mm long. For the sake of the assignment, all pallets with these dimensions will simply be named CHEP pallets.

2.1.3 Custom size pallets

Within the warehouse packaging for one production line is all delivered on custom pallets that have dimensions of 1100mm wide by 1200mm long, so that the boxes fit on the pallet optimally. Thus, looking like CHEP or block pallets, they are slightly larger.

2.2 Packaging warehouse

2.2.1 Storage methods

The packaging warehouse makes use of three different types of storage methods; adjustable pallet racking, open bin-shelving, and paternosters.

Figure 2.2.a: Adjustable pallet racking (from www.ar-racking.com)

Adjustable pallet racking is the most commonly used method for storing materials on pallets. Due to their adjustable beams, the racks can be easily reconfigured to store different sizes of goods or changes in products that need to be stored. Access paths are parallel to the racking allowing for direct access to pallets without the need for specialized equipment.

Figure 2.2.b: Open bin-shelving (from www.amazon.com)

Open-bin shelving is the most basic method for storing SKUs and also the least expensive option. Picking is done by hand from the front pick-face, with a typical pick rate of 50-100 picks per hour (dependent on the type of product). Replenishment is also done from the front, thus requiring picking and replenishment to be scheduled at different times.

Figure 2.2.c: Paternoster storage system (from www.apexauctions.com)

A paternoster is a vertical carousel system that makes use of rotating trays, to grant easy access to products whilst saving floor space. By simply typing the bin location onto the key pad, the paternoster rotates the bins until the right location is in front of the pick face.

2.2.3 Layout

Currently, the packaging warehouse is divided into two areas; labels & sleeves and packaging (boxes, caps, etc.). There are six rows of racks with large lanes between them allowing for easy picking by fork-lifts. Besides this, there are five paternoster inventory systems, which are used to store labels. AutoCAD drawings of the warehouse only showed the pallet racks, thus all other equipment in use had to be hand measured (measuring tape and laser measuring equipment) and scaled onto the drawing is seen below.

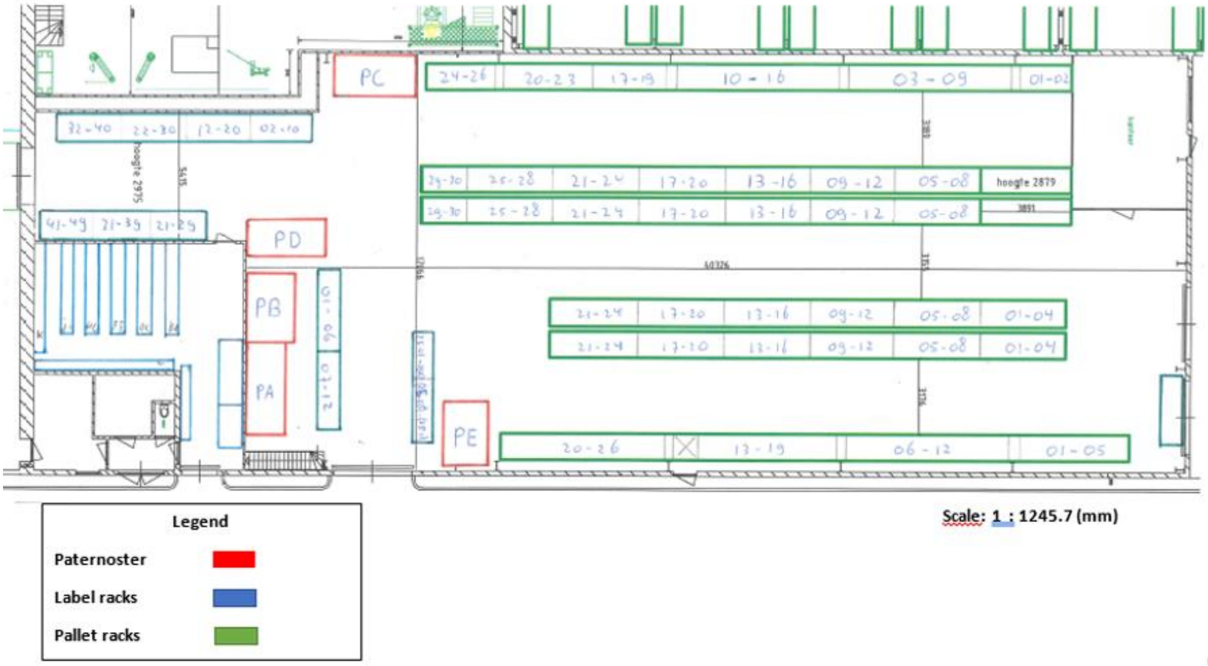

Figure 2.2.d: Scale drawing of packaging warehouse

For more details on the pallet based storage in the warehouse refer to appendix B, figure B.6.

2.2.3 Inventory capacity

For ease the capacity of the warehouse has been divided into three sections; packaging warehouse, paternosters, and conditioned label room. Their total capacity comes down to 2495 label bins and 559 spots for pallets. An overview of the exact capacity for each of the sections is available in appendix B. With the help of the SAP system and a daily stock count for around one month (25 work days), the inventory utilization for the packaging warehouse section was determined. Inventory utilization is defined as; the rate of space occupied by storage (Staudt et. al, 2014, p. 6)

$$InvUt = \frac{Inv\ CapUsed}{Inv\ Cap}$$

Where $Inv\ CapUsed$ is the average space occupied by inventory (m^3) and $Inv\ Cap$ is the total warehouse inventory capacity (m^3).

For our purpose, the *Inv CapUsed* is given in terms of full storage bins and *Inv Cap* as the total number of storage bins available, due to materials having different dimensions. On average the utilization of pallets is 72% and 91% for labels.

2.2.4 Storage policy

Overall the storage policy is of the dedicated storage type with the SKUs allocated to certain areas based on their ADR classification (e.g. flammable, acidic, etc), and is carried out by the warehouse management system. Virtually the entire warehouse capacity is separated into 5 zones; Hall 1 - 3 for raw materials, finished goods, and packaging, with only the first and the latter affected by ADR regulations.

Now there is no real storage policy in use inside the packaging and label warehouse, besides some restrictions that limit the allocation of some SKUs. Firstly, the safe pack boxes (delivered on custom sized pallets 1080*1200mm) are always stored on the floor bins due to their weight. For the labels, some require a constant temperature as this maintains their integrity better, resulting in a smaller loss when running on a production line. Thirdly, some of the paternosters have a max load of 150kg per tray and thus based on the weight of the labels (max is around 12kg) they are allocated between the five systems in the warehouse. Finally, the remaining materials are given a storage bin based on their height and subsequently whether they fit in the different sized storage bins (more info on the sizes in appendix A.1).

2.2.5 Processes

In the packaging warehouse, there are multiple processes that take place namely; replenishment, order picking, ERP administration, and back flushing of rest materials. For the connection between the warehouse and the rest of the plant, refer to appendix A, figure A.7. Due to the focus of the research, we will only look at the order picking process in detail through the use of a flow chart.

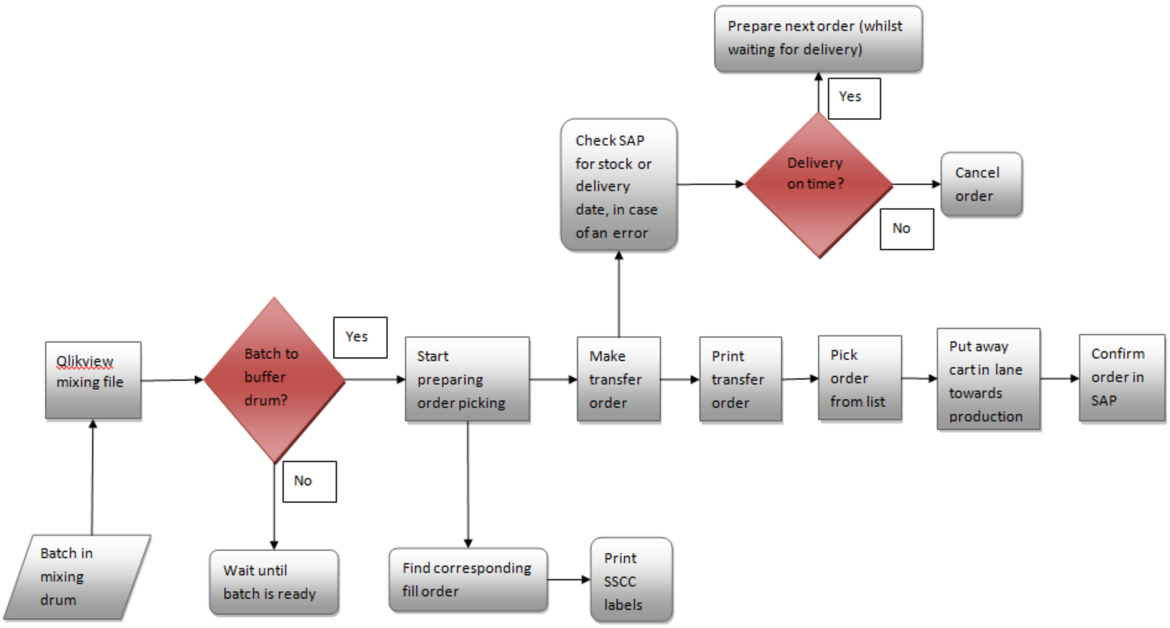

Figure 2.2.e: Flow diagram order pick process

2.3 Mezzanine

Above the production line, there is storage space for flasks and caps (used in four different production lines). These are fed to their respective stations through dosing bunkers (flasks) and cap hoppers (bottle caps), examples seen in the images below.

Figure 2.3.a: dosing bunker (Dutch Tec Source) & cap hopper(triton160.com)

In the mezzanine storage is random, with only minimal indicated storage locations, and no fixed layout. Therefore, there is an opportunity for improvement to make better use of the available space, to increase its use to the rest of the plant. A scaled drawing can be seen below.

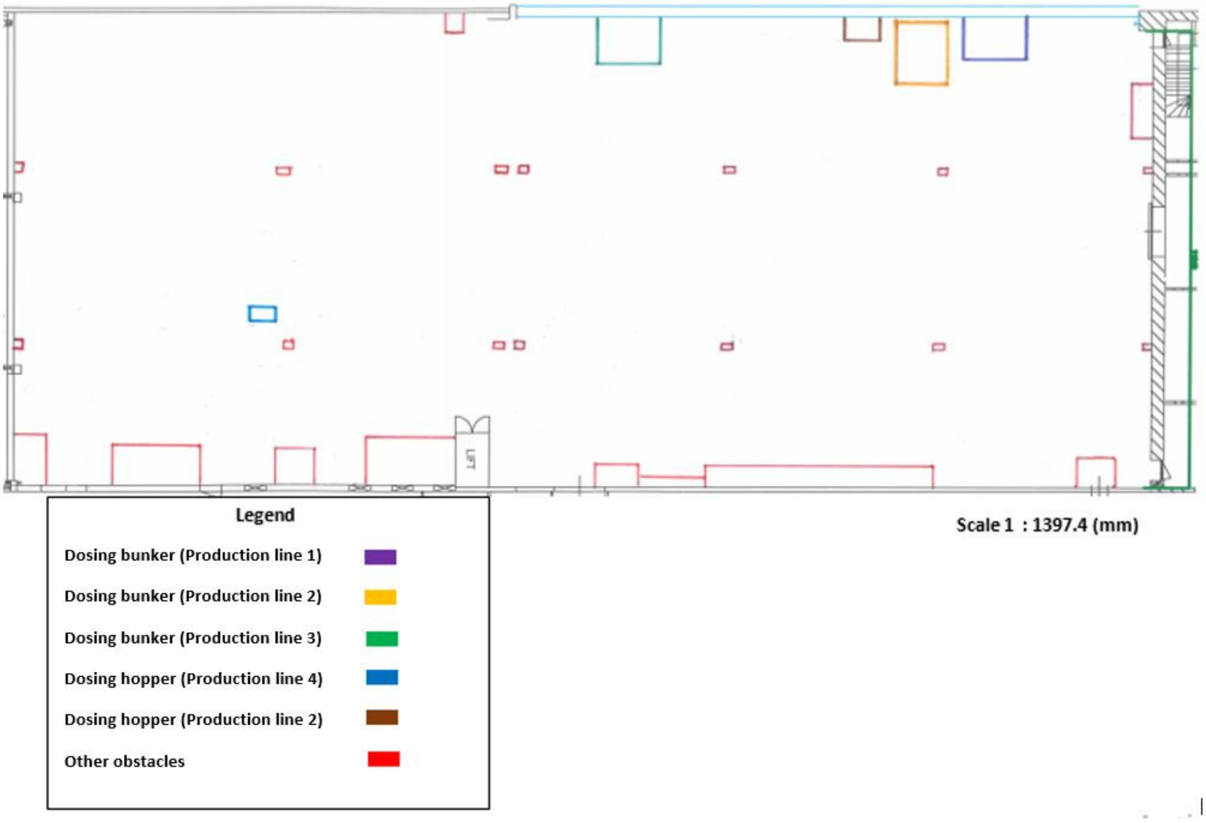

Figure 2.3.b: Scale drawing of mezzanine

2.4 Recap

Chapter 2 started off with an explanation of the three different types of pallets (EURO, Blok, and custom) used in the packaging warehouse, as well as the three types of storage methods (pallet racking, shelving, and paternosters). This was then followed by the layout of the packaging warehouse, it's inventory capacity used (72% pallet bins & 91% label bins), and the order picking process. Finally, the layout of the mezzanine was discussed in paragraph 2.3.

