Bachelor thesis

Solving wastes and increasing efficiency at a parcel delivery company

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Management Summary

Cycloon is a parcel delivery company that operates at 48 different locations all over the Netherlands. The company operates in a highly competitive business, which makes it important to tackle occurring wastes. Wastes are any form of disruption that withholds the product flow in the warehouse from running more efficient. When the company wastes too many resources, the company decreases its already low margins in a competitive sector. This research aims to first gather a list of wastes that occur in the warehouse. Afterwards, solutions are introduced on how to minimize the effects of wastes which increase the efficiency. Running the warehouse more efficiently means that the warehouse operates the same throughput in number of parcels with less resources. The main research question that is answered is:

> How can we discover the unknown wastes that withhold the warehouse from running more efficiently, and how can these wastes be solved?

We first acquire the most impactful wastes in the warehouse, this is done by acquiring all information about the parcel flow throughout the warehouse, both visually (with a BPM chart (Business process management chart) and a physically (a chart of the flow of products through the warehouse)). This acquired information about the warehouse was compared to the different categories of wastes that were found in the literature. This concluded in a reduced list of three different wastes, with all of them having their own solution.

The different wastes all have their own solution to be resolved, which are:

1. Missed parcels

Parcels that have not been picked up from the conveyor are currently walked around individually, which takes a lot of time when this is done often per night. To minimize this wasted time, the solution is to transport these parcels in bulk so that the total time it takes to transport the missed parcels decreases. The gain of this solution is a 70% decrease in transport waste of the missed parcels. This is calculated by comparing the time it took before to transport the missed parcels and compare this to the theoretical solution.

2. Loading dock order

The second waste that we decided to approach is the loading dock order. The solution is to decrease the waste by sorting the roll containers in a different order. The current practice is alphabetically (which is arbitrarily made up). The solution is to do this by quantity. If this is done, the high-quantity roll containers are moved to the closest loading dock. When this is the case, the loading dock time decreases by 15.0% or 15:40 minutes. This is calculated by comparing the current situation to the theoretical solution.

3. Defects due to labels

On the conveyor, there is a human element that is picking up the parcels, which can go faulty. i) when a parcel is missed or picked up when it is not needed to, parcels get moved to the wrong location, which results in the parcel being delivered days later. ii) another worse situation was when a whole roll container was driven to the wrong location, which resulted in a batch of parcels getting to the right location days later. These events decrease customer satisfaction greatly, which is bad for the operation. The solution replaces certain letters on labels, which get often confused. This reduces the waste and also increase customer satisfaction when packages do not get delayed.

The three different solutions all decrease the specific waste in their way. However, a common denominator is that even though all solutions are only a minor inconvenience to the operation, they all theoretically improve the efficiency of the warehouse product flow. Therefore, all solutions should be applied. This research should not be seen as the one solution to decrease all the wastes, but rather as a first step in a path to efficiency.

Preface

This research is the result of the final two modules of my bachelor 'industrial engineering and management' at the University of Twente. In my thesis, I investigated bottlenecks and wastes at the warehouse of Cycloon. The research was performed over a long period, and I would like to thank a few people who helped me through the process.

First, I would like to thank Cycloon for allowing me to conduct my research. The employees have always had an open attitude towards my research and there have been many people who have invested time into my project. I would like to take a special moment to thank my supervisor, Wouter van Wijngaarden. Due to circumstances he was put on the spot to guide me through the process but has always guided me when necessary, through efficient meetings and flexibility.

Secondly, I would like to thank my University supervisor, Wouter van Heeswijk. The process of my bachelor's thesis has taken quite some time, and especially the start was complicated. However, he has persisted in handing me the needed feedback when I needed it the most. Also, I would like to thank my second supervisor, Ipek Seyran Topan for helping me with the accessory tasks and scheduling meetings even when she had little time.

I hope you enjoy reading my thesis.

Kind regards,

Patrick Bakker

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Glossary

Term	Definition
Business process management (BPM)	Business process management concerns the guided way of depicting the product warehouse flow.
Concept	A concept is a plan or intention that is constructed before any specified limitations.
Conveyor	An automatic transportation belt that transports parcels through the warehouse. parcels get picket up on this conveyor by multiple different employees.
Dabba	The online database and data system
Data System	The used data system for Cycloon is Dabba. This system is used to model any KPIs and to support most use of data to construct a smooth operation flow.
Design	A plan made to show how a pattern is worked. An example is the research design, which shows a constructed pattern in how the research is done.
Inbound	All the parcels that enter the warehouse
MPSM	Managerial problem solving method
Outbound	All the parcels that leave the warehouse
Process	*'a series of actions or steps taken in order to achieve a particular end.'*(oxford languages, 2024). However, in this research, the process mostly refers to a parcel going through the warehouse getting sorted or more specifically at a station.
Roll container	A transportation tool that can be used to more easily move quantities of parcels. It is about 1 meter in with and has a tire on each of the 4 corners.

Station	A station is a similar word for a task or a subprocess, within the business process management.
Supply chain	The supply chain is the whole process of all the actions involved in the distribution of the process. An important difference is the distinction between the entire supply chain of Cycloon and only the product warehouse flow within the referenced outlines.
Substation	Locations all over the Netherlands to which parcels get delivered from the warehouse and from which bikes are delivered to the houses
Waste	Any form of disruption that withholds the product flow in the warehouse from running more efficient
Warehouse	The warehouse is the location of Cycloon which is located in Utrecht. Here, all the parcels are sorted and sent to smaller locations throughout the Netherlands.

Chapter 1 Problem Identification

In Chapter 1, the start of the research is clarified. Chapter 1.1 clarifies at which company the research is executed, and an introduction to the problem is provided. In Chapter 1.2 the provided problem is dissected in the problem cluster. Lastly, in chapter 1.3 a framework is provided to clarify what the research entails and the goals of the research are listed.

1.1 Company introduction

To ensure a good image of the company, a general company introduction is provided. To find the research problem, a more specific introduction to the warehouse is given. Both the general and more specific explanations entail different layers of essential knowledge.

1.1.1 General company introduction

Cycloon is a parcel delivery company that has locations throughout the Netherlands. Incoming parcels get brought to a delivery centre located on the outside of city Utrecht. Afterwards, they get divided per truck stop location. The parcels get delivered by trucks to twelve substations located throughout the Netherlands. At these substations, the parcels get loaded on bikes and delivered by employees. Next to the twelve substations, there are also partner locations.

In the specific location of Utrecht, there is a new cooperation between Cycloon and Bol, in which they plan to increase the total number of parcels by tenfold. Bol is a website where customers can order products online which are delivered by them. The most important factor of the collaboration for the project is the fact that more than half of the parcels sorted at the warehouse come from Bol. The collaboration between Bol and Cycloon also results in better future predictions of the workload, which helps in the planning of employees. For the collaboration, the warehouse was moved from Nieuwegein to Utrecht. However, the location is only planned to be in full use in 2 years. Next to that, the increase in throughput is planned for the upcoming 5 years. A way the process can get more complicated is when personal factors like workload and stress can get neglected with a more complex system. Such a system can have more trouble filling in shifts, which might ask employees to work longer. Cycloon however does not want to lose these principles because that was the foundation this company was based upon.

On the inbound side, trucks come in regularly between 15:00h and 3:00h. They leave the building without cargo. On the outbound of the warehouse, the trucks drive away with parcels and afterwards drive back with empty trolleys. This is the ideal situation, but in reality, the trucks also drive empty to or away from the warehouse. In the warehouse, trucks come from a total of 11 different lines that deliver trolleys and pallets to be sorted. The different lines are sorted on letter but to illustrate how many lines there are they are also listed in numbers. After trolleys and pallets are delivered, a whole process is undergone to sort the parcels onto these different lines to be returned to. There are quite a few exemptions to this, for example, extra suppliers to the operation. These factors are disregarded because of the limit of the

research, which is explained in Chapter 1.2.2. An overview of the different lines that trucks drive through and the different stops that they make can be seen in Table 1.

Table 1 Different outbound truck destinations

Line	Stop location
1=A	**Hilversum, Amsterdam Amsterdam-west, Alkmaar, Haarlem, Heemskerk**
2=B	**Alphen ad rijn, Leiden, Zoetermeer, Noorwijk, Denhaag**
3=C	**Gouda, Delft, Rotterdam**
4=D	**Gorinchem, Breda, Bergen op zoom, Breda-oost, Tilburg**
5=E	**Den Bosch, Eindhoven, Veghel, Uden, Oss**
6=F	**Wageningen, Arnhem, Ede, Nijmegen**
7=G	**Zutphen**
8=H	**Enschede, Nijverdal, Almelo, Hengelo**
9=J	**Leeuwarden, Groningen**
10=K	**Lelystad, Almere**
11=I	**Hoofddorp**
12=M	**Utrecht**
13=P	**Sittard-geleen**
14=X	**Amersfoort**
15=Y	**Gouda postbussen**
16=Z	**Zwolle**

1.1.2 Specific warehouse location

The specific location the research focuses on the general warehouse located in Utrecht. The building itself is quite tall and openly designed (there is a lot of space). One side of the building is located fully with loading docks from which trucks can load and unload the parcels. On the inside, there is a conveyor (conveyor belt or sorting line) where parcels get placed, which takes up a large part of the location. The rest of the location is filled with places where full roll containers and parcels can be placed. At the moment, only one of the two conveyors is used. In the future, with the upcoming increase in workload, the other conveyor is also used. A map of the Cycloon part of the warehouse can be seen in Figure 1.

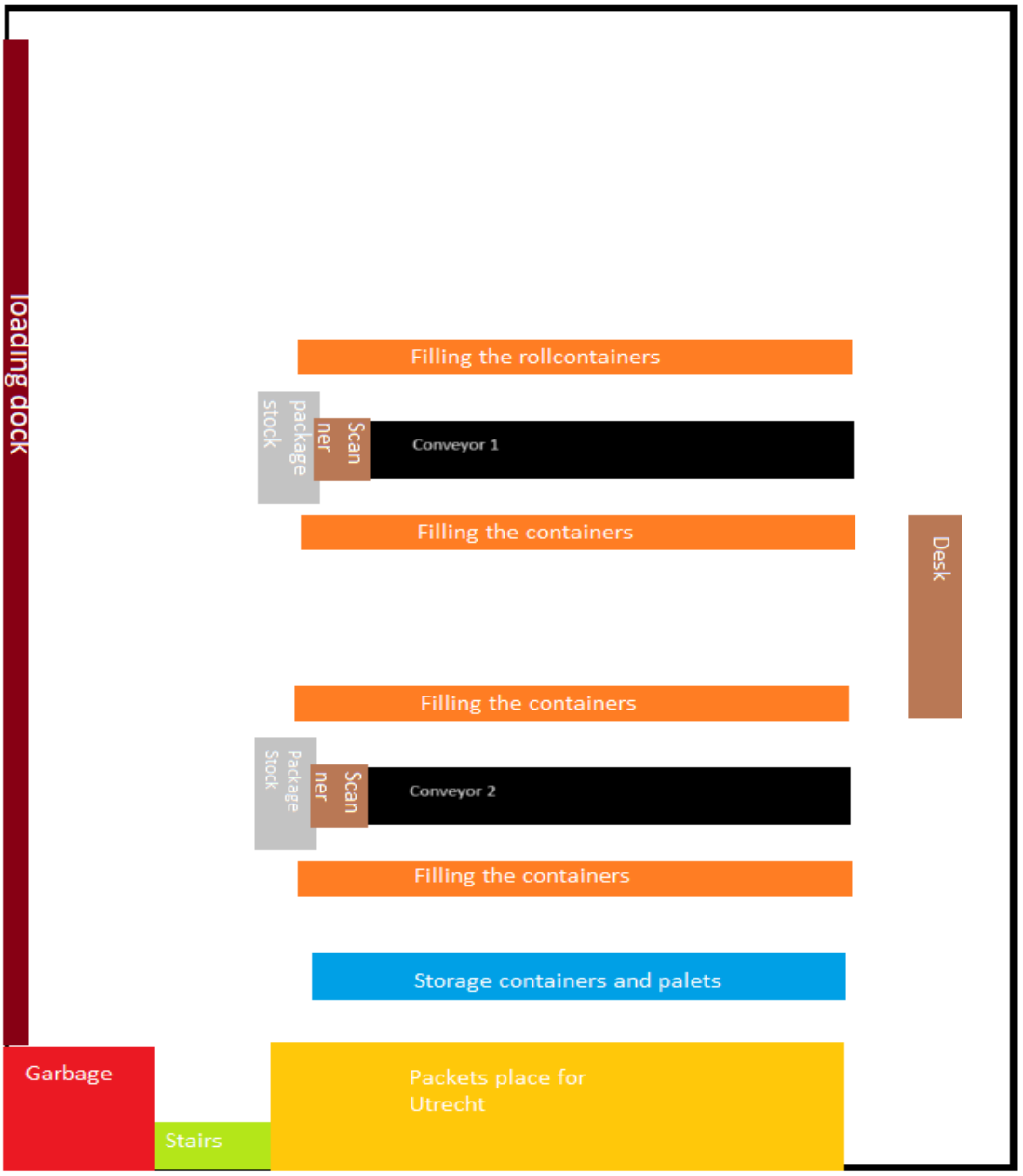

Figure 1 Warehouse floor plan

To give a more general image of the product flow, this is explained briefly. Trucks filled with roll containers enter the warehouse at the loading dock, where they get unloaded. The unloaded roll containers move to the parcel stock, where they get unloaded on a large table in front of the scanner. This is where the parcels get scanned and afterwards get picked up again at the corresponding roll container at filling the containers. If such a container is loaded fully, it is moved back to the loading dock, where every truck stop has its own location. Once all parcels are sorted and the comparing truck has arrived, the parcels leave the warehouse to go to the location.

The general direction of the research was determined by talking to the employees of Cycloon about what they would like to achieve with the research. It is directly clear that efficiency and effectiveness are two important concepts in this company. This is clear when comparing

these factors to their business sector and because of the competitiveness in the industry, something that has to be improved constantly. Therefore, we decided together with Cycloon that the efficiency and effectiveness of the sorting operation would be where the focus of the research is. Later, in Chapter 1.1.3, the further specifications of the research are decided.

1.1.3 Finding the problem description

The current increase in throughput of the location in Utrecht, the many distributors, and the many lines to the substations make it difficult to keep an oversight of what is currently happening and changing in the warehouse. The sector in which Cycloon operates is highly competitive and it is therefore essential that the process gets performed as efficiently as possible. “Global competition between companies is becoming increasingly stringent, resulting in companies having to understand their customers better. Customers no longer only need quality products, but also need excellent and timely service.” as told by Adi Firmansyah (2020). Currently, the business has a near-zero profit. The product flow needs to be more efficient to keep competitive with the evolving industry, the business can not only focus on increasing product value. The efficiency is not maximised because of the changes in the warehouse in combination with that many new ideas are continually implemented. We discovered a problem, there is an unclarity in where the wastes are in the product flow. Night shift employees are operating and running the warehouse itself, however, there is no one responsible for improving the efficiency of the process specified in the warehouse. The company would like to know what can be done to improve the efficiency of this process and how to resolve the wastes.

1.1.4 Scope of the problem

For this research, it is important to acknowledge the limitations in the size of the research. If this is not done properly, the research loses its focus, and in return results in a lot of quantity but a lack in quality. The research follows the warehouse logistics of the location in Utrecht. This means that, the research starts from the moment that the trucks with roll containers enter the warehouse. The research is guided by the product flow and includes most elements. The end of the product flow in the warehouse also means the limit of our research. This is the moment when the roll containers filled with parcels leave on a truck to go to another location. The outmost included elements are the loading and emptying of trucks.

Another important distinction in the scope of the problem relates to the different parcels that are sorted in the warehouse. There are two types of products: parcels and envelopes. Both of the types arrive and leave on different conveyors and are therefore easily differentiated. The parcels are sorted on the ground level of the warehouse. The envelopes are sorted on the first floor of the warehouse. The research only focuses on the parcels.

Lastly, other aspects are disregarded. A few of these aspects are employee rosters and the future projects. The research only follows the product flow where products go in and out to make this research more efficient. By adding in other factors, the true problems are overwhelmed without reaching the core problems. Another factor that is disregarded is the process at the substations where employees sort parcels to eventually be driven by bikes to the end customer. A specificity in this project is the fact that the Utrecht parcels also get

driven by bikes directly from the warehouse. Because this directly driven out service is a special product flow which is a process related to the substations, this is disregarded.

1.2 The problem cluster

Currently, a lot is happening at the warehouse in Utrecht. This is not only shown in the fact that the warehouse has gotten an increase in size by moving from Nieuwegein but also a lot of different projects like extra new sorting ways are being worked on. The product flow through the operation in the warehouse is getting more complicated, which causes wastes. Heerkens (2017), describes the rules of thumb to identify a core problem. Possible core problems are problems that do not have a cause linked to them anymore. Further, a core problem should be a problem that can be affected and for which a solution can thus be figured out. When we analyse the product flow for wastes, this is when the core problem arrives: There is no clear oversight on the whole process in the warehouse, this is core problem 1. There is some information about the product flow for general function of the warehouse but this is not further investigated. Another core problem is: Warehouse operations are continuously changing, this is core problem 2. This core problem is solved when a solution for the found wastes is researched.

