IMPROVING THE OVERALL QUALITY OF THE WAREHOUSE OF SIERS INSTALLATIETECHNIEK

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Improving the overall quality of the warehouse of Siers Installatietechniek

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Preface

Dear reader,

You are about to read the bachelor thesis “Improving the overall quality of the warehouse of Siers Installatietechniek.” This thesis has been performed at Siers Installatietechniek, a Siersgroep department. This is my final assignment for the Bachelor of Industrial Engineering & Management at the University of Twente. This thesis aims to make recommendations on how to improve the warehouse of Siers Installatietechniek, which is inside the warehouse of Siersgroep.

I want to thank Siers Installatietechniek for allowing me to perform my thesis here. I want to thank all the employees of Siers Installatietechniek, the ICT department, and the warehouse workers for helping me when I had questions. I also want to thank my supervisor Niels Hartogsveld, who guided me with feedback in weekly meetings and when I had urgent questions, he was available to answer them. With him, this thesis was possible.

I also want to thank my UT supervisor, Breno Alves Beirigo. With him, this thesis was also possible. I want to thank him for the meetings and critical views on topics to get me on the right track. I also want to thank Alessio Trivella for being my second supervisor.

Finally, I want to thank family and friends for their help and support in finishing my thesis.

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Management summary

This research has been performed at Siers Installatietechniek in Oldenzaal. Siers Installatietechniek is making less profit because of inefficiencies in its warehouse. In the case of Siers Installatietechniek, the current process used by the warehouse workers, work preparers who order materials, and the mechanics who use materials is not under control. This results in significant deviations in the actual stock and the stock in the ERP system. As a result, a direct financial problem is caused by delays and failure costs in projects with missing materials. This research aims to increase the overall quality of the warehouse. After making a project cluster and meetings with stakeholders, we came to the following main research question:

How to increase the picking efficiency and use less storage capacity in the Siers Installatietechniek warehouse?

Context analysis is conducted to understand the situation in the warehouse of Siers. This is done by performing an observation study at the warehouse of Siers and working there for two days. A business process model is made for the project and general stock materials. The general stock has a stock level, and the project stock does not have a stock level.

After mapping the process, a literature review is performed to answer the main- and sub-research questions. We needed to know how to increase picking efficiency and use less storage capacity. We concluded that a new slotting strategy is an effective way to do that. After more research, we found the ABC analysis.

After performing the ABC on picking frequency and material groups and making a heatmap, we concluded that the travel distance could be reduced to 14.7%.

Data analysis was conducted to find outliers in the stock deviations of the materials of Siers Installatietechniek. After analysing this, we found possible solutions for these products. Also, interviews are performed on how to make the process of picking and returning materials more effective and on whether the ERP system is working sufficiently in the warehouse.

After this, all the findings were scored based on the following KPIs. Costs, feasibility, accuracy, efficiency, and decreased stock deviations. These KPIs had weights assigned to them, which the supervisor from Siers decided, and the best solutions were found.

These solutions were also recommendations to the company, and the highest-rated solutions are listed below:

- A Warehouse management system with a scanning system.
- New slotting for T and U racks.
- Periodic material countings.
- Separation between tubes.
- New slotting for V racks.
- Have warehouse workers with material knowledge.
- project stock in a fixed place together.
- Use 4PS advice orders instead of Appeee.
- Closed warehouse with a counter.
- Unit and shelf location must match between Appeee and 4PS.

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1 Introduction

This bachelor thesis is conducted at Siers Installatietechniek. This thesis is about improving the overall quality of part of a warehouse, which is from Siers Installatietechniek. This will be done in multiple ways to address various warehouse components. In the first section, an introduction will be given. The problem will be addressed in the second section, and the research design will be handled in the third section.

1.1 Company description

Siers Groep Oldenzaal supplies in the field of underground infrastructure in the Netherlands. Gas, water, electricity, telecom, and heat: Siers conducts extensive projects for its clients. From consultancy and engineering to project management, delivery, aftercare, and warranty. Siers is a medium-sized player in the Dutch market. Siers Installatietechniek B.V. operates within Siers Groep Oldenzaal, which is my place in the company. Siers Installatietechniek is a specialist in electrical installations and they also focus on sustainable solutions for the energy transition. For instance, solar panels, and charging stations.

Within the projects Siers Installatietechniek runs, various facets of the work have to do with the warehouse. The warehouse contains stock items and stock that has been ordered for specific projects. The warehouses of Siers fall under the logistics department and are managed by the head of the logistics department, together with the management of Siers. In the specific case of Siers Installatietechniek, the current process used by the warehouse workers, the work preparers, who order materials, and the mechanics who need items needs to be sufficiently under control. This results in significant deviations in the actual stock and the stock in the ERP system. On the one hand, this creates a severe financial problem and delays and failure costs in projects for which material needs to be included.

Work preparers are the people that order all the materials and make sure that all the materials needed are in the warehouse at the right time. They also communicate with the customers, warehouse workers, and mechanics. After that, the warehouse worker picks the material which is already in the warehouse with the material which is ordered and is put in place in front of the warehouse, then the mechanic will take the materials and use them for the project to work on/ finish the project. After that, the stock-keeping units or SKUs can be returned, and the project stock can be returned. The project stock, which is not often used, is in front of the warehouse, and the SKUs are in the back. Project stock is often specialised equipment used only for that project. There are things to improve in the warehouse. Such as the layout, there are stock differences. The ERP system could be better, and there is no fixed process for picking and ordering materials.

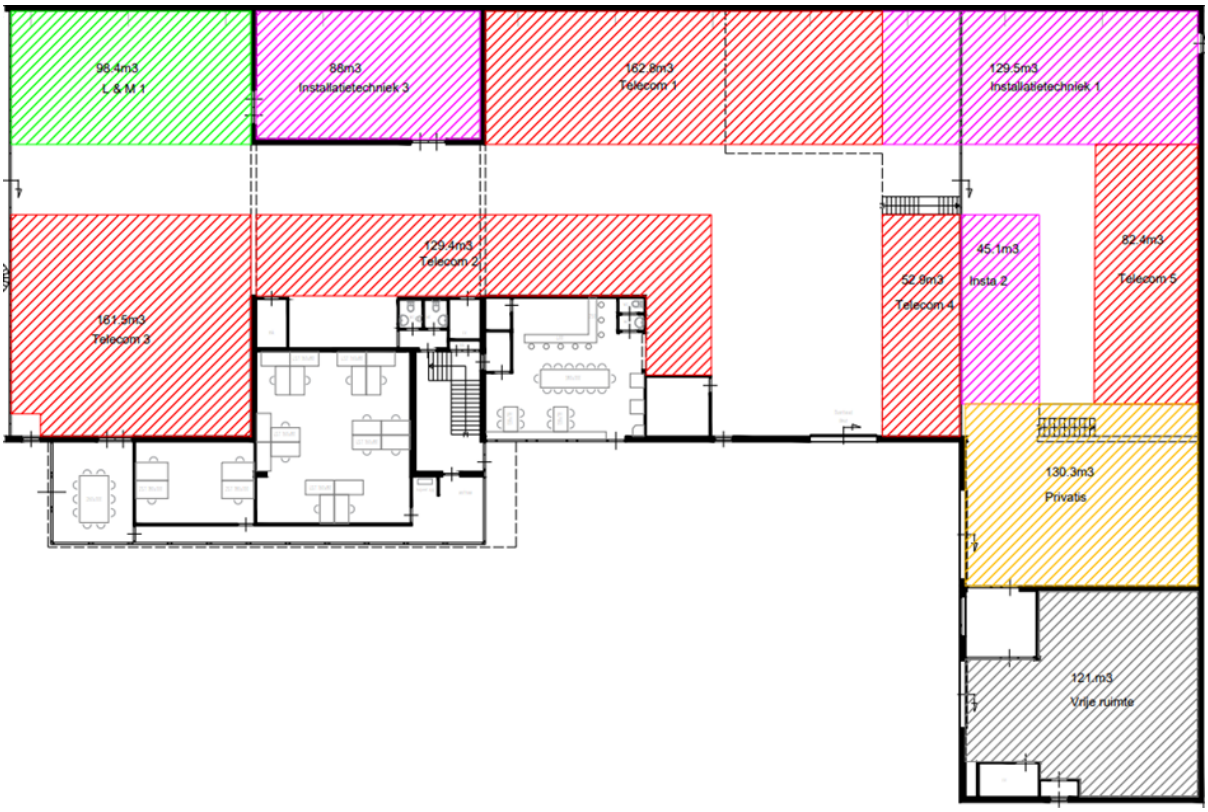

Figure 1- The layout of the warehouse of Siers; the scope of this research is part of Siers Installatietechniek, the purple part.

The warehouse of Siers Installatietechniek has the following layout shown in Figure 1. The purple part is from Siers Installatietechniek. The part of Telecom 4 is where all the departments locate their materials for the projects conducted. Siers delivered this drawing.

The warehouse of Siers Installatietechniek has two kinds of stock. Project stock and general stock. The project stock is stock ordered for the project itself and can be brought back, but it is invisible and does not have stock and an article number, so it is not in the system as it is specialised for that project. There is also general stock, which is actual stock-keeping units, such as screws and nuts and more installation technology-related materials, such as cable lugs, shown in Figure 2.

Figure 2- An example of the material used by Siers Installatietechniek.

1.2 Research aim

This thesis focuses on improving the process's overall quality regarding warehouse stock, project stock, and all related processes. This thesis is about optimising the warehouse process by reducing deviations from the requirements that apply to general business operations, eliminating waste such as unnecessary/double actions, and preventing stagnation in the subsequent sub-processes, such as failure costs during the execution of projects, which in turn leads to less profit. This thesis is about improving the warehouse's overall quality.

1.3 The problem

This section identifies the action problem, the problem cluster, and the core problems.

1.3.1 Identification of action problem

Problem identification is the first step of the managerial problem-solving Method in the book The managerial problem-solving Method (Heerkens & Winden, 2017).
The Managerial problem-solving method states that a problem exists when there is a discrepancy between the norm and reality. The norm is a perfectly working warehouse, and the reality is that part of Siers Installatietechniek of the warehouse needs to be fixed. This is because the efficiency could be improved, there are many stock deviations, and the ERP system is challenging in its ease of use. This results in less profit and failure costs due to missing materials during projects for Siers.

The action problem is:
The warehouse does not function sufficiently.

Figure 3 shows the problem cluster of the warehouse of Siers Installatietechniek.

1.3.2 Problem cluster and the core problem

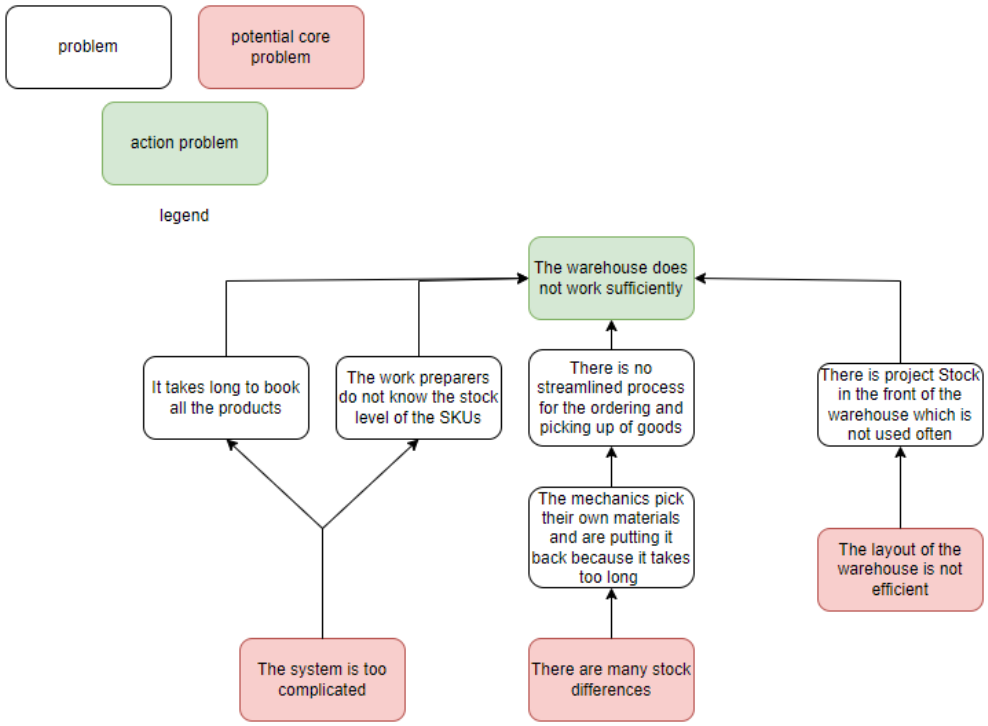

Figure 3- problem cluster

- The work preparers do not know the stock level of the SKUs.

When starting a project, the warehouse workers have no access to the stock levels of the SKUs in the warehouse. When they want to know a material's stock level, they must go to the warehouse. This is a problem because it takes valuable time to go to the warehouse, and finding the material is also challenging.

- It takes long to book all the materials.

It takes a long time to book all the materials, especially when materials from different departments need to be booked.

- The ERP system is too complicated.

Because of that, a potential core problem is that the system is too complicated. The work preparers should see all the stock levels and where the material is located when they search for it. Also, booking the materials is a lengthy process.

- There is no streamlined process for the ordering and picking of goods.

There is no streamlined process for the ordering and picking of goods is also a problem as when a project is started, multiple people are ordering the goods, and there is no fixed process for picking up the materials, which can eventually result in stock differences.

- The mechanics pick their own materials and are putting it back because it takes too long.

The mechanics pick their materials and put them back because it takes too long, according to them. This can result in wrong stock levels of the material. This is more of a behavioral problem, which is hard to fix but can be fixed with a more effective and streamlined picking method. Sometimes the mechanics pick their materials but do not put write them off in the system and do not write them back up when putting them back, or the materials are put back because the warehouse workers think they are written up.

- There are many stock differences.

There are many stock differences which is a potential core problem. Every year the stock is counted, and there are massive differences in the stock, which costs the company money.

- There is project stock in the front of the warehouse which is not used often.

There is project stock in front of the warehouse, which is not used often. Project stock is specialised for a specific project and may or may not be used in another project. This means that the layout is not efficient.

- The layout of the warehouse is not efficient.

The layout of the warehouse is not efficient. The distance the warehouse worker travels is significantly more significant than it should be. This can result in lower peak capacity used in the warehouse, which needs to be high as Siers is already struggling with the capacity of the warehouse.

As this thesis is about improving the whole quality of the warehouse, all these core problems will be assessed by making recommendations.

1.4 Research design

To improve the quality of the warehouse, research questions were made. These try to improve the overall quality of the warehouse of Siers Installatietechniek. However, there are some restrictions and limitations to this thesis. Also, deliverables are defined.

1.4.1 Main research question

How to increase the picking efficiency and use less storage capacity in the Siers Installatietechniek warehouse?

This is the main research question of this thesis. The main goal of this thesis is to improve the overall quality of the warehouse. The picking efficiency and storage capacity are one of the main inefficiencies of this warehouse, according to the assignment description and conversations with managers, warehouse workers, and work preparers.