As mentioned in 1.2.4 there is the problem of inefficient use of company resources in the current situation, which leads to excess spending on outsourcing, pressure on order-pickers and overall lower warehouse efficiency. Thus, to improve the current situation it is important to look at how resources like time, money and people can be used in a more beneficial way for everyone. These aspects will be discussed in further detail in the next chapter, where the investigation of travel distance & time, as well as other KPIs, is touched upon.

3 Issues

In this chapter, we continue with a more in-depth approach to the issues that exist in the current situation, and how they contribute to the inefficient use of resources. Recall, in chapter 1 all the problems were laid out, of which pick times, travel distance, outsourcing, and faulty shipments are discussed. Starting off with paragraph 3.1, the routing of order-pickers and the corresponding pick times & distance travelled is touched upon. Then, paragraph 3.2 continues with the significant outsourcing to an external warehouse provider. In paragraph 3.3 we take a closer look at the mezzanine and how the current situation influences the put away time. Paragraph 3.4 then looks at the overall effect blocked goods have on the current storage situation, ending with the use of storage bins based on pallet type in paragraph 3.5.

3.1 Distance & pick time

To get a clearer picture of the reason behind the high travel distances, as mentioned in paragraph 1.2.3, we spent a couple of days observing their work and drawing their movements onto a printed layout of the warehouse. This process, known as a spaghetti diagram, is a simple yet effective tool to visualize the path of an item or person through a process, in a continuously flowing line. Figure 3.1.a shows a snapshot of one of the spaghetti diagrams made, where the different colors depict the order pickers path for each of the production lines.

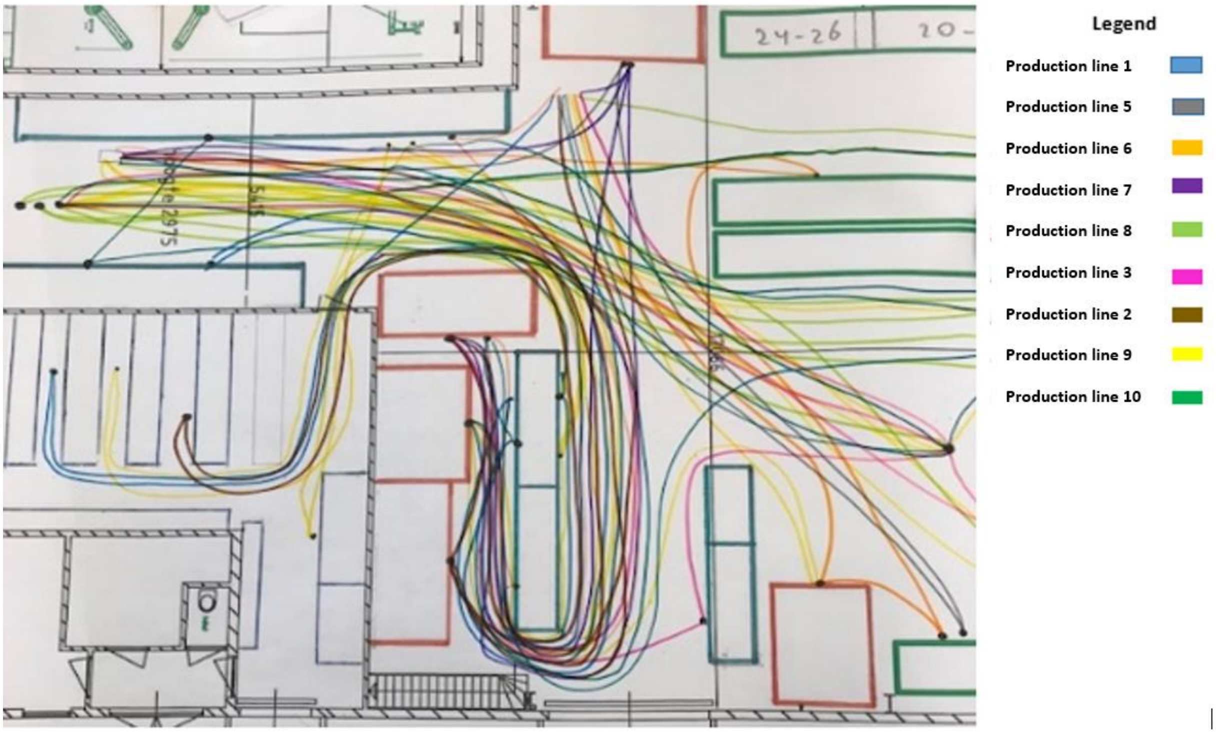

Figure 3.1.a: Spaghetti diagram order picker

Figure 3.1.a shows a lot of movement having to go around the middle storage rack to reach the paternosters on the other side, which hints at an inefficiency. We can also see that there is a lot of going back and forth between shelves/paternosters to pick the required materials on the pick list, which could be caused by bins not being large enough to carry the amounts needed or simply not being near each other, leading to an extra movement to complete the task.

Subsequently, different order pickers were observed throughout their workdays for a few weeks, to record their movements and the time needed for different pick lists. Pick times were calculated using a stopwatch, and noting down the times spent on walking and each location visited. Based on the visited locations, distance could be measured using the scaled layout of the warehouse. Close contact with the order pickers, whilst conducting the measurements, led to an enhancement in the understanding of the situation. Around 100 orders were observed and relevant data was recorded in a table (appendix B.2), then analyzed to have an overview of the average pick time for each production line, in combination with the distance travelled to pick the items. The outcome of the mentioned research is shown in figure 3.1.b.

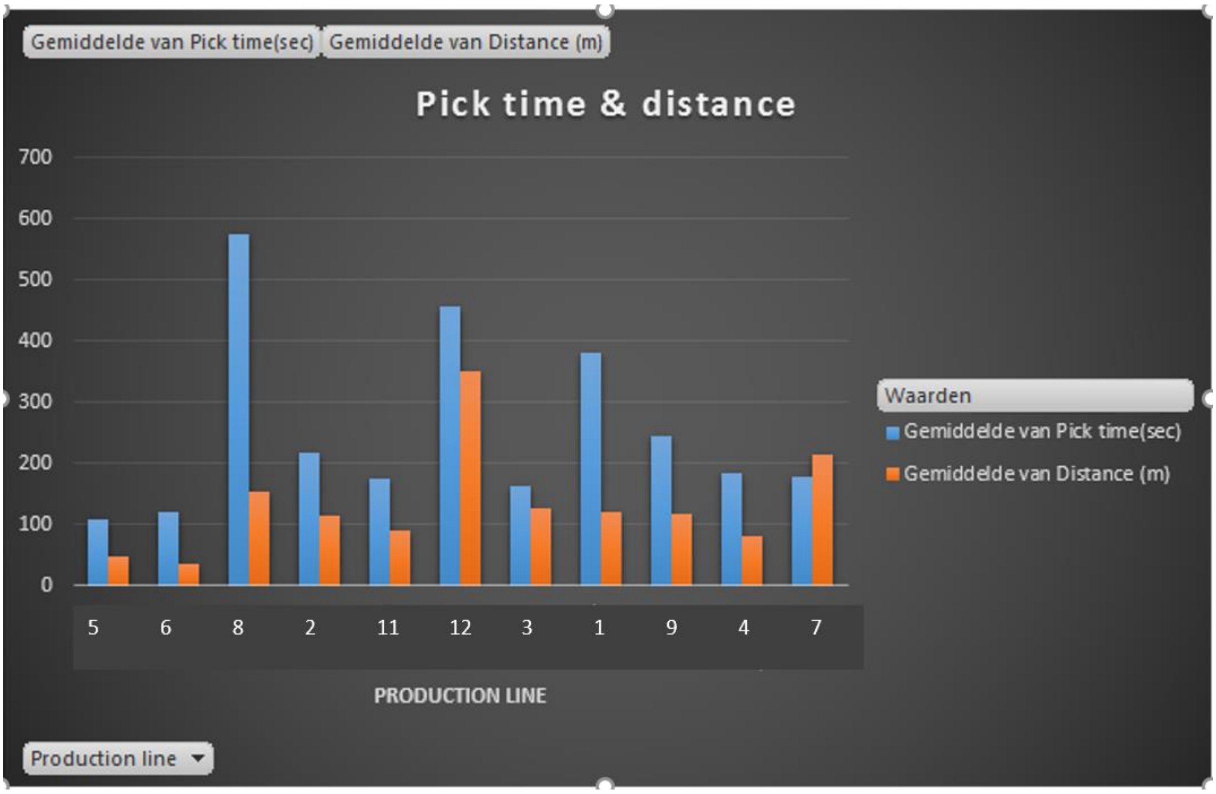

Figure 3.1.b: Pick times(per order) & distance per production line

From figure 3.1.b we can see that some production lines require significantly more pick time than others, this comes down to a combination of more order lines, inconvenient allocation of the required SKUs throughout the warehouse and labels in bins out of pick reach (either needing a forklift or a ladder). Overall the pick time (per full order, thus travelling + retrieval) is an average of 3 minutes and 36 seconds, whereas the average distance travelled is around 115 meters (considering there can be >20 orders in a shift), which in addition to all other activities carried out by the order picker can amount to more than 10 kilometers travelled in a day.

3.2 Outsourcing

Recall the problem cluster in paragraph 1.2.3, where in the current situation a large part of the products is stored at an external warehousing Company Y, alongside rework products. However, due to the focus on the packaging warehouse and the mezzanine, only the external storage of packaging materials is taken into account. Below is a table that contains all the costs related to the movements, administration and storage of goods at the external warehouse. The administration is almost always conducted through the online portal due to the significant amount of extra costs when done by phone or fax, but in some rare cases might be done (e.g. internet connection down).

Action	Cost	Unit
Storage (non-ADR goods)	€ 0,40	Pallet
Storage (ADR-goods)	€ 0,20	Pallet
Administration (through the online portal)	€ 8,36	Truck (not necessarily full)
Administration (through fax/phone)	€ 26,64	Truck (not necessarily full)
Gas measurement	€ 64,07	Container
Entry and removal costs	€ 3,62	Pallet
Sealing pallets	€ 3,35	Pallet
Unloading 40ft container	€ 278,57	Container
Transport	€ 125,81	Shipment (Y-X -Y)

Figure 3.2.a: Overview of costs at external storage facilitator

Invoices for the services provided are received on a weekly basis, at the end of each week, and thus the costs related purely to the physical storage are thus accumulated over 7 days. Figure 3.2.b shows the number of pallets outsourced to Company Y over 2017 and most of 2018, which were multiplied by the costs of storage (1,40 per week), shown by the white columns. The handling costs associated with the outsourcing were calculated by subtracting the weekly storage costs from the total costs on the weekly invoice, and are shown in grey.