An important factor to the problem cluster is the occurrence of the unknown wastes. As explained in the glossary, a waste is defined as: any form of disruption that withholds the product flow in the warehouse from running more efficient. A warehouse in practice can never run 100 percent efficient, because there are always considerations to be made between different KPIs. For example, a warehouse can be efficient on employee cost but not on throughput or the number of defects. This is how it is known that there are unknown wastes, but it is not yet know what these actual wastes are.

All these previously named issues result in one action problem at the company, which is: the product flow running inefficiently. The main business is to keep the company running, and there are still parts that could run more efficiently. However, the parts that can run more efficiently are unknown at the moment and therefore a business opportunity. The true solution to the core problem is to first find the actual wastes so that the company knows the opportunities. Afterwards, these wastes also need to examined so that the company profits from the research. These causes and effects are shown in Figure 2.

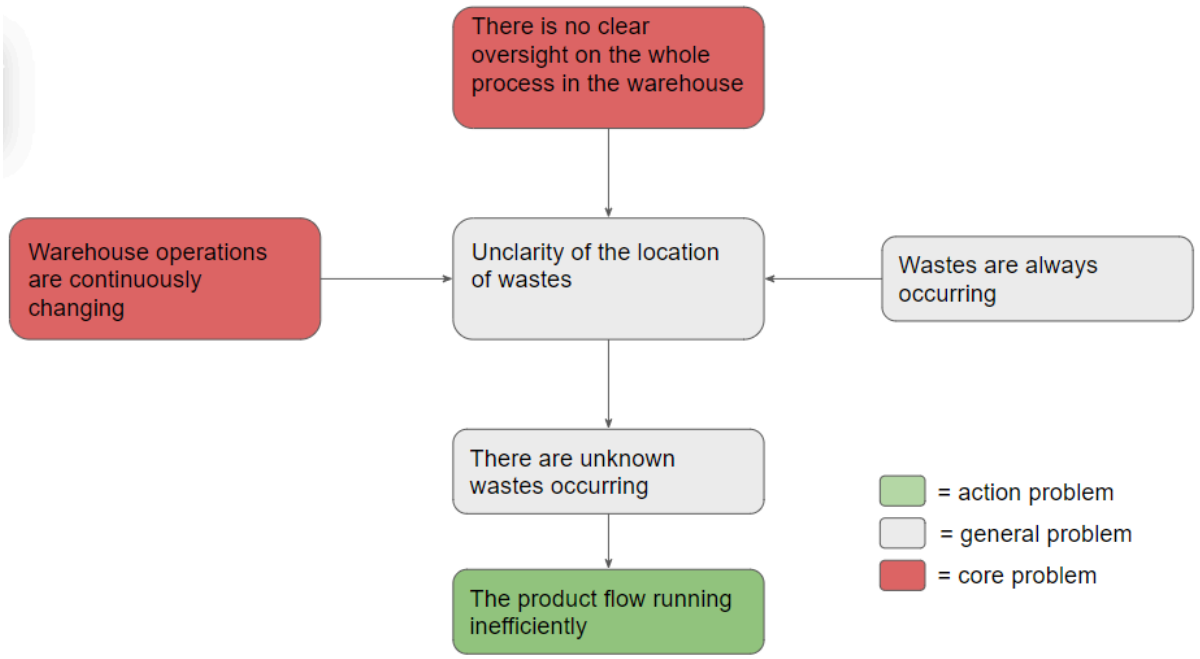

Figure 2 Problem cluster

1.3 Research approach

A way to approach the core problem is needed to ensure a valid research. This is done by formulating the main research question, which properly envisions the main goal of the research. To answer the core research question, a list of sub-research questions is provided to systematically answer this main research question.

The focus of the research is the core problem, which is that it is not known what the wastes in the warehouse are. The other core problem is to research to find a solution to minimise the wastes. The hypothesis is that these wastes cause the warehouse to run inefficiently. The centre itself runs alright without any major catastrophic delays, but still there are a lot of factors which can be improved. The problem in this case however is that the cause of these problems to make the product flow run even smoother is not known. First, the knowledge is acquired of what these causes are. Second, a plan is made to help solve these problems. With keeping in mind the steps of clearing up the product warehouse flow and searching for problems, the following one main research question is formulated.

> How can we discover the unknown wastes that withhold the warehouse from running more efficiently, and how can these wastes be solved?

To find an answer to this complex research question, there is a division into sub-research questions. The research can be divided into two different processes. First, there is the phase in which the wastes are found. Secondly, there is the solution generation for the wastes.

1.3.1 Warehouse analysis phase

In the first phase (questions 1 to 6) it is investigated what the warehouse process looks like and corresponding wastes are found. This is done by constructing a business process management (BPM) chart and analysing the product flow. Understanding the current flow of products does not guarantee a direct list of wastes, therefore the actual wastes still need to be found and confirmed through other information sources. To ensure the validity of the first phase of the project, a second separate search for the wastes is performed. This is done through interviews with employees who experience these problems themselves.

1. How can the product flow through the warehouse be visually represented?

The product flow representation technique is investigated in Chapter 3. This question is a knowledge question that is answered by researching other sources.

2. What are possible methodologies for analysing wastes in the warehouse?

The methodologies are investigated in Chapter 3. This question is a knowledge question that is answered by researching other sources.

3. What is the current flow of products throughout the warehouse?

The product flow is investigated in Chapter 4. During this chapter, the visual representation is built from the investigation in the warehouse.

4. What are the wastes found through an interview with employees?

The experienced wastes are investigated in Chapter 5. During this chapter, a structured conversation is held with employees who experience the product flow themselves. This results in a second list of possible wastes.

5. What are the wastes found through an analysis of the product flow?

The wastes are investigated in Chapter 6. This question is answered by analysing the previously found visual representation during research question 2. Deep diving into this visual representation results in the discovery of the wastes.

6. How can the experienced wastes of the employees be aligned with the expected wastes found through the analysis, and how does this impact the trueness of the found wastes?

The product flow is investigated in Chapter 6. This question compares the resulting wastes, from the previous two research questions. This comparison allows us to improve the validity of the waste list.

1.3.2 Waste solution phase

The second phase of the research (questions 7 and 8) approaches the found wastes. The solutions for the found wastes are researched. Also, we can come up with corresponding recommendations that help to solve the initially found wastes. The solutions for the wastes are also evaluated and see what the advantages and drawbacks are.

7. How can the impact of the wastes on the product flow be decreased?

The future preparations are investigated in Chapter 7. This question researches possibilities to improve the product warehouse flow. During this chapter, possibilities are provided and compared to ensure the best result.

8. How can the solutions be evaluated and are they recommended for implementing in the warehouse operation

The proposed solutions are evaluated in Chapter 7. Here, any drawbacks and costs are highlighted to ensure the company can make a well-evaluated choice in whether to implement the solutions.

The research questions provide to help to systematically tackle the problem of the unknown wastes. The questions also provides a structure for the research now that the goal of the research is known.

1.4 Conclusion

Chapter 1 explains the set-up for the research at Cycloon, where the research focuses on the warehouse in Utrecht. It provides a general company introduction, alongside a problem description. The first core problem is: there is no clear oversight of the whole process in the warehouse. This means that some wastes are occurring that are generally unknown. The unknowingness is important because without knowing the core problems the company can not influence them. The second core problem is: that wastes negatively influence the efficiency. The fact that the wastes negatively influence the efficiency is important because tackling the wastes improves the efficiency in a competitive industry. To approach the two different core problems, the research question formulated is:

> How can we discover the unknown wastes that withhold the warehouse from running more efficiently, and how can these wastes be solved?

The research consists of solving the two different core problems. Core problem 1 involves the visualization of the wastes, which allows for a list of what the different wastes are. Core problem 2 involves the solutions to the wastes. The solutions minimize the waste and thus increase the efficiency.

Chapter 2 Problem Approach

In Chapter 2, the structure of the research is clarified and defined. First, the different analysis methods are explained and the types of data-gathering methods are listed. In Chapter 2.2, the possible limitations are explained and the scope to take away possible assumptions to gather a specified framework.

2.1 Managerial problem-solving method

To ensure the research is valid, a specific research method is used. For this research, it is the managerial problem-solving method by Hans Heerkens, (2017), shown in Figure 3. This problem-solving method is easy to implement. It follows a total number of seven steps. In Chapter 1 the first step, problem identification, was already extensively executed and in Chapter 2 the few steps of the method are further performed. Furthermore, the next steps explain how they are performed throughout thesis.

Figure 3 Managerial problem solving method (Heerkens, H, 2017). Solving Management Problems Systematically

Problem approach

When the problem is identified, an appropriate approach needs to be found to ensure a valid solution. In this research, approach is used which is which has been tailored to the more specified topic. This approach focuses on bringing about the warehouse flow of products with many possibilities. This is the reason for writing Chapter 2.

Business process management

To approach the problem in the warehouse, a complete analysis is necessary. The specific problem is not already known and therefore before zooming in, the wastes first have to be

allocated. There are a few core problems that need to be solved, these core problems have already been identified in Chapter 1.5. To identify the different wastes, the product flow through the warehouse is researched. This is done physically (how the products move through the warehouse), and systematically by the business process management chart. When this information is known, it can be compared to the found literature.

Problem analysis

When the construction of the different BPM systems is done, a list of possible wastes can be researched. To understand if these wastes are appropriate, conversations with employees are needed to see their vision. Next to that, a look at the provided data is essential. For the wastes, different categories apply, these categories are researched in Chapter 3.2.1. This categorisation helps to analyse factors of different wastes.

Solution generation

When the possible wastes are defined (might be one or a list of three), improvements to change the product warehouse flow are proposed. To represent the improvement, a proposed change in the current BPM system can be made. A few examples of possible changes are an extra scan point for the parcels where the visibility of the product flow is increased, an increase in productivity in a specified station or a different order of packaging or a decrease in batch size.

A way to ensure that the above-mentioned changes dissolve the problem is to first define the current waste and in what way the waste causes a problem for the whole supply chain. Extra to that, an impact list needs to be specified on what the changes improve but also a risk list is important to ensure that no other new wastes impact the product flow too much.

Decision-making

When we have made the list of possible solutions, the next step in the process arrives. Not all possible solutions are executed because of a limit in time for the research but also of a limit in the resources in the company. Researchers in combination with the company make a decision on what options are most appropriate to this research. This decision is best made by discussing the solutions, advantages, and drawbacks with employees in the office. A small but not concluding list of factors that is influential when making this decision: feasibility, expense, and durability. The most appropriate approach is chosen through a multi-criteria analysis. Factors of this analysis are further discussed and decided upon during Chapter 6.

Implementation

In the implementation phase, the solution comes into action and solves the discussed problem. The solution is only theoretical because the warehouse product flow is quite complicated and can not just be changed overnight. Another reason for not just implementing the idea is that it takes a lot of time and effort to implement the idea in the warehouse. The solution is however implemented into the previously analysed business process management system. With changing the model, changes are easily visible to employees in

the company. This entails that the true implementation phase is not possible, and the research ends before this phase.

Solution evaluation

The solution is judged upon three different attributes: research, judgment, and choice. This is also told in the book by Hans Heerkens which explains the importance of these aspects. These evaluations are best performed by contacting colleagues who give their expert opinions on the practical implications. The best way this is done is by visually presenting the results. They make it easier to communicate and evaluate the solutions. The visually presented results enable us to not only evaluate the solution ourselves but also to have other visions on the propositions. Possible other problems that might arise and the problem not going away totally are important factors that are discussed in step 7 of the managerial problem-solving method.

2.2 Important factors for the overall research

For the overall research, there are several essential research design options to think about. These factors have different angles from which the research can be seen. The most significant angles are discussed in Chapter 2.2 to ensure that they are considered before the upcoming research.

2.2.1 Limitations and specifications

With the research having a limit on how long it can take, there should be a distinction between the focus and the interesting side problems. A few of these problems that are not included because of the scope of the project are efficiency regarding distributors, motivating employees, and moving to another location. It is essential to have focus points because of the limited time and not having to research the wrong aspects.

One focus point of the research relates to the employees in the warehouse, the fact that they do not operate as machines gives them weaknesses but more importantly also a variety of strengths. However, when talking to the employees it should be held in mind that the focus of the research is about the product warehouse flow itself, and employees are a part of the process. On the other side, the focus is also important when analysing the more mechanical part of the product warehouse flow because the research is not about improving a single machine. When designing the business process map, there should be a distinction between whether the process starts when parcels enter the warehouse or much earlier. This limitation can be described as the fact employees can give information that is untrue and can be limited in giving their opinion about solutions.

The other limitation is the limited focus of the research. While first the whole product flow in the warehouse shall be visualised, afterwards the product flow visualisation can be supported by data to analyse the least efficient parts. Since this is the focus of the research,

there is not a complete analysis of these problems that can be improved. This distinction does not result in a definition of the research but reduces the direct effect on the company.

2.2.2 Deliverables

To ensure a clear goal of the research, a list of the deliverables of the report is provided. While a textual report is also delivered, here is a small list of more conceptual deliverables:

1. A business process management map explaining the product flow through the warehouse
2. A list of wastes and how they impact the warehouse product flow
3. Recommendations on what is needed to eliminate the waste and improve the efficiency of the product warehouse flow

2.2.3 Validity and reliability

Both validity and reliability are important when researching the problems that occur in the sorting centre. These two factors are important to keep in mind. The validity is inspected, to ensure the trueness of the research. The reliability is considered to ensure the reproductiveness of the research. These factors are explained in the following two paragraphs.

The validity of the research regards if the research is also the situation. On the other side, reliability regards when the research is reproduced so that the actual same results re-emerge. The validity of the research is ensured by approaching the problem from different sources to see if they do not contradict. A few, but not all, of these perspectives are data from Dabba, employee interviews, and practical experiences. When experiencing contradictory results, a direct check should be made since this contradictory information could corrupt the whole research.

Having proper reliability of the research is more difficult to achieve since there are quite a few uncontrollable factors in the research. Some of these uncontrollable factors are the fact that new sorting machines are being tested and new personnel with different qualities are hired quite often. This is because the current sorting centre is relatively new compared to the data used. A lot of factors are ever-changing, just as the experience of new employees, from which some have worked there much longer than others. Focusing on the current situation and limiting the changing factors throughout the centre results in having the best reliable outcome.

2.3 Conclusion

Chapter 2 explains the general set-up of the research. The structure of the research is based on the Managerial problem solving method by Heerkens (2017). This research has seven different steps to ensure validity. The seven different research steps are:

1. Problem identification

2. Problem approach
3. Problem analysis
4. Solution generation
5. Decision-making
6. Implementation
7. Evaluation

In Chapter 2, each of the seven different steps of the approach are explained on how to do this. Next to that also the importance of each step is addressed. Other factors that ensure proper research are added further on. These factors are *Limitations and specifications,* and *Validity and reliability.* To enable to evaluate if the goal of the research was accomplished, a list of deliverables is added.

1. A business process management map explaining the product flow through the warehouse
2. A list of wastes, including their solution
3. Recommendations on what is needed to improve the efficiency of the product warehouse flow

Chapter 3 Literature Review

To ensure that the research is methodologically correct and comparable to external research, Chapter 3 is added. Firstly the used business process management is explained and afterwards used concepts are clarified. The goal of Chapter 3 is to make sure that the research questions can be further answered with full substantiating literature. This is done by selecting techniques and knowledge which are useful for the research. In Chapter 3 the research question itself is not answered but a fundament is built to further build upon.

3.1 Finding a visual representing technique

Research question two is all about visually representing the current product flow throughout the warehouse. This question asks for a technique, following the unclarity in how to represent the product flow. The solution is to use the business process management technique, which is further explained in Chapter 3.1.2.

3.1.1 Business process management

Business process management is a generic way in which a product flow can be described, in this research the product flow in a warehouse. This BPM system makes it easier to explain certain aspects to colleagues and outside people. Within the BPM, there are a lot of different ways the supply chain itself can be depicted. While some techniques are used more often than others, there are also less-used ways that are more applicable to this research. There is a methodological handbook of the used tokens in Appendix B. Furthermore, any used techniques regarding the business process management methodology are based on the book by Weske (2007).

“Business Process Management (BPM) is a “hot topic” because it is highly relevant from a practical point of view, while at the same it offers many challenges for software developers and scientists” (Weske, 2007). This tells us that business process management is indeed a useful and widely used technique. It is important to define the technique and the steps. This creates more reproducibility of the research.