1.4.2 Sub-questions and knowledge questions

- **What are the processes of the warehouse?**

By answering this knowledge question, the researcher will get an insight into how the warehouse works. This requires a mapping of the current flows of the goods and the sourcing. By doing field days, it can also be seen where it goes wrong. So, this question will be answered by doing observations and interviews. During these observations, we can see what is happening in the warehouse and what is meant to happen because of the discussions.

- **What is a relevant method to increase picking efficiency and decrease storage capacity?**

A literature study is conducted to answer this question. This method will be analysed, and it will be compared to an alternative.

After the conversations with stakeholders, it also became clear that many people would like to change how picking and returning materials work. To try and improve that, the following question has been formulated:

- **How can we make the process of picking and returning materials more effective?**

Interviews will answer this question as this is primarily a qualitative question. This could be the main reason for deviations in the stock, which we want to prevent. This will also help improve the quality of the warehouse as there is no streamlined process in the warehouse.

The assignment description states that there are many stock differences between the ERP system and the actual stock in the warehouse. This question has been formulated to find out why there are many stock deviations on some of these materials.

- **Are there materials with more stock deviations than others, and why?**

This question will be answered by doing data analysis and looking at the data of the stock and time stamps to see if there is an outlier and try to figure out why and solve it. With this data, the company can decide to count the stock of those materials more often or implement the solution if there is a solution.

After the observation study, it became clear that there is an enterprise resource planning (ERP) system, not a warehouse management system (WMS). To find out if this is working sufficiently, the following question has been formulated:

- **Does the enterprise resource planning (ERP) system work sufficiently?**

Interviewing warehouse workers will answer this question, ask the warehouse worker what they find essential and compare it with the current ERP system.

1.4.3 Limitations and constraints

The limitations of this project are as follows:

- It must be executed within the given magnitude of 420 hours. This can influence the implementation phase and the evaluation phase.
- The causes of the core problem are not completely clear, so that is the knowledge that is missing, but that can be solved by asking mechanics, warehouse workers, and work preparers. Those are the people that also will be involved in the problem-solving process.
- The existing situation must be modified because making a new warehouse is a radical solution.
- The means at my disposal are the opinions of the mechanics, warehouse workers, and work preparers and the data gathered about the layout and the stock countings.
- This report will only be about the part of Siers Installatietechniek and not about the other departments in the warehouse, like Siers L&M, Siers Telecom, and Privatis.
- Another limitation is that the warehouse worker with all the stock countings suffers from a long-term illness, meaning there is only one stock count for this thesis.
- Also, data can be off due to mechanics picking materials independently and not putting them in the system. This can be partly mitigated by interviewing those mechanics.

The constraints are that the project complies with general laws, regulations, and quality standards such as ISO-9001 and ISO-27001.

1.4.4 Deliverables

- Mapping of the current situation of the sourcing and the flow of goods of the company
- A report with recommendations directly implementable for the company
- Interview results

According to the managing board of Siers, these deliverables are enough to decide.

1.4.5 Assessment of validity and reliability

For research, high validity and reliability are essential. For the interviews to have high reliability, the researcher should always ask the questions similarly. For validity, the questions asked should answer the researcher's questions and be straight to the point. For the observations, the reliability can be high by using a standardised observation protocol. The validity is essential to define the variables being observed clearly.

2 Context analysis

The chapter contains the context analysis of the warehouse of Siers Installatietechniek. This is done by answering the first research question of this thesis.

What are the processes of the warehouse?

These are the processes from ordering materials to picking and returning the materials. This is done by executing an observation study in the warehouse and informally asking work preparers. A business process model comprises the project and general stock to map this process.

2.1 Business process model

For this thesis, BPM is needed to map the current process of the flows of the materials and the sourcing of materials. Understanding the existing processes will be able them to communicate their internal business operations uniformly if they can comprehend these procedures in a graphical notation (Object Management Group Business Process Model and Notation, 2023). There is a distinction between two kinds of stocks at Siers Installatietechniek. The project stock and general stock. For these, the high-level process of the materials is the same, but there are some differences. Figure 4 shows the high-level process of a project.

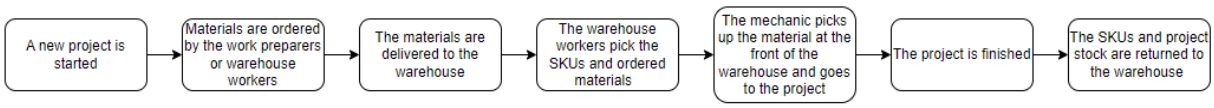

Figure 4- High-level process of a project

2.1.1 General stock

The general stock is stock-keeping units in the warehouse of Siers Installatietechniek. These have a fixed place and are ordered when empty. Figure 5 shows the BPM of the general stock.

Incoming SKUs

When SKUs come to the warehouse, truck or mail carriers deliver them, depending on the size of the ordered project. It could be a small material or a giant roll of cables. The package is unpacked with an arrival document. This document has an order number that can be filled in in 4PS. This document is also scanned and added to the 4PS page of that order to show that it has come in. When everything is done, it is placed in the assigned place of Siers Installatietechniek or one of the other departments. These arrivals are often planned for Monday or Wednesday.

Ordering SKUs

The warehouse workers order the SKUs. When picking up the orders, they see the empty box. When the materials are needed, it is viewed in advisory order in 4PS. If it is not in, they will order it by making an invoice, which will be ordered in 4PS.

Picking SKUs

For the SKUs, the warehouse workers get a list in the mail from Appeee. Appeee is an app where things can be ordered from the warehouse. The materials are picked from the place. On that list, the location is known in terms of the shelf where it is. These materials are put in front of the warehouse and are written off in 4PS. The materials are then taken by mechanics, who can take them back or not. When the materials are taken back, they are booked back up.

Assumptions

- The materials are always booked up or written off.
- The warehouse workers pick the materials.
- The materials are always put in the right place.

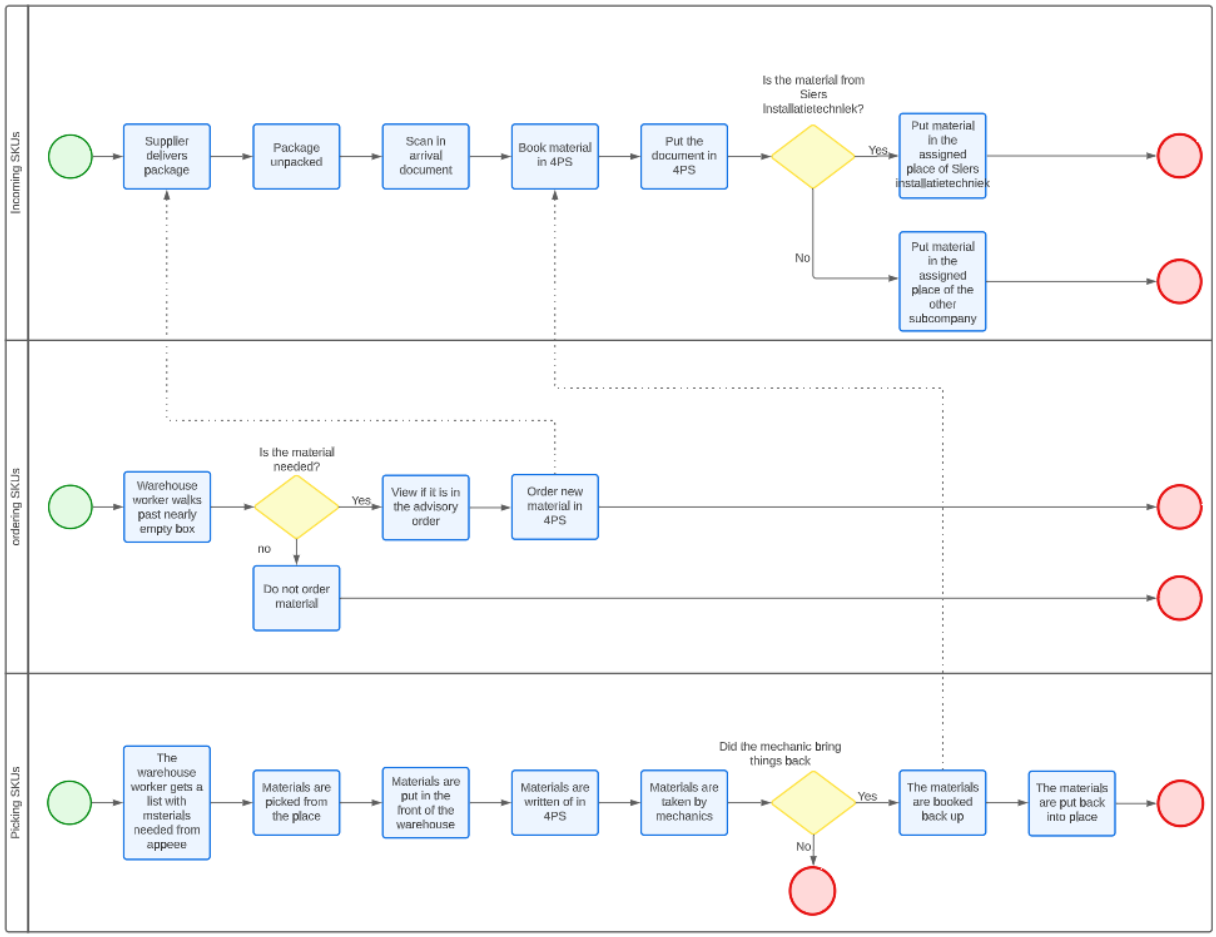

Figure 5- Business process model of the SKUs

2.1.2 Project stock

The project stock contains materials that are specially bought for one project. These are used only sometimes after that project. It could be used only if a work preparer knows it is there. Figure 6 shows the BPM of the project stock.

Incoming project stock

The incoming project materials are scanned the same way as the normal SKUs, but in 4PS, it is already assigned to a project number. The warehouse worker will make a sheet in Excel with the project number, the project name, the work preparer, and the date of arrival. The paper is put on the material and in the place reserved for that project. The researcher ordered this per project number so that the materials of that specific project are together.

Ordering project stock

When a project is started, calculations and drawings are made. Then materials are ordered by the work preparers.

Picking project stock
The materials are already in front of the warehouse. The mechanics pick up materials as they know the project code and name. When materials are not used, or the project is cancelled, it will be put with other stock.

Assumptions

- There is always a project code assigned.
- The drawings and calculations are always correct.

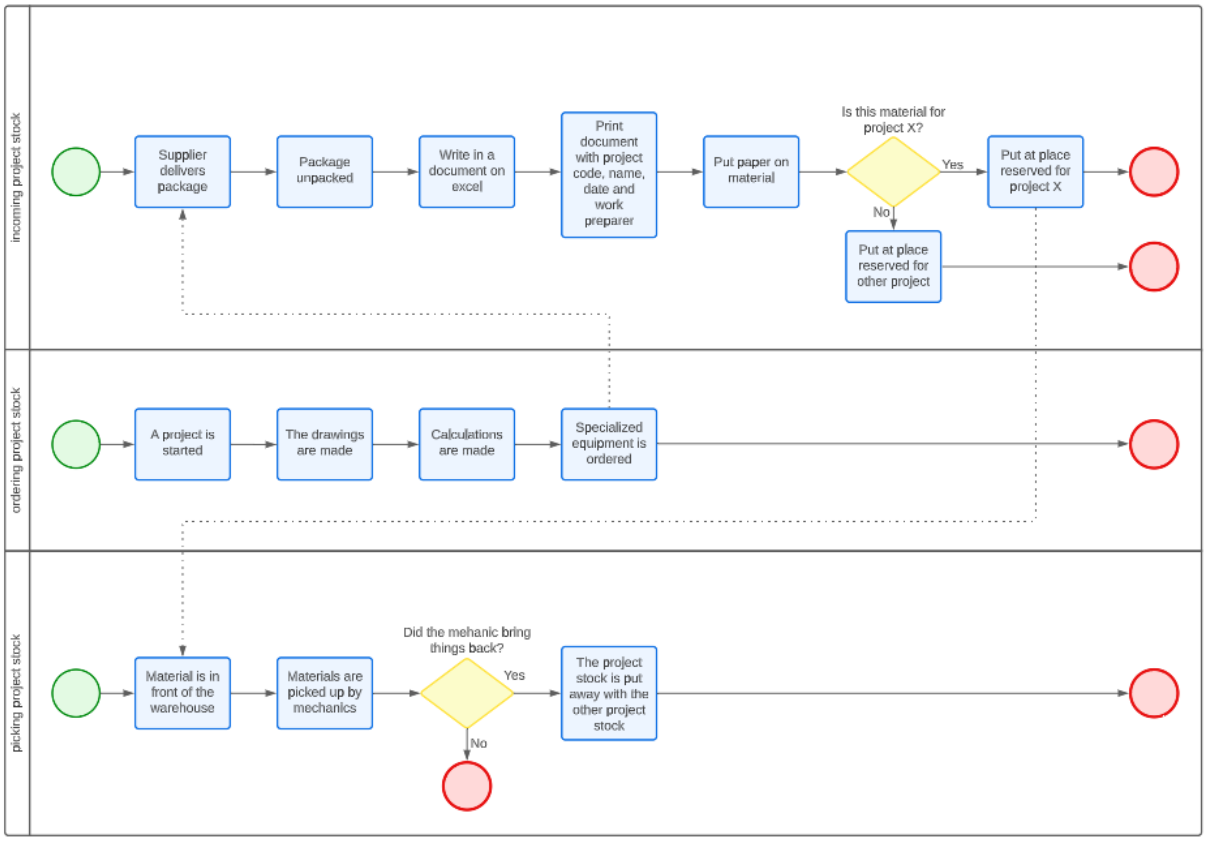

Figure 6- Business process model of the project stock

2.2 Conclusion

The processes of the logistic flows of the warehouse of Siers Installatietechniek have been mapped in this chapter. By executing this context analysis, the processes in the warehouse are understood better and are one step closer to solving the core problem. The biggest differences between the normal stock and project stock are that normal stock has a fixed place, a stock level, and is listed in the ERP system. Appendix A business process model shows a larger display of the business process models.

3 Literature study

In this part of the thesis, the context analysis and the research questions will be used to perform a literature study. This literature study will be used to get insights on answering the research questions. This will be done in different sections. Section 1 will be about the main research question. The other sections are about the sub-questions. The question answered with this literature study is:

What is a relevant method to increase picking efficiency and decrease storage capacity?

3.1 Main research question

How to increase the picking efficiency and use less storage capacity in the Siers Installatietechniek warehouse?

Suitable storage location assignment policies must be designed for an efficient warehouse order-picking procedure. (de Koster, Le-Duc, & Roodbergen, 2007) ; (Petersen, Aase, & Heiser, 2004) According to the report of Vitasek, O'Donoghue, & Harrity, (2007), an excellent slotting strategy enables a company to have more space utilisation, which will give a more efficient warehouse and gives better inventory control. ABC analysis is a well-known slotting method that helps pick efficiency and uses less storage capacity. It is worth taking a good look at this slotting method.