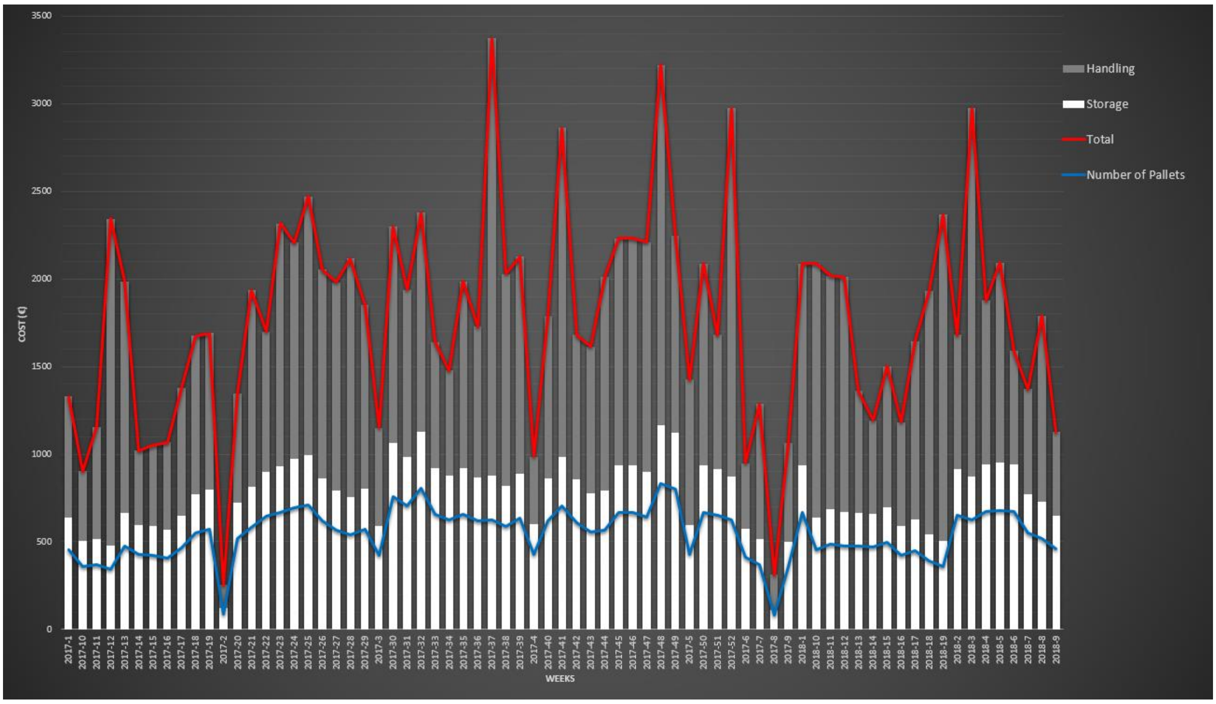

Figure 3.2.b: Costs of outsourcing per week

In the graph above we can see that the number of pallets (blue line) that were outsourced increased throughout 2017 to eventually stabilize, and started a slow decent at the end of 2017/beginning 2018. This might be due to efforts to decrease the overall operating costs throughout Company x that were introduced at the beginning of 2018, and the attempt to free up space within the company by reducing excess stock and relocation. Nonetheless, the average still lies above 500 pallets outsourced each week which contribute to the costs of the warehousing operation, especially in terms of handling & transport. For almost every week, the handling costs make up more than half of the total invoiced. Therefore, trying to find a solution that can reduce the external storage, more specifically the handling, is of significant importance to a more efficient operation.

3.3 Put-away time

As mentioned in chapter 2.3 there is no real storage policy or layout for the mezzanine leading to a disordered layout and unclear view of where empty storage locations can be found. Unclarity leads to inefficiency in this case as employees need to search through the 'maze' of stacked pallets, causing heightened put away times, even when two employees are working. Put-away time is a widely used warehousing KPI, which is defined as follows: the lead time since a product(s) has been unloaded to when it is stored in its designated place (Staudt et. al, 2014, p. 5)

$$Pu = \frac{\sum \Delta t(Sto)}{Pal\ Sto}$$

Where $\sum \Delta t(Sto)$ is the time between the instant when the product is unloaded until its storage and $Pal\ Sto$ is the number of pallets stored. In this instance the put away time was measured at different moments in time to form an average. Appendix B.1 shows 31 measurements conducted in the mezzanine, where two employees would time from the moment the first pallet is in the door opening until the last one is put away. Resulting from this, was an average time of around 1:07 minutes per pallet, which would be higher when only one employee would be busy putting away pallets to their designated spots.

3.4 Blocked goods

Recall the problem cluster in chapter 1 mentioning the problem of faulty shipments from suppliers. Even though tackling this issue falls out of scope (e.g. requires supplier analysis etc.), we decided to look at the effect it has on the current situation. Figure 3.4.a shows the faulty shipments per supplier of packaging, for all of 2017 and most of this year as well.

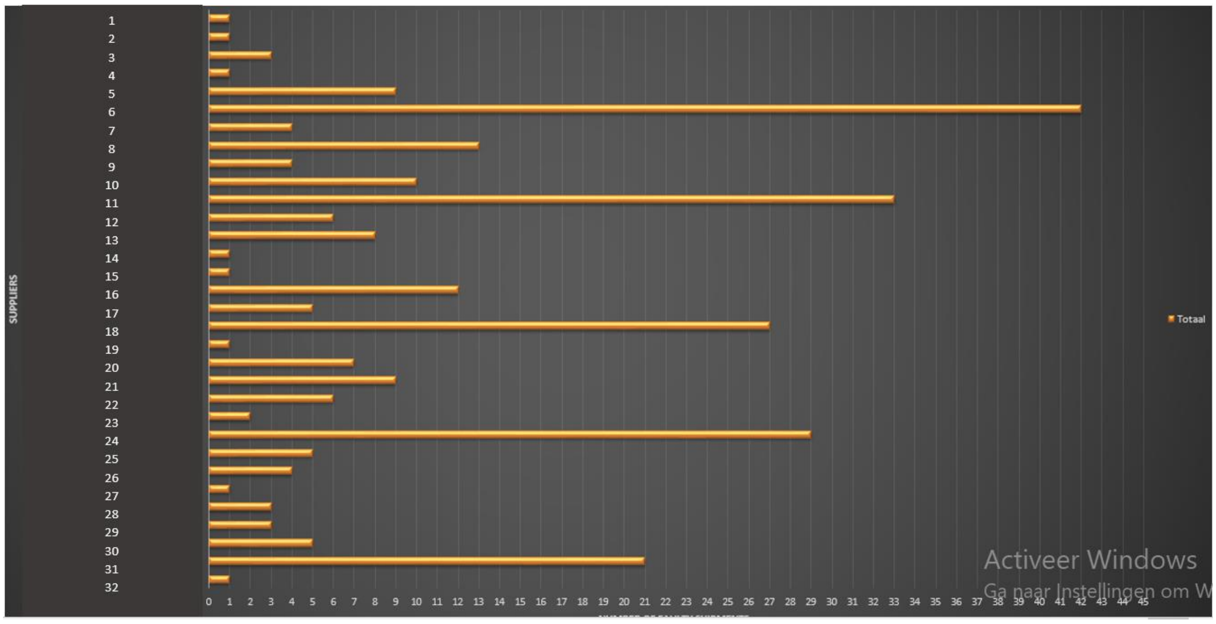

Figure 3.4.a: Number of faulty shipments per supplier

Evidently, the impact is quite large with some suppliers delivering thousands of faulty units each month. In terms of impact on our research, on average fourteen pallets of blocked goods take up much needed storage space in both the packaging warehouse and the mezzanine. These figures were obtained through observation whilst collecting data on storage capacity, and thus could be an even larger burden to the warehouse operation.

3.5 Storage bin use

Whilst collecting data on the current inventory capacity used (refer to 2.2.3), we noticed there are quite a lot of storage bins filled with different sized pallets than should be there, 800mm wide instead of 1000 and vice versa. Intuitively this leads to loss of space, as the pallets either don't completely fill the available bin or overlap into another bin, possibly blocking it. In the figures below the possible configurations based on the width of the rack and its subsequent bin width are shown. They depict a frontal view of the rack, where the colored block is either a EURO or a Blok pallet, and the remaining space in mm is shown beneath (e.g. 200 or 800). All configurations have at least a 4cm clearance on either side of the pallets, to allow for accessibility and prevent damage to adjacent pallets when removed from the rack.

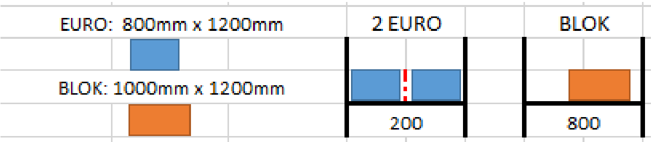

Figure 3.5.a: Pallet division 1800mm rack

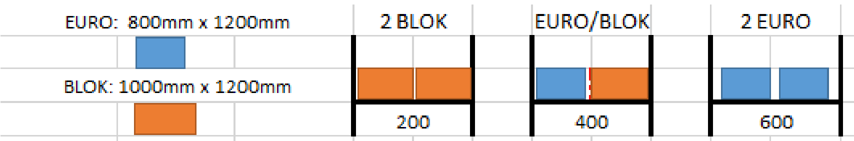

Figure 3.5.b: Pallet division 2200mm rack

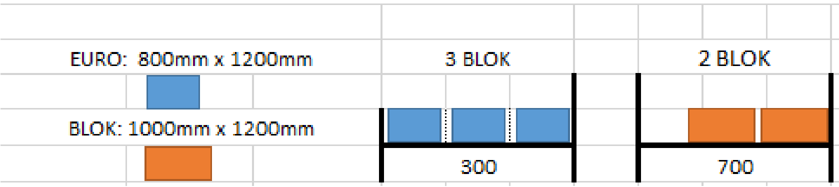

Figure 3.5.c: Pallet division 2700mm rack

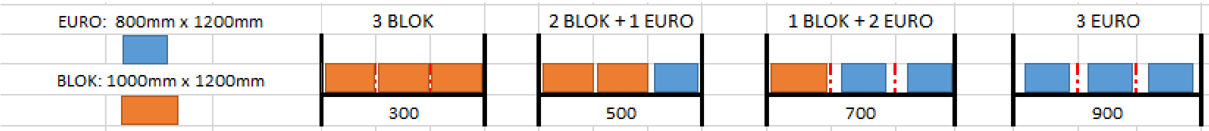

Figure 3.5.d: Pallet division 3300mm rack

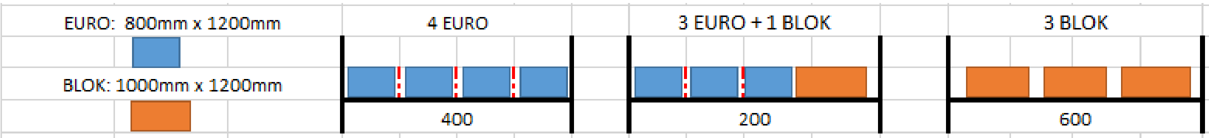

Figure 3.5.e: Pallet division 3600mm rack

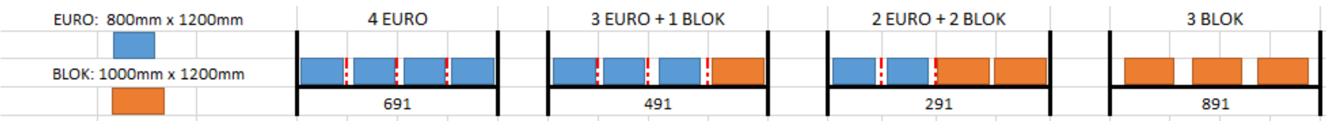

Figure 3.5.f: Pallet division 3891mm rack

The images above show the possible combinations of pallets that can be stored on the different rack widths, where the leftmost image is always the best option in terms of space used (e.g. figure 3.5.a, the second image shows a loss of 1 whole pallet).

For around twenty days the amount of 'EURO bins' filled with blok pallets and vice versa were then counted and filled into excel, to calculate the loss of pallet space. For each pallet in the wrongful place, a loss of 200mm in space is encountered, which multiplied by the tally of wrongful pallets gives the total loss of space. The final loss of pallets is calculated through the following steps'

1. $EURO\ bins\ with\ Blok\ pallets * 200mm = Loss\ mm\ (Blok)$

2. $Blok\ bins\ with\ EURO\ pallets * 200mm = Loss\ mm\ (EURO)$

3. $\frac{Loss\ mm\ (EURO)}{800} * \frac{Loss\ mm\ (Blok)}{1000} = pallet\ loss$

After the period of data collection, the average loss of pallet space was found to be fifteen pallets, which is a loss of around 3% of the total available capacity.