Within business process management, there is also an existing methodology on how to properly handle the problem. The methodology has a total of 6 steps, as seen in Figure 4. The methodology focuses on first identifying the process and discovering how the process currently works. Afterwards, an analysis can be made through the thought of a model. In the process analysis phase, possible problems can be seen and analysed how they influence the process. These insights on weaknesses enable the process to be redesigned into a more proper model where wastes are minimised. Afterwards, the model needs to be put into reality and changes have to be made to the process. Lastly, in the lifecycle, there is the process monitoring and controlling phase where the applied changes have to be evaluated to see how they have influenced the weaknesses and the process as a whole. This methodology helps to guide the research in a more structured way, which increases its reliability. (Szelągowski, 2018)

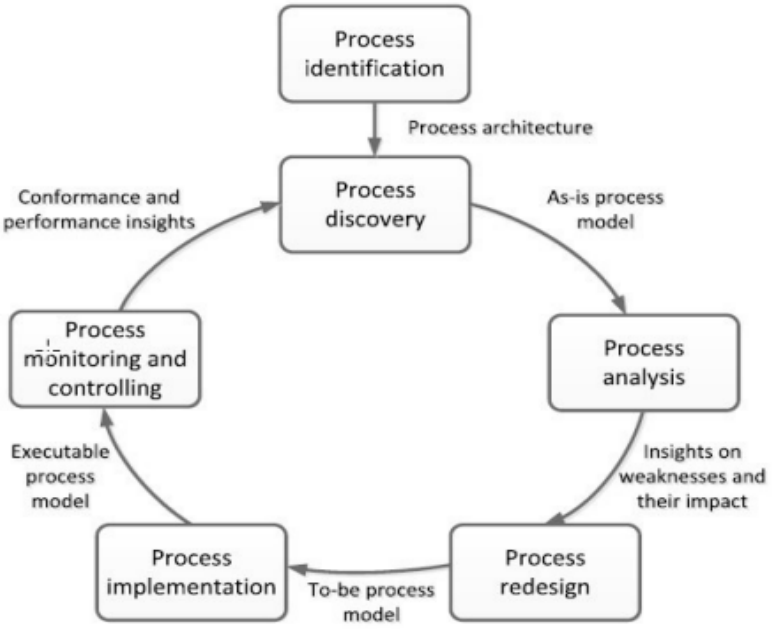

Figure 4 The BPM lifecycle (Szelągowski, 2018, p. 3)

3.2 Analysing wastes techniques

Research question 3 is all about finding multiple wastes throughout the visual representation. There are a lot of different approaches that are found in the literature, with all having their own angle. In Chapter 3.2, the different approaches are listed and explained.

3.2.1 Value stream mapping

Singh (2010) defines value stream mapping as follows: ‘Value stream mapping is an enterprise improvement tool to help in visualizing the entire production process, representing both material and information flow. Defined value stream as a collection of all activities value added as well as non-value added that are required to bring a product or a group of products that use the same resources through the main flows, from raw material to the end customers’ (Bhim Singh, 2010).

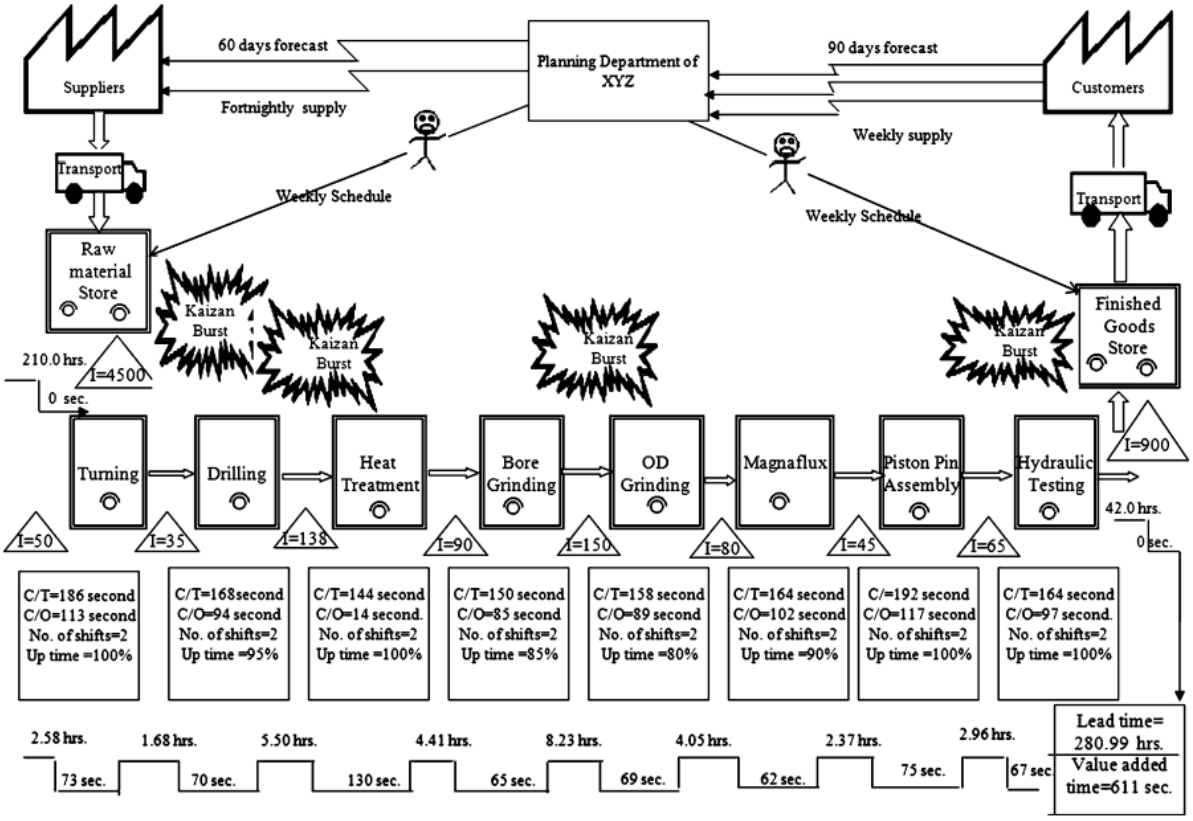

Figure 5 Example of value stream mapping (Singh, 2010)

Within the value stream mapping, there are different categories which are defined to clarify how to make the product flow more efficient. These categories are listed as wastes, where each waste in turn also has their own way of minimising its effect. The following list are the seven different wastes.

The seven wastes

1. Overproduction
2. Waiting
3. Transport
4. Inappropriate processing
5. Unnecessary inventory
6. Unnecessary motion
7. Defects

(Peter Rich, 1997)

3.2.2 Three types of production

Within the management and efficiency maximisation of processes, there is a lot of knowledge to be applied. However, there needs to be a distinction to which information is useful and appropriate to the problem. Knowing the different types of production allows the

search for individual wastes. This is done by comparing the differences between production techniques and looking at what is necessary to maximise the efficiency of a production type.

The three-way diffusion of the different streams of approaches can be seen in Figure 6. For the problem, there are two different production types which are applicable, with the first being mass production. Here the focus lies on mass production, which is all about having a high product turnover. The second applicable production type is the lean production, the lean production is also important to use because wastes are eliminated and value is added, which is also the aim of the research. Here a combination shall have to be found in what stages to have a focus on which of the two production types.

	Craft Production	*Mass Production*	*Lean Production*
Focus	Task	Product	Customer
Operations	Single items	Batch and queue	Synchronized flow and pull
Overall Aim	Mastery of craft	Reduce cost and increase efficiency	Eliminate waste and add value
Quality	Integration (part of the craft)	Inspection (a second stage, after production)	Prevention (built in by design and methods)
Business Strategy	Customization	Economies of scale and automation	Flexibility and adaptability
Improvement	Master-driven continuous improvement	Expert-driven periodic improvement	Workforce-driven continuous improvement

Figure 6 Attributes of different production types (Ross & Associates Environmental Consulting, 2004, p. 68)

3.2.3 Waste management

Within lean management, there is a method for identifying wastes by classifying them into seven different categories. Each category has a different meaning and they are important for our research to understand. This is because when understanding different types of wastes, it is easier to identify more specific problems to efficiency. If this is not known, the view is disrupted. Up next, is an explanation of the seven wastes:

1. Over-production waste

Over-production waste happens when the production is more than what is needed. This is possible in a warehouse when products are sorted more often and on a specific order when this is not needed.

2. Processing waste

Processing waste is apparent when work is performed on the product with it not adding value.

3. Transport waste

There is transport waste when a product is experiencing unnecessary material movement. This is the case when a parcel is moved multiple times across the warehouse, while this does not have to be done.

4. Waiting-time waste

Waiting-time waste is occurring there when a man or machine is idle or has waiting time. This is quite upfront and is the case when a man or machine is unable to attend to the work.

5. Inventory waste

There is inventory waste when there is an abundance of raw material inventories and supplies. These excessive products are caused by big batch sizes and long lead times.

6. Motion waste

Motion waste occurs when workers are unnecessarily moved. An example of this is employees having to walk a bit to gather information, only for them to have to walk back around again.

7. Defects

Lastly, there are the possible defects. These happen when a product is not properly processed and therefore the work has to be done again.

A lean system declares war on waste or “muda”. These wastes are classified into 7 types:
1. Over-production waste
2. Processing waste
3. Transport waste
4. Waiting-time waste
5. Inventory waste
6. Motion waste
7. Defects

(Domingo, Rene T. 2015)

3.2.4 Six sigma

When the variability in a process is high, there is also a high level of failure in return. On the other hand, when the variability in a process is low this also results in a low number of failures or defects, this is the focus of Six Sigma (Montgomery & Woodall, 2008). The basis for Six Sigma lies in statistics and data-driven analysis. There are a total of five different steps to undertake to decrease the variability and to apply six sigma. These steps can be seen in Figure 7.

Table 3
Collation of the DMAIC phases (1–5; left column) and Smith's (1988) generic sub-problems (I–IX).

1. *Define*: problem selection and benefit analysis	I. *Goal-setting* (determining what one wants and appropriate levels of relevant objectives)
2. *Measure*: translation of the problem into a measurable form (CTQ), and assessment of the current situation	II. *Description* (determining through observation and thought what happens to be the case) III. *Research* (the acquisition of knowledge through directed investigation) I. *Goal-setting* (based on the results of description and research, reformulate one's goals)
3. *Analyze*: identification of influence factors and causes that determine the CTQ's behavior	IV. *Diagnosis* (providing causal explanations of why things are what they are)
4. *Improve*: design and implementation of adjustments to the process to improve the performance of the CTQs	V. *Design* (determining how to achieve a desired state or end). This involves three subtasks: VI. *Alternative generation* VII. *Prediction of effectiveness* VIII. *Evaluation of alternatives* IX. *Persuasion* (gaining the consent of others)
5. *Control*: adjustments of the process management and control system in order that improvements are sustainable	V. *Design*, possibly followed by IX. *Persuasion*, to develop and implement a control system

Figure 7 Explanation of the different DMAIC phases (Jeroen de Mast, Joran Lokkerbol 2012, p. 609)

3.2.5 Lean management

Within the literature on resolving wastes and increasing the efficiency of product flows, there is another view. This view is called lean management and is described by Randhawa (2017) as follows: “Lean manufacturing is a philosophy of successfully tackling and eliminating waste in the manufacturing system”. The lean management theory by Womack and Jones (1996) is based on five different principles, with the list and the explanations as follows:

1. **Specify Value:** Create value for the customer
2. **Value stream:** To highlight non-value-adding waste, identify the value stream.
3. **Flow:** Create value flow without interruption, waiting or scrap.
4. **Pull:** Produce only what is pulled by the customer
5. **Perfection:** Realization of an ideal situation by consistent and holistic identification and elimination of non-value-added activities or wastes associated with a business function or service. These principles are embodied in Lean principles that focus on waste or ‘muda’ identification and subsequent elimination.

3.2.6 5s methodology

An improvement upon the lean principle is the 5s methodology. This methodology is a more practical approach which helps to put the work into categories. To apply the 5s methodology, the five different wastes have been given a new category which is more applicable and set to be used.

1. Sort
2. Set
3. Shine
4. Standardise
5. Sustain

(Khairunnisa et al., 2020)

3.3 Conclusion

Chapter 3, answers the different knowledge questions that are asked in Chapter 1. Chapter 3 provides different sources and perspectives on warehouse efficiency. Sources that do not align with the research are also added because parts of these sources might still provide information for this research. The importance of Chapter 3 is to provide paths to identify the unknown wastes in any way possible. The first research question that is answered is research question 2:

1. How can the product flow through the warehouse be visually represented?

The business process methodology is a widely known technique to visually represent the product flow throughout supply chains. This technique can also be used to analyse the smaller product flow throughout the warehouse. The BPM is also viable because it is highly relevant from a practical point of view. These reasons provide a construct on why to use the BPM for the research.

2. What are possible methodologies for analysing wastes in the warehouse?

With the broadly different visions in the literature, there are different views on how to acquire the wastes and improvements in a supply chain or a product flow in a warehouse. With these researchers all having their perspectives, they were all listed and have to be used to guide the core problem answered in the upcoming chapters. An important methodology for analysing wastes is to categorise possible wastes. This can be done by a lean classification system:

1. Over-production waste
2. Processing waste
3. Transport waste
4. Waiting-time waste
5. Inventory waste
6. Motion waste
7. Defects

The seven different categories allow for a more systematic search for the wastes. This systematic way is a first step in looking at what the waste is. When it is known what the waste is, quantifying and analysing it is viable. So both the BPM techniques are used complementary to the lean classification.

Chapter 4 Problem Analysis

In Chapter 4, the systematic building of the BPM model is described. Firstly, any important process-specific factors about this model are listed and explained. Chapter 4.1, explains the process of building the model. This is done by first drawing a general image of how the model was represented and afterwards explaining the model itself.

A semi-structured interview is also presented, this separate research for wastes allows for testing the validity of the problem analysis of the research. The focus of Chapter 4 is to represent the warehouse product flow from varying perspectives. These different perspectives of the warehouse product flow allow the search for possible occurring wastes.

4.1 Warehouse product flow visualisation

The first step in analysing the business process is mapping the warehouse product flow itself. The goal of the mapping is to combine the physical process of the parcel itself but also to visualise the knowledge streams which are needed for key decisions to be made. An example of the first step is that a parcel can only be sorted when it has been scanned into the used data system. This requires physical actions but also the data needs to be transferred within the data system. For the systematic way of doing this, there are a lot of different options that can be considered. We choose the Business process management way, which was researched in Chapter 3, because this grants the option of visually depicting the difference between when an action is needed and when an action can directly be undertaken.

4.2 Prerequisite assumptions

A clear list of any assumptions is to be made first in order to be able to make the model. The assumptions are explained in chapter 4.2. The two assumptions are important to list to prevent inconsistencies. “Describing and classifying these assumptions is purposeful because it allows for re-interpretation” Recker, Jan (2014). Describing the assumptions also allows for the re-interpretation of the model.

1. The visual representation only represents an ordinary situation and does not include special situations for parcels. One example of this is when a parcel drops on the ground and breaks. The general representation does not mean that the whole BPM system does not work because actually, this can give us a clear image for most of the BPM system. When for example a process starts most of the time at 20:00h but due to planned business starts at 19:30h, still the same general wastes appear. Therefore, it is important to keep these prerequisite assumptions in mind and not to forget them but still not to falsify the BPM system.

2. Another important assumption about the research is related to the accuracy of the scheme. Due to the growth in number of parcels, the warehouse has expanded over the time of the research. Therefore, the product flow is included in the way it was in

the latest version at the time of representing the scheme. This gives the most accurate list of wastes in the end but there might be some wrong information because the product flow might have changed.

4.3 General information on the product flow

To map out complex product warehouse flows, it can be important to gather some widespread information about it. “The simplest way to define qualitative research is to note that the results are primarily expressed with words” Kim sydow campbell (1997). Since this part of the research is mostly about generating information about the warehouse it is important to know that information generating is done mostly on a textual level. Information generation focuses primarily on quantity and knowing different perspectives on the warehouse.

In Chapters 4.3.1 to 4.3.4, different side activities are listed which influence the whole product flow. These factors are essential for us to build the BPM model. Next to that, it is also important to understand these to understand the listing of the possible wastes. The different factors are:

The time schedule

The warehouse operates in hours during the night. These limited operating hours and the dependability of processes on each other make it insightful to know the time schedule.

The conveyor and roll containers

The core of the warehouse is sorting parcels on the conveyor, after which they are moved around. This is researched to illustrate how this process is done and to realise important aspects of this part.

The locations and destinations

Parcels arrive and leave the warehouse to many destinations. These different destinations are an important part of how to separate the incoming parcels. Therefore, the different destinations are researched are and how they influence the process.

The unhappy flow

During the regular process, parcels come in at the warehouse, are separated and leave again. However, there is also a separate process line for parcels that do not fit the regular process, which is called the unhappy flow. The unhappy flow is analysed to see if it is important to the occuring wastes at the warehouse.

4.3.1 Time schedule

The warehouse in Utrecht works in night shifts, where the parcels get dropped from 20:00h until somewhere in the night but this is quite varying. Dropped parcels get stocked in front of a conveyor. This process from using the conveyor starts at 22:00h and works till approximately 7:00h but this can vary depending on the workload and the productiveness through the night. Full roll containers get moved to other locations from halfway through midnight till the end of the morning, depending on the workload. The time planning is more clearly noted in Table 2.

Table 2 Warehouse operation hours

Activity	Timestamp
Inbound	15:00h-3:00h
Conveyor	22:00h-7:00h
Outbound	6:00h-10:00h

4.3.2 Conveyor and roll containers

On the conveyor, parcels first get scanned and afterwards picked up by employees on the conveyor. Every employee has one or two stop locations from which they must pick up parcels, the parcels are labelled by a number and letter combination. When a parcel gets picked up, it is put in a roll container. Another employee is responsible for ensuring that the roll containers get put to a location where all roll containers are sorted per line. This employee is also responsible for putting a new roll container in place and labelling it correctly. Currently, there are two different conveyors available, where one has a much higher throughput than the other conveyor. The slower conveyor is currently used only because this one does not put too much pressure on the workers on the tire. This conveyor has a throughput of around 2.5 to 3.0 parcels per second. The faster conveyor is still being tested and not used generally and is exempted from the research.