It became clear that by performing ABC analysis, the efficiency of the inbound delivery process has increased by 10.71%, while the efficiency of the outgoing delivery process has increased by 6% (Jemelka, Chramcov, & Kříž, 2016). The new outcome allowed the business to boost profit while lowering other direct costs. One of the most common methods for managing inventories is activity-based costing, or ABC-analysis, which classifies stock into three groups (a, b, and c) based on consumption levels or other levels. (Katana, sd). A Items should always be in the warehouse because they comprise 20% of the materials and 80% of turnover. B items are the next ones, with a 15% turnover, while C goods are the infrequently used ones, with a 5% turnover. To reduce picking time for warehousing, A goods should be easier to pick up than C products and be located closer to the warehouse's entrance. The advantages include improved high-value inventory control, more precise demand forecasts, and intelligent pricing (Vaiana, 2022). It is stated that an ABC analysis has the following procedures (Alqahtani, 2023).

1. Determine the value of the chosen criteria for each item (e.g., demand or picking frequency)
2. Calculate the summation of the values of the individual items.
3. Calculate the percentage value of each item concerning the total volume of the selected criteria,
4. Sort the items based on their percentage values from best to worst.
5. Calculate the cumulative percentage values.
6. Examine the cumulative percentage values and group the items into three classes based on the classification rule.

In the case of (Alqahtani, 2023), the solution proposed has saved 50 hours of travel time at a sugar company.

According to (Kampf, Lorincová, Caha, & Hitka, 2016), One of the methods that help businesses control their costs is ABC Analysis. It offers comprehensive data that makes it possible to track how

resources have been used inside an organisation. It enables management to assess whether costs are consistent with their spending goals.

What are the advantages and disadvantages of the ABC analysis?

Its main benefits are the simplicity of understanding and ease of usage of ABC analysis. The materials are categorised according to the yearly use value derived from the annual demand and average unit price. (Bragg, 2013) (Zaerpour, Le-Duc, & de Koster, 2012) However, it is well-acknowledged that the classic ABC analysis contains a significant flaw that could sometimes limit the method's effectiveness. A considerable financial loss could result from using only one criterion. Due to a potential material halt or high inventory levels, class C items with a long lead time or class A items that are prone to obsolescence, for instance, may experience financial losses. (Emmett & Granville, 2007) (Piasecki, 2009) (Waters, 2003). This could be fixed by a pro-active attitude of the warehouse workers in terms of knowing the lead times and good contact with the manufacturers of the materials.

What are good KPIs for the ABC analysis?

The dependent variable is the quality of the warehouse, which for a slotting problem, often can be measured in travel time or travel distance. For example, the paper of (Kapou, Ponis, Plakas, & Aretoulaki, 2022) uses travel distance as their KPI and (Alqahtani, 2023) uses travel time for this thesis, travel distance will be used because it is better to measure.

Are there alternatives for the ABC analysis?

ABC XYZ analysis is the same as ABC analysis. The difference is that the analysis's findings enable the division of stockpiles into groups based on forecasting precision and the regularity of demand for material categories. Three groups of materials in the XYZ analysis can be categorised as follows:

- X material group has a fixed size of demand or need and is characterised by slight periodic variations, resulting in good forecasting accuracy,

- The minor swings in demand and necessity for the Y material category allow for average forecasting accuracy.

- The fluctuating demand and necessity for the Z material category make forecasting less accurate. (Nowotyńska, 2013)

Another alternative is the Fast-moving, Slow-moving, and Non-moving Analysis or FSN. Where fast-moving goods are placed adjacent to the loading area, slow-moving goods are placed next to fast-moving goods, and non-moving goods are placed next to slow-moving goods at the spot farthest from the loading area. (Tambunan, Syahputri, Rizkya, Sari, & Cahyo, 2018)

After consideration, we chose the ABC analysis. This is because the ABC XYZ analysis requires data which cannot be delivered from Siers. The other method the fast-moving, slow-moving, and non-moving analysis looks a lot like the ABC analysis but more literature is available for the ABC analysis.

3.2 Sub-questions

For the sub-questions, there is also a literature review. The sub-questions are listed below:

- Are there materials with more stock deviations than others, and why?
- Does the ERP system work sufficiently?

Are there materials with more stock deviations than others, and why?

For this sub-question, statistics will be used to find these negative outliers. These outliers can be calculated as follows (Bhandari, 2022)

1. Sort your data from low to high.
2. Identify the first quartile, the median, and the third quartile.
3. Calculate your IQR or interquartile range = q3 – q1.
4. Calculate your upper fence = q3 +1,5*IQR.
5. Calculate your lower fence = q1 - 1.5 *IQR.
6. Use your fences to highlight any outliers and all values outside your fences.

All the outliers on the upper side will be investigated to find a cause for this outlier.

Does the ERP system work sufficiently?

For this research question, the researcher wants to interview users of the ERP to give recommendations to the company on the ERP eventually. This can be done using the MoSCoW system, which helps prioritise requirements based on importance and urgency. MoSCoW is a well-known method of managing requirements priority. It represents the four categories of must, should, could, and will not have. (MoSCoW Prioritization, 2020)

3.3 Conclusion

This chapter makes considerations for solving the main research question and sub-research questions. Choices are made for the Main Research Question, where ABC analysis is the chosen option for improving picking efficiency and space utilisation. For the sub-research question, the methods are also described.

4 Effective picking and returning process

In this section of the thesis, interviews are conducted. Recommendations will be made on how to make the process of picking and returning materials more effective. This section of the thesis will help answering this question:

How can we make the process of picking and returning materials more effective?

4.1 Findings

For this interview, questions have been asked of mechanics, work preparers, and warehouse workers. The question was**: How do you think that the process of picking and returning materials can be more effective?** With this open question, we can get information which can be recommended to Siers Installatietechniek.

Interview mechanics

The findings of the interviews with six different mechanics are as follows regarding the process of picking and returning the materials:

- Longer opening hours of the warehouse.

Many mechanics have the problem that the warehouse is already closed after a working day. The warehouse closes at 16:30 while the working day ends at 16:00. If they then want to hand in materials and they are at a further distance, it is too late, and they are expected to be at the construction site at 07:30. Then it is almost impossible to hand in and pick up materials before or after the time.

- The materials are picked on time.

When the mechanics need materials, they often must pick them up and return them themselves. They then put this in Appeee, and the warehouse workers put it in 4PS after. This feels superfluous to them since they are mechanics rather than warehouse workers. This has several causes, according to the mechanics. The warehouse part of installatietechniek is not organized well, other departments take precedence, and the warehouse workers need to gain material knowledge of installation technology.

- Better ordering of the work preparers, who first must look at the project stock.

The work preparers must always look at the project stock before ordering new materials. When a project is started, the other project stock is overlooked, but things are ordered immediately. This means that project stock remains for a long time. If the work preparers first look at what is left before ordering it, it saves much space in the warehouse that can be filled in better.

- Have material delivered to the construction site instead of to the warehouse.

The mechanics say that sometimes it will be much easier if they can deliver materials to the workshop instead of the warehouse. That saves time because you do not have to pick it up anymore. This can become difficult if they deliver it too late.

- A closed warehouse with a counter.

All mechanics think that a closed warehouse with a counter where everything is ready for you is a helpful solution. This saves time for the mechanics, but this is a problem because the warehouse workers could not have that time. A clean and tidy warehouse can solve this. A closed warehouse

means that the mechanics are not allowed to enter the warehouse and that every time they need materials, it is already picked, and they can get them at the counter.

- Have warehouse workers with material knowledge.

The mechanics think that the warehouse workers have limited knowledge of the materials of Installatietechniek, which causes the mechanics to search for materials themselves. Some also say they believe they pay more attention to other departments.

Interview with warehouse workers

The findings of the interviews with two different warehouse workers are as follows:

- Better ordering of the work preparers, who first must look at the project stock.

The warehouse workers, just like the mechanics, think that the work preparers should do better ordering. They must know what materials are in the warehouse already. This will save storage space for other materials.

- Scanning system so they do not have to put everything in 4PS individually.

The warehouse workers find that a scanning system can save time to put more time into the Installatietechniek warehouse. This can be a system with RFID or with barcodes.

- Closed warehouse with a counter.

Also, for the warehouse workers, a closed warehouse with a counter is best for an effective warehouse, but first, the warehouse must be clear and clean.

- Units and shelf locations must match.

Sometimes there is a difference between Appeee, where the orders come in, and 4PS, where the orders are booked. When warehouse workers print the Appeee form from the mail, the shelf location and the unit are sometimes incorrect. This is a lot of work searching for the material and could be more efficient.

Interview with work preparers

The findings of the interview with a work preparer are as follows:

- All SKUs are only available for warehouse workers.

This will ensure that mechanics will no longer pick their materials, and the warehouse workers will book every material. This means that the warehouse workers must know the materials. Otherwise, it could delay the project.

- All project stock is available for mechanics and warehouse workers.

Also, mechanics will look at the usefulness of certain materials. As the project stock is not booked, mechanics could pick it up. If the warehouse worker is busy, the mechanic can pick up these materials and go to the project.

- A dedicated place for returned and picked materials.

This will help avoid getting the mechanics in the warehouse if unnecessary, and nobody will be in the warehouse of the warehouse worker. This will also be faster for the mechanics as they do not have to look for materials and can go faster to a project.

- Booking and documenting the project stock.

This makes it more transparent for the work preparer so that not too much is ordered. Furthermore, the warehouse also becomes more evident as a result. If the project stock is unnecessary for future projects, it can be brought to the attic.

- project stock in a fixed place together.

Currently, a lot of project stock is mixed up. If this is sorted on a project basis, the mechanic does not have to search for long and earn more money for the company. This can be done, for example, by estimating how large the project is and making a separate room for it. When the project is finished, it can then be booked back.

4.2 Conclusion

By conducting interviews with multiple stakeholders and with the help of lean 5S, findings were made to increase the effectiveness of the warehouse of Siers Installatietechniek. The main recommendations of the interviews were:

- Longer opening hours of the warehouse.
- The materials are picked on time.
- The work preparers must always look at the project stock before ordering new materials.
- To have material delivered to the construction site instead of the warehouse.
- A closed warehouse with a counter.
- To Have warehouse workers with material knowledge.
- Scanning system so they do not have to put everything in 4PS individually.
- Units and shelf locations must match.
- All SKUs are only available for warehouse workers.
- All project stock is available for mechanics and warehouse workers.
- A dedicated place for returned and picked materials.
- Booking and documenting the project stock.
- project stock in a fixed place together.

5 Data analysis

In this thesis section, data analysis is done by calculating outliers in the materials counting conducted at the end of every year. As stated in the limitations, there is only one stock counting available. For this, the outliers were calculated, and questions were asked to mechanics and warehouse workers on why these materials could be a negative outlier. This section of the thesis will help answering this question:

Are there materials with more stock deviations than others, and why?

5.1 Data gathering

For the actual data gathering of the stock counting, there was no data of only Siers Installatietechniek. For this, we used two Excel sheets, one for the stock counting of the entire warehouse and a materialist of Siers Installatietechniek. Then a list was made with the stock counting of Siers Installatietechniek, which can be found in Appendix B counting list of Siers Installatietechniek.

5.2 Data validation

For the data validation, all the shelves of the warehouse of Siers Installatietechniek have been examined. So, the eventual missing and extra article numbers have been added to a good place with the correct counting. These are added from the counting sheet of the whole warehouse to the materialist of Siers Installatietechniek. The data that has been changed can be found in the appendix.

5.3 Data analysis

In the actual analysis of the 491 materials, nineteen materials have stock differences all the other materials did not have any stock differences. Four of these materials with stock differences are negative. All the materials with stock differences are outliers because there are so many materials with no differences. Furthermore, when calculating the outliers with all the steps from the literature review, this still holds. This means the reason behind the stock differences for the four materials must be found. Figure 7 shows the four materials with negative stock counting. Figure 8 shows the box plot of these differences. It shows that all the positive and negative countings are an outlier.

Artikelnumber	description	total revenue
104757	TEHALIT M5692 VK-FLEX 30 L=500MM GRIJS	-839,16
104212	WAV VSV ET BUIS 3/4 GRYS LG4	-15,40
104211	WAV SOKKENBUIS 3/4 CREME LG4	-13,60
102676	RVS OMEGAPROFIEL TYPE 2 (25X35X25MM), (LGT=3M.) ME	-9,17

Figure 7- the four materials that need to be analysed

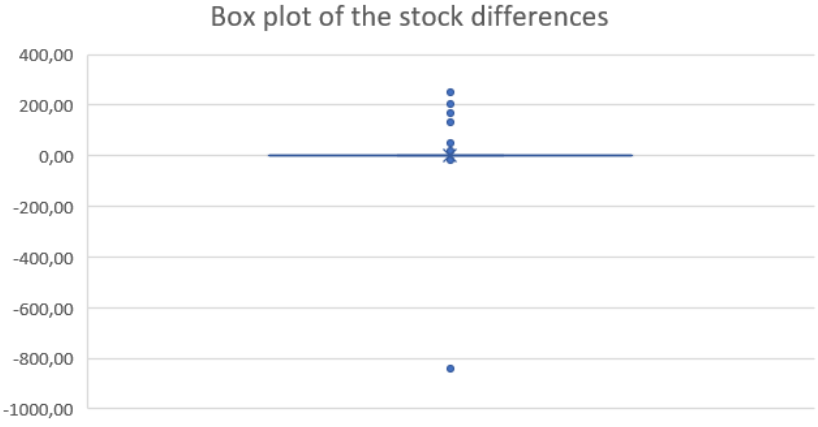

Figure 8- box plot of the stock differences, where everything except for the zero values is an outlier.

To get an impression of what kind of materials Siers Installatietechniek uses, the pictures of three materials are shown in Figure 9.

Figure 9- TEHALIT M5692 VK-FLEX 30 L=500MM GRIJS or material 1, WAV VSV ET BUIS 3/4 GRYS LG4 or material 2, and WAV SOKKENBUIS 3/4 CREME LG4 or material3

5.4 Findings

- Material 1: This is a Siers telecom material, which is another department of Siers, which does not lie in the scope of this thesis.
- Material 2. This has a stock cost of -15,40 because it lies next to the WAV VSV ET BUIS 5/8 GRYS LG4, which to the eye, looks the same. The WAV VSV ET BUIS 5/8 GRYS LG4 has a price difference of +4,44. Figure 10 shows material 2 in the warehouse.

Figure 10- the 3/4 GRYS and 5/8 GRYS next to each other

- Material 3 has a stock cost of -13,60, which is the fault of the warehouse worker for not booking them back up correctly from a project.
- RVS OMEGAPROFIEL TYPE 2v (25x35x25MM), (LGT3) ME or material 4. 9,17-euro worth of stock is lost with that counting. This is because it cannot be counted. The warehouse worker tried to count it, which was almost impossible, especially when the whole warehouse needed to be counted once at the end of the year. Figure 11 shows material 4 in the warehouse.

Figure 11- RVS OMEGAPROFIEL TYPE 2v (25x35x25MM), (LGT3) ME

5.5 Conclusions

By executing the data analysis, we found three outliers for Siers Installatietechniek. These outliers were given to the warehouse workers, and we searched for reasons for these outliers. We found several reasons for these outliers, materials 2 and 3 were not separated. This means that a simple separation between these tubes can help. For material 4, it is tough to count, especially once a year. This means that periodic counting could be an exciting solution.

6 Enterprise resource planning system

This section is about the ERP system of Siers, which is 4PS. In this part of the thesis, interview questions will be asked of the warehouse worker. Appendix C interview questions show the interview questions asked. This section of the thesis will help answering this question:

Does the ERP system work sufficiently?