3.6 Recap

In paragraph 3.1 we saw that the average pick time per order is 3 minutes and 36 seconds, with a related distance travelled, of 115 meters. Both of these figures are significant seeing that there are thousands of orders picked each year. Following this, we had a closer look at the outsourcing and the different costs associated with it. Noticeable was the large portion of the weekly costs spent on the external handling of the storage at Company Y and sending pallets back-and-forth when needed, when compared to the 20 cent per day. Hence, this portion of the total costs of outsourcing show possibilities for savings. In paragraph 3.3 the time taken to put away pallets received in the mezzanine, was foun to be 1 minute and 7 seconds per pallet when working with two employees. This is a significant amount of time considering the size of the mezzanine, and could possibly be reduced by changing certain aspects of its layout. Next, we noticed there are substantial amounts of blocked goods delivered by suppliers each year. Another worrying effect seen in paragraph 3.4 is the average of 14 pallet spots occupied by blocked goods, which is space that could have been used more efficiently. Finally, paragraph 3.5 shows the problem of inefficient use of the pallet racking with blok sized pallets placed in Euro sized locations and vice versa, which leads to an average loss of space of 15 pallets. In the next chapter we search, through literature to find some background that can help solve the problems mentioned in this chapter.

4 Literature

This chapter comprises the literature on warehouses found through research questions 13 and 14 from phase 5 (found in 1.6.5), regarding layout options, storage methods, and order-picking. First off, paragraph 4.1 digs deeper into layouts, how locations of receiving and shipping play a role and how aisles should be configured. Paragraph 4.2 continues with the storage side of the warehouse; policies for locating goods and storage methods. Finally, paragraph 4.3 showcases the different available methods/techniques available for order-picking. Literature used in this chapter comprises of Bartholdi & Hackman (2016), Richards (2011), de Koster et al. (2007), and Link51(Racking & Warehouse storage guide).

4.1 Layout

4.1.1 Location of receiving and shipping

The locations of the receiving and shipping areas within a warehouse play a role in determining what are convenient storage locations for fast and slow-moving goods. The configuration of receiving and shipping can either be a *flow-through configuration* or a *U-flow configuration*, shown in the figures below.

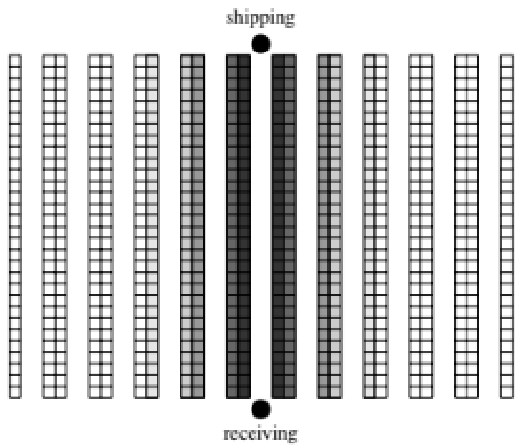

Figure 4.1.a: Flow-through configuration (from Bartholdi & Hackman 2016)

In the flow configuration shipping and receiving are on opposite sides of the warehouse, creating aisles that are all similar in convenience in terms of distance from either location. In figure 4.1.a the darkest color locations show the most convenient and get less convenient as u move further to the left or right from the middle aisle.

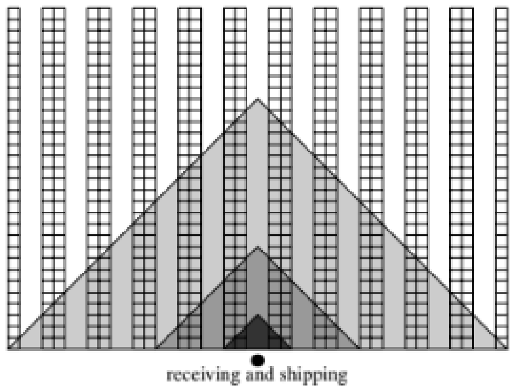

Figure 4.1.b: U-flow configuration (from Bartholdi & Hackman 2016)

In the case that receiving and shipping are on the same side of the warehouse, the number of convenient locations is very limited, as can be seen by the small shaded triangle at the bottom. To get a better comparison between the two configurations, the features of each are laid out in the table below.

Features	**Flow-through**	**U-flow**
Receiving & shipping	Same side of the warehouse	Opposite sides of the warehouse
Convenience	Most convenient become better, less convenient become worse	Many storage location of equal convenience
Product movement	Extremely high volume	Strong ABC skew (very few SKUs account for most activity)
Warehouse	Preferable when the building is long and narrow	Allows expansion along with the other three sides of the warehouse
Others	All products flow in the same direction so there is less opportunity for interference	Provides dock flexibility for both shipping & receiving
	Reduces any efficiencies that might be gained from dual cycle transactions	Permits more efficient use of forklifts (put away & retrieval in one assignment)
	Conservative design	Minimizes truck apron (space for turning without striking fixed objects) and roadway

Figure 4.1.c: Flow-through vs U-flow (after Bartholdi & Hackman)

4.1.2 Aisle configuration

Commonly, aisles in the warehouse are oriented parallel to the direction of material flow, so travelling between storage and receiving is reduced. To support more direct travel to certain storage locations it can be beneficial to add a cross aisle, however, the downside is a loss of floor space that could have been used for pallet storage. Figure 4.1.d shows a simple set-up with one cross-aisle for more direct access.

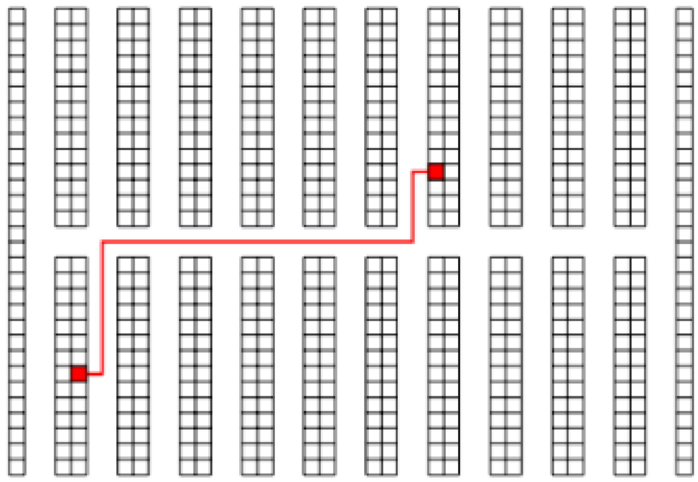

Figure 4.1.d: Cross-aisle (from Bartholdi & Hackman 2016)

K. Gue and R. Miller have suggested that reorganizing some aisles into angled cross-aisles, could reduce travel times by up to 20% when forming a fishbone layout. However, this type of layout requires a larger warehouse to make up for the lost space but is compensated by the direct travel to a central point of receiving and shipping (shown by the black dot). Thus, the fishbone layout is most effective when most pallet movement is to/from the central point.

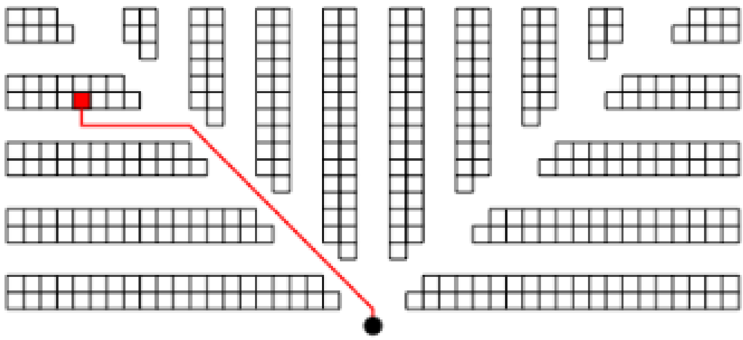

Figure 4.1.e: Angled aisles (from Bartholdi & Hackman 2016)

4.2 Storage

4.2.1 Policies

Policy	**Explanation**	**Limitations/Characteristics**
Random	Every incoming pallet/number of similar products is assigned a random location, chosen from all free locations with an equal probability	1) High space utilization at expense of travel distance 2) Only for the computer-controlled environment, otherwise turns into *closest open location storage*
Closest open location	First empty location encountered by the employee is used to store the product	1) Usually causes full racks around the depot and emptier towards the back (if there is excess capacity) 2) Similar performance to random storage when only full pallets are used
Dedicated	Each product is stored in a fixed location	1) Location reserved even for products out of stock 2) Lowest space utilization (sufficient space reserved for every product so maximum inventory level can be stored) 3) Order-pickers become familiar with product locations (advantage) 4) Helpful if products have different weights (in order of weight to obtain a good stacking sequence without additional effort)
Full turnover	Distributes products over the storage are according to their turnover	1) Products with the highest sales located at the easiest accessible locations 2) Slow moving products are located somewhere towards the back 3) Cube-per-order index (COI) rule, defined as the ratio of the item's total required space to the numbers of trips required to satisfy its demand per period (lowest COI closest to depot) 4) Loss of flexibility and consequently loss of efficiency (demand rates vary constantly, thus product assortments leading to reshuffling)
Class-based	Group products into classes in and assigned to the dedicated area of the warehouse	1) Storage within the area is random 2) Classical way is pareto analysis (fastest moving contains 15% stored but contributes to 85% of turnover) 3) Classes are determined by some measure of demand frequencies (e.g. COI or pick volume) 4) Fast moving usually, A-items, next B, then C (usually 3, however sometimes additional gain with extra classes with respect to travel times)

Figure 4.2.a: Overview of storage policies (after de Koster et al.)

4.2.2 Equipment

Within warehouses, there are different types of storage equipment available dedicated to the type of product that needs to be stored. Pallet-based SKUs are stored in pallet racking or can simply be stored on the floor, and boxes or single items can be stored in bin-shelving or static/dynamic racks.

Pallet storage

Adjustable pallet racking is a type of racking which makes use of adjustable beams allowing for easy readjustment of the rack's layout. Despite this, it is still a very strong storage system once in place and gives easy access to all pallets stored.

Double-deep pallet racking, a similar variant to adjustable pallet racking in the sense that it can easily be adjusted to accommodate different pallet heights, however, pallets are stored two deep in lanes. Thus, it is a highly space-efficient storage system, but does give way to a Last in First Out approach as the front pallets are usually picked first.

Narrow aisle pallet racking, allows fork lift trucks to work in aisles that are almost half the width of the more common adjustable pallet racking, as well as increasing the use of floor space and the height of the racks. Specialized lift trucks that make use of rails or wires for guidance along the aisles are used in this set-up and are either 'man-down' (operator stays at ground level) or 'man-up' (the cabin with the forks goes up to the pick face).

Push-back pallet racking, is a type of racking that makes use of lanes that can be up to 10 pallets deep. Beams have rollers on them at a small incline towards the pick face, so that the remaining pallets roll forwards whenever a pallet is picked from the lane. This type of storage is useful for bulk storage and handling as the set-up is according to 'first in, last out' principle.

Drive-in pallet racking, requires minimal space for access aisles, as pallets are stored on beams in the depth of the racking that can be accessed with a fork lift by driving-in in to the store or retrieve goods. This system works especially well for batch based loads, as the first pallet in a lane is always the last out. However, this system utilizes floor space fully through pallet storage up to 11 meters in height.

Mobile pallet racking makes use of racking on guide tracks installed into the floor, allowing the racks to move using electric motors. The desired aisle can be chosen and all other racks will move to form one operating aisle to access the location. Access speed is lowered due to waiting for the racks to move into the right position, but space is used fully. Mobile racking is a very good option for cold stores as the rooms storage capacity is used fully, minimizing the building size needed (cutting costs).

Pallet live storage is a similar system to double-deep as it makes use of inclined lanes fitted with rollers, but is different in the replenishment operation. Pallets are loaded into the opposite end of the lane allowing for 'first in, first out' selectivity and provides for automatic stock rotation.

In figure 4.2.b the different types of racks are compared based on features like space utilization and speed of access, on a five point scale with '+ +' being the highest and '- -' the lowest.