4.3.3 Locations and destinations

Cycloon is a large company that operates throughout the whole of the Netherlands. We list the important factors that are involved with the volume of the company, which is all over the Netherlands. The operation of Cycloon must incorporate several stops with parcels for different locations on one truck to ensure that the least distance is driven. There are a total number of 14 destinations, where a destination is a location that roll containers with parcels get driven to. Each different destination has its own smaller warehouse where all parcels get sorted onto bikes to be driven. There is also another important definition, which is a line. A line is driven by a truck but can incorporate multiple destinations and even smaller sub-activities. A line is represented by a letter on a sticker or label which is the middle box, whereas the location is represented by a number on the sticker which is the right box. An example of the sticker that is added to the parcel can be seen in Figure 8.

Figure 8: Example of a parcel label

Another important factor in the warehouse is that in the entire process, a lot of trucks get rented from other businesses. This work involves a lot of communication and effort to run smoothly. Not only do the trucks get acquired from outside the operation but also employees are outsourced. With the trucks, this is a factor that itself does not influence the research because these employees perform on the same levels of warehouse productivity and reliability compared to regular employees.

To also give an image of the sheer volume of the operation, it can be important to give some extra information. In a roll container, in the case of Cycloon, an average of 85 parcels fit. This number can be different in other operations because Cycloon only distributes a specific order size. Of these filled roll containers, an average of 180 are sent off per night. When multiplying these two, it comes to a total average of 15,000 parcels per night.

The most important information is that parcels get driven out of the warehouse on trucks that drive to one or multiple locations. The location to which a specified parcel has to go is not important to the research because only the general product flow is researched instead of how single parcels move.

4.3.4 Unhappy flow

Next to the regular product flow, there is also a separate sorting line, which is called the unhappy flow. This sorting line is involved with all the parcels that are not allowed to go

through the regular conveyor. For a parcel to enter this line, there are very different reasons. A few but not all of these reasons are: when a parcel is broken, when the size or weight is out of bounds or when there is no proper sticker in place. Because of the widely different problems that can occur with the parcels, the solutions to this also vary compared to the regular conveyor. Therefore, a specialized team of on average two employees are involved with this line. These employees are working mostly autonomously, which allows the regular process to continue without any large delays. Because of the different nature of these specific wastes and also this conveyor having a vastly different operating structure, the product flow is not further analysed.

4.3.5 Conclusion of the general imaging

Chapter 4.3, gathers information about different factors in warehouse logistics. This information is essential to build the BPM model in Chapter 4.4, but it also has another important factor. This information also gives important context to the model, since assumptions are made, and some information can not easily be put into a simple model. Later phases of the research, investigate the gathered information further.

4.4 Formulating the BPM model

In Chapter 4.3, all the important information is gathered that is needed to understand warehouse logistics. Chapter 4.4, provides the steps that are necessary to build the BMP model. Lastly, the BPM model is provided. Chapter 4.4, explains the steps that are made to build Figure 9 and Figure 10. Chapter 4.4 is added to ensure the reproducibility of the model. Next to that, it also has the value of properly interpreting the model. Already in this part of the research, some specifications help us further to gather the wastes in later Chapters 5 and 6.

Since the parcels do not get dismantled and simple move through the warehouse, it is most clear to follow the possible paths that a single parcel can undertake. The parcels enter the system at the start of the process. Here, parcels enter the warehouse on trolleys in batches of different trucks and different vehicles. The parcels that enter from this place form a stock, which does not start the further process until later when the conveyor starts. The conveyor itself is depicted as quite a large part of the whole product warehouse flow. At every part of the conveyor, parcels can get picked up if they belong to an employee who is responsible for several stop locations.

Next up in the path of a parcel, we have the conveyor. At this part of the BPM, there is one important distinction that needs to be made. While it looks like every parcel is checked individually per stop location, this is not true. The case is rather that the conveyor is constantly rolling, and that employees have to keep up with the pace. The larger number of parcels indeed get checked carefully, but it might be possible for a parcel to have been missed. The workload per employee is an important factor at this stage because the employee can either be overwhelmed or underwhelmed. An underwhelming employee does not work efficiently enough, which is bad for productivity. However, an overwhelmed employee has a workload that is too high, which enables the employee to make mistakes in not picking up parcels or picking up the wrong parcels. The balance between the two factors is important, but also difficult to get exactly right.

After the conveyor ends, the parcels that are still on there fall onto a table. These parcels have an appropriate location but have not been picked up. This happens mostly because the employee who had to pick it up had a high workload at that specific time. Another employee picks up these parcels to return to the appropriate roll container. This workload is not done by one specified employee and is not a full-time task but is rather picked up by a few different employees.

There is also a different lane, which also has practical implications for the process. For the roll containers to move to the warehouse, a lot of different trucks move to the location, which is called the inbound. These trucks also leave with roll containers back to the specific destination, which is called the outbound. The roll containers get loaded on and from the trucks on a loading dock. It is important to know when the roll containers have to be moved to the appropriate loading dock because it can be quite some work to move them. It is also important to know when the trucks can move away from the loading dock, so they do not have to wait too long.

There is one different version of the BPM, which is depicted in Figure 10. When a roll container is filled with parcels, it needs to be replaced by a new one. For this, two employees are constantly walking by either side of the conveyor. If the roll container is filled, the roll container gets rolled away to the loading dock and put in the right place by another employee. Afterwards, a new roll container is gathered and put into the empty place. Lastly, a proper sticker with the letter and number is picked up and put onto the roll container, such that it is labelled for transport. If this is done, the employee can start again with filling the roll container. This process only has one roll container for which the process is depicted but in reality, this process is run with 14 different roll containers all situated along the conveyor.

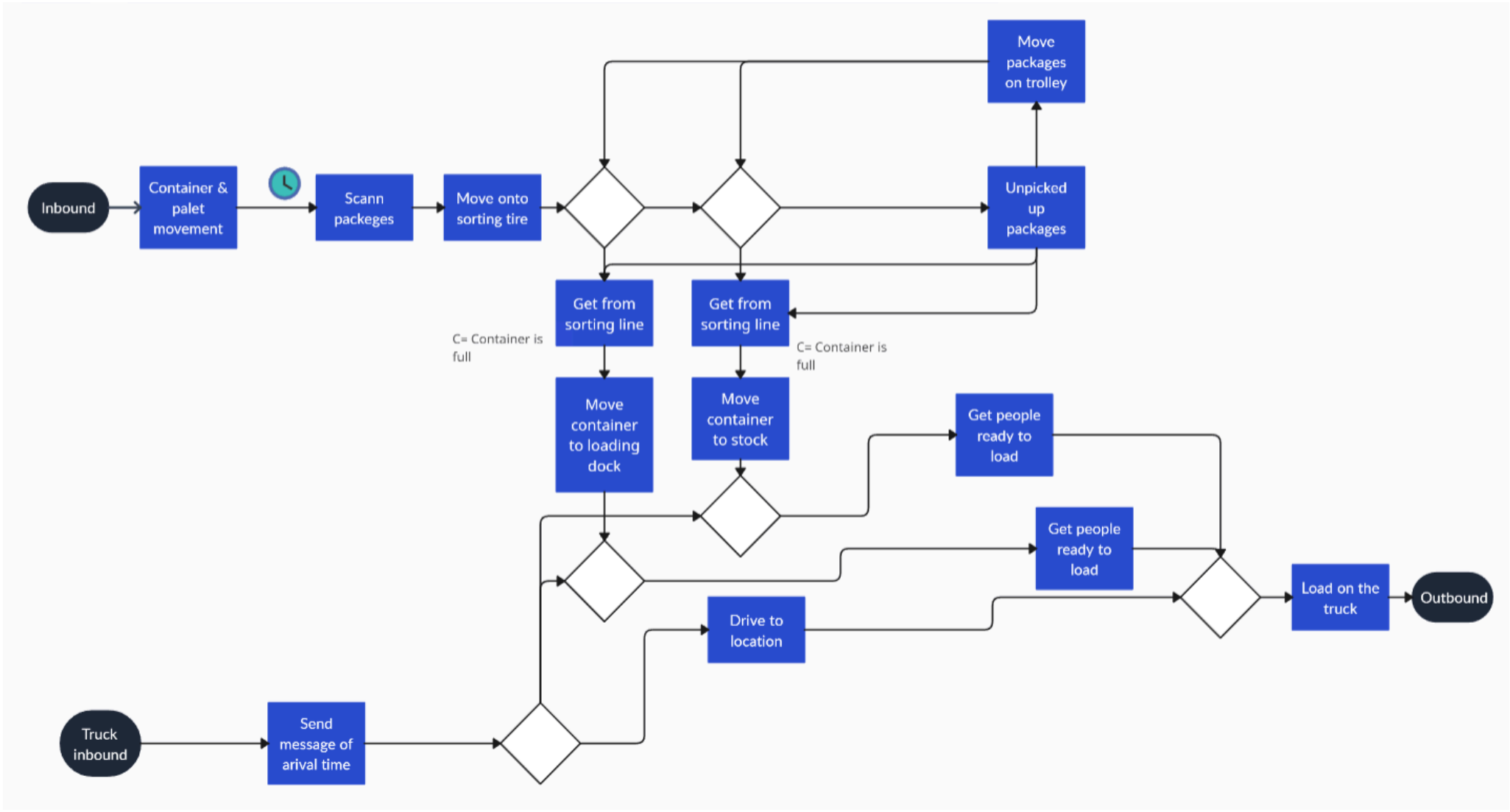

Figure 9 The simple business management chart

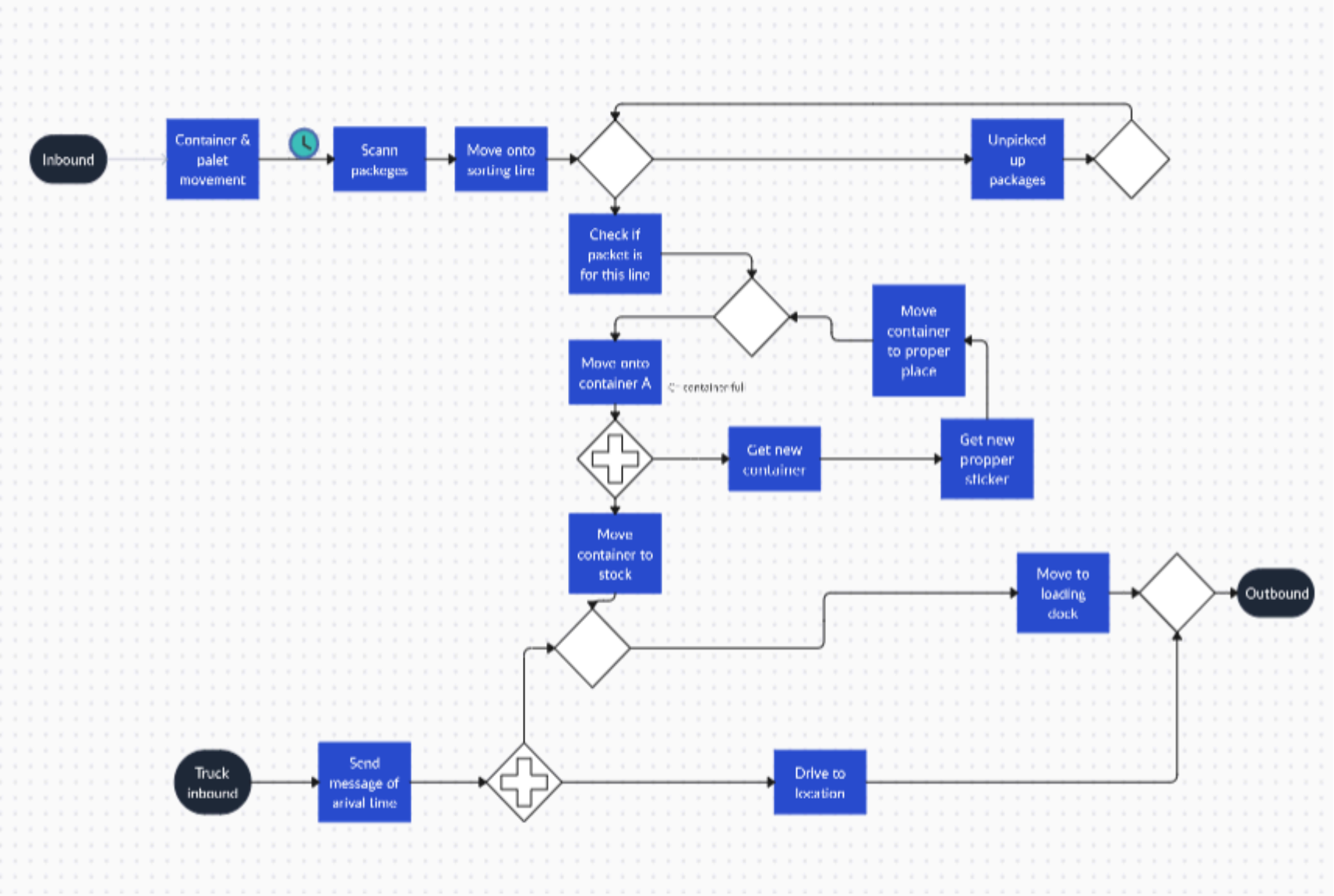

Figure 10 The BPM with extra information about switching roll containers

4.5 Physical travel distance of product

Chapter 4.4, explains the systematic flow of the product through the warehouse. There is however also one important perspective on the flow of products that was have not yet touched upon, which is the physical travel distance of products. The physical travel distance of products is the distance that parcels travel. This is important because it allows us to see if any transport waste is currently happening.

To graphically represent the physical travel distance of products, ‘Figure 1 Distribution floor plan’ is modified. Parcels that enter the warehouse are dropped off at the loading dock, after which they are moved to the parcel stock. Subsequently, the parcels are scanned, this is where the possible variation in physical travel distance arrives. At the conveyor, parcels get picked up on the possible roll container, which can be at the start of the conveyor, at the end of the conveyor or in between. When roll containers are filled they get rolled back to the loading dock which is sorted in alphabetical order to be picked up when the truck arrives. The conveyor is ordered on quantity, which is different from the order of the loading dock. Full roll containers which are moved back need to be viewed to which loading dock they need to be rolled to. There are a total of 16 different lines and therefore also 16 different physical travel distances of roll containers. It is complicated and unnecessary to illustrate all different travel distances but figure 11 is shown to give an idea of the situation. To more easily understand the difference in distance, there are only illustrated routes on the top side of the conveyor however, these parcels can also be picked up on the opposite side of the conveyor. The shortest package route in the coloring includes the route to the proper loading dock which may be far away. The distance travelled on the conveyor is not related to the distance travelled on the loading dock. The reason for including the figure is to illustrate how a package near the start of the conveyor has a lower distance back to the start of the conveyor.

When parcels do not get picked up they travel to the end of the conveyor and have to be manually handled to move back to the proper roll container, this takes up a lot of transport waste. Also, here it is important that when a stop destination letter number combination which is at the start of the conveyor is not properly picked up, a relatively large distance haves to be walked compared to a letter number combination which is near the end of the conveyor because of the order of the line. Examples of when parcels are not picked up can be seen in Figure 12.