6.1 Findings

It became clear that 4PS is the main program of Siers' warehouse. For example, one of the functions is inventory management of the warehouse and other warehouses when they are short of materials. The most used tools are the purchase order function to book materials as they come in and the article diary to book them out for a project or when they are returned. The main advantage is inventory management. The warehouse workers have identified several features that need to be added, including having an extensive list of materials for booking in and booking out. They must constantly switch between different departments, which can be time-consuming throughout the day. This problem is also the most urgent. Additionally, there are instances where suppliers need to change article numbers, resulting in the receipt of incorrect materials. The Siers Appeee app used for creating material issuances sometimes utilises different units than 4PS, which can confuse. Overall, the warehouse workers are satisfied with 4PS.

According to the warehouse workers, a Warehouse Management System (WMS) is less prone to errors, and based on their experiences, it also improves efficiency. When asking questions, it became clear that it needs the following functionalities, which came from the open question: **which functionalities are a must-have, should-have or a could-have for a new WMS.** The results are shown in Table 1. These results came from interviewing the warehouse worker.

	Must-have	Should-have	Could-have
inventory control	x		
cycle counting	x		
Slotting tool		x	
Advisory orders			x
Barcode scanners	x		
Location of materials	x		
Automatic ordering			X

Table 1- MoSCoW table of the functionalities of the WMS

After the interview, the warehouse worker said he liked the idea of cycle counting, an effective inventory management method that decreases work pressure. This is because they must count everything at the end of the year.

6.2 Conclusions

By interviewing warehouse workers, we gained insights into the functionalities of 4PS and a warehouse management system in the warehouse of Siers. Table 1 shows these insights with the help of the MoSCoW system. The warehouse workers are satisfied with 4PS, but a warehouse management system will increase efficiency in the warehouse.

7 ABC-Analysis

For this section of the thesis, the travel distance of the warehouse of Siers installatietechniek has been decreased with the help of the ABC-Analysis and an overview of the warehouse is made with a heatmap of Siers Installatietechniek's warehouse. This ABC analysis has been made using the picking frequency of the materials and the material group of the materials. With the mechanic's help, we know how to put materials in a material group. However, first, the data on the picking frequency was gathered (Alqahtani, 2023). States that an ABC analysis has the following procedures.

1. Determine the value of the chosen criteria for each item (e.g., demand or picking frequency)
2. Calculate the summation of the values of the individual items.
3. Calculate the percentage value of each item concerning the total volume of the selected criteria,
4. Sort the items based on their percentage values from best to worst.
5. Calculate the cumulative percentage values.
6. Examine the cumulative percentage values and group the items into three classes based on the classification rule.

7.1 Picking frequency

Figure 12 shows the picking frequency of the materials of Siers installatietechniek. The first column is the material code, and the second is the number of picks since January first, 2023. The picks are from January first because Siers installatietechniek has been a separate company since the beginning of this year.

Row Labels	Count of Documentnr.
103887	35
103981	32
103980	28
103881	21
102646	16
104212	14
104432	14
103885	11
104286	10
103062	9

Figure 12- the picking frequency of the top ten most picked materials of the warehouse of Siers Installatietechniek.

These were then put in the material list of Siers Installatietechniek. After this, it is known that 69.5% of all materials have not been picked this year. The theory of the ABC analysis says that 20% of the materials should have 80% of the turnover. At Siers Installatietechniek, 20% of the materials have 89.4% of the picks.

These were the result following the steps of (Alqahtani, 2023).

Step 1 is the picking frequency.

Step 2, the summation of all those picks is 491.

Steps 3, 4, and 5 were done in Excel by dividing the number of picks of the material in question by the total number of picks. Then sort it from high to low. In the end, we added these together so that you get the cumulative percentage picked, creating this line chart Figure 13.

In step 6, we said that the first 5% of the materials picked are in group A, which is also used in (Thieuleux, sd). Group B are the rest of the materials which have been picked more than one time this year. Group C are the materials which are picked one time. Lastly, Group D are the materials which are not picked this year. Four classes have been chosen due to the extreme large number of materials which were not picked at all. This will help to get a better overview of the warehouse. A mechanic will look at the materials which still need to be picked to assess their usefulness to decrease storage capacity.

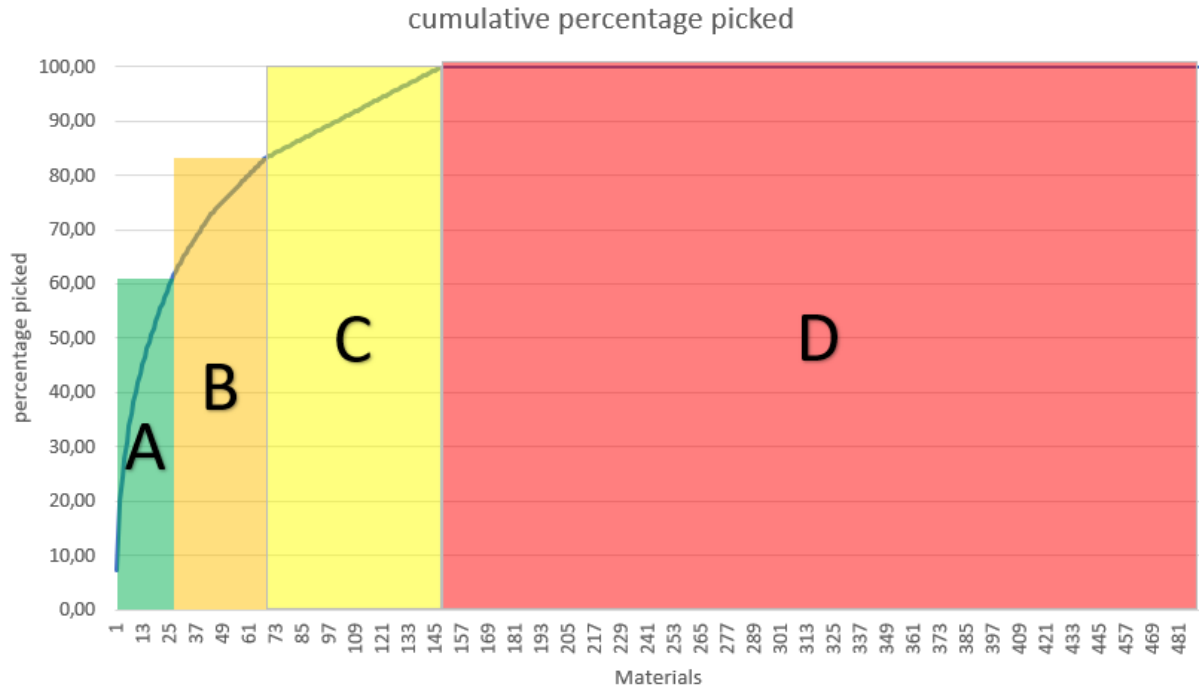

Figure 13- the cumulative percentage picked at Siers Installatietechniek with the A, B, C, and D divisions.

7.2 Heatmap of the warehouse of Siers Installatietechniek

With the help of the picking frequency and the material list, a heatmap has been made. Figure 18 and Figure 19 show the heatmaps of different racks. This heatmap represents the warehouse of Siers Installatietechniek, where the materials are stock-keeping units. This heatmap gives an overview of the picking frequencies of the warehouse of Siers Installatietechniek. The box's width in this heatmap does not precisely represent the box's width in the warehouse, and some boxes are stacked on each other. Above all the different racks, there is a bar which says V-01. This represents the top of the rack. When the material is stored in V-01-03, it is placed in the third row. The exact locations are unknown in the data and not for the warehouse workers. This also means that the precise locations of the warehouse are different from those in the heatmap, but they are in the same row, which we validated in the warehouse itself. At the top left, the V-03 rack is there when walking straight ahead. On the right of them are the V-02 and V-01 racks. The standard walking route with the starting point is depicted in Figure 14. The travel distances are also measured from this starting point. Figure 15 shows the picture of the V racks with a schematic view of where it is in the warehouse.

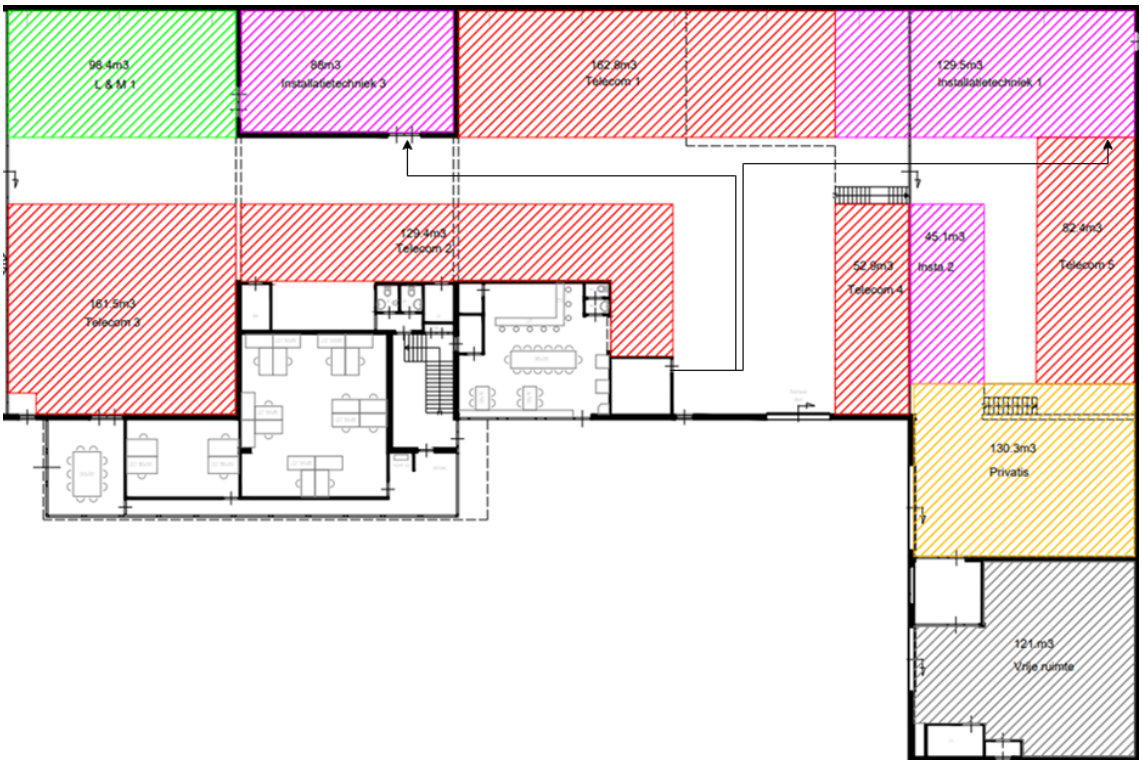

Figure 14- standard walking route to the left is the v rack, and to the right, the T and U racks with the starting point.

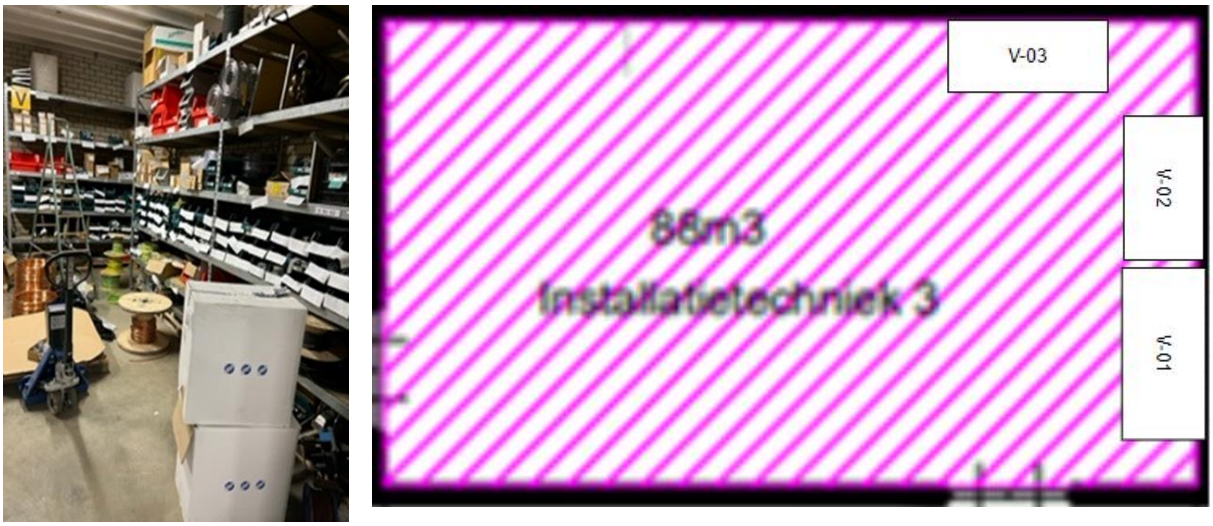

Figure 15- V racks with V-03 ahead and V-02 and V-01 on the right side

The V-00 inside closed-room materials are on pallets, which cannot be moved due to material costs. Outside, the V-00-00 outside the closed room is stuck to the ground, so they cannot be moved. The V room racks are much bigger than the other racks of Siers Installatietechniek, so that is something to keep in mind when making a new slotting. Figure 16 shows V-00 outside and inside the locked room.

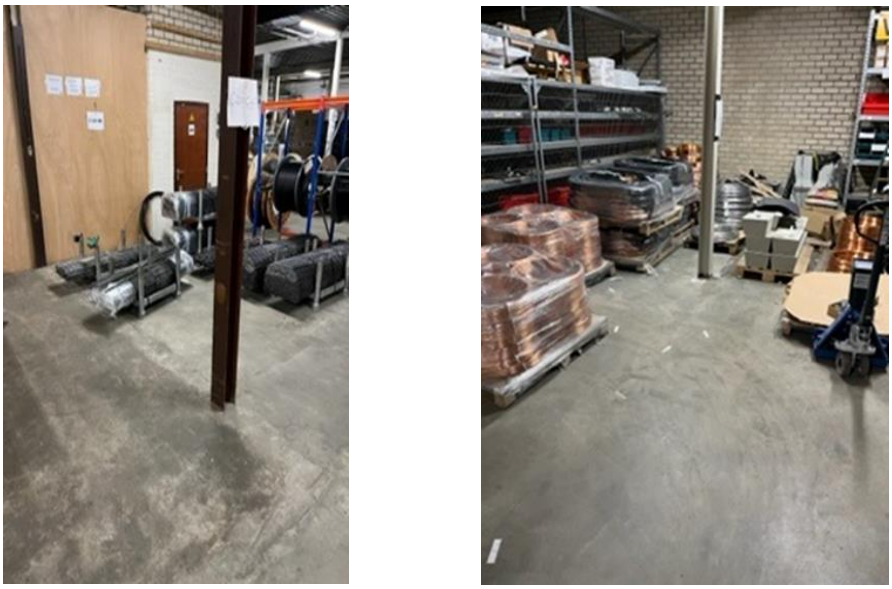

Figure 16- V-00 outside and inside the room, respectively

When entering the warehouse, straight to the right are all the pipes, which multiple departments use. This means that they are not subject to change. After that, on the other side of the warehouse, there is an aisle with the U and T racks. The U racks are on the right, and the T racks are on the left. The racks in the back belong to the T racks, and the white cells represent the aisle. Figure 17 shows the T and U rack and a schematic picture of where these racks are in the warehouse.