Features/Rack types	**Adjustable**	**Double-deep**	**Narrow aisle**	**Push-back**	**Drive-in**	**Mobile**	**Live storage**
Space utilization of floor area	+ -	+	+	+ +	+ +	+ +	+ +
Utilization of cubic storage space	+ -	+	+	+	+ +	+ +	+
Access to individual pallet leads	+ +	+ -	+	+ -	- -	+ +	+ -
Speed of access & throughput	+ -	+ -	+	-	-		+
Efficiency in stock rotation	+ -	+ -	+	+	-	-	+ +
Efficiency in stock control	+	+ -	+	-	+ -	+	+ +
Specialized handling equipment	N/A	Needed	Needed	N/A	N/A	N/A	N/A
Ease of re-location	+ +	+ -	+ -	- -	+ -	-	-
Ease & speed of installation	+ +	+	+ -	-	+ -	-	-
Adjustability of beam positions	+ +	+	+ -	N/A	- -	+ -	N/A

Figure 4.2.b: Overview of features for different racking types (after racking guide)

Bin-shelving or static rack

Shelving is one of the cheapest and simplest storage methods that can be used to store cartons or loose items. Usually, they are only about 0.46-0.61 meters deep but can be up to 0.91 meters deep. Typically, picking is done at a speed of 50-100 picks per hour for one person.

Gravity flow rack

These are a type of shelving that similarly to push-back pallet racking makes use of inclined lanes with rollers. The shelves can be anywhere between 0.91 and 3 meters deep, and products automatically roll towards the pick-face when something is taken from a location. Typical speeds are 150-500 pick per hour, dependent on the SKU.

4.3 Order-picking

4.3.1 Break-down

In general, the order-picking process contributes to around 55% of a warehouse's operating costs and can be broken down into more detail, as follows; (Bartholdi & Hackman, p.25)

Activity	% Order-picking time
Traveling	55%
Searching	15%
Extracting	10%
Paperwork and other activities	20%

Figure 4.3.a: Order-picking process (retrieved from Bartholdi & Hackman)

Noticeable, are two significant contributors to the total time taken to pick an order, travelling and paperwork/other activities. When designing the layout or the picking process it is therefore essential to minimize the time spent travelling as much as possible to reduce the amount of time 'wasted'.

4.3.2 Picking methods

The different picking methods used in today's warehouses are shown in the table below.

Methods	Description
Paper pick lists	- Pick list will detail the order number, location, product code, description and quantity to be picked - Place fastest-moving items closest to dispatch (minimize travel) - Utilize a trolley/cage/pallet truck/forklift truck for picking - Write down any discrepancies onto the pick list
Pick by label	- Labels are printed on a sheet (in pick order) - Picker attaches a label to each item picked and returns any unused labels to a supervisor
Pick by voice	- Operators use a headset and microphone together with a small computer attached to a belt/worn on the wrist - WMS sends information to the picker through voice commands and the operator can communicate back to the system - Increases accuracy and productivity and allows for real-time updates regarding potential storages
Barcode scanning	- Barcodes are used to identify products, locations in the warehouse, containers (cartons, pallets..), serial and batch numbers - Can be one-dimensional or 2-d (allows more data to be stored in a smaller space) - The hand-held scanner has a screen and a trigger, it scans the barcode, deciphers it and stores or transmits it to a computer - Wearable computers are typically worn on the wrist on the wrist or lower arm and feature a screen and a small keyboard/touch screen, with the option of a finger-mounted scanner
RFID	- Data is exchanged between tags and readers and depending on the frequency, may or may not require line of sight - There are two types of RFID tags: A) Passive, no power source, limited data storage, read-only, and have a limited read range B) Active, have their own power source, have a larger data-storage capacity, have a read/write capability and are readable from a greater distance - Difficult and costly to implement
Pick by/to light	- Uses light-indicator modules mounted to shelving, flow racks, pallet racks or other storage locations - Begin the process by scanning a barcode on a shipping carton which denotes the next order number to be picked: 1) All pick locations for that particular order light up in the zone where the picker is located 2) A digital display gives the quantity needed, and once that amount is picked the the operator turns of the light to indicate that item has been picked 3) Continue until the order in that area is completed - The operator chooses their own best pick path

Figure 4.3.b: Pick methods (after G. Richards)

4.3.4 Guidelines for lifting and loading

When picking products manually it is very important to lift properly and in the most ergonomically sound way, to reduce stress on employees and long-term injuries. In figure 4.3.c are some basic guidelines for the weight that can be lifted from different heights and at different distances from the body (e.g. arm's length), so that chances of excessive strain on the employee are kept at a minimum. Note, that these are for infrequent picking of up to about 30 movements per hour.

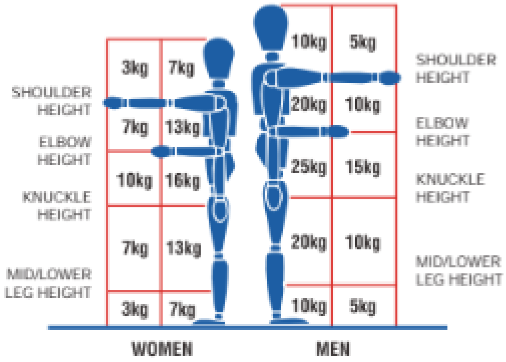

Figure 4.3.c: Risk assessment for manual picking (from racking guide)

Significant reduction in weight limit occurs as soon as the product moves into the zone at arm's length, as well as below knee or shoulder height. Thus, in designing the pick faces for manual order picking and the allocation of products among the shelving, the emphasis needs to be on lifting as close to the body as possible within the 'safe zones'.

4.4 Recap

In chapter 4 we took a step back from the research project and had a look at what information is already available in the literature. Firstly we had a look at the layout in paragraph 4.1 to assist us in deciding what kind of layout would be useful for the new situation. Layout decisions consist of the configuration of material flow (either U-flow or Flow-through) and the wanted aisle configuration. In paragraph 4.2 the different storage policies that could be of use to the allocation of materials at Company x, as well as the different storage methods that can be used in combination with these are investigated. Finally, the chapter ends with a detailed analysis of order picking as this is one of the main burdens for the warehouse employees at Company X. This paragraph gives insight into different techniques used in the warehousing environment, the make-up of the process itself, and a short glance at ergonomics in manual picking. The information gathered in this chapter can help in decisions making and shaping the new situation.

5 Solutions

In this chapter, we make use of the data collected on the different problems that influence the current situation and make use of the literary background in the previous chapter to suggest a solution. In some cases, literature might not be able to provide an optimal solution, as theory is never one size fits all, and some problems might require some further development of what is already known. The chapter is divided into a section of short-term developments (5.1), that require minimal interference to improve the current situation, and a section containing two solutions that require more strategic decisions to be made.

5.1 Short-term

5.1.1 Mezzanine

At the moment the mezzanine is divided into a combination of storage locations and free storage, with a random storage policy and some lanes (containing materials for the three bunkers). Besides this materials have stored that need to go to the production lines using the elevator, appendix E contains a full list of the products and their movement type (e.g. elevator or bunker). Below we will go into more detail on how the new situation will change from the current layout.

Current situation

1. There are 204 pallet spots available as storage locations, in addition to approximately 184 unlabeled pallet spots, giving a total capacity of 388 pallet bins.
2. Each week an average of 786 new pallets of packaging are delivered (based on historic data of 74 weeks), giving a turnover of $\frac{786}{388} = 2.03$ times the full storage
3. 26 SKUs stored in the mezzanine have to go down using the elevator which on average takes 4 minutes from pick to production line, which takes approximately 622 hours a year based on the number of pallet movements (appendix E.3)

New situation

Remember in the current situation employees store incoming goods randomly amongst the storage locations available, whereas the rest of the available space is used similarly to closest open location (except that there are no marked locations), with pallets simply being stored wherever space is available. In paragraph 4.2.1 we saw the different storage policies available as well as some of their details. Based on the needs in the mezzanine (create more space, reduce put away time, and improving accessibility), the tendency is towards either dedicated or highest turnover storage. The major advantage of dedicated storage is that it allows order pickers to easily remember storage locations. Full turnover, products with the highest turnover are placed in the best accessible locations and slow-moving products are located further backwards. For this specific case, we decided to combine aspects of both policies to form a new layout. Dedicated storage locations were created to reduce put away time since this would help order pickers find locations faster. Additionally, extra space was created (even though one of the aspects of this policy suggests otherwise) because products will no longer be randomly stored but are placed in a way that utilizes as much of the floor space as possible without hindering accessibility (number of lanes, lane width, and space for maneuvering pallets). To determine the size of the lanes, and their distance from their respective bunkers/hoppers the turnover was used, hence full turnover policy. The result of the combination can be seen in figure 5.1.a.

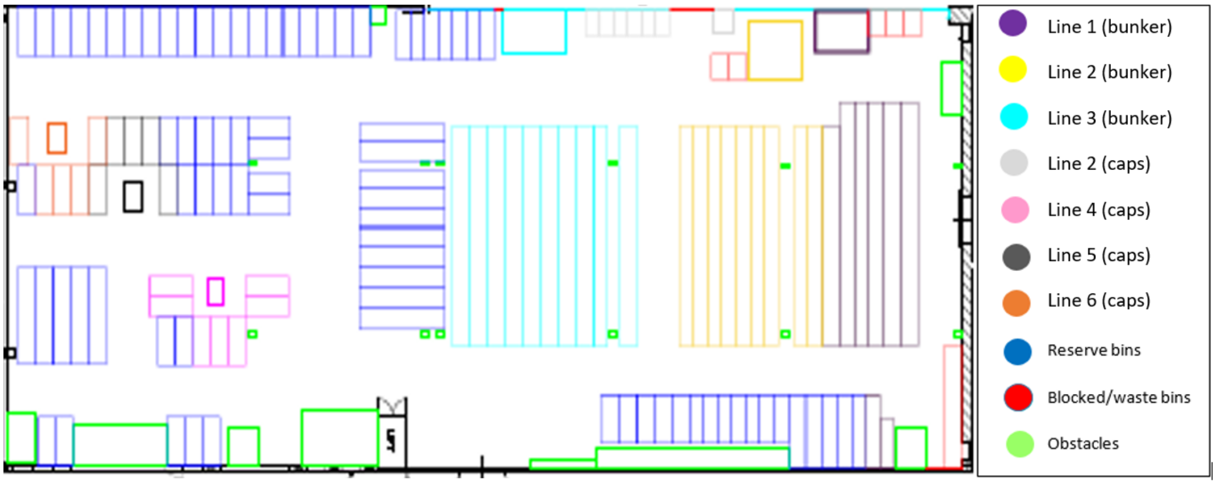

Figure 5.1.a: New layout mezzanine

1. Each of the bunkers will have dedicated storage lanes, with the dimensions for each based on the average batch size (in pallets), calculated using historic pick data (appendix E.3)
2. The cap hoppers all have u shaped dedicated storage around them for easy picking, also based on average batch size
3. Space for some blocked goods is reserved right next to the receiving location, so they can be loaded into Company Y freights who have dropped of their goods directly. The cost of storage at Company Y can then be forwarded to the suppliers.
4. Goods currently going down with the elevator can be moved to the packaging warehouse (appendix E.4)
5. Total of 480 pallet spots in the new layout: $new - old = 480 - 388 = 92\ extra\ spots$
6. Pallet spots currently used by Line 5 and Line 6 caps will be free (4 dedicated and average 11 free)

Costs vs. benefits

Firstly the storage locations need to be painted and labeled to accommodate the dedicated storage policy, and the dedicated lanes. Despite 480 pallet locations being available, they will not have to be drawn as separate pallet sized squares, but instead lanes of different depths are used (single, double, three, four, nine and ten pallets). Second the Line 5 and Line 6 cap hoppers will need to be transported upstairs and connected to their respective production line underneath. Finally the SKUs no longer stored in the mezzanine will need to be moved down to the packaging warehouse and vice versa. An overview of the costs associated with these three investments can be seen in figure 5.1.b.