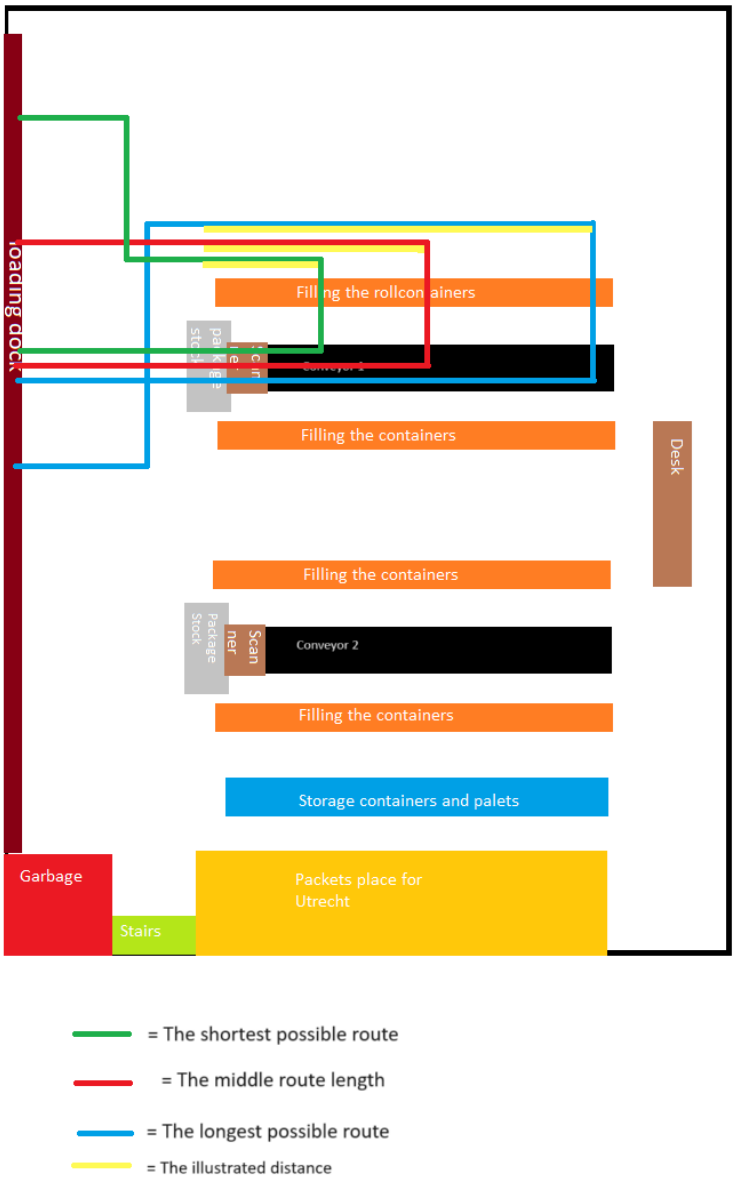

Figure 11 Possible travel distance for regular parcels

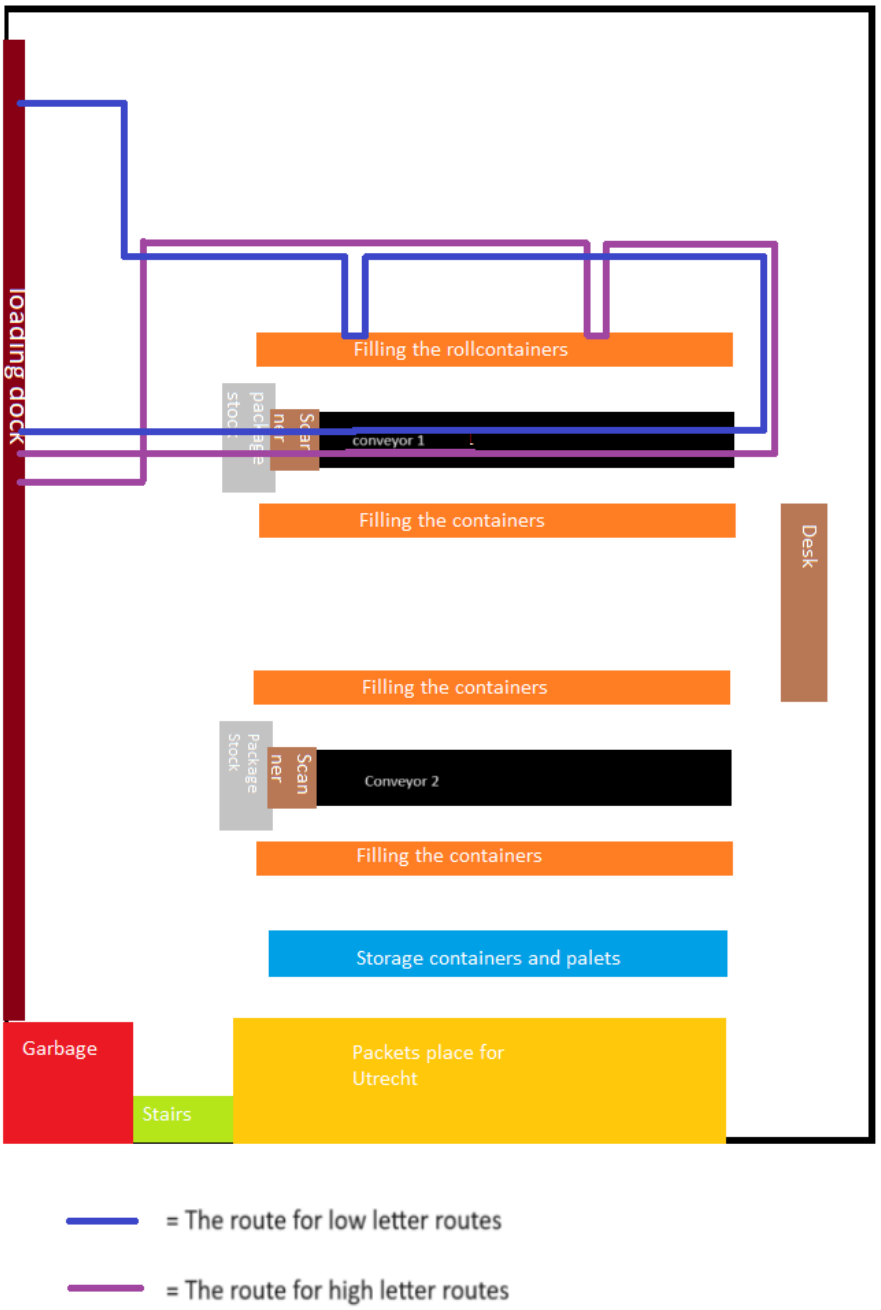

Figure 12 Possible travel distance for missed parcels

4.6 The semi-structured interview

To ensure that the upcoming gathered wastes throughout the research in Chapter 6 are true, there needs to be a simultaneous separate check. For the separate check, the experience of the employees is used. While this personal data can be a bit subjective, the comprehensive understanding of the product warehouse flow gives another valuable information source. The semi-structured interview is performed to validate the analytical findings and learn if there are any wastes that are missing. “Credibility is a unique concept in qualitative research. One of

the main means of achieving credibility is by performing a member check or validation interview". As told by Eli Buchbinder (2010), performing a validation interview is a generally accepted method of testing the validity of the wastes that are researched.

There are three different results that the semi-structured interview can give compared to the results found in the analytical research (Chapter 6), the first being that both results are the same, which makes it probable that these wastes are valid. The second result is when the semi-structured interview results in new wastes. This might entail that the other research is not true but can also be explained that the experience is different and that the found wastes are on another scale like social wastes. The last result that can be found is when the other research finds wastes that are not found in the semi-structured interview. This might be the most interesting because this allows the finding of wastes that nobody knows about, however, these wastes also could be wrong. In this case, more talks with employees need to be held to find the validity of these options. The questions and answers to the semi-structured interview can be viewed in table 3.

4.6.1 Approach to the semi-structured interview

We held the semi-structured interview during the night when the process was running. This allowed us to ask questions to 6 different employees who were performing the specific tasks themselves at the moment. The interviews took around 10 minutes per employee and were partially about their expertise in the warehouse and their general view on tasks that were relating to their expertise. Next to that, this more informal approach allowed us to directly see examples of the answers of the semi-structured interview, which in turn gave us more information compared to only asking specific questions with follow-up questions. This approach not only provided the answers but also gave more intangible knowledge about the process and the specified wastes.

4.6.2 Important factors to interview

To ensure that the semi-structured interview data is internally consistent and coherent for analysis, there are a few factors that have to be kept in mind, according to Naresh Malhotra, (2006). These factors are here to reinforce the neutrality of the results. Another important factor of the semi-structured interview is to define the goal and to properly select the test group. The semi-structured interview is only held for a few employees, which results in an incomplete image of the wastes in the product warehouse flow. However, this is not a problem because the employees who are asked the questions have sufficient knowledge about the whole warehouse.

It is important to envision the goal of the semi-structured interview. When having an open conversation about problems that are experienced during the process, it is important to encode the opinions of the employees who are asked the questions, properly and not misinform them. Also, in informal conversations, intelligible questions should be asked to get a proper view, otherwise miscommunications can occur.

Semi-structured interview *key factors*

Questions should be:
* Appropriate
* Intelligible
* Unambiguous
* Unbiased
* Omnicompetent
* Appropriately coded
* Piloted
* Ethical

(Naresh Malhotra, 2006)

Table 3 Semi-structured interview questions and answers

Question	Answer
Do you know any larger wastes that have been solved previously?	Scanning parcels with a second scanner. However, this was not a better way due to the increase in wrongly scanned parcels.
What are current wastes that are under investigation?	Installing a second conveyor however this still needs a lot of research.
What are any problems concerning the variance of workload per day?	Switching in who needs the most help still needs a lot of insight however employees are eager to help each other in this.
Wheat are the problems relating to the difference in workload between lines?	Different lines are helped by the responsible employee when required. It is easy to see which line need the most help because there will be the most parcels on the missed parcels stack. However, this is a big waste because twice as much work needs to be done to stack this correctly. A problem which may occur is that employees will pick up the wrong parcels when having a high workload.
What are any problems concerning the unhappy flow?	The unhappy flow is a big problem but because there are many different reasons a parcel could end up in the unhappy flow this is quite difficult to solve. Currently, there are two experienced employees working on this line to ensure no influence on the regular parcel flow.
Do you experience any social problems from the executing work force? (like unproductivity, missing knowledge or underemployment)	Every employee has its strengths. Sometimes it is difficult when people call in sick on the last minute and the work has to be done by the people left. Employees are hard-working and willing to work extra shifts, and currently there are projects running to educate some people to be given

	more responsibilities.
What are current wastes that need investigation to solve?	An automatic scanner could be ideal. Also, the second conveyor could in the future work when volume is increased even more. Standardise how many employees need to be at how many destinations.
Do you perceive any future wastes with the increase in numbers in the upcoming years?	Our second conveyor could solve this but this could lead to other problems that we do not yet know of.
Are there any recommendations for possible wastes that need investigation for me?	Lines are overflowing compared to other ones, this could be an attention point.

4.6.3 Most valuable results

The semi-structured interview, is performed informally. This allows the gathering of information from the employees who know the specific questions but also to ask more follow-up questions to properly understand the different aspects of the specified wastes. The questions and answers of the interview are presented in table 3.

1. Diversity of employee responsibility

The most important finding was the diversity in tasks among employees who work on the product flow. When one employee falls behind on their responsibilities, the employees next to them help to pick up the parcels that they miss. Next to that, the end of the conveyor indicates which employees missed their parcels. When parcels are not picked up they end up on a roll container at the end of the conveyor, when the frequency of one destination is higher, this means one employee fails to pick up some of their parcels. This indication also allows other employees to judge who requires more general help. This flexibility only works because of the experience of some employees, which is important for the product flow to continue to run smoothly. There is however one important factor, which is that due to the employees helping each other, the image of the overloaded lines is a bit less insightful. However, this still is a quite practical tool to help at the moment the conveyor is running.

2. Difference in workload

Other wastes that were found during Chapter 5 are mostly related to employee-specific experiences. One thing is that some lines can get overloaded on quite specific instances compared to other lines. This creates the problem that some parcels are missed during the time a parcel can get picked up from the rolling tire. When a parcel is missed, the rolling tire moves the parcel to the end of the line and afterwards the parcel has to be moved back by an employee himself.

Another effect that the difference in workload has on the process is that employees also pick up the wrong parcels and put them on the roll container. This results in a parcel being sent off in the wrong direction.

3. Contract flexibility

The employees also portrayed a problem relating to the employee contracts. This is because the employees are switched relatively fast due to rules with asylum seekers. This constant switch of employees is difficult, especially when the experience of employees results in them making fewer mistakes. However, these flexible contracts also have one important positive result, which is that the warehouse can switch around quite swiftly when work varies from the forecast.

4.7 Conclusion

Chapter 4 provides information for the problem analysis of the wastes. The chapter is involved with the different perspectives of the warehouse. General information is provided to understand the product flow. A list of information that could include wastes is the time schedule, the conveyor and roll containers, the locations and destinations, and the unhappy flow. Research question 3 is answered:

3. What is the current flow of products throughout the warehouse?

The parcels arrive at the inbound side of the warehouse. Here, parcels are stalled till the conveyor begins to operate. The parcels are sorted by different employees, who are responsible for their destinations. Filled roll containers are returned to the loading dock to be eventually picked up by trucks when they arrive. There are three different aspects of the flow of the products:

1. The general imaging of possible important perspectives of the product flow
2. The systematic flow of the process in the BPM
3. The physical travel distance of parcels in Figure 11 and Figure 12

To ensure the validity of the wastes that are listed in Chapter 5, there is an added semi-structured interview. This interview is involved with the wastes on a practical level. This was performed mostly at an informal level, which allowed us to gather more background information on problems. Next to the background information, it also gave us more practical examples to direct problems. This chapter also answers research question 4:

4. What are the wastes found through an interview with employees?

The biggest finding of the semi-structured interview was the waste of time when a parcel does not get picked up properly. The distance from the end of the conveyor to the roll

containers in the front is quite far, which results in a lot of extra transport waste. Next to that, parcels can also get picked up wrongly, which results in a single parcel being transported to the wrong destination. There was also the discovery of the waste: the diversity of employee responsibility.

Next to the wastes found, there is also the finding that the process is more intangible than expected. Employees help each other when necessary, however, this results in the waste: motion waste when this is done too often. After the wastes are found of the main research, the comparison between the two is researched to see how many similarities there are between the three main findings and the more general answers of the interview.

Chapter 4 started with the problem analysis in the warehouse. The different perspectives of the product flow through the warehouse were important to be addressed because a waste is intertwined between different perspectives. To ensure the wastes found are valid, a separate semi-structured interview was performed.

Chapter 5 Descriptive Analysis of the Wastes

In Chapter 4 a visual representation of the current situation of the product flow in the warehouse is made. In Chapter 5 this representation is analysed to see which wastes show up. This is done by comparing wastes that were found in other literature to the different information sources that were shown before. These found wastes were afterwards confirmed by the held interviews. These three different information sources allowed us to come up with abstract wastes, which are specified in Chapter 5.

5.1 Structured analysis of the BPM

The process discovery, gathers information, which can be compared to the different wastes that were discovered in Chapter 3. A distinct process is needed to constructively compare the vastly different perspectives.

Just incorporating the business process management chart (Figures 11 and 12) might not be enough to capture the highest impacting waste in the company. This does not mean business process management is negligible, however, it is more looking for the highest impacting wastes. When also enforcing a value stream map-like analysis onto the product warehouse flow, a more data-driven result is visualised, which entails quantified wastes. A few of these data sets which are not yet quantified are the workplace per employee and the distance walked to different loading docks. These are a few data sets that are already known abstractly but not specifically.

There are a few key performance indicators (KPIs) which are essential to the value stream map, which can also be used for this specific research project. It is important to realise that a full value stream map is not utilised for the research because not the whole supply chain is analysed but still there is much to use. The first important KPI is the lead time and the possible difference in this. The second factor is the cycle time (C/T) and the change over time (C/O). Also, the uptime is interesting, this is the percentage of time that the machine is up and running. Lastly, there is the yield, the percentage of parts that pass inspection. This can be especially appealing because at the conveyor, often parts are not taken properly off.

“Problems in waste management have become more and more complex during recent decades…… However, in practice, there are many factors and influences – often mutually conflicting – criteria for finding solutions in real-life applications.” Charisios Achillas (2013). Selecting which waste to solve in the warehouse might be complicated because wastes are often intertwined with each other, also the increase in throughput in the warehouse increases the complication. The wastes that are highly visible in the warehouse product flow are selected to be minimised. This is because these wastes are both impactful and easily discovered.

The specific wastes are found by comparing categories of wastes to the information about the warehouse. This comparison was best performed by systematically looking at a first waste like over-production waste and looking if and where this occurs. Afterwards, every information is compared to the second waste and perceived if processing waste is occurring.

To perform the comparison, a lot of insight and experience in analysing waste is needed because it is quite arbitrary. However, the creativity of this also allows for a waste to be as large or small as the performer can think of.

5.2 Physical travel distance of products

In Chapter 4, two different graphical representations of the flow of products are created: the systematic flow and the physical travel distance. In Chapter 5.2, the physical travel distance is analysed for any possible wastes. The most comparable types of wastes for the physical travel distance are motion waste and transport waste

5.2.1 Three different transport ways

When viewing the physical product flow (figures 11 and 12), quite a few things can be concluded. The first thing is that there are a lot of different physical travel distances originating from the different routes that parcels arrive at. One second interesting factor that the physical travel distance has is when a parcel is missed, a lot of extra distance has to be travelled. The product flow can be differentiated into three different categories with different attributes:

1. Conveyor

On the conveyor, parcels move automatically along the line. If a parcel has to travel a long way, this has few effects. The movement is cheap and the time it takes is short. Minimizing the length of the conveyor has few effects because energy costs are negligible compared to employee costs.

2. Roll containers

Roll containers are situated from the moment a parcel is picked up and moved to the loading dock. The most important aspect of this phase is that the parcels are moved in bulk, with an average of 85 parcels per container. While moving the roll containers is heavier than moving parcels single-handedly, the quantity compensates this effect. Minimizing roll container length has more effect compared to minimizing the conveyor.

3. Single parcels

Single parcels require the most effort to move. They are handled physically by personnel, which takes up the most time. Next to that, personnel cost is also higher compared to the electric cost of running the conveyor. If the single parcel effect is minimized, the total transport cost time is affected maximally. Therefore, moving parcels single-handedly should be avoided most frequently.

By specifying the three different categories, one waste can be seen. The waste is that parcels travel a lot of distance in inefficient ways. When this effect is minimized, the travel cost time is greatly reduced, which also saves a lot of costs. One important factor in this is that the solution might increase the transport waste because there might be more movement

of the parcels however this is in more efficient ways. Here the raw travelled distance is not measured but the travelled distance cost. The travelled distance cost is the cost of moving a product, which is higher when done individually compared to automatically on a conveyor. Minimizing the single parcel length makes the biggest impact out of the three categories.