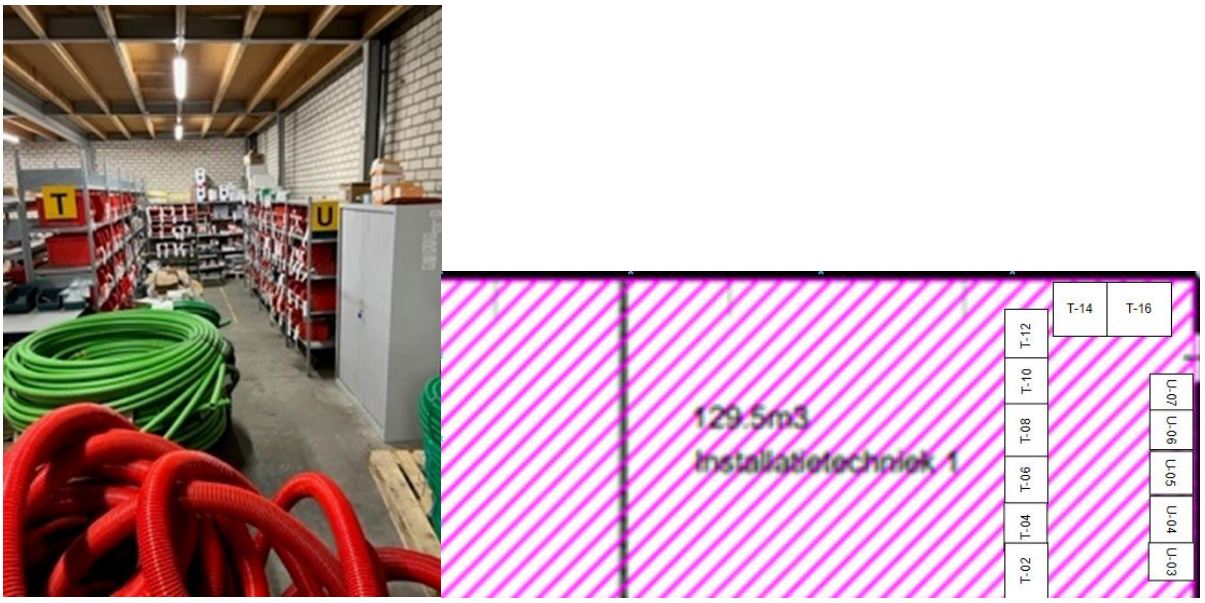

Figure 17- the T and U rack

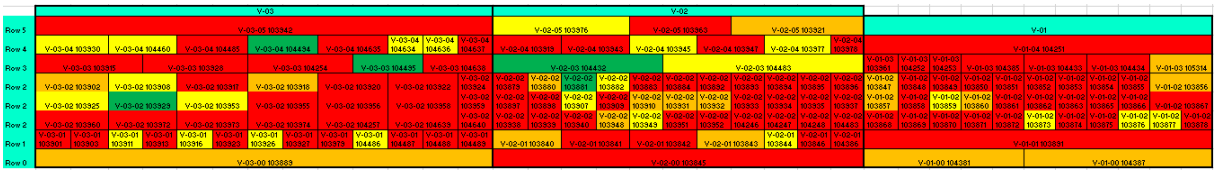

Figure 18- heatmap of the V racks of the warehouse of Siers Installatietechniek

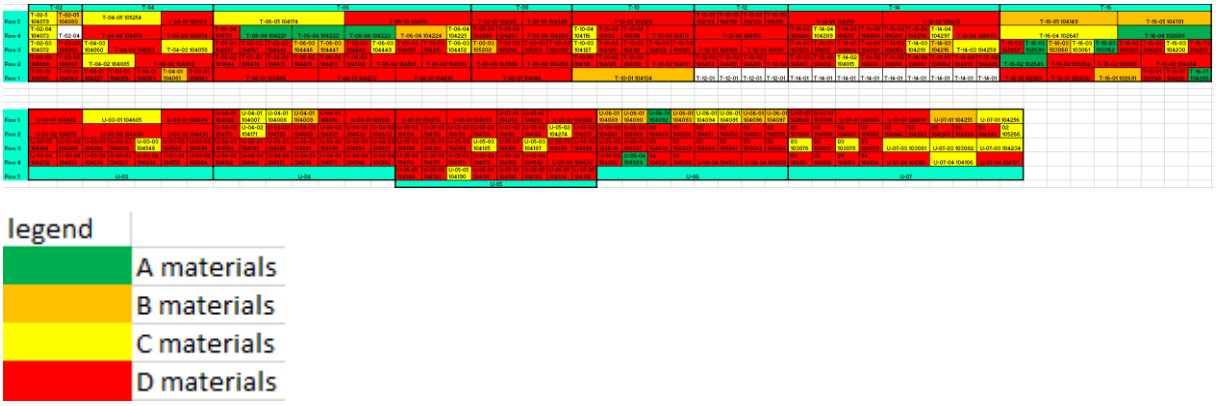

Figure 19- Heatmap of the T and U racks of the warehouse of Siers Installatietechniek

In Figure 19, the heatmap of the warehouse of Siers Installatietechniek is shown, and a bigger heatmap is shown in Appendix D Heatmap of Siers Installatietechniek. The left side shows the row number, and the rack number is on top. The contents of the cells are, for example, T-02-04, which means that the material is in rack T-02 and row 4. The exact location is not tracked in 4PS. The blank space between the T and U racks is the aisle between those two racks. Between the V and T racks are project stock and Siers Telecom racks. There are more racks with project stock, but these do not have any picking frequencies, so these are not included, and Siers Telecom is outside the scope of this thesis. Also, all the T, U, and V racks have their height and length, which is not depicted in the heatmap. The T and U racks are two rows of racks opposite each other. The V rack is in a different place in the warehouse.

7.3 Travel distances

For the ABC analysis, the travel distances of the changeable SKUs are measured before it will be executed. These are shown in Table 2. The travel distances are the KPI for this ABC analysis. After the ABC analysis, the travel distances will be measured again to see if there is an improvement. The starting point is the point shown in Figure 14 which is the point where both lines start. The travel distances are measured to the middle of a rack. There is no distinction between left or right materials, as the data from Siers also does not have an exact location.

Rack	Total distance
T-02	41,65m
T-04	42,95m
T-06	44,25m
T-08	45,55m
T-10	46,85m
T-12	47,18m
T-14	48,15m
T-16	49,45m
U-03	43,8m
U-04	44,8m
U-05	45,8m
U-06	46,8m
U-07	47,8m
V-01	32,3m
V-02	34,9m
V-03	38,8m

Table 2- travel distances of the different racks in the Siers Warehouse

The total travel distances are computed for each category. This will be done for the T and U racks and V racks, respectively. This is because these racks must have different ABC analyses due to the limitations of this thesis, which are that the materials in the V racks are Siers BOPA materials and the U and T racks are Siers Installatietechniek materials. The total distances are calculated by summating the multiplication of the picking frequency times the distances to the rack for the A, B, and C categories. So when the picking frequency of material x is three then it will be three times the distance to the rack. Table 3 shows the travel distances for the T and U racks. Table 4 shows the total distances for the V racks.

Category	Total Distance
A	3729.2m
B	2101.75m
C	1837.75m
Total	7668.7m

Table 3- total distances for the T and U racks

Category	Total Distance
A	2036.3m
B	1557.5m
C	835.2m
Total	4429m

Table 4- total distances for the V racks

7.4 Material grouping

The materials of Siers are categorised with the help of a mechanic for validation. These materials must be laid together. Otherwise, it will not be a clear warehouse. The picking efficiency will decrease when these materials are on a different rack or shelf. Table 5 shows the material groups of Siers Installatietechniek.

Material groups/brands	place
ABB and ATT big items	T-02, T-04, and T-06-05
Klau	T-06-02 and T-06-03
Mounting material	T-06-04 and T-16
Metal brackets	T-06-01, T-08-02, T-08-03, and T-08-04
cable	T-08-01, T-08-05, T-10, T-12, and T14-05
Other	T-14-02, T-14-03, and T-14-04
Peha	U-03
Phoe	U-04-01
EA	U-04-02, U-05-02
HGR	U-04-04, U-05-03, U-05-04, and U-05-05
Earth leakage circuit breakers	U-05-01
Wisk	U-06-01
ATT small items	U-06-02, U-06-03, and U-06-04
Card distribution clamp	U-07-01
Tape	U-07-02, U-07-03
Wago welding clamps	U-07-04
Cable lug	V-01-02 and V-01-03
VDS	V-02-01
Tule, press connector, press sleeves	V-02-02
Roof terminal	V-02-04 and V-02-05
Connection terminal	V-03-01
Other	V-03-02 and V-03-03
Dehn	V-03-04

Table 5- Material Grouping of Siers Installatietechniek

7.5 Improved slotting

When making this improved slotting, it had been considered that different material boxes have different widths and that there must be a rack free for new SKUs. These SKUs are believed to have the most picks as they are ordered per project. Consequently, the travel distance could not decrease as much as we want.

Figure 21 shows the improved slotting of the T and U racks. In Figure 20 a high-level flowchart is made on how to come to this improved slotting. The material groups with the highest picking frequencies or the A items are the closest to the entrance. The materials group with the least amount of picks or the D items are farther away from the entrance. The reason that the best racks do not have only green is because of the decision to group the materials with their material groups. This decision has been made because the warehouse worker could be confused when all the materials are mixed up, which could influence efficiency.

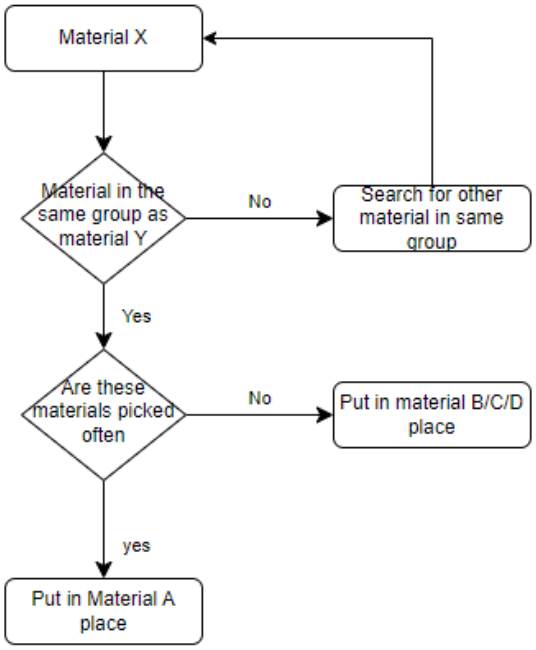

Figure 20- High level process of the improved slotting

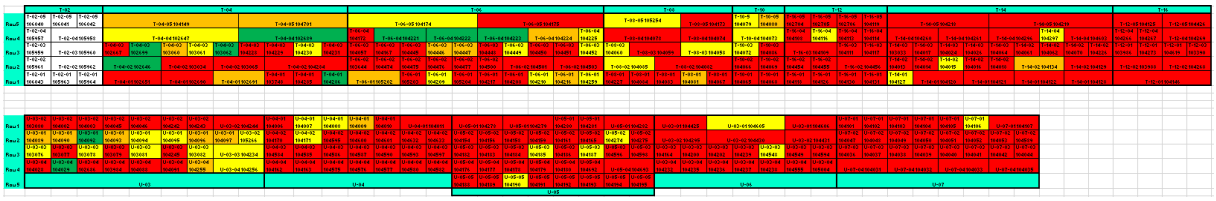

Figure 21- Improved slotting of the T and U racks

The height of the racks is also considered for the improved slotting of the V racks. Everything over the third shelf requires a ladder. This could be more efficient. The improved slotting is shown in Figure 22, and a bigger picture of the heatmaps is shown in Appendix E heatmap of improved slotting.

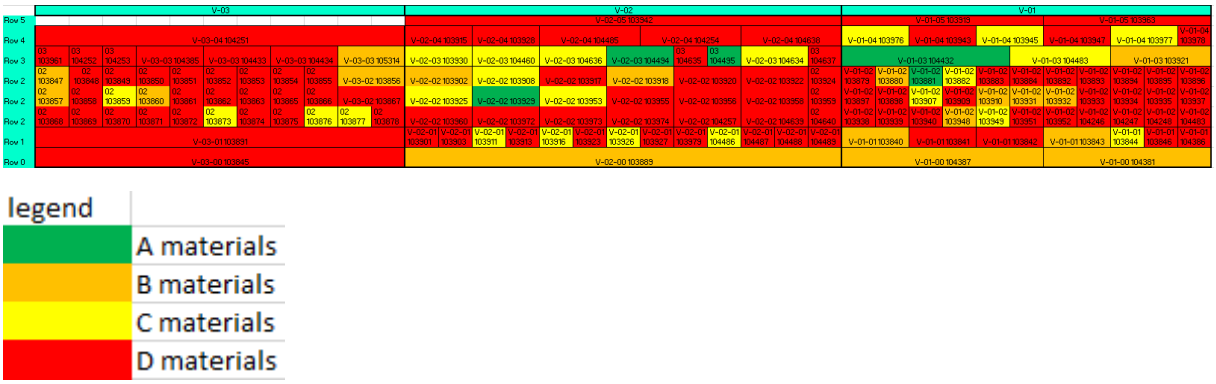

Figure 22- Improved slotting of the V racks

7.6 New travel distances

After the ABC analysis, the new travel distances are calculated. Table 6 shows the new travel distances for the U and T rack.

Category	Total Distance
A	3294.8m
B	2031.15m
C	1553,75m
Total	6619.43m

Table 6- New travel distances of the T and U racks

With the help of the ABC analysis based on picking frequency and material groups, the total travel distance of the T and U racks has decreased by 14.7%, even without using the most optimal rack, because of new SKUs. These SKUs are believed to have the highest picks and are in the same material group.

Table 7 shows the new travel distances of the V rack.

Category	Total Distance
A	1863.4m
B	1558.8m
C	797,5m
Total	4219,7m

Table 7- New travel distances of the V rack

With the help of the ABC analysis based on picking frequency and material groups, the total travel distance of the V rack has decreased by 4,72%.

7.7 Conclusion

Materials are grouped into categories with the help of the ABC analysis. Travel distances are computed as a KPI for the ABC analysis. Using the heatmap, an improved slotting is made based on picking frequencies and material groups. The materials are grouped with the help of the mechanics. The travel distances of the T and U racks decreased by 14,7%, and the travel distances of the V rack decreased by 4,72%.

8 Solutions

In this thesis section, the solution generation and the solution choice are conducted. The solution generations are solutions coming from the main- and sub-research questions. The solutions will be chosen by assigning weights to KPIs and scoring the solutions based on these KPIs. These weights are assigned by the supervisor of Siers Installatietechniek.

8.1 Solution generation

While elaborating on the main- and sub-research questions, several solutions were found to solve the action problem. All of these are listed and explained below:

- Longer opening hours of the warehouse.

Having longer opening hours could provide more flexibility for warehouse workers to pick up materials and have fewer time constraints. Also, the mechanics have more time to work on a project. This can result in increased efficiency.