Investment	**Details**	**Cost (€)**	**Calculation**	**Total cost (€)**
Painting storage locations	Paint (± 60m per can, ± 790m)	6.50	14*6.50	91.00
	Rent (per day, max 24 hours)	8.50	2 * 8.50	19.00
	16 hours overtime (1.8 FTE, 4 FTE needed)	63.00	16 * (4 * 63.00)	4032.00
	Floor labels (131 locations)	22.50	131 * 22.50	2947.50
	Total			7089.50
Moving Line 5 + 6 hopper upstairs	Assembly materials (tubing, etc.)	400.00		400.00
	16 hours (2 FTE)	35.00	16 * (2*35)	1120.00
	Total			1520.00
Reorganizing SKUs to the right storage locations	8 hours (2 FTE)	35.00	8 * (2*35)	560.00
Total				**9169.50**

Figure 5.1.b: Short-term investments mezzanine

Next, we looked at the savings (€) in terms of extra space created and time used inefficiently. Storage costs saved for the additional pallet spots could simply be calculated using the given 20 cents per pallet/day. However, most of the costs are in the transport & handling (recall paragraph 3.2), which were calculated based on the number of Company Y trucks per week over the last year, and its associated costs. By dividing this first into the cost per pallet €7.43 and then into days, the €1.06 seen in figure 5.1.c was formed. Time spent on getting SKU's from the mezzanine to the production line was calculated based on the number of elevator movements (either pallet picked or frequency) multiplied by the average assumed time of four minutes (getting a pallet to production line when making use of the elevator).

Saving	**Details**	**Cost (€)**	**Calculation**	**Total saving (€)**
Storage locations	Storage cost (day/pallet)	0.20	92 * (0.2 * 365)	6716.00
	Handling & transport cost (per day/pallet)	1.06	(1.06*365)* (2*92)	71189.60
	Total			77905.00
Moving Line 5 + 6 hopper upstairs	15 pallet locations newly available in packaging warehouse	0.20 + 1.06	(0.2*15*365) + [(0.41*15)*(1.06*365)]	3474.44
	Elevator (Multi, ABL, cGMP, 1 FTE)	35.00	(236.60 + 110.58 + 154.23) *35	17549.35
	Total			21023.79
Total				**98928.79**

Figure 5.1.c: Potential savings

Even though cost reduction is an important driving factor, in this research the human factor (being the order picker or another warehouse employee) is also significant. Therefore, the table below highlights other benefits of the possible new situation.

	Change	**Old situation**	**New situation**
Storage locations	Dedicated storage	Random storage with some fixed locations, led to higher put away times (more searching for empty locations)	Easier to put away pallets received and retrieve the right SKUs when it is needed
	Blocked goods section	Easy to lose sight of blocked pallets, that then use up space in the mezzanine for long periods of time	Blocked goods can be taken by unloaded Company Y freights to be stored externally (costs billed to the supplier)
Moving Line 5 + 6 hopper upstairs	Travel distance to Line 5	26 meters in the warehouse 93 meters across the shop floor **Total of 119 meters per order**	Caps are stored in u-shape around the hopper, so no more travel distance
	Travel distance to Line 6	26 meters in the warehouse 96 meters across the shop floor **Total of 122 meters per order**	Caps are stored in u-shape around the hopper, so no more travel distance
	Travel distance to Line 9	55 meters across the shop floor **Total of 55 meters per pallet**	12 meters in the warehouse (dependent of exact location) 19 meters across the shop floor **Total of 31 meters per pallet**
	Travel distance to Line 1	67 meters across the shop floor **Total of 67 meters per pallet**	12 meters in the warehouse 27 meters across the shop floor **Total of 39 meters per pallet**

Figure 5.1.d: Non-monetary benefits (*distances are approximations)

Finally, for clarification purpose, all of the above will be combined into a small overview of all the benefits the new situation for the mezzanine has to offer.

Potential Improvements	
Extra storage space	92 new pallet spots created upstairs, providing enough room: to cope with overflow, broaden the variety of SKU's for the bunkers (product enrichment), or other uses
Cost reduction	Potential cost reduction of €89759.29 (savings - investment)
Reduction of elevator use	Reduction in the loss of time associated with using the elevator, by starting off with bringing three product groups down (ABL, Multi, Kugler). Can become completely obsolete over time when deciding to move all SKUs using the elevator to the packaging warehouse.
Reduction in distance travelled	Line 5: 119 (meter per order)* 1546 (orders 2017) = 183974 meter Line 6: 122 (meter per order)* 2645 (orders 2017) = 322690 meter Line 9: 24 meter per pallet * 1659 (pallets 2017) = 39816 meter Line 1:28 (meter per pallet) * 1579 (pallets 2017) = 44212 meter **Total: 590.69 kilometers**

Figure 5.1.e: Potential Improvements

5.1.3 Storage policy

Returning to paragraph 2.2.4, we know the current storage policy is random, with some restrictions linked to the products (weight and height of pallet). The issue with this storage policy is that it doesn't take travel distance and thus the subsequent pick time into account, by allocating with almost equal probability (based on restrictions). Out of the five storage policies mentioned in figure 4.2.a class-based storage is the best option to deal with the mentioned issues. The reason for this is that the zones can be used to create convenient locations based on for example pick frequency.

To update the current storage policy to a version that takes greater care of minimizing travel distances and pick times, a Pareto analysis was used on the pick frequency of the SKU's. Production data for the whole of 2017 and up to May of this year was converted to its individual components through the BOM. All products not stored in the packaging warehouse, mezzanine and/or label storage were left out of perspective, as these are not within the scope of the research. Separate analysis for the labels and the pallet-based SKU's led to an ABC classification for these two product groups, that can be used to allocate products to storage bins. Thus, in this case, a class-based storage would help remove excess travel distance & times as more frequently used SKUs are located in more convenient locations.

There are however some restrictions that will be added to the class-based storage policy, to ensure optimal use of space. Labels will be marked as A/B/C in the ERP system, based on the Pareto analysis carried out. They will also have the restrictions on weight, diameter, and width. This restriction will determine where they are located in the shelving (weight determines the pick height, recall paragraph 4.3.4), as well as the paternoster that is able to store them.

For the pallet-based storage, the same classes will be used, but different restriction plays a role. The custom sized pallets carrying product Z materials will always be stored on ground level, as they are too heavy, and are thus left out of perspective. For all the other goods, restrictions will include a pallet type (Euro/blok) and the height of the full pallet.

5.1.3 Implementation

Mezzanine

The following steps need to be taken in the mezzanine to implement the suggested improvements;

1. Two days have to be planned for the painting of the lanes and storage locations
2. Storage locations need to be labeled
3. New storage locations need to be embedded into the ERP system
4. SKUs that will no longer be stored in the mezzanine need to be allocated to storage locations in the packaging warehouse
5. SKUs stored in the mezzanine need to be moved to the right locations

Storage policy

The following steps need to be taken to successfully implement the storage policy in the warehouse;

1. Contact suppliers of packaging and labels for dimensions of the products/pallets, and their weights.
2. In cases where information is lacking, manually gather the data from the products currently in stock
3. Create an overview file for both the labels and the pallet-based storage, that contains all the required information
4. Add the label A/B/C to the products and their restrictions into the ERP system
5. Do the same for the storage locations
6. Determine zones for the classes
7. Once this is completed, products should be moved to the right locations based on the locations provided by the ERP system

5.2 Long-term

5.2.1 Solution 1

This first solution consists of two changes to the packaging warehouse; (1) reorganization of the vertical carrousel locations, and (2) refurbishment of label racks

Reorganization

By reorganizing the locations of the vertical carrousels in the packaging warehouse, more space for pallets will become available, travel distances and pick times will be reduced. Figure 5.2.a shows the new layout after the reorganization.

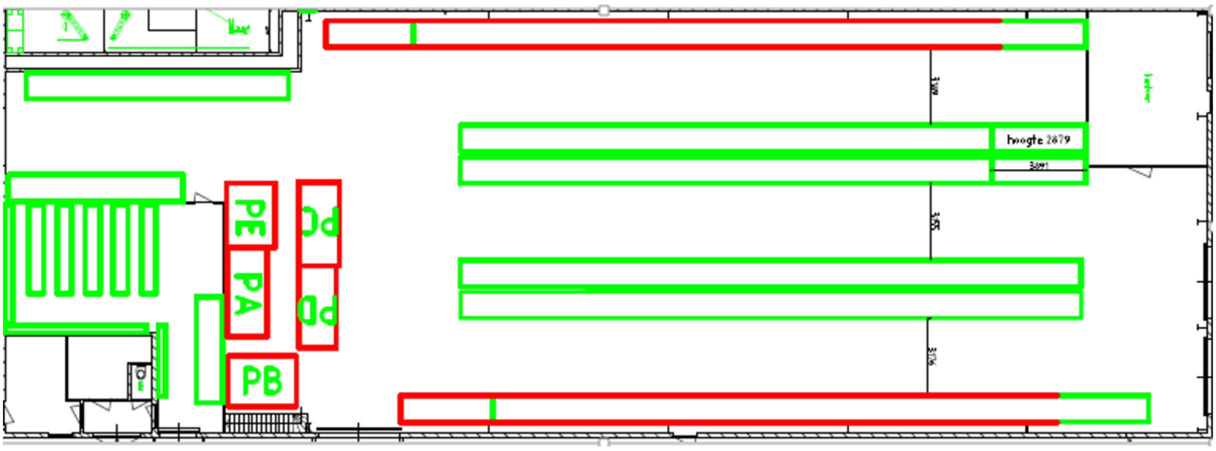

Figure 5.2.a: Layout 1 packaging warehouse

Visible is the clustering of the vertical carrousel into one zone to minimize the travel distances and subsequent time wasted on travelling. In addition to this, extra floor space becomes available, which is filled with extra pallet racking.

Refurbishment

To accommodate for the loss of the label bins that were located in the two label racks, which have been removed in the new layout to relocate the vertical carousel, the remaining label rack needs to be refurbished to accommodate more bins. This also gives the opportunity to increase the ergonomic aspect of the label picking and increase the picking speed. Recall paragraph 4.2, where we mentioned gravity flow racks, which like the name suggests make use of gravity to move the product to the pick face. By doing so it is easier to implement FIFO (first in first out) storage, as well increasing the picking speed and the accessibility.

Based on this idea we thought of a slanted rack that instead of rollers is simply made of plywood at an approximate 5 degree angle. Labels will then be placed on their side with a partitioning on each side, behind each other (between 3-4 deep, depending on the diameter), with approximately 36 bins (based on the most common thickness of 6,5 cm) per shelf. This would give a total of 1512 bins well above the necessary (426) to accommodate for the loss of shelving (181 bins) and what used to be the old shelves (245). This leaves an assumed 1086 bins, which can be used to allocate extra labels now stored in the bottom layers of some of the pallet racking (95 bins).

Shelves will be filled with bins according to the weight of the labels, to improve the ergonomics of the pick operation, based on the weight limits suggested by Link 51 (racking guide, figure 4.3.b).

All labels currently in the store are somewhere between 5-13 kg a piece, and the breakdown of the bins will be as such:

- Below mid lower knee-height: 0 - 7 kg
- Midlower knee to knuckle height: 7 - 10 kg
- Knuckle to elbow height: 10 - 13 kg
- Elbow to should height: 7 - 10 kg
- Above shoulder height: 0 - 7 kg

Costs & benefits

Below we deduct all the costs associated with the changes made to the current situation for solution 1. External FTE is assumed to cost around 50 euro unless known otherwise, and internal FTE at 35 Euros.

Turnover of the warehouse was calculated in the same fashion as for the mezzanine :$\frac{231}{559} = 0.41$.

Investment	Details	Cost (€)	Calculation	Total cost (€)
Reorganization of vertical carrousel	Emptying of vertical carrousels (10 hours, 4 FTE)	35.00	10*(4*35)	1400.00
	Disassembly & relocating (40 hours,2 FTE)	50.00	40*(2*50)	4000.00
	Rerouting electricity & cables (Moekotte, 4 hours, FTE)	43.00	4*43	172.00
	Assembly materials	500.00		500
	Total			6072.00
Creation of new pallet spots	Pallet racks (layers of 4); - 1 x 2700mm - 1 x 3300mm - 2 x 3600mm	-(±400) - (±450) - (±500)	(1*400) + (1*450)+ (2*500)	1850.00
	Assembly materials	300		300
	Assembly (16 hours, 2FTE)	50.00	16*(2*50)	1600
	Total			3750.00
Refurbishment of label racks	Plywood shelves (42 pieces)	74.25	42*74.25	3118.50
	Aluminium partitioning (36 per shelve), cost per m	4.38	(42*36) *4.38	6622.56
	Wood restrainers (1 per shelve)	5.62	42*5.62	236.04
	Assembly (80 hours, 2 FTE)	35.00	80*(2*35)	5600.00
	Assembly materials (self-drilling screws, ± 4800)	71.50		71.50
	Total			15648.60
Total				**25470.60**

Figure 5.2.b Costs solution 1

Next, we calculated the potential savings of the different changes, in terms of time spent walking around the label shelve (recall figure 3.1.a) and pallet spots that created due to labels being allocated elsewhere. Followed by the non-monetary benefits in figure 5.2.d.