5.2.2 Loading dock order

"A logistics process is a sequence of value-adding activities that puts the right product in the right place at the right time. The best logistics process is the one that achieves this mission at the least total cost, and maximum customer value. Any logistical process that has been in place for some time is a likely candidate for re-engineering." Dr. Barry E Prentice (1998). The logistical order like the loading dock order can be analysed to see if it can be ordered more efficiently. Currently, the biggest cost of the specific loading dock order is walking distance which, combined with its low cost of changing the order around is a good start to see if there is a specific waste occurring.

After the parcels are sorted onto roll containers, they get moved to the loading dock. This is where they are stored until every roll container of the line is filled and when the outbound truck is near the warehouse. These roll containers are all listed in alphabetical order, which makes it easy to put them into the right order but this creates transport waste. To minimize this effect, it is analysed from which loading docks the roll containers are loaded onto the outbound trucks.

5.3 Defects

In the business process management chart, there are a lot of different lines from which parcels have to be picked up. As told in Chapter 5.1 the missed parcels influence the process negatively. The percentage of missed parcels is called the yield, and the total number of missed parcels is called defects. When parcels get picked up wrongly in the line, the parcels get travelled to the wrong location and have to be returned the next day to the warehouse. These defects are caused by human error and can not be removed but can be minimized. Only a small effect on the total number of parcels which get picked up wrongly can have a great effect on customer satisfaction. The waste, which can be phrased is: minimising the number of defects on the conveyor.

Defects on the Cycloon conveyor

The fact that human errors, or defects, happen at a warehouse where employees work is not strange. However these human errors often have causes outside of the employees as told by Sidney W. A. Dekker (2002). "Human error is systematically connected to features of peoples tools, tasks and operating environment. Progress on safety comes from understanding and

influencing these connections.” Sidney W. A. Dekker tells to seek for the reason that these defects are happening outside of the human error itself.

On the conveyor there is a human element which is picking up the parcels. When this is done wrongly, parcels get moved to the wrong location, which results in the parcel being delivered days later. Another worse experience that happens is that sometimes a whole roll container is driven to the wrong location, which results in a bach of parcels getting to the right location days later. These events decrease customer satisfaction greatly and therefore need to be minimized. The parcels are picked up wrongfully this can have two reasons. The first reason is that the conveyor runs to fast but influencing this would greatly decrease the total number of parcels that are picked up from it. The second reason why parcels are missed from the conveyor can be that the labels on the parcels are unclear to read. This problem can be specified as that employees confuse labels of different parcels with each other.

5.4 Listing the most appropriate waste

When comparing the different types of wastes from Chapter 3 to all the gathered information about the process in Chapter 4, a few different wastes were concluded. The wastes which are discovered are: the missed parcels, the road to the loading dock and the defects. All three wastes are researched because they are all relatively simplistic. This allows us to spread the solutions and recommendations for the company.

Chapter 5, concludes several wastes through conversations with employees who enabled us to get a second list of wastes. This was done in a quite different way compared to the combination of Chapters 4 and 6. Chapter 6.5, discusses if these wastes align to check their validity.

The first waste that was comparable to both the descriptive analysis and the semi-structured interview is the defects. In both researches, this problem was realised, which means that it is valid to investigate this in further chapters. The second part of wastes is related to the unnecessary motion of people or products. In both researches, it was evident that there is a possibility to reduce the amount of motion. The unnecessary motion of people or products can be split into two different wastes: the missed parcels and the road to the loading dock. Another waste that was found only in the semi-structured interview was the diversity of employee responsibility, this waste is however less in line with the research and therefore not be further researched. In the end, it can be concluded that the results of both types of research align and the found wastes are valid.

Table 4 List of the different wastes

Wastes found in descriptive analysis	**Wastes found in semi-structured interview**
the missed parcels	The missed parcels
The defects	The defects

Transport waste to the loading dock	Diversity of employee responsibility
	Motion waste when this is done too often

5.5 Conclusion

Chapter 5, analyses the different perspectives of product flow from Chapter 4. The descriptive analysis of the wastes was performed by comparing the lists of wastes found in the literature to the information about the product flow. This allowed us to conclude a list of the wastes that occur in the warehouse, and allowed us to answer research question 5:

> 5. What are the wastes found through an analysis of the product flow?

The first waste that was found was the inefficient transport ways of parcels. When parcels are moved individually by an employee, this is costly. The transport waste that occurs can be greatly decreased by moving the parcel in bulk on a roll container or by moving it along the conveyor.

The second waste is the randomly ordered loading dock order. This arbitrarily causes some high-quantity loading docks to be ordered the furthest away. Doing this simply causes a lot of transport waste.

The third waste is the number of defects along the conveyor. When a parcel on the conveyor is not picked up, this causes more work. When a parcel is wrongly picked up, it moves to the wrong destination, which causes delays and customer dissatisfaction. Decreasing the number of defects is beneficial and decreases the waste.

The sixth research question was answered:

> 6. How can the experienced wastes of the employees be aligned with the expected wastes found through the analysis, and how does this impact the trueness of the found wastes?

We compared the wastes found in Chapter 5 to the semi-structured interview. This allowed us to validate these wastes. The semi-structured interview analysed more wastes than the descriptive analysis but also the same wastes. Therefore, the wastes found in the descriptive analysis align but more wastes are occurring. The research focuses on the three found wastes, but it is known that there are more wastes that influence the product flow.

Chapter 6 Process Redesign

Chapter 5, lists wastes that negatively impact the warehouse product flow. In Chapter 6, these wastes are researched to see what can be done to change the effect. Since three different wastes are tackled, they are handled separately. This allows the presentation of different options to the company, which has the biggest impact in case one solution is not viable. In this chapter the raw solution is compared to the current situation, only in Chapter 7 any possible costs are also evaluated.

6.1 Missed parcels

Missed parcels are currently walked to the proper roll container physically by one employee. These individual trips do not take up much time per trip but accumulated do take up much time. 'Time wasted in waiting can be reduced through effective planning and optimal resource allocation', Naicker Deviakumarie (2017). The optimal resource allocation in this case is to find a different transport way for the missed parcels, which currently take up quite some time and therefore waste. To decrease the effect of the transport waste, the missed parcels are travelled back in bulk rather than individually. When a half-full roll container is filled with missed parcels, it is returned to the beginning of the conveyor to go through the process again. Specific calculations of the time saved can be viewed in appendix C. The idea of a half-full roll container is because if the roll container is filled up more, the chance of not seeing a parcel that is laying underneath other parcels increases. However, in practice, it might be better to alter how full the roll container needs to be in order to walk the missed parcels route. Another solution to minimise the number of parcels being missed is to utilize a trolley. Such a trolley has a higher visibility of all the parcels that still need to be placed upon a roll container.

The biggest drawback to the current system is that the waste is hardly visible. When parcels are moved back to the right roll container, this takes only a small amount of time. These time costs are only little but are a lot accumulated. To calculate the initial time cost and the time cost of the solution, there are some important assumptions to notice:

1. An employee walks 1m/s
2. Missed parcels are put on the conveyor at a regular interval
3. The number of missed parcels is 5 parcels/15 minutes
4. An employee walks 0.5 m/s with a roll container
5. There is always an extra employee available to move the filled roll container
6. Searching for the right 43 parcels on the roll container takes a total of 3 minutes

When subtracting the old transport way for missed parcels from the new one, the total time save is 37 minutes. The advantage of the proposed solution is substantial for one night. Another thing that can be seen from the calculation of the waste is the actual waste that is occurring. The total time the initial transport ways cost is almost an hour. Which could not be seen at first because the transport of individual parcels is difficult to witness. The

implemented solution can be witnessed in Figure 13. The change in the BPM is only little with a condition on the top right. The condition being that the trolley is full.

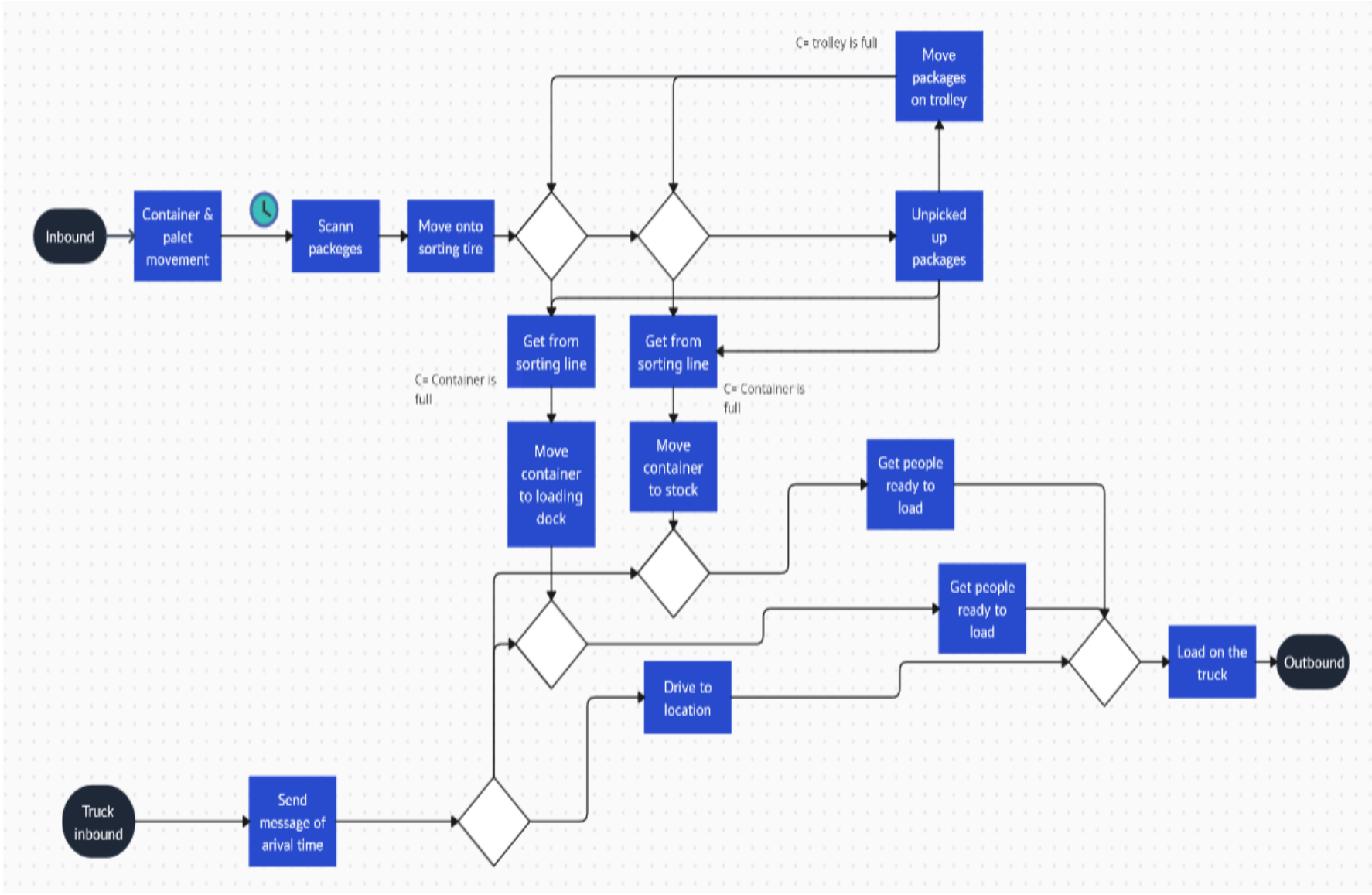

Figure 13 The BPM for the missed parcels solution

6.2 Loading dock order

The second waste is: the loading dock order. A vehicle routing problem (VRP) is about the route optimization problem introduced by Dantzig and Ramser. A solution for such a routing problem incorporates many different parameters and is a systematic solution for it. However, it is not applicable for the solution proposed to the warehouse because in the warehouse there is a much simpler solution. The idea to decrease the transport waste is to sort the roll containers not in the order that is currently the case namely alphabetically (which is arbitrarily made up), but to do this by quantity. If this is done, the high-quantity roll containers are situated in the nearest place and also picked up in that place. When this is the case, the travelled distance decreases and in return, the personnel cost decreases. To calculate the saved cost, the initial cost is calculated first.

6.2.1 The current analysis of the loading dock order

The approach to this waste starts with the analysis of the total meters per different line. In this calculation, the average line distance is taken from the moment they are perpendicular to the parcel scanner. The reason for picking this specific moment is that on average, this is where the full roll container is handed to the employee who handles moving the roll containers to the loading dock. The distance from this point to the loading dock per roll container is under the Column: ‘Distance per line’. The distance per line is multiplied by the rounded-up average number of containers per line to calculate the total distance per line. The solution to the transport waste is to order the roll containers on quantity instead of alphabetical order. To do this the average roll container order per night is first needed which is:

Table 5 Total distance walked per night

Line	Total number of packages per line	Average number of containers per line	Rounded off	Distance per line	Total distance per line in Meters
a	2339	27.52	28	27	742.98
b	2884	33.93	34	51	1730.40
c	1492	17.55	18	39	684.56
d	1169	13.75	14	33	453.85
e	732	8.61	9	27	232.52
f	2266	26.66	27	21	559.84
g	222	2.61	3	21	54.85
h	1559	18.34	19	21	385.16
j	956	11.25	12	15	168.71
k	556	6.54	7	45	294.35
l	247	2.91	3	57	165.64

m	488	5.74	6	0	0.00
p	204	2.40	3	0	0.00
x	1035	12.18	13	53	645.35
y	0	0.00	0	0	0.00
z	865	10.18	11	15	152.65
				Total distance per night	6270.85

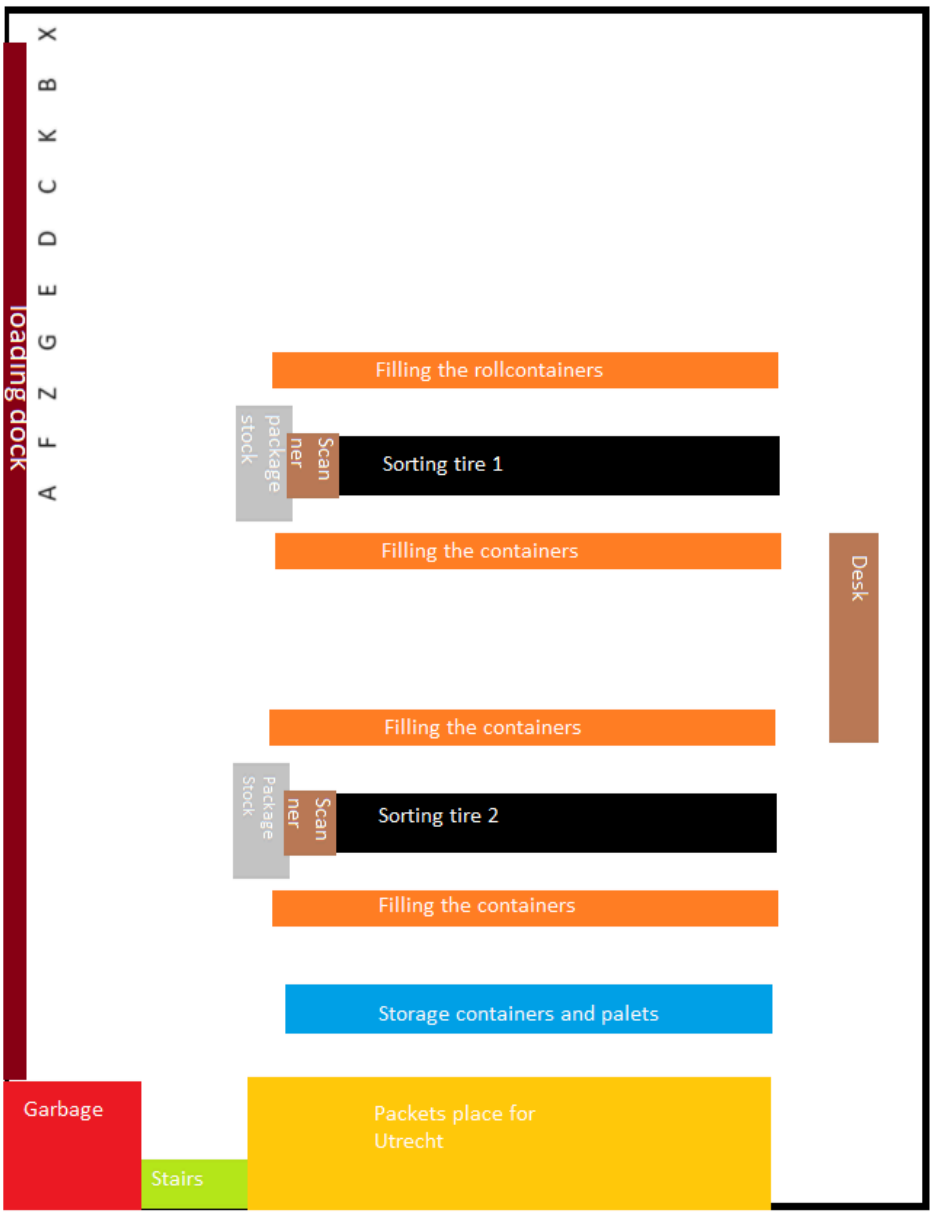

Figure 14 Warehouse floor plan with the initial loading dock order

6.2.2 The solution analysis of the loading dock order

To calculate the total distance travelled by the solution, the lines are ordered on quantity. Afterwards, the line with the biggest quantity is assigned the first slot in the loading dock order. The biggest quantity line is not given the shortest route because the third slot is the shortest route. However, ordering the lines on quantity gives some advantages, like it being more easily applicable, while the difference in walked distance is only little. Therefore, the solution is to order the lines on quantity.