- The materials are picked on time.

Often the materials of Siers Installatietechniek are picked too late or not at all, which results in mechanics going into the warehouse to search for the materials themselves. If we can prevent that the materials are not picked at all, we can minimise mechanics' delays, resulting in more profit. This can be done for example by managers who order that everything must be picked in time.

- Better ordering of the work preparers, who first must look at the project stock.

Suppose there is a system which prioritises reviewing project stock before ordering new materials. It will facilitate a more organised warehouse with more space because less is ordered. This space can be used for other projects.

- Have material delivered to the construction site instead of to the warehouse.

Direct delivery will save time for the warehouse workers and the mechanics as they do not have to take the materials on their bus. However, it can be hard to realise this on a smaller project if no one is at the construction site.

- Have warehouse workers with material knowledge.

Training warehouse workers on material knowledge can enable them to manage the inventory more effectively and provide better assistance to mechanics. A new full-time warehouse employee with more material knowledge is also possible.

- Booking and documenting the project stock.

Implementing a system for booking and documenting project stock will let the work preparers see that certain materials are already in the warehouse. Less will be ordered, creating a cleaner warehouse.

- Project stock in a fixed place together.

Allocating a fixed location within the warehouse for project stock and putting the project stock of one project together will result in less confusion. If this is sorted on a project basis, the mechanic does not have to search for long and earn more money for the company.

- Closed warehouse with a counter.

Creating a closed warehouse with a counter will increase inventory management. A closed warehouse means that the mechanics are not allowed to enter the warehouse and that every time they need materials, it is already picked, and they can get them at the counter.

- Unit and shelf location must match.

Ensuring that the unit and shelf locations match between Appeee and 4PS will reduce errors and enhance overall efficiency when picking materials. This will also save a lot of time, which can be used to improve other aspects of the warehouse.

- All SKUs are only available for warehouse workers.

Limiting access for the SKUs to only warehouse workers will improve inventory control. This is because nobody except for the warehouse workers can access the warehouse and take these materials.

- All project stock is available for mechanics and warehouse workers.

Making all project stock accessible to mechanics and warehouse workers will create fast access to materials required for ongoing projects. Also, when a product is not delivered, the mechanic can think of alternatives.

- A dedicated place for returned and picked materials.

Designating a specific area within the warehouse for returned and picked materials will help maintain organisation and prevent confusion.

- Separation between tube materials.

A system to separate tubes will make them easier to locate and count, giving a more accurate stock level and better inventory control, as many of the deviations were from that part of the warehouse.

- Periodic material countings.

Regular material counts will help minimise inventory errors and help with efficient planning and ordering. This can be done by making a system and counting one rack every week.

- A Warehouse management system with a scanning system

Implementing a WMS will provide comprehensive control over warehouse operations, including inventory management, order processing, and tracking, leading to improved efficiency and accuracy, and implementing a scanning system, such as a barcode or RFID technology, will automate inventory management and reduce manual errors associated with manual data entry.

- One extensive materialist on 4PS with all the departments.

If 4PS has one extensive material list, it will decrease the time spent for the warehouse worker to book the materials. More time can be used to pick up the materials on time and for other warehouse activities.

- New slotting.

Reorganising the placement of items in the warehouse based on demand or frequency of use will optimise space utilisation, reduce picking time, and enhance overall efficiency. This will result in more profit for Siers as the mechanic can go faster to the project.

- Use 4PS advice orders instead of Appeee.

Transitioning from using Appeee to 4PS advice orders will make a more streamlined process for warehouse workers because it is easier to book these materials. This time can be used to do more material picks per day.

8.2 Solution choice

For the solution choice, we determined KPIs with my supervisor of Siers and linked weights to them. After this, the solutions are scored from grades 1 to 5 so that the best solutions have the highest grade.

KPIs

Costs – 10%

This KPI measures the cost of the implemented solution. It evaluates the expenses associated with implementing the suggested changes, including investments in technology, training, infrastructure upgrades, and other relevant costs. High costs will be graded 1 and low costs 5.

Feasibility - 15%

Feasibility assesses the practicality and viability of the proposed solutions. It considers factors such as resource availability, technical requirements, operational capabilities, and potential barriers or constraints that may impact successful implementation.

Accuracy - 30%

Accuracy evaluates the extent to which mechanics receive the correct materials for their tasks. It considers order accuracy, item identification, labelling, and documentation to ensure suitable materials are delivered to the right individuals.

Efficiency – 15%

Efficiency measures how effectively resources are utilised within the warehouse. It optimises workflows, minimises waste, and maximises productivity through streamlined processes and effective time management.

Decreased stock deviations – 30%

Stock Deviations track the extent to which discrepancies occur between physical inventory and recorded stock levels. This KPI aims to minimise stock discrepancies, reduce inventory errors, and ensure accurate stock management through regular monitoring.

After the brainstorming session with warehouse workers, work preparers, managers, and mechanics, scores were given to the solutions. Table 8 shows these results. Appendix F explains the scores and why these solutions are scored like this.

Solution	Costs	Feasibility	Accuracy	Efficiency	Decreased stock deviations	total
Longer opening hours of the warehouse.	3	4	4	3	2	3.15
The materials are picked up on time.	4	4	3	4	4	3.7
The work preparers must always look at the project stock before ordering new materials.	3	5	3	4	3	3.45
Have the materials brought to the construction site.	4	2	4	4	3	3.4
Closed warehouse with a counter.	4	5	3	5	4	4
Have warehouse workers with material knowledge.	2	4	5	4	4	4.1
Unit and shelf location must match between Appeee and 4PS.	4	4	4	4	4	4
All SKUs are only available for warehouse workers.	5	4	3	3	4	3.65
All project stock is available for mechanics and warehouse workers.	5	4	4	3	3	3.65
A dedicated place for returned and picked materials.	4	5	3	4	4	3.85
Booking and documenting the project stock.	4	4	5	3	3	3.85
Project stock in a fixed place together.	5	4	5	4	3	4.1
A Separation between tubes.	4	5	4	4	4	4.15
A Warehouse management system with a scanning system.	1	4	5	5	5	4.55
Periodic material countings.	3	5	4	3	5	4.2
One extensive material list on 4PS with all the departments.	5	0 (not possible)	3	5	2	2.75
New slotting for T and U racks.	4	5	4	5	4	4.3
New slotting for V racks.	4	5	4	4	4	4.15
Use 4PS advice orders instead of Appeee.	5	4	4	4	4	4.1

Table 8- solution choice after a brainstorming session

8.2.1 Conclusion

It can be concluded that a warehouse management system is the best solution according to the brainstorming session. The worst solution is one extensive material list on 4PS with all the departments, which was not possible according to the ICT department.

8.3 Implementation plan

For the ratings above four, an implementation plan is made. These are most likely to be implemented by Siers Installatietechniek.

A Warehouse management system with a scanning system (4.55).

- Research and select a suitable WMS solution based on the needs of the warehouse of Siers Installatietechniek.
- Customize the WMS to align with 4PS.
- Provide training to warehouse workers on how to use the WMS most efficiently.
- Evaluate the WMS thoroughly before going live.

New slotting (4.23).

- Communicate the new, improved slotting to warehouse workers and ICT. The ICT needs to change these materials' location in 4PS.
- Monitor and measure the effectiveness of the new slotting strategy and adjust as needed.

Periodic material countings (4.2).

- Make a schedule with a plan on what rack to count on which date.
- Develop procedures for counting and implementing countings on 4PS.
- Analyze results and act where necessary.

The separation between tubes (4.15).

- Make separations.
- Place in between the tubes.

Project stock in a fixed place together (4.1).

- Make room in the warehouse where the project stock needs to be.
- Estimate how big the project is and make room for that specific project.
- Put all the project stock of that project together.
- Evaluate the leftover project stock on its usefulness in other projects. If it is valid, place it in the new project; otherwise, throw it away or put it in the attic for later use.
- Document what is put in the attic; it will save time later.

Have warehouse workers with material knowledge (4.1).

- Provide training to existing warehouse workers by mechanics.
- Search for a new full-time employee or a mechanic that wants to go to the warehouse.

Use 4PS advice orders instead of Appeee (4.1)

- Let the ICT department make a new process for ordering materials from the warehouse.
- Provide training to the stakeholders on how to effectively use 4PS advice orders.
- Communicate the new solutions well and ensure they are familiar with the new process.

Closed warehouse with a counter (4.0).

- Ensure a well-organized warehouse.
- Ensure that all material requests are requested at least 24 hours before.
- Make a counter area where mechanics can pick up materials.
- If there are returned materials, the material codes must be sent to the warehouse worker to book the materials back correctly.

Unit and shelf location must match between Appeee and 4PS (4.0).

- Make a list what materials do not match between Appeee and 4PS.
- Send the list to ICT, which must be changed in Appeee.

9 Conclusions, discussion, and recommendations

This thesis section will consist of the conclusions, discussions, and recommendations. The conclusions will consist of the main findings and the answers to the research questions. The discussion will include limitations and specific findings for a research question. For the recommendations, there will be recommendations to the company and future research.

9.1 Conclusions

During this thesis, multiple conclusions can be made based on the findings. As this thesis was about increasing the overall quality of the warehouse, various facets of the warehouse were touched upon.

The main research question of this thesis is: **How to increase the picking efficiency and use less storage capacity in the Siers Installatietechniek warehouse?**

This part was done by doing an ABC analysis on the racks of Siers installatietechniek. This was done based on picking frequencies and material groups. By categorising the materials on A, B, C, and D, a heatmap was made of the warehouse of Siers Installatietechniek. By computing the travel distances, the average travel distance to a rack was calculated, which is the KPI of the ABC analysis. A new slotting was made with the help of the heatmap, and eventually, a reduction in the travel time was realised of 14.7% for the T and U racks and 4,72% for the V racks. The racks' height was also considered above the third shelf for the V rack. A ladder is needed to pick materials there.

For the sub-questions these conclusions can be made.

How can we make the process of picking and returning materials more effective?
The main findings of this sub-question are found by doing interviews. The questions were asked to mechanics, work preparers, and warehouse workers. These recommendations were made.

- Longer opening hours of the warehouse.
- The materials are picked on time.
- The work preparers must always look at the project stock before ordering new materials.
- Have material delivered to the construction site instead of to the warehouse.
- A closed warehouse with a counter.
- Have warehouse workers with material knowledge.
- Scanning system so they do not have to put everything in 4PS individually.
- Units and shelf locations must match.
- All SKUs are only available for warehouse workers.
- All project stock is available for mechanics and warehouse workers.
- A dedicated place for returned and picked materials.
- Booking and documenting the project stock.
- project stock in a fixed place together.

We can conclude that there are enough points of improvement to make the process of picking and returning materials more effective.

Are there materials that have more stock deviations than others, and why?

By doing data analysis on the most recent stock counting, which was the only one available, to look for negative outliers. After that, we looked for reasons why these are negative outliers. We found that this year's counting was positive, and the reasons for these outliers were that there were no separations between tubes and that some materials were hard to count if there was only one counting in a year. Periodic material counting, where specific racks are counted in a particular week, could help to mitigate this problem.

We can conclude that few materials have more stock deviations, but solutions for the products with stock deviations were found to decrease them.

Does the enterprise resource planning (ERP) system work sufficiently?

By interviewing the warehouse workers, findings were made on the ERP and warehouse management system, which is not in this warehouse. These findings on the WMS were put in Table 1 with the help of the MoSCoW system, which categorises these functionalities as must-have, could-have and should-have. The warehouse workers are satisfied with 4PS, but from previous experience, a warehouse management system will help a lot with the efficiency of the warehouse.

9.2 Discussion

Several points have been discussed in this thesis, and these limitations will be discussed here.

How to increase the picking efficiency and use less storage capacity in the Siers Installatietechniek warehouse?

There were some points of limitation for this question.

- The precise location of the materials is not known.

It is only known on which rack and shelf the material is. For the heatmap, it had a consequence that the exact location of the material is different from in the warehouse, but it is on the good shelf. For the travel distances, we took the middle of the rack as the distance for the whole rack. The precise location could also be implemented in 4PS, but is hard to implement. This is because multiple boxes with materials are on top of each other in the same shelf.

- The T and U racks must be separated from the V racks.

Some materials cannot be moved. Everything at the V racks still needs to be in the V racks. This is because they are materials from the company BOPA, which is part of Siers Installatietechniek. Also, the same departments used the tubes and may not be moved, and some materials may not be moved because of the price of the materials.

- Picking frequencies could not be accurate and are only from this year.

Mechanics sometimes pick materials in the warehouse and do not put them in Appeee. At the beginning of this assignment, it was said this was a big problem. However, after asking the mechanics and warehouse workers, they say that the warehouse workers control that much better from the beginning of this year. The reason that there is only data from this year is that Siers Installatietechniek has been a separate company since the beginning of this year.

- New SKUs have the best place in the T and U racks.

This resulted in a lower travel distance decrease. It is expected that these would have the highest picking frequency in the warehouse, so they must be in that place, but there has yet to be data.

Are there materials with more stock deviations than others, and why?

- Only one stock counting.

We wanted more stock countings for this question, but the employee who has them suffers from a long-term illness. This means that we only had one stock counting for this thesis.

- Data validation

For data validation, we looked in the warehouse of Siers and concluded that not everything was on the correct shelf, on the right rack or not on the material list. These were later added with their accurate counting.

- Only three materials had a negative count.

The assignment descriptions say that Siers Installatietechniek suffers a lot from stock deviations, but only this counting cannot be concluded from the research question.

9.3 Recommendations

In this thesis, multiple recommendations can be made for the company or further research.

9.3.1 Recommendations to the company

The solutions were ranked in this thesis, and we recommend that every solution with a score of 4 or higher should be seriously considered. Solutions with a score over 3.5 should also be considered. The solutions with a score under 3.5 are less likely to give long-term solutions for Siers Installatietechniek. My advice is not to consider them as a recommendation for Siers Installatietechniek. Table 9 shows the ranking of these solutions and my advice to Siers Installatietechniek.

Solution	Grade	Advice
A Warehouse management system with a scanning system.	4.55	Seriously consider
New slotting for T and U racks.	4.3	Seriously consider
Periodic material countings.	4.2	Seriously consider
A Separation between tubes.	4.15	Seriously consider
New slotting for V racks.	4.15	Seriously consider
Have warehouse workers with material knowledge.	4.1	Seriously consider
Project stock in a fixed place together.	4.1	Seriously consider
Use 4PS advice orders instead of Appeee.	4.1	Seriously consider
Closed warehouse with a counter.	4	Seriously consider
Unit and shelf location must match between Appeee and 4PS.	4	Seriously consider
A dedicated place for returned and picked materials.	3.85	Consider
Booking and documenting the project stock.	3.85	Consider
The materials are picked up on time.	3.7	Consider
All SKUs are only available for warehouse workers.	3.65	Consider
All project stock is available for mechanics and warehouse workers.	3.65	Consider
The work preparers must always look at the project stock before ordering new materials.	3.45	Not consider
Have the materials brought to the construction site.	3.4	Not consider
Longer opening hours of the warehouse.	3.15	Not consider
One extensive material list on 4PS with all the departments.	2.75	Not consider

Table 9- my advice for the company

It can also be considered to mix two solutions, such as booking and documenting the project stock and placing it in a fixed place together.