Saving	Details	Cost (€)	Calculation	Total saving (€)
Reorganization of the vertical carrousel	Walking time to PA/PB/PD (±15 sec, 1 FTE, ±50 x per day)	35.00	((15*50/360)*35)*365	26614.58
Creation of new pallet spots	Storage cost (day/pallet)	0.20	56 * (0.2 * 365)	4088.00
	Handling & transport cost (per day/pallet)	1.06	(1.06*365)* (0.41*56)	8883.22
	Total			12971.22
Refurbishment of label racks	Storage cost (day/pallet)	0.20	15 * (0.2 * 365)	1095.00
	Handling & transport cost (per day/pallet)	1.06	(1.06*365)* (0.41*15)	2379.44
	Total			3474.44
Total				**43060.25**

Figure 5.2.c Savings solution 1

Based on these calculated benefits (savings) and investment (costs) required to implement solution one, we can calculate a return on investment (ROI);

$$ROI = \frac{benefits - investment}{investment} * 100\% = \frac{43060.25 - 25470.60}{25470.60} * 100\% = 69.06\%$$

Thus, in monetary terms solution, one is a sound investment as it has a positive ROI of almost 70%.

	Change	Old situation	New situation
Reorganization of the vertical carrousel	U – shaped pick zone	Multiple actions with intermittent walks to collect all the required labels from the different paternosters	Easy access to all paternosters
	Travel distance	Approximately 16m (±50 x per day)	Approximately 4m
Refurbishment of label racks	Accessibility	Use of ladder/hook to reach labels in the back of the bin	Labels roll forward as soon as the previous one is picked, allowing for easy access
	Ergonomics	No real consideration of allocation of labels (e.g. 13kg label above shoulder height), causing unnecessary strain	Labels placed on the right height, based on weight risk assessment
	Travel distance to KL	Approximately 17m	Only small distance to paternoster or location on refurbished shelving (max ± 6m)
	Travel distance to bin mn	Approximately 15m	Only small distance to paternoster or location on refurbished shelving (max ± 6m)
	Space creation	521 labels bins	1512 label bins = 991 new bins

Figure 5.2.d: Non-monetary benefits (*distances are approximations)

5.2.2 Solution 2

The second solution also consists of two changes that need to be made; (1) reorganization of the vertical carrousel locations, and (2) the procurement of new paternoster

Reorganization

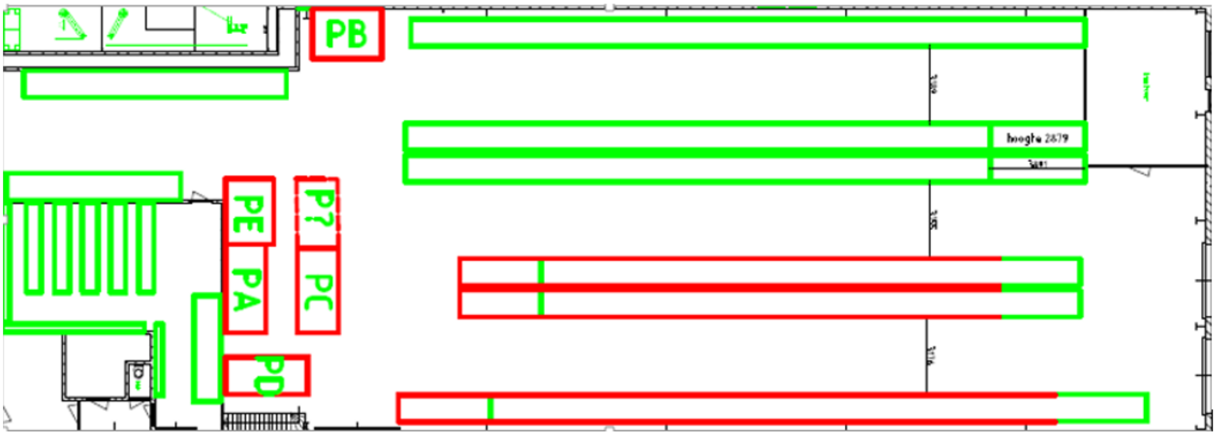

Figure 5.2.e: Layout 2 packaging warehouse

Similarly to solution 1, the vertical carrousel locations will be reorganized and new pallet racks will be installed. The configuration is exactly the same, except for the placement of 1 extra paternoster (P?), which will have similar dimensions to the PC (appendix B.1).

By reorganizing to the new layout of solution 2, two pallet racks of 3600mm can be placed, and one of 2700, with 4 layers for each. This gives a total of 44 new pallet places.

New paternoster

The new paternoster needs to be large enough to cope with the loss of shelving (181 label bins), and in the best case should also be able to carry the label bins currently inside the pallet racks (95 label bins). Thus, a minimum of 276 label bins needs to fit inside the new paternoster. In terms of dimensions, it would be best that the new storage unit has similar dimensions to PC, but could be taller to accommodate more bins. PC has 360 bins divided over 40 shelves, which gives around 9 bins per 10 cm of height (±4,00 high).

Based on the clearance of the rack shelving, the paternoster could, in theory, be 6m high, giving 20 extra shelves or 180 bins. Then the total amount of possible bins would stand at 540.

Costs & benefits

Based on different forums/websites where the price was estimated at ± €20,000 for a vertical carrousel (2500x1500x4000), which could be seen as five thousand per extra meter in height, this was used as an assumption for the price of our paternoster.

Investment	**Details**	**Cost (€)**	**Calculation**	**Total cost (€)**
Reorganization of vertical carrousel	Emptying of vertical carrousels (10 hours, 4 FTE)	35.00	10*(4*35)	1400.00
	Disassembly & relocating (40 hours,2 FTE)	50.00	40*(2*50)	4000.00
	Rerouting electricity & cables (Moekotte, 4 hours, FTE)	43.00	4*43	172.00
	Assembly materials	500.00		500
	Total			6072.00
Creation of new pallet spots	Pallet racks (layers of 4); - 1 x 2700mm - 2 x 3600mm	-(±400) - (±500)	(1*400) + (2*500)	1400.00
	Assembly materials	300		300
	Assembly (12 hours, 2FTE)	50.00	12*(2*50)	1200
	Total			2900.00
Refurbishment of label racks	New paternoster (2500 x 1500 x 6000)	30000		30000
	Assembly (16 hours, 2 FTE)	50.00	16*(2*50)	1600
	Total			31600
Total				**40572.00**

Figure 5.2.f: Costs solution 2

Saving	**Details**	**Cost (€)**	**Calculation**	**Total saving (€)**
Reorganization of the vertical carrousel	Walking time to PA/PB/PD (±15 sec, 1 FTE, ±50 x per day)	35.00	((15*50/360)*35)*365	26614.58
Creation of new pallet spots	Storage cost (day/pallet)	0.20	44 * (0.2 * 365)	3212.00
	Handling & transport cost (per day/pallet)	1.06	(1.06*365)* (0.41*44)	6979.68
	Total			10191.68
New paternoster	Storage cost (day/pallet)	0.20	15 * (0.2 * 365)	1095.00
	Handling & transport cost (per day/pallet)	1.06	(1.06*365)* (0.41*15)	2379.44
	Total			3474.44
Total				**40280.70**

Figure5.2.g: Savings solution 2

Based on these calculated benefits (savings) and investment (costs) required to implement solution one, we can calculate a return on investment (ROI);

$$ROI = \frac{benefits - investment}{investment} * 100\% = \frac{40280.70 - 40572.00}{40572.00} * 100\% = -0.72\%$$

Based on this negative ROI solution two might not be the best possible option in terms of money, however, in this calculation, the return over time was not calculated. Thus, over time the solution could still be profitable, however in the short-term (e.g. a year) it is not.

	Change	Old situation	New situation
Reorganization of the vertical carrousel	U – shaped pick zone	Multiple actions with intermittent walks to collect all the required labels from the different paternosters	Easy access to all paternosters
	Travel distance	Approximately 16m (±50 x per day)	Approximately 4m
New paternoster	Accessibility	Use of ladder/hook to reach labels in the back of the bin	Order to the picker, simply press the location and the system will rotate to that bin
	Ergonomics	No real consideration of allocation of labels (e.g. 13kg label above shoulder height), causing unnecessary strain	No carrying as the work bench is at working height allowing for easy picking
	Travel distance to KL	Approximately 17m	Only small distance to paternoster or location on refurbished shelving (max ± 6m)
	Travel distance to mn	Approximately 15m	Only small distance to paternoster or location on refurbished shelving (max ± 6m)
	Space creation	276 labels bins	540 label bins = 264 new bins

Figure 5.2.h: Non-monetary benefits (*distances are approximations)

5.2.3 Pugh matrix analysis

To choose one of the two options that would best fit the current situation at Company X, a weighted decision has to be made based on some background to support that decision. A commonly used method is the AHP analysis, which is a multi-criteria decision making tool that utilizes math and psychology to find a solution that is most optimal in terms of the criteria set. However, in this case, other stakeholders (e.g. warehouse employees) were already involved during the process of the project and are not necessarily the ones that make the final implementation decision. In this case, a set of criteria/objectives was given by the management team that functions as a standard that each solution needs to meet.

Based on this set of six criteria deemed important, an alternative method, the Pugh matrix analysis was used. A Pugh matrix is a team-based process for concept selection, that compares concepts/solutions to the 'ideal' of each stakeholder. This is a simple tool that grades different options on a 0-5 scale based on a set of criteria and then multiplies this score by the relevant importance of each of these criteria (also 0-5 scale).

To get a more balanced outcome we decided to ask both supervisors (who have different wants for the outcome) to grade the importance of the criteria, and then use the average weights for the analysis. The outcome can be seen in figure 5.2.i.

	Importance						
Criteria	**Supervisor 1**	**Supervisor 2**	**Supervisor 3**				
Travel distance	2	3	3				
Pick time	4	4	4				
Ergonomics	3	4	2				
Implementation	3	2	1				
Cost reduction	4	5	4				
Storage space	5	4	5				
Weights	**Travel distance**	**Pick time**	**Ergonomics**	**Implementation**	**Cost reduction**	**Storage space**	
Average weight importance	2,7	4	3	2	4,3	4,7	
Factors	Travel distance	Pick time	Ergonomics	Implementation	Cost reduction	Storage space	
Solution 1	4	5	3	2	4	5	
Solution 2	3	3	5	3	2	3	
Score (average weight importance x factor)	**Travel distance**	**Pick time**	**Ergonomics**	**Implementation**	**Cost reduction**	**Storage space**	**Total**
Solution 1	10,7	20,0	9,0	4,0	17,3	**23,3**	**84,3**
Solution 2	8,0	12,0	15,0	6,0	8,7	14,0	63,7

Figure 5.2.i: Analysis matrix

5.2.4 Implementation

In terms of implementation, both solutions will need quite some work, both are shown below.

Solution 1

1. All prices used are indications, thus to calculate the actual savings, bids have to be obtained from suppliers of the required materials
2. Similarly to implementing the storage policy, suppliers of the labels have to be contacted to create a list of dimensions and weight for the different SKUS
3. Based on the outcome of the ABC analysis, weight and dimensions, the layout for the new shelves will need to be made
4. This can, in turn, be used to create a technical drawing for construction, as well as getting an actual number of bins created
5. Materials have to be purchased and time has to be freed so that the technical department can start construction
6. Once completed the bins have to be registered into the ERP system, so that it can generate an allocation based on the suggested storage policy
7. The SKUS need to be moved to the right locations
8. A planning has to be made for when the vertical carrousels will be moved and installed
9. Suppliers of pallet racking have to be contacted for a bid and availability, for installing the required racking

Solution 2

1. All prices used are indications, thus to calculate the actual saving bids have to be applied for with suppliers of the required materials
2. A planning has to be made for when the vertical carrousels will be moved and installed
3. Suppliers of vertical carrousels have to be contacted for a bid and availability for the installation of a new system in the warehouse

4. New storage locations have to be entered into the ERP system to generate new SKU allocations, based on the suggested storage policy
5. Suppliers of pallet racking have to be contacted for a bid and availability, for installing the required racking

6 Discussion

In this chapter, we discuss in short what issues may have arisen throughout our conducted research and what could have been done differently to perhaps improve the quality of the methodology used.