Table 6 New distance travelled to the loading dock

Lines ordered on quantity	Average number of containers per line	New distance per line in Meters
b	33	27
a	27.5	21
f	26.7	15
c	17.6	21
d	13.8	27
x	12.2	33
z	10.2	39
e	8.6	45
k	6.5	51
g	2.6	53

Table 7 New total distance travelled to the loading dock

Destination	Average number of containers per line	New distance per line in Meters	Total distance per line
a	27.52	21	577.87
b	33.93	15	508.94
c	17.55	27	473.93
d	13.75	39	536.36
e	8.61	51	439.20
f	26.66	21	559.84
g	2.61	33	86.19
h	18.34	33	605.26
j	11.25	27	303.67
k	6.54	57	372.85
l	2.91	15	43.59

m	5.74	0	0.00
p	2.40	0	0.00
x	12.18	45	547.94
y	0.00	0	0.00
z	10.18	27	274.76
		Total new distance per night	5330.40

The new distance the employee has to walk per night is, 4292m. The new distance can be compared to the old distance when we receive the new time save 100%-4150/5551=15.0%. This transfers to a total of: 1m/s* (6270-5330)=940 seconds or 15:40 minutes.

It is important to acknowledge that the travelled distance per line is only the distance walked towards the loading dock. This is because employees who move the roll containers also have some other tasks and it is difficult to incorporate the employee walking back a distance when they often walk towards another place.

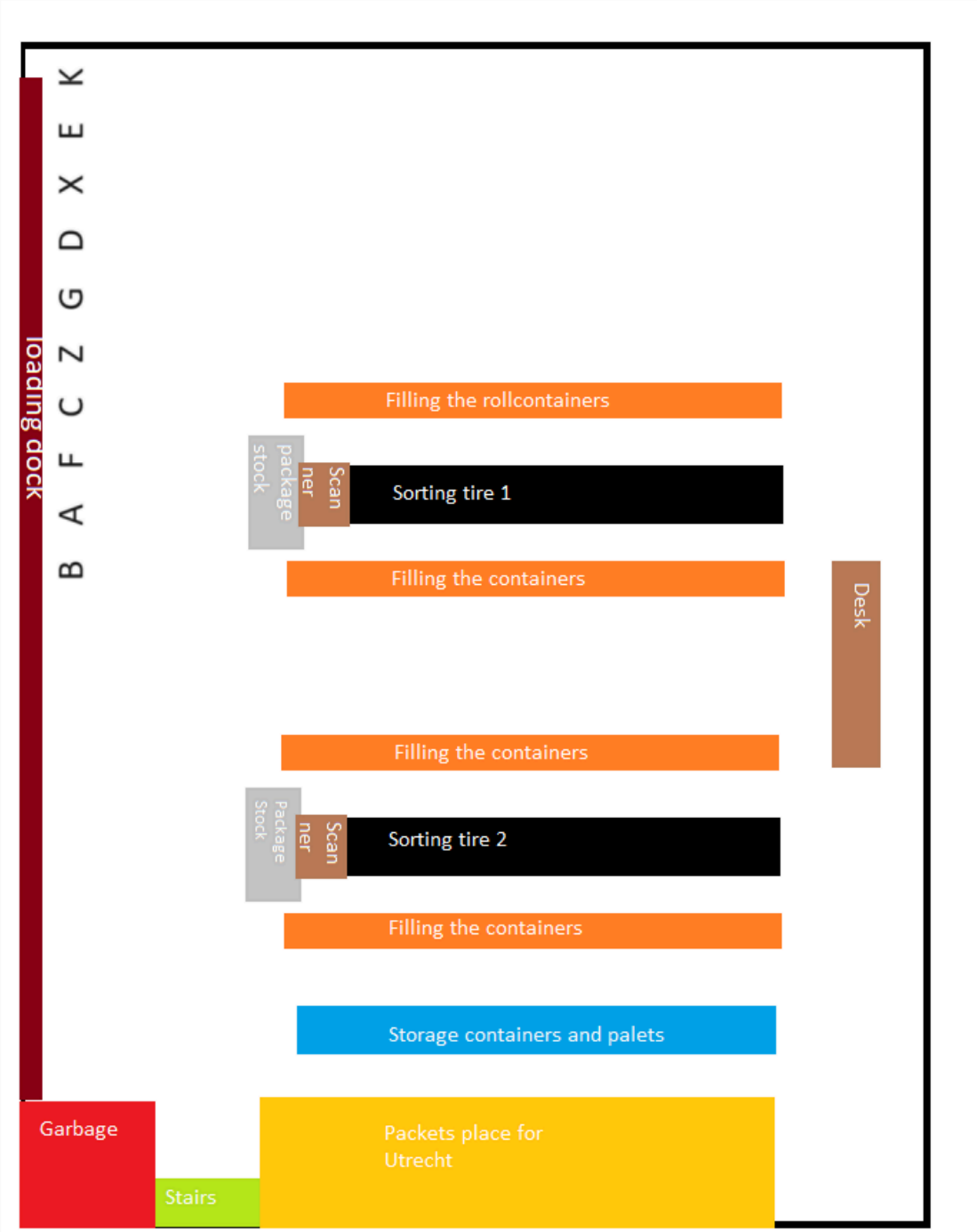

Figure 15 Warehouse floor plan for the proposed solution

6.3 Defects due to labels

Picking up parcels is currently done with a label, which is depicted in Figure 10. Currently, every line has a letter on the label, ranging from A to K. Next to the slot for the letter is another slot with a number on it. This number illustrates the corresponding stop location for the truck. Picking up the parcels and scanning for the appropriate letter and number combination is a stressful task and a human element which can not be eliminated. This effect can however be minimized, for which there is a proposal.

The importance of avoiding look-alike labels is explained by Larmené-Beld (2018). This literature research finds that a lot of medical errors are made because of wrong labelling. A few options that are suggested are tall man lettering, a colour-coded system, or a contrasting background. These solutions are however best applicable in labelling on medicine, which has quite a long text and is different compared to the labels of Cycloon which only has one letter on it. Therefore, the labels of Cycloon need another, more situation-specific solution.

Currently, the letters which are located on the labels are ordered in alphabetical order, which makes it compact. However, some letters look confusing when scanning multiple parcels in a short time period. The letters which look alike are: (C, D), (C, G), (E, L, F). For this there is no true comparable scientific evidence, however it is closely related to the research by Larmené-Beld (2018). Larmené-Beld also signals the importance of look alike labels and explains the impact of small changes. We eliminate: C, F, E, for knowing which letter combination to avoid. For the new letters to use for the eliminated letters, letters are chosen that look least like the already used letters. This results in letter and line combination:

Table 8 Old and new letter labelling order

Line	Old letter	New letter
1	A	A
2	B	B
3	C	D
4	D	G
5	E	H
6	F	J
7	G	K
8	H	L
9	J	M
10	K	P
11	L	Q
12	M	R
13	P	S
14	X	X
15	Y	Y
16	Z	Z

It is quite difficult to measure the effect of the newly chosen letter combinations. There is no data on how many defects there currently are, and there is also no data on how the proposal influences the situation. However, from the theoretical argument, it can be concluded that the proposal has a positive effect on the warehouse product flow with minimal costs.

6.4 Conclusion

Chapter 6 presented the solutions for the listed wastes, which are: moving the missed parcels in bulk, changing the loading dock order and changing the used letters on labels. Wastes ‘missed parcels’ and ‘loading dock order’ have generated quantitative conclusions which save the company time and money. The conclusion of waste ‘defects’ has generated a qualitative conclusion which not expressed in numbers. Chapter 6, answers the following research question:

7. How can the impact of the wastes on the product flow be decreased?

Missed parcels are currently walked to the proper roll container physically by one employee. These individual trips do not take up much time per trip but accumulated do take up much time. The solution to minimise the waste is to transport the missed parcels in bulk. The drawback of this solution is its robustness. Moving the parcels in bulk feels slower because the time is spent accumulating them at once instead of dispersing them. The advantage of this solution is that it saves an average of 37 minutes per night.

Currently, the loading dock order is random, which allows some highly occupied roll container destinations to be the furthest away. While other low-occupied roll container destinations are closest. The solution to this is to have the highest quantity destination to be closest so that the walked distance is less. This solution saves 20:59 minutes.

Difficult to read labels cause parcels to be missed on the conveyor or to be picked up wrongly. This causes extra transport waste of the parcels to be delayed. A solution to lower the waste is to make the labels more distinct by deleting look alike letters. The letters that are eliminated are C, F, and E. Calculating the precise effect is difficult, but the problem itself has been noted, and the solution is viable. Other viable options for solutions are tall man lettering, a colour-coded system, or a contrasting background.

Chapter 7 Evaluation

Over the process of the research, there were continually open conversation with the accompanist about the research process and how the research aligns with the current warehouse situation. During the research, however, some assumptions have been made and choices have been made. Therefore, the process of research is evaluated. This is also the next step in the managerial problem-solving method by Hans Heerkens (2017).

7.1 Process evaluation

There were some process deviations which were discovered which influence the end result. These deviations are evaluated to know how they occurred and how they influenced the research. During the start of the research, there was the discovery of a problem which continued throughout the research, which is that the actual waste is not known. It is known that there are wastes throughout the warehouse product flow but these wastes first need to be found. The search for wastes succeeded during this research, when finding out that the wastes through analysis of the graphical representation aligned with the semi-structured interview. There is however an important fact, and that is that it is possible that there is another waste which was not found through both analyses. This fact does not dismiss our research and its effectiveness but makes it possible that there is another solvable waste to increase the efficiency of the product flow throughout the warehouse.

Another related factor to the possibility of there being other wastes has to do with the choosing method of the wastes. The wastes were selected by comparing the literature on wastes and the gathered information about the warehouse process. This process is quite arbitrary, which in can cause the probability of there being other viable wastes.

7.2 Solution evaluation

The research, generates three different solutions for the listed wastes. Two different solutions have an accompanying calculation of cost (found in Chapters 6.1 and 6.2), and the other solution has a textual explanation (found in Chapter 6.3). Chapter 7.2, presents a discussion on the solutions.

1. Missed parcels

Currently, the missed parcels are transported physically per parcel or set of parcels. The generated solution for this is to instead do this in bulk. This has the advantage of decreasing transport waste by 70% but also has some drawbacks.

The first drawback is that the proposed bulk transport way is robust. Travelling with a roll container around the different destination roll containers is a large task (it takes over 4 minutes). While this saves time in the total time count, it might feel like a larger task because the time is added up at one-time point instead of more. This feeling can be minimized by making one employee responsible for this task and explaining the difference.

Another drawback of this solution is that the responsible employee have to search for the right parcels on the bulk roll container. A parcel can get missed when a total of 43 parcels are on a roll container for 14 destinations. This can result in the parcel having to be rolled around again on another roll container round.

Evaluating the missed parcels waste solution, the drawbacks conclude that the roll container can be a more robust task than handling it individually. A solution for this might be to generate another mechanic to roll around the missed parcels. We can conclude that there are multiple small drawbacks but the total time save is large.

The implementation of this solution only has a few steps. First a trolley needs to be bought. Since the trolley will be used to travel around many parcels over a distance, it is necessary for it to have enough space and to be fast to move around. After the trolley has arrived the employees at the end of the conveyor need to be instructed to now only move around the missed parcels after a while. A pitfall of the implementation might occur when employees still perform the old transport way, so this needs to be checked.

Table 9 Decision-making factors for implementing the missed parcels solution

Decision-making factors	
Cost	An appropriate transport trolley can be bought for about 235 euro. This is the general price for which it can be bought online.
Change over time	When an appropriate transport way has been found, the solution can be fully implemented in a few nights
Direct drawbacks to the operation	In the new operation way, one person needs to be made responsible for the trolley. Problems occur if this is forgotten.
Gain	Decreasing transport waste for missed parcels by 70% or 37 minutes.

2. Loading dock order

Currently, roll containers are sorted in alphabetical order near the loading dock. When all parcels have been sorted they are picked up by a truck which arrives at the loading dock in another order. To minimize the transport cost, the order of roll containers and truck loading dock order are ordered differently.

A drawback of this solution is that all the roll containers are ordered on volume. This results in all the high-volume lines being on one side and all the low-volume lines on the other side. A disadvantage of this is that on one side of the loading dock, there is little space to walk

around due to the multiple roll containers in front of each other. This can result in the employee having less room to move around the roll containers.

Another drawback that this solution generates is that the roll containers are no longer ordered in alphabetical order, which makes it easier to make mistakes because the alphabet is a similar order than a seemingly random order. A solution to this would be to change the labels of different lines, which would cause administrative work. This is not a huge drawback but still needs to be discussed when implementing the solution.

To implement the new loading dock order, a few aspects have to change on a certain day. First, the labels which tell which roll containers need to be situated at the loading dock need to change in between night shifts, which can be easily done by printing and changing a piece of paper. Secondly, there are truck drivers that drive the same route each day, they need to be instructed to drive to another loading dock. Lastly, the employee who is responsible for separating roll containers to the right loading dock, needs instructions that the loading dock order has changed. The pitfall of the implementation is that the three steps all have to be performed between two night shifts on a specific day, if one of the three steps is not performed the product flow will not function.

Table 10 Decision-making factors for implementing the loading dock order solution

Decision-making factors	
Cost	10 euro, for a one time changing of the labels on the loading dock.
Change over time	When the new labels have been put on the loading dock, the involved employees receive an email that the operating order has changed but the work stays the same. This can be done overnight.
Direct drawbacks to the operation	The operation should not be affected too much by the change. A possibility might be that some experienced truck drivers still drive to the old loading dock but the is just a minor inconvenience.
Gain	Decreasing loading dock time by 22.7% or 20:59 minutes

3. Misread labels

Currently, the labels incorporated for different lanes include the letters A till Z. Another fact is that sometimes parcels are missed or picked up wrongly on the conveyor. Clearing out letters that look-alike decrease the probability that and employee picks up the wrong parcel. When linking these two facts to each other, the solution is to change the used letter set. The first evaluated disadvantage of this solution is that the letters are no longer alphabetically

ordered without interruptions. While there are only a few letters that are skipped, this can still be inconvenient. This is however a minor drawback compared to the reduced number of defects. Another drawback to the new solution is that there is a lot of communication needed with partners.

The implementation of the different labels is the most prone to mistakes. Suppliers like Bol and Zara have to be contacted that there is a new letter combination for specific locations. Changing the labels is done by sending the new file to the companies but the most important aspect is that this is all done on exactly the same day, this should be done by the employee who has contact with these suppliers. When a company does not do this on the exact day all the packages that are labelled are transported to the wrong location. Contacting the suppliers to change the labels should however be easy and it can be done by sending an e-mail with the new letter combination and the date.

At the warehouse, there also needs to be an update. Labels on the conveyor need to be replaced. Replacing the labels is easy, but they need to be printed in time since the letter destination combination is changed. Labels for the conveyor are located at a central point so they can just be put there. The labels on the loading dock are laminated, so this needs to be done first, but they can also be replaced easily. Also, for this implementation, it is important that the changes are executed on the same day. Employees who separate parcels also have to be informed that the lettering system changed, however for them the work itself does not change so just a simple notification should be fine.

Table 11 Decision-making factors for implementing the labels solution

Decision-making factors	
Cost	30 euro, for changing the labels on the parcels. For having to throw away some unused labels.
Change over time	Labels are printed by partners at the operation, they can be sent the new letter combinations overnight. Also, changing a few roll containers at the operation should only take half an hour.
Direct drawbacks to the operation	The operation can be much affected if the change is not done properly. A bunch of parcels can be sent to the wrong destination. However, because the change is quite simple, this should not be a problem when properly coordinating the change with the different partners.
Gain	Increase of customer satisfaction per newly not missed parcel.

7.3 Conclusion

Chapter 7 evaluates the process of the research. The structure of analysing the product flow allows for the possibility of missing some highly influential wastes. This can be noted by finding extra wastes during the semi-structured interview. The research however focuses on the three wastes found in both analysis.

The different solutions all provided different evaluations. Each solution also has a drawback. It is interesting for the company to also know these drawbacks because then they can make their decision whether to implement the solutions to the wastes. In the end, this evaluation allowed us to properly judge the research. Chapter 7 answers research question 8:

8. How can the solutions be evaluated and are they recommended implementing in the warehouse operation

Transporting the missed parcels in bulk decrease the specific transport waste by 70% or 37 minutes. A drawback to this solution is that the bulk transport way feels less efficient because the transport is done accumulated at once. However, when this is implemented correctly, it saves more than is the disadvantage. Therefore, implementing the solution is suggested.

Ordering the loading dock order on quantity decreases loading dock time by 20:59 minutes. A drawback to the solution is that many high quantity loading docks are right next to each other, which makes the space crowded. This crowdedness takes some time to adapt to but because there is one employee responsible for this the adaptation time is short. The crowdedness do not outweigh the saved time from the decreased transport waste and therefore it is advised to implement the solution.