9.3.2 Recommendations for further research

In this section, possibilities for further research have been described.

- During this thesis, a warehouse management system has been recommended. Further research needs to be done on which WMS is the most optimal and how to implement this WMS and couple it to 4PS.
- The data analysis consists of only one year of stock countings. When more are available, we recommend further researching the outlier materials and finding solutions for these materials. Also, this should be analysed for future counts.
- During this thesis, I met with the managing board of Siers for the overall layout of Siers. It is now divided, but it could be optimised. Further research could be done with the help of another student or an employee.

References

Alqahtani, A. Y. (2023). Improving order-picking response time at retail warehouse: a case of sugar company. *SN Applied Sciences*. doi:10.1007/s42452-022-05230-6

Bhandari, P. (2022, november 11). *How to Find Outliers | 4 Ways with Examples & Explanation*. Retrieved from scribbr: https://www.scribbr.com/statistics/outliers/?_ga=2.6023155.170389210.1687766018-585297758.1680246679

Bragg, S. M. (2013). *Inventory Management.*

de Koster, R., Le-Duc, R., & Roodbergen, K. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research, 182*(2), 481-501. doi:/10.1016/j.ejor.2006.07.009

Emmett, S., & Granville, D. (2007). *Excellence in Inventory Management: How to Minimise Costs and Maximise Service.* Liverpool Academic Press.

EPA. (2022, October 31). *Lean Thinking and Methods - 5S*. Retrieved from EPA: https://www.epa.gov/sustainability/lean-thinking-and-methods-5s#:~:text=5S%20is%20a%20cyclical%20methodology,This%20results%20in%20continuous%20improvement.

Heerkens, H., & Winden, A. v. (2017). *Systematisch managementproblemen oplossen.* Noordhoff Uitgevers.

Jemelka, M., Chramcov, B., & Kříž, P. (2016). Design of the storage location based on the ABC analyses. *AIP Conference Proceedings, 1738*(1). doi:10.1063/1.4951909

Kampf, R., Lorincová, S., Caha, Z., & Hitka, M. (2016). The Application of ABC Analysis to Inventories in the Automatic Industry Utilizing the Cost Saving Effect. *Naše More (Dubrovnik), 63*(3), 120-125. doi:10.17818/nm/2016/si8

Kapou, V., Ponis, S. T., Plakas, G., & Aretoulaki, E. (2022). An Innovative Layout Design and Storage Assignment Method for Manual Order Picking with Respect to Ergonomic Criteria. *Logistics*. doi:10.3390/logistics6040083

Katana. (n.d.). *ABC inventory: get the most out of your best-selling products*. Retrieved 2023, from katanamrp: https://katanamrp.com/abc-inventory/#:~:text=The%20ABC%20analysis%20of%20inventory,items%20being%20the%20least%20important.

MoSCoW Prioritization. (2020, march 26). Retrieved from productplan: https://www.productplan.com/glossary/moscow-prioritization/#:~:text=MoSCoW%20prioritization%2C%20also%20known%20as,will%20not%20have%20right%20now.

Nowotyńska, I. (2013). An Application of Xyz Analysis in Company Stock Management. *Modern Management Review*. doi:10.7862/rz.2013.mmr.7

Object Management Group Business Process Model and Notation. (2023). Retrieved from bpmn: https://www.bpmn.org/

Petersen, C. G., Aase, G. R., & Heiser, D. R. (2004). Improving order-picking performance through the implementation of class-based storage. *International Journal of Physical Distribution & Logistics Management,, 34*(7), 534-544. doi:10.1108/09600030410552230

Piasecki, D. J. (2009). *Inventory Management Explained: A Focus on Forecasting, Lot Sizing, Safety Stock, and Ordering Systems.* Ops Publishing.

Tambunan, M. M., Syahputri, K., Rizkya, I., Sari, R. M., & Cahyo, M. D. (2018). Storage design using Fast moving, Slow moving and Non moving (FSN) analysis. *MATEC Web of Conferences, 197*, 5. doi:10.1051/matecconf/201819714005

Thieuleux, E. (n.d.). *ABC XYZ Analysis in Inventory Management: example in Excel*. Retrieved June 20, 2023, from abcsupplychain: https://abcsupplychain.com/abc-xyz-analysis/

Vaiana, D. (2022, march 07). *What is ABC analysis and how can you use it in inventory management?* Retrieved from quickbooks.intuit.com: https://quickbooks.intuit.com/r/midsize-business/abc-analysis-inventory-management-principles-classifications/

Vitasek, K., O'Donoghue, K., & Harrity, C. (2007). *Warehousing & fulfillemtn Process Benchmark & Best Practices Guide.* WERC and Supply chain Visions.

Waters, D. (2003). *Inventory Control and Management.* John Wiley & Sons Incorporated.

Zaerpour, N., Le-Duc, T., & de Koster, R. (2012). Determining the number of zones in a pick-and-sort order picking system. *International Journal of Production Research,, 50*(3), 757-771. doi:10.1080/00207543.2010.543941

Appendix A business process model

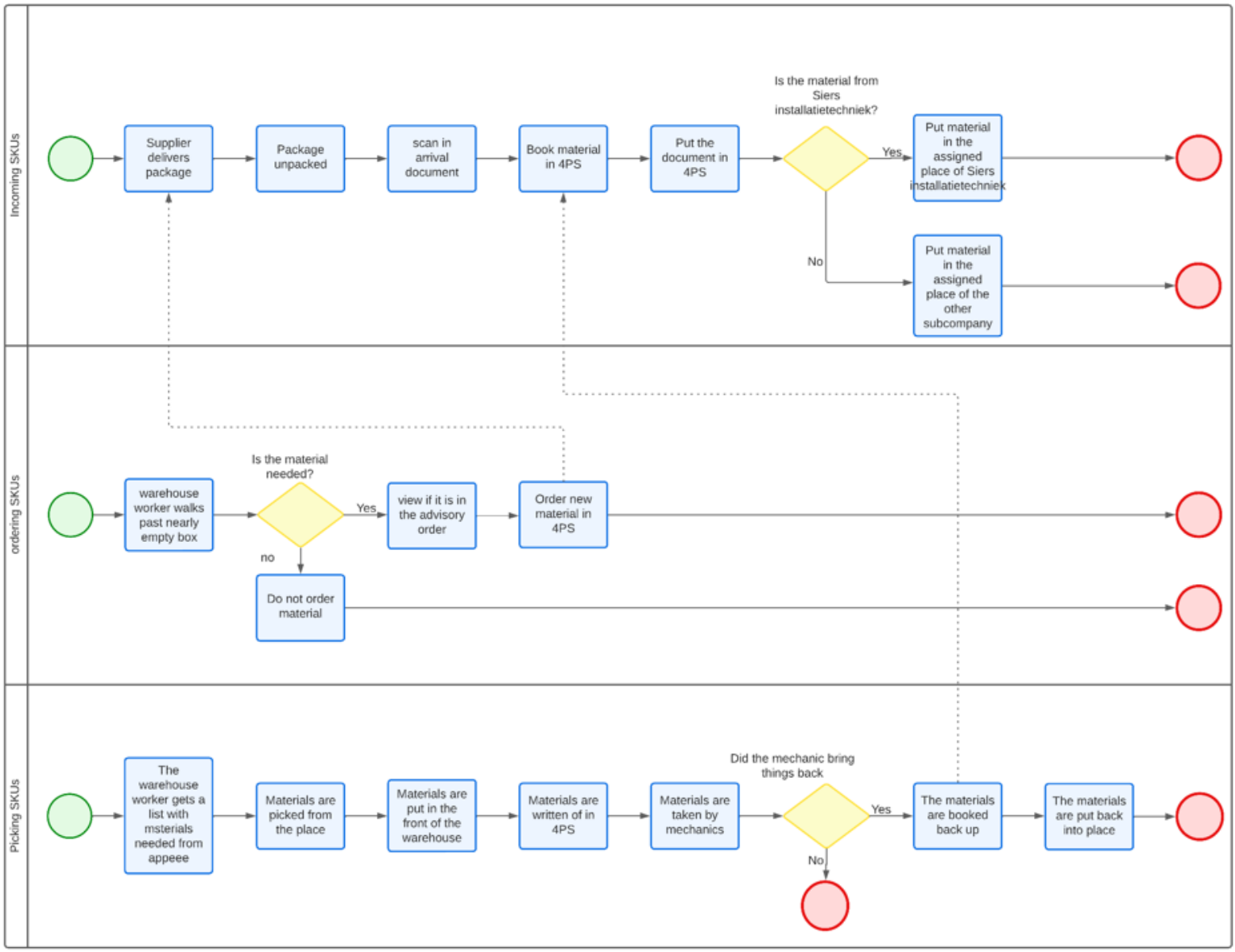

Figure 23- Business process model of general stock

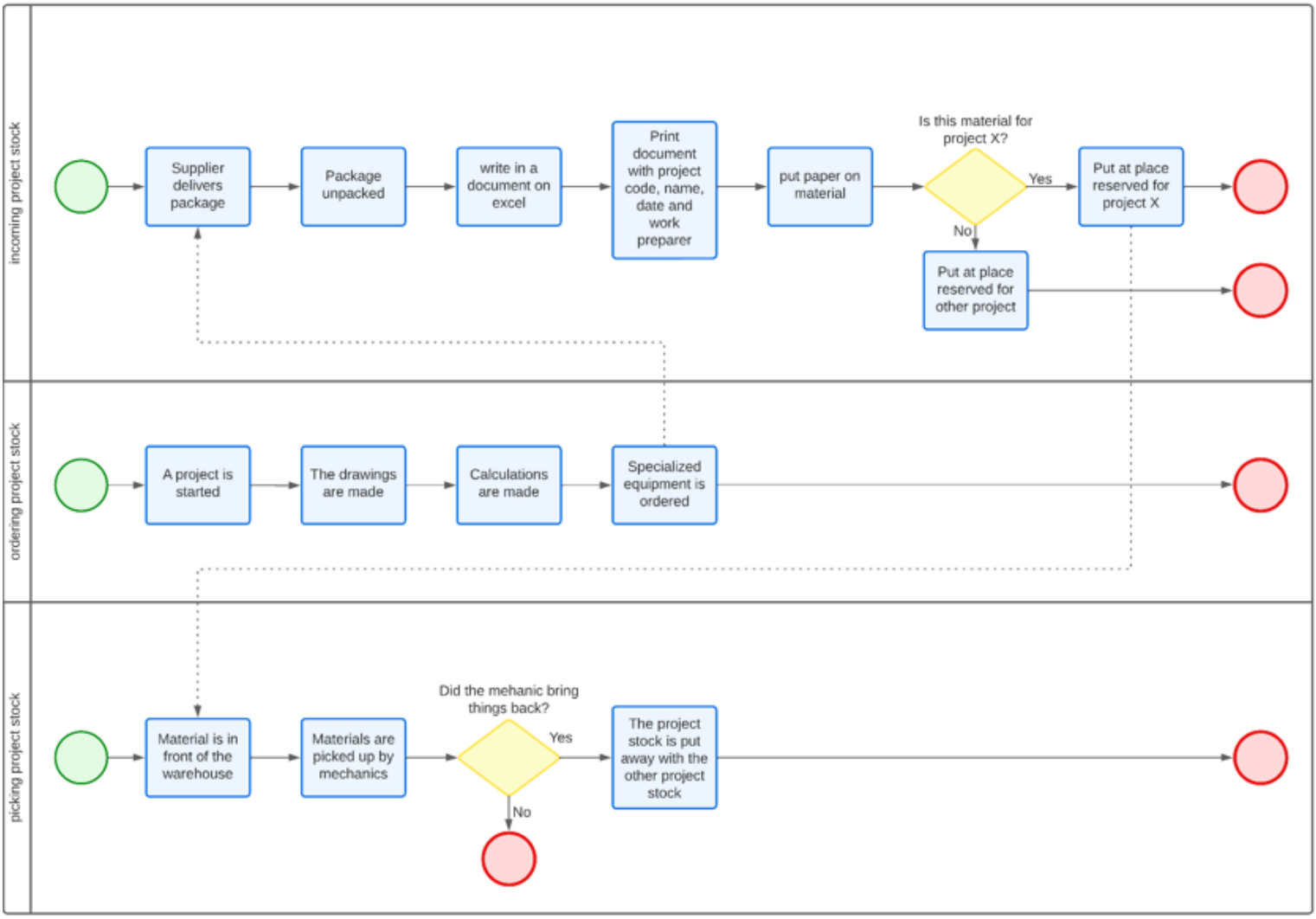

Figure 24- Business process model of project stock

Appendix B counting list of Siers Installatietechniek.

Artikelnr. = article number

Eenheidscode = unit code

Schapnummer = shelf number

Omschrijving = description

Totale opbrengsten = total revenues

Artikelnr.	Aantal (Inventarisatie)	Eenheidscode	Schapnummer	Omschrijving	Vestiging	totale opbrengsten
104757	0,00	ST	M-05-01	TEHALIT M5692 VK-FLEX 30 L=500MM GRIJS	OLD27	-839,16
104212	139,00	ST	A-00-00	WAV VSV ET BUIS 3/4 GRYS LG4	OLD27	-15,40
104211	31,00	ST	A-00-00	WAV SOKKENBUIS 3/4 CREME LG4	OLD27	-13,60
102676	0,00	LGT	C-01-00	RVS OMEGAPROFIEL TYPE 2 (25X35X25MM), (LGT=3M.) ME	OLD27	-9,17
102646	200,00	ST	T-16-02	JMV KABBEUG VERZ 32MM DS100	OLD27	0,00
102647	12.000,00	ST	T-16-04	KABELBEUGEL 9-10 MM, VERZINKT (DS=500ST)	OLD27	0,00
102648	0,00	DOOS	L-03-01	SOL CLIPS 7-10MM GR.L25MM	OLD27	0,00
102651	150,00	ST	T-16-01	JMV KABBEUG VERZ 50MM DS50	OLD27	0,00
102661	34,00	DOOS	M-01-03	SOL CLIPS 14-20MM GR.L35MM	OLD27	0,00
102667	26,00	DOOS	T-16-04	SPIJKERCLIPS 8-10MM, GRIJS #MEPAC (DS=100ST.)	OLD27	0,00
102686	20,00	ST	U-07-01	AARDVERDKLM 1X6+1X25MM2	OLD27	0,00
102689	4.500,00	ST	T-16-04	JMV KABELBEUGEL VERZ. 15-16MM (DS=500ST)	OLD27	0,00
102690	1.050,00	ST	T-16-01	JMV KABELBEUGEL VERZ. 19-20MM (DS=350ST)	OLD27	0,00
102691	650,00	ST	T-16-01	KABELBEUGEL 25-26MM, VERZINKT #JMV (DS=150ST.)	OLD27	0,00
102699	11,00	DOOS	T-16-03	SPIJKERCLIPS 5-7MM, LENGTE 20MM, WIT #MEPAC (DS=10	OLD27	0,00
102704	8,00	DOOS	T-12-05	KABELBEUGEL ENKEL 5MM (DS=100ST.)	OLD27	0,00
102705	8,00	DOOS	T-12-05	KABELBEUGEL ENKEL 12MM (DS=100ST.)	OLD27	0,00
102706	7,00	DOOS	T-12-05	ELMO KLEMSCHELLE LICHTGRAU16MM [KRT=100ST.)	OLD27	0,00
102747	0,00	STUKS	L-06-02	PRE-LOADED SPLICE & PATCH SHELF 2U RIGHT, 96XSC/AP	OLD27	0,00
103033	9,00	ZAK	T-14-03	VERBINDINGSSOK 5/8# BUIS, GRIJS (ZAK=50ST.)	OLD27	0,00
103034	7.000,00	ST	T-16-02	JMV ZADEL 7/8MM VERZINKT DS500	OLD27	0,00
103060	11,00	DOOS	T-16-03	MEPA SPIJKERCLIPS 8-10 MM, (DS=100ST)	OLD27	0,00
103061	18,00	DOOS	T-16-03	MEPA SPIJKERCLIPS 11-15MM (DS=100ST)	OLD27	0,00
103062	2,00	DOOS	T-16-03	MEPA SPIJKERCLIPS 16-19MM (DS=100ST)	OLD27	0,00
103065	750,00	ST	T-16-02	JMV KABBEUG VERZ 38MM DS75	OLD27	0,00
103076	22,00	ROL	U-07-03	TAPE 15MM BREED, BLAUW #COROPLAST (ROL=10M.)	OLD27	0,00
103077	57,00	ROL	U-07-03	TAPE 15MM BREED, WIT #COROPLAST (ROL=10M.)	OLD27	0,00
103078	52,00	ROL	U-07-03	TAPE 15MM BREED, BRUIN #COROPLAST (ROL=10M.)	OLD27	0,00
103079	40,00	ROL	U-07-03	TAPE 15MM BREED, ROOD #COROPLAST (ROL=10M.)	OLD27	0,00

Figure 25- stock counting of Siers Installatietechniek where red is a negative counting.