6.1 Observation

A significant portion of the data collected relied on observation and manual data collection, which can have an impact on the results. For instance, the pick times per order were calculated with the use of a simple stopwatch and tagging along with the order picker. In the best scenario, one would have access to GPS trackers that would record the movements of the order pickers throughout their work day. Later on, this data could then be analyzed to get exact movement times and distances. However, in this case, this type of technology was not available, and the research required an indication of the times and distances that was as close to reality as possible. Therefore, the data is sufficiently accurate but could be improved with the use of GPS/RFID tracking technology.

6.2 Order picking

6.2.1 Repetitions

For most of the repetitions carried out, it would have been wishful to have at least twice as many data points to reduce the variation and chance of error. However, due to the limited time span of the research, it was not possible to collect more data. Therefore, data like blocked pallets should be seen as an indication based on a snapshot of time (mostly only a month of repetitions).

6.2.2 Pick time per order

For the order picking process, the time per order was calculated which includes all steps of the process. In the case that observation could have been carried out with multiple people, a separation could have been made between the different aspects that make up a pick (travelling, searching, etc.). Therefore it is important to note that the pick time used in this research refers to the total pick time per complete order.

6.2.3 Means of transport

Finally, there was no distinction between the means of transport in the calculation of pick time, as orders are made up of different movements (forklift for vertical pallet movement, pallet truck for horizontal pallet movement, and picking by hand). Therefore, data might be a bit skewed as some orders are completely by hand, some are a combination of the above, and some are only a forklift/pallet truck.

7 Conclusion

The current situation sketched to us at the beginning of this research was a combination of several problems in the inbound goods stream at Company X. With the help of a problem cluster, this was narrowed down, in chapter 1, to a condition where resources were used inefficiently, specifically: *people, space, and capital*. Which led to the central research question *How can resources (people, space, and capital) be used more efficiently in inbound goods at Company X?,* and the sub sequential sub questions (section 1.6) that guide the investigation of the separate aspects. The IST-SOLL methodology was the guideline to our research, setting the current situation in chapter 2, related problems in chapter 3, theoretical background for a new situation in chapter 4, and eventually, a new situation was formed in chapter 5.

In chapter 6 we looked at what could be implemented in the short-term and what could be done in the long-term. Starting-off in the short term the advice for Company X to definitely implement the suggested new situation for the mezzanine. In the described scenario dedicated storage lanes are used to increase the storage space to 480 pallet spaces, an increase of 92 pallet locations, without having to increase the size of the mezzanine falls right in line with the more efficient use of space. Besides this moving the Line 5 and 6 cap hoppers to the mezzanine will guard order pickers against walking 590.69 km a year, as this allows other SKUs to be stored closer to the respective production lines, making better use of your people. Finally, the suggested improvements allow for a decrease in the use of the elevator and a reduction in outsourced storage, saving €89759.29 (potential savings – investments, see figure 5.1.b & c) in the first year of implementation, hence making better use of capital available.

Furthermore, a change in storage policy was suggested, which can be implemented as a stand-alone project or in combination with the longer term solution. By implementing the new storage policy, products are allocated more efficiently in terms of space usage (pallet dimensions) and accessibility (A/B/C locations).

In the long-term section solution, 1 came forward as the best option after a Pugh matrix analysis, based on six factors believed to be important probes for any outcome of this research. With an overall weighted score of 84,3 compared to 63,7 for option 2, it was quite clear that this was the better of the two. Thus the advice is to implement solution 1 in the near-future making use of the storage policy, as it requires the restrictions of the labels, but could also be implemented without it. The suggested solution would create 991 new bins for labels and 56 new pallet spots, again without having to expand the space available. Saving €17589.65 (potential savings – costs, see figure 5.2.b & c) in the first year, also shows that this new layout makes better use of capital.

In the next chapter additional advice will be given, and for further details on implementation, one can refer back to chapter 5, where both the implementation of the short-term and the long-term solutions are described.

8 Advice

In this chapter, any possibilities for improvements noticed throughout the research, but don't directly align with the scope, are noted down or worked out slightly. These could be seeds for further research or smaller standalone projects to investigate them in more detail.

8.1 Container deliveries

Currently some products are delivered in containers from China to the Company Y site to be unloaded there and transported to the plant on pallet base when needed. Due to the risks of pests, organisms or insects getting caught in with the shipments suppliers fumigated their containers with gasses like Methyl bromide, which can be harmful to human well-being. Therefore, these containers need to be subject to a gas measurement, to assess the risk, before opening. Once the containers are cleared, and when needed to be ventilated, the contents are unloaded, palletized, and stored in their warehouse.

For the triggers the current situation is as follows:

1. box (57.5cm L x 37.5cm W x 32cm H) contains 270 pieces
    a. There are 24 boxes on a pallet (6480 pieces)
    b. They each weigh 8.24kg + 30kg for the pallet = 228kg total
2. They are delivered in 40ft containers (appendix E.1)
    a. Max load 28470kg
    b. 22 pallets are sealed from each container, thus 22*24 = 58 boxes per container = 58*270 = 142560 pieces per container (at Company Y)
3. Handling costs for each container are € 504,34 (recall price indications in figure 3.2.a);
    a. Gas measurement: € 64,07
    b. Unloading: € 278,57
    c. Administration: € 8,36
    d. Sealing pallets: $22\ pallets * €\ 3{,}35 = €73{,}70$
    e. Entry costs: $22\ pallets * €\ 3{,}62 = €\ 79{,}64$

After informing whether it would be possible to perform gas measurements in-house (requires a 4 day course + the purchasing of the measuring equipment), a call to the EVO (a Dutch association for companies with an international logistics network) presented a different option. According to them, fumigating is carried out in countries like China in an attempt to conform to the ISPM-15 standards. This is regulation 15 of the International Standards for Phytosanitary Measures, which requires packaging to be treated against pests and other harmful substances that could disrupt an ecosystem in a foreign country. However, by making use of heat treated pallets, fumigating is not necessary, and the shipment will be up to ISPM-15 standards (appendix E.2). By doing so, gas measurements and palletizing the cargo will not be necessary.

Based on the triggers, the new situation is as follows:

1. A 40ft container can fit 23-24 EURO pallets
    a. 23 pallets: $23 * 6480 = 149040\ pieces$
    b. 24 pallets: $24 * 6480 = 155520\ pieces$
    c. Costs new HT pallets ± € 10 (MS pallets): € 230 – 240 per container
2. No handling needed at Company Y
    a. Saving (23 pallets): $€\ 230 - €\ 504{,}34 = -\ €\ 274{,}34$ per container
    b. Saving (24 pallets): $€\ 240 - €\ 504{,}34 = -\ €\ 264{,}34$ per container
3. Approximately 20 containers are unloaded at Company Y each year

a. Possible saving (23 pallets): $€\ 274{,}34 * 20\ containers = €\ 5486{,}80$
b. Possible saving (24 pallets): $€\ 264{,}34 * 20\ containers = €\ 5286{,}80$

Appendix E.3 gives an overview of the costs associated with transporting the triggers from Company Y to the plant in 2017. The total cost of this operation amounts to € 28.059,51, and could be cut out when unloading the containers directly on site. Solely based on the shipments of triggers the total savings could amount to between **€ 33.346.31** and **€ 33.546,31**, dependent on the exact type of container used and how many EURO pallets can be stored inside. To get more exact figures data on container shipments should be retrieved from either suppliers or Company Y, and when combined with all other products delivered in containers could result in even higher savings. Besides saving on costs, the environmental footprint of the plant of Company X could also be significantly reduced, as the constant transport back and forth is cut out of the operation.

In terms of implementation, Company X should make new agreements with suppliers to deliver the products on HT pallets and label the containers with necessary ISPM labels to avoid unnecessary gas measurements, as well as get an indication of the costs of using HT pallets. In the case that it would not be possible to cut out the problem at the start of the chain, the costs of buying the necessary gas measurement equipment lie around € 5.000 plus a training (2-4 days) of around € 1.000, meaning an investment of ± 6000 would need to be made.

8.2 Scanning

Company X already makes use of scanning devices in their outbound (finished goods) warehouse, but still relies on the classic pick by list method on the inbound side of the operation. As we have seen in figure 4.3.a, paperwork & other activities make up 20% of the total time spent picking an order (recall average pick time per order is 3:37 min, thus around 43 seconds). Besides the time wasted on searching from a paper pick list and adjusting by hand when quantities don't match, it is also a noteworthy waste of paper (with about four A4 sheets printed per order) & printing ink, well over a hundred thousand orders are picked each year. By changing to scanning employees will have a lower risk of making errors and picking from a location can directly be updated in the ERP system. The total cost of investment would need to be calculated and weighed against the benefits, nevertheless the fact that the system is already present within the plant and all the possible benefits should at least spark interest in modernizing the order picking process.

8.3 Visual triggers

8.3.1 Instruction screens

To ease the process of filling the bunkers and hoppers in the mezzanine and reducing the chance of errors, instruction screens could be used. A small screen or tablet could be connected to the computer used by the line operator on the shop floor, fitted with a tool (e.g. VBA). For example, the operator types the batch number and size into a line on the excel file and presses on start. VBA then searches through a data file, that contains batch numbers and their corresponding SKUs, of items stored in the mezzanine. The list should contain the article number, the number of pieces in a box/tray and the storage lane where it is stored. The operator upstairs can see which lane they should retrieve materials from and how many boxes should be emptied, to make the process as simple as possible. When they are finished they should be able to press a button that resets the tool and marks the job as completed.

8.3.2 Color coding

The dedicated storage lanes in the mezzanine could be fitted with colored lines on the floor (e.g. green, orange, red) so that operators know when the lanes should be replenished with materials from the reserve locations. For instance, reaching the orange part of the lane means replenishment is needed, and as soon as red is reached replenishment is urgent. The exact size of each of the spaces should be determined bases on the throughput speed of that particular lane and the lead times of new deliveries of the material from suppliers.

8.3.3 LED guidance

To be able to reduce the put away time in the mezzanine Company X could think of implementing light guidance. LED strips could be attached to the floor starting at the two unloading doors and then go through the aisles with small side-branches going to the storage locations known by the ERP system. By making use of a scanner (either stationary or hand held) at the receiving end of the mezzanine, a computer system could light up the LED strips that lead to the location given by the ERP system. The operator could then simply follow the lights to the allocation storage location without too much effort.

Of course, with more experience, operators will know approximately where all the storage locations are, but by implementing a system as described the chances of errors would be significantly reduced and anyone working there at that instance would be able to put away goods received.

Literature

Baker, P., Canessa, M. (2007). Warehouse design: a structured approach. European Journal of operational research, Volume 193, Issue 2, 1 march 2009, Pages 425-436.

De Koster, R., Leduc, T., & J Roodbergen, K. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research, 182*(2), 481-501.

Francielly Staudt, Maria Di Mascolo, Gülgün Alpan, Carlos M. Taboada Rodriguez. Warehouse performance measurement: classification and mathematical expressions of indicators. ILS 2014 - 5th International Conference in Information Systems, Logístics and Supply Chain, Aug 2014, Breda, Netherlands. pp.1-9, 2014.

J Bartholdi, J., & T Hackman, S. (2016). *Warehouse & Distribution Science Release 0.97* (Rev. ed.).

Rouwenhorst, B., Reuter, B., Stockrahm, V., van Houtum, G.J., Mantel, R.J., Zijm, W.H.M. (2000). Warehouse design and control: Framework and literature review. European Journal of Operational Research, Volume 122, Issue 3, 1 may 2000, Pages 515-533.

Richards, G. (2011). *Warehouse Management: A complete guide to improving efficiency and minimizing costs in the modern warehouse*. London, United Kingdom: Kogan Page Limited.

T.S. Chan, F., & K Chan, H. (2011). Improving the productivity of order picking of a manual-pick and multi-level rack distribution warehouse through the implementation of class-based storage. *Expert Systems with applications*, *38*(3), 2686-2700.

http://www.ar-racking.com/en/storage-systems/industrial-racking/pallet-racking/adjustable-pallet-racking-ndash-ar-pal

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4465480/

https://www.begra.nl/magazijnstellingen/palletstelling/palletstelling-zelf-samenstellen