Changing the look-alike letters on the labels to decrease defects is an unsure solution. Measuring the effect is impossible for the span of this research, and therefore the true effect is unknown. However, the waste of the defects occurring is known, and the solution is easy to implement. There are other solutions known like: tall man lettering, colour coded system, and contrasting background. It is recommended to further research the effect of changing look alike letters and research the other ideas as well.

Table 12 Combined decision-making factor table for the three solutions

Decision-making factors			
Waste	Missed parcels	Loading dock order	Misread labels
Cost	An appropriate transport trolley can be bought for about 235 euro. This is the general price for which it can be bought online.	10 euro, for a one time changing of the labels on the loading dock.	30 euro, for changing the labels on the parcels. For having to throw away some unused labels.

Change over time	When an appropriate transport way has been found, the solution can be fully implemented in a few nights	When the new labels have been put on the loading dock, the involved employees receive an email that the operating order has changed but the work stays the same. This can be done overnight.	Labels are printed by partners at the operation, they can be sent the new letter combinations overnight. Also, changing a few roll containers at the operation should only take half an hour.
Direct drawbacks to the operation	In the new operation way, one person needs to be made responsible for the trolley. Problems occur if this is forgotten.	The operation should not be affected too much by the change. A possibility might be that some experienced truck drivers still drive to the old loading dock but the is just a minor inconvenience.	The operation can be much affected if the change is not done properly. A bunch of parcels can be sent to the wrong destination. However, because the change is quite simple, this should not be a problem when properly coordinating the change with the different partners.
Gain	Decreasing transport waste for missed parcels by 70% or 37 minutes.	Decreasing loading dock time by 22.7% or 20:59 minutes	Increase of customer satisfaction per newly not missed parcel.

Chapter 8 Conclusion

Chapter 8 discusses the conclusions of the research done at Cycloon. It includes the different results and how they influence the product process flow. Next to that, future research is recommended that is needed to incorporate the limitations of the research.

8.1 Research questions

Chapter 8.1 answers the research questions posed in Chapter 1. The questions are used to structurally answer the main research question.

1. How can the product flow through the warehouse be visually represented?

The business process methodology is a widely known technique to visually represent the product flow throughout supply chains. This technique can also be used to analyse the smaller product flow throughout the warehouse. The BPM is also viable because it is highly relevant from a practical point of view. These reasons provide a construct on why to use the BPM for the research.

2. What are possible methodologies for analysing wastes in the warehouse?

With the broadly different visions in the literature, there are different views on how to acquire the wastes and improvements in a supply chain or a product flow in a warehouse. With these researchers all having their perspectives, they were all listed and have to be used to guide the core problem answered in the upcoming chapters. An important methodology for analysing wastes is to categorise possible wastes. This can be done by a lean classification system.

3. What is the current flow of products throughout the warehouse?

The parcels arrive at the inbound side of the warehouse. Here, parcels are stalled till the conveyor begins to operate. The parcels are sorted by different employees, who are responsible for their destinations. Filled roll containers are returned to the loading dock to be eventually picked up by trucks when they arrive. Three different aspects of the flow of the products are known:

-The important perspectives of the product flow

-The systematic flow of the process in the BPM

-The physical travel distance of parcels in Figure 11 and Figure 12

4. What are the wastes found through an interview with employees?

The biggest finding during the semi-structured interview was the waste of time when a parcel does not get picked up properly. The distance from the end of the conveyor to the roll containers in the front is quite far, which results in a lot of extra transport waste. Next to that, parcels can also get picked up wrongly, which results in a single parcel being transported to the wrong destination. We also discovered another waste which is the diversity of employee responsibility.

5. What are the wastes found through an analysis of the product flow?

The first waste that was found was the inefficient transport ways of parcels. When parcels are moved individually by an employee, this is costly. The transport waste that occurs can be greatly decreased by moving the parcel in bulk on a roll container or by moving it along the conveyor.

The second waste is the randomly ordered loading dock order. This arbitrarily causes some high-quantity loading docks to be ordered the furthest away. Doing this simply causes a lot of transport waste.

The third waste is the number of defects along the conveyor. When a parcel on the conveyor is not picked up, this causes more work. When a parcel is wrongly picked up, it moves to the wrong destination, which causes delays and customer dissatisfaction. Decreasing the number of defects is beneficial and decreases the waste.

6. How can the experienced wastes of the employees be aligned with the expected wastes found through the analysis, and how does this impact the trueness of the found wastes?

We compared the wastes found in Chapter 5 to the semi-structured interview. This allowed us to validate these wastes. The semi-structured interview analysed more wastes than the descriptive analysis but also the same wastes. Therefore, the wastes found in the descriptive analysis align but more wastes are occurring. The research focuses on the three found wastes, but it is known that there are more wastes that influence the product flow.

7. How can the impact of the wastes on the product flow be decreased?

Missed parcels are currently walked to the proper roll container physically by one employee. These individual trips do not take up much time per trip but accumulated do take up much time. The solution to minimise the waste is to transport the missed parcels in bulk. The drawback of this solution is its robustness. Moving the parcels in bulk feels slower because the time is spent accumulating them at once instead of dispersing them. The advantage of this solution is that it saves an average of 37 minutes per night.

Currently, the loading dock order is random, which allows some highly occupied roll container destinations to be the furthest away. While other low-occupied roll container destinations are closest. The solution to this is to have the highest quantity destination to be closest so that the walked distance is less. This solution saves 20:59 minutes.

Difficult to read labels cause parcels to be missed on the conveyor or to be picked up wrongly. This causes extra transport waste of the parcels to be delayed. A solution to lower the waste is to make the labels more distinct by deleting look alike letters. The letters that are eliminated are C, F, and E. Calculating the precise effect is difficult, but the problem itself has been noted, and the solution is viable. Other viable options for solutions are tall man lettering, a colour-coded system, or a contrasting background.

8. How can the solutions be evaluated and are they recommended for implementing in the warehouse operation

Transporting the missed parcels in bulk decrease the specific transport waste by 70% or 37 minutes. A drawback to this solution is that the bulk transport way feels less efficient because the transport is done accumulated at once. However, when this is implemented correctly, it saves more than is the disadvantage. Therefore, implementing the solution is suggested.

Ordering the loading dock order on quantity decreases loading dock time by 15.0% or 20:59 minutes. A drawback to the solution is that many high quantity loading docks are right next to each other, which makes the space crowded. This crowdedness takes some time to adapt to but because there is one employee responsible for this the adaption time is short. The crowdedness do not outweigh the saved time from the decreased transport waste and therefore it is advised to implement the solution.

Changing the look-alike letters on the labels to decrease defects is an unsure solution. Measuring the effect is impossible for the span of this research, and therefore the true effect is unknown. However, the waste of the defects occurring is known, and the solution is easy to implement. There are other solutions known like :tall man lettering, colour coded system, and contrasting background. It is recommended to further research the effect of changing look alike letters and research the other ideas as well.

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How can we discover the unknown wastes that withhold the warehouse from running more efficiently, and how can these wastes be solved?

The visualisation of the wastes was mostly done by gathering information about the warehouse operations. The BPM chart was the biggest visualisation itself but also gathering extra information was essential. This information was compared to the different categories of wastes to make a list of what wastes are occurring. The different wastes all need a tailored solution in order to minimize the effect. The different solutions are to transport the missed parcels in bulk, ordering the loading dock on quantity, and to change the letters used on the labels.

8.2 Recommendations

From our research we discovered three different wastes for which we have researched possible solutions and drawbacks. For each solution, the best approach to the operations and possible other implications are discussed.

1. Bulk transport system

At the category missed parcels, we have quantified the waste that occurs when moving missed parcels individually. When a parcel is failed to be picked up, it moves along the conveyor to the end. When it is here, it is moved to the missed roll container individually. Our proposed solution is to move around the parcels in bulk on a trolley. This solution has been theoretically calculated to save time and therefore we advise applying the solution. The proposed solution saves a total of 37 minutes per night. One thing that is however highly recommended to be further researched, is if there are any other bulk transport systems that might be more time saving. One solution to this might be to utilize a trolley or wagon.

2. Different loading dock order

The second categorised solution is the different loading dock order. When roll containers are filled with parcels, they are moved to the appropriate loading dock. The waste that occurs is that there is a lot of unnecessary movement of roll containers. An example of this is that one line with the highest quantity of roll containers is located furthest away. The solution to this is to change around the loading dock order to where the highest quantity loading dock destinations are located closest to the conveyor. An aspect which needs some practical testing is if cropping the high quantity lanes does not inflict disorder into the operation. Still, we advise utilizing our loading dock order solution because of the reduction in transport waste.

3. Defect due to labels

The last categorised solution is to avoid look-alike labels on the parcels. Currently, parcels are wrongly picked up from the conveyor. When such a parcel is wrongfully picked up, it is moved to the wrong destination and it takes a few days before it correctly arrives at the destination. The solution which is provided is to avoid letters which look-alike. The solution is easy to apply but increases customer satisfaction. The solution of avoiding the use of letters which look-alike seems logical in theory, it still requires research if it actually works. If it proves to work, the company also has to contact third parties who print the labels on the parcels. Due to the uncertainty and the possibility of changing the label, we advise to not directly implement the solution. However, due to the chance of increasing customer satisfaction with a simple change, we advise taking a further look at this opportunity. Other solutions to the labels are: tall man lettering, colour coded system, or contrasting background.

8.3 Limitations

The research was focussed on only the warehouse operations and in a period where the operation was changing. This caused our research to be limited in a few aspects, which had some drawbacks to the end results.

In the beginning of the research, it was decided to focus our research only on the happy flow. However, the unhappy flow is also a huge part of where there is a lot to gain. The parcels that end up here are only a small portion of the parcels but here is also a lot of waste occurring.

Another aspect that was missed were the different suppliers that operate in communication with the warehouse. These suppliers have varying output, which makes it difficult to predict the workload throughout the year. We realised that this variation takes a toll on some different employees, who already have to work long night shifts.

8.4 Practical contribution

The practical contribution of this study is to provide the company with a list of wastes that strongly influence the efficiency of the product flow at the warehouse. It also entails different explained solutions which minimize the waste. The different solutions should be seen as a first step to decrease the waste. However, the wastes found are only a few and there are more wastes which could be identified within the warehouse.

8.4 Future research

During the research, we have made several choices that have limited the scope of the proposed solution. This was needed to properly figure out what the wastes are at the warehouse, but we have also seen some interesting business opportunities to further analyse.

The first opportunity that was seen is that the unhappy flow is quite unorganised. It was decided to not include this into the research because it is so vastly different to the happy flow, but we have taken a glance into it. It is an easy part of the operation to forget because only a small percentage of parcels end up on this part of the product flow and two dedicated employees independently run this part, however it takes up quite a lot of time which is wasted.

The second opportunity that that was witnessed has to do with the structure of analysing wastes. We compared the information about the warehouse to the different wastes in the literature. This reasoning however also granted some area for uncertainty of missing a bottleneck. We advise to further analyse the product flow to see if there are any more wastes to decrease.

The third opportunity that we have not researched has to do with the output of the conveyor. We have used the total number of parcels that enter each line per night but not in what order. It might be possible but not probable that the first 15 parcels enter the same line, which is a problem for the efficiency of the conveyor. If this happens, further steps need to be taken to

tackle this problem. Another opportunity arises with an analysis of the missed parcels output. These parcels are currently directly brought back to the proper roll container but if there is a pattern in which lines are missed this can be of huge value to know.

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Appendix

Appendix A: Semi-structured interview: Dutch

Table 13 Semi-structured interview: Dutch

Question	Vragen	Answer
Do you know any larger wastes that have been solved previously?	Weet je van vorige knelpunten die eerder zijn opgelost?	pakketten scannen met 2 scanners maar dat werkte niet veel sneller maar meer fouten
What are current wastes that are under investigation?	Lopen er momenteel projecten om huidige knelpunten op te lossen?	Een 2de scan baan maar daar moet nog veel aan gewerkt worden
What are any problems concerning the variance of workload per day?	Zijn er problemen met de variatie in pakketten per dag?	het schakelen vergt veel inzicht per nacht wie waar hulp nodig is maar gaat redelijk goed, idereen helpt elkaar.
Wheat are the problems relating to the difference in workload between lines?		Er wordt geholpen als een line meer hulp nodig heeft en daar tijd voor is. Het is makkelijk te zien als een line meer hulp nodig heeft door aan het einde te kijken vanuit welke line pakketen worden gemist. Ondanks dat dit wel zonde is want dubbel werk. Een extra probleem wat hierbij kan komen kijken is dat door hoge werkdruk werknemers soms de verkeerde paketen oppakken wat ervoor zorgt dat die naar de verkeerde locatie gaan.
What are any problems concerning the unhappy flow?	Weet je van problemen gerelateerd aan de unhappy flow?	De unhappy flow is een groot probleem maar doordat er veel verschillende oorzaken zijn is dit erg moeilijk op te lossen. Momenteel zitten er 2 ervaren personen op die per paket bekijken wat er gedaan kan worden

Do you experience any social problems from the executing work force? (like unproductivity, missing knowledge or underemployment)	Ervaar je problemen op een sociaal vlak van de werknemers(zoals onproductiviteit, missende kennis of te weinig werknemers)	Iedere werknemer heeft zijn kwaliteiten. Soms is het lastig als een werknemer afzegt en we met minder mensen staan. Werknemers werken erg hard en willen graag extra lange dagen werken. Momenteel lopen er projecten om werknemers op te leiden en extra taken te geven.
What are current wastes that need investigation to solve?	Wat zijn de huidige knelpunten die onderzocht moeten worden?	Is een scanboog handig, moet er een 2de scanner bijzijn. Standaardiseren aantal werknemers per plek. Ook willen werknemers elkaar helpen bij werk wat teveel wordt maar dan wordt snel hun eigen werk vergeten, dit kan voor fouten zorgen.
Do you perceive any future wastes with the increase in numbers in the upcoming years?	Zie je komende knelpunten met de verhoging in aantal pakketten in de aankomende jaren?	Onze 2de rolbaan kan dit oplossen alleen wordt het werk hierdoor moeilijker
Are there any recommendations for possible wastes that need investigation for me?	Zijn er aanwijzingen voor mogelijke knelpunten die onderzoek nodig zijn voor mijn project?	Punten zijn soms overbelast, dit kan minder inzicht nodig hebben.

Appendix B: The BPM guidebook

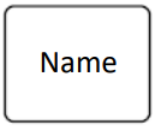
Business process management is a general concept but there are quite a few variations. Therefore, we clarify our used ways.

BPM guidebook

In this part, all the graphical elements of the business process management that are used are defined. There are also a lot of different iterations within the business process management, therefore we provide our used definitions. Rather than building the model itself, in Chapter 4 only the needed definitions and tokens are provided.

Task, subprocess

A task or subprocess is a performance in the supply chain. This is a physical task that is performed.



Start event

The start event indicates the start of the BPM diagram, after which the supply chain runs.

End event

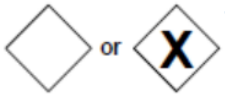
The end event ends the process of the particular product. This does not mean the whole process stops but rather indicates that the process analysis stops. These after-end events can happen when actions are still required for outside parties. Or in the case of the research for events that are outside the scope of the research.

Control flow

The control flow guides the process between tasks and is followed when one task ends and starts the following.

Exclusive gateway

An exclusive gateway is only activated if all the control flows into the gateway are fulfilled. When one control flow is not yet completed, the next can not start yet.



Parallel gateway

A parallel gateway initiates multiple control flows from it simultaneously.

Association (read/write)

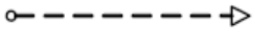
An association is a sort of control flow limited to data objects.

Lane

The different pools represent the difference between different parties (the sorting centre, the customers and other external parties) which might undertake action.

Message flow

A message flow indicates communication between different pools.



Appendix C: Missed parcels calculations

Missed parcels are currently walked to the proper roll container physically by one employee. These individual trips do not take up much time per trip but accumulated do take up much time. We calculate the initial time and the new time during the next few paragraphs. To decrease the effect of the transport waste, we impose to take the back the missed parcels in bulk rather than individually. When a half full roll container is filled with missed parcels, we impose to return them to the beginning of the conveyor to go through the process again. When a half full roll container is filled with on average 85/2=43 parcels, this saves some time.

To calculate the total time profit, we first calculate the initial time cost. When a parcel is missed, the average distance it takes to walk to the designated roll container and back is 2 * 10m = 20m. We assume that the average employee walks 1m/s. The total time it takes to return a parcel is 20m * 1m/s = 20s. The total number of parcels missed is: 5 parcels/15minutes. When we multiply the total number of parcels missed per night by the average time it takes to return a parcel, we get: 20s * 5 parcels / 15 minutes * 4 * 8 = 3200 seconds

To calculate the total time it takes for the solution, we have to take in a few extra steps. A trip with the roll container to the front of the conveyor takes 20 meters. Because a roll container is heavier than without, we imply the speed of the employee to be 0.5m/s. To unload a roll container with 43 parcels on the running roll container takes 3 minutes. A total trip with the roll container takes 20 m * 2 / 0.5m/s + 3 minutes = 260 seconds. The average total time the imposed solution takes is 260 * ((5 * 4 * 8) /43) = 967 seconds

When we subtract both solution from each other we arrive at the total time save per night which is 3200-967= 2233 seconds = 37 minutes.

Notes

Future tense

Correctly reference images

Check correctness references in text

Page numbers