104136	0,00	M	M-05-02	NEXA H07RN-F ECA 3G2.5 RI100	OLD27	250,19
104758	0,00	ST	M-05-01	TEHALIT M5693 DRAADGOOT FLEX 40 L500MM R7035	OLD27	206,71
104213	23,00	ST	A-00-00	WAV VSV ET BUIS 1 GRYS LG4	OLD27	179,69
104133	0,00	M	M-05-02	NEXANS YMVK DCA-S2 3X2,5MM2 RING 100 METER	OLD27	166,92
103751	0,00	M	L-04-06	LAPP H07V-K 1X2,5 GG RI100	OLD27	151,06
103967	0,00	ST	A-00-00	ALUMINIUM OPVANGER 16MM MASSIEF EX. KLEM (L=3 M.)	OLD27	131,52
104759	0,00	ST	M-05-01	TEHALIT M5691 DRAADGOOT FLEX 20 L500MM R7035	OLD27	66,42
104204	41,00	ST	A-00-00	WAV PVC ET LF BUIS 3/4 CR LG4	OLD27	65,60
104214	37,00	ST	A-00-00	WAV VSV ET BUIS 1 1/2 GRYS LG4	OLD27	47,67
102738	0,00	ST	M-03-01	WAV VSV SOK 1 GRYS	OLD27	31,72
104110	0,00	M	L-04-04	DONNE VD ECA 2,5MM2 GEEL/GROEN DOOS 100 METER	OLD27	27,19
104027	0,00	ST	L-01-06	MENN WCD CEE 3P 16A 230V TWIN	OLD27	21,14
104019	0,00	ST	L-01-06	MENN CONTSTP 16A3P 6H230V ERGO	OLD27	18,65
104203	35,00	ST	A-00-00	WAV PVC ET LF BUIS 5/8 CR LG4	OLD27	4,44
103596	0,00	SET	L-03-06	K-MERKER, GEEL, MAAT 65, OPSCHRIFT H (SET=50 ST.)	OLD27	2,31
102646	200,00	ST	T-16-02	JMV KABBEUG VERZ 32MM DS100	OLD27	0,00
102647	12.000,00	ST	T-16-04	KABELBEUGEL 9-10 MM, VERZINKT (DS=500ST)	OLD27	0,00
102648	0,00	DOOS	L-03-01	SOL CLIPS 7-10MM GR.L25MM	OLD27	0,00
102651	150,00	ST	T-16-01	JMV KABBEUG VERZ 50MM DS50	OLD27	0,00
102661	34,00	DOOS	M-01-03	SOL CLIPS 14-20MM GR.L35MM	OLD27	0,00
102667	26,00	DOOS	T-16-04	SPIJKERCLIPS 8-10MM, GRIJS #MEPAC (DS=100ST.)	OLD27	0,00
102686	20,00	ST	U-07-01	AARDVERDKLM 1X6+1X25MM2	OLD27	0,00
102689	4.500,00	ST	T-16-04	JMV KABELBEUGEL VERZ. 15-16MM (DS=500ST)	OLD27	0,00
102690	1.050,00	ST	T-16-01	JMV KABELBEUGEL VERZ. 19-20MM (DS=350ST)	OLD27	0,00

Figure 26- stock counting of Siers Installatietechniek where green is a positive counting.

Appendix C interview questions

Interview questions about 4PS, the ERP system of Siers

1. Can you explain how the company is currently using 4PS
2. In what ways has 4PS helped manage your warehouse
3. What features and tools of 4PS do you use the most at Siers?
4. What are the main benefits Siers installation engineering has gained from using 4PS?
5. Are there any areas where 4PS is not performing well or needs improvement?
6. What features or tools are you currently missing in 4PS?
7. How important is it to you to have these missing features in 4PS?
8. Can you indicate which of these missing features is your highest priority?
9. On a scale of 1 to 10, how would you rate the performance of 4PS in your company?
10. Can a WMS help this warehouse become more efficient?
11. which functionalities are a must-have, should-have or a could-have for a new WMS?

Appendix D Heatmap of Siers Installatietechniek

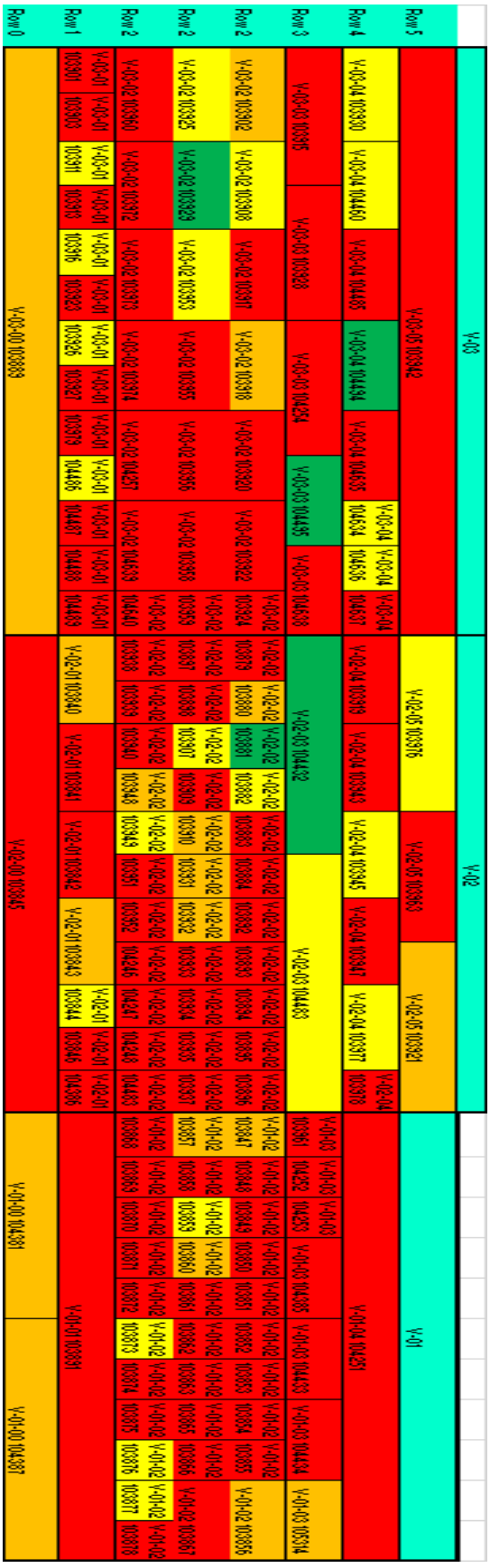

Figure 27- Heatmap of the V rack of the warehouse

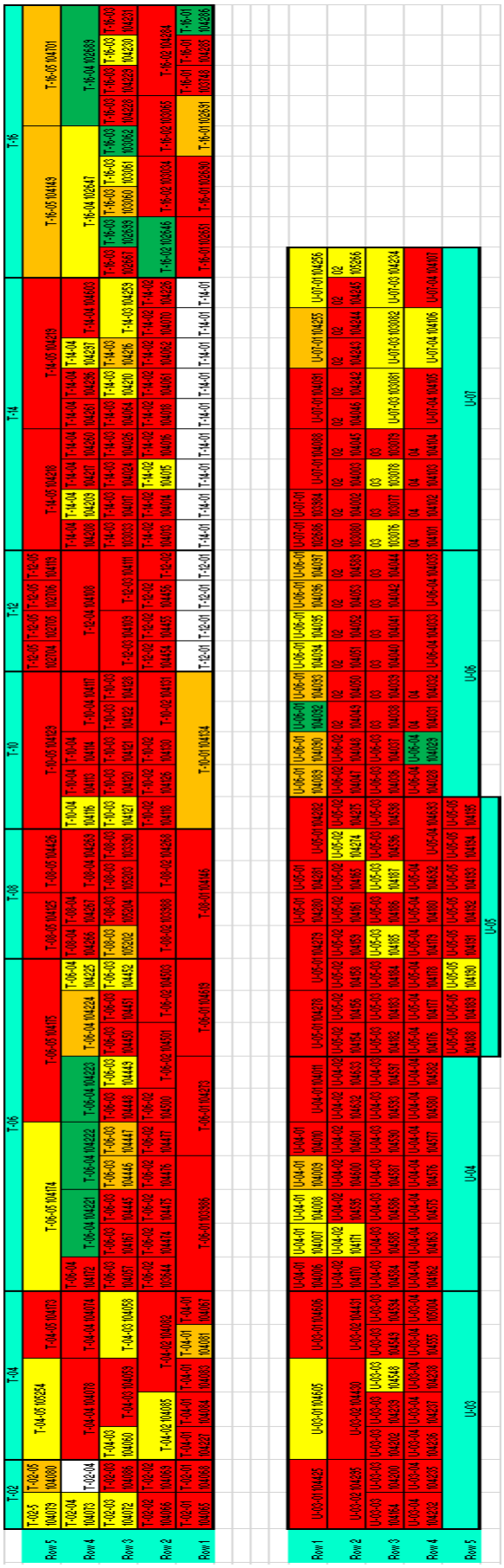

Figure 28- Heatmap of the T and U rack of the warehouse

Appendix E heatmap of improved slotting

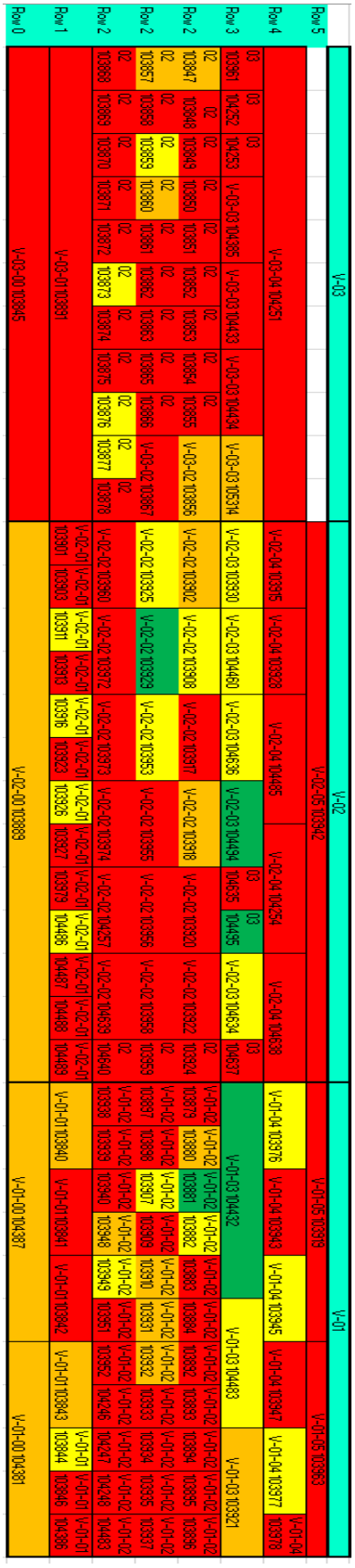

Figure 29- Improved slotting heatmap of the V rack

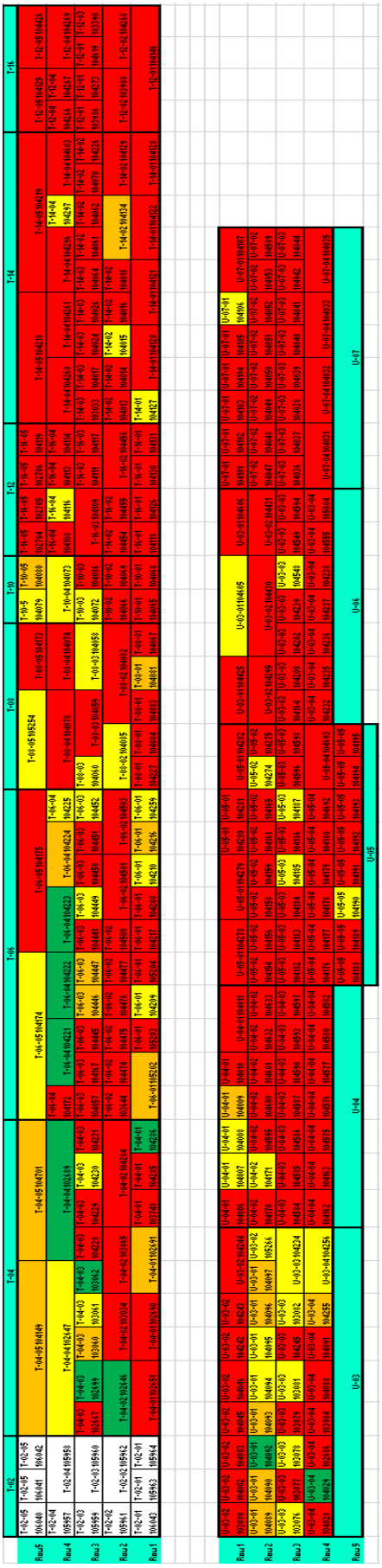

Figure 30- Improved slotting heatmap of the T and U racks

Appendix F Explanation of the scores

- Longer opening hours.

Cost 3: Because longer opening hours could cause higher costs in wages.

Feasibility 4: Extending opening hours does need adjustments to work schedules.

Accuracy 4: Longer opening hours provide more time to pick the right things.

Efficiency 3: The processes in the warehouse are not going faster by more extended opening hours. However, mechanics have more time to bring their materials back, which gives them more time to work on the project.

Decreased stock deviations 2: Longer opening hours will not directly impact stock deviations.

- The materials are picked on time.

Cost 4: The cost is low but may include working overtime as other things could stay behind.

Feasibility 4: It is feasible until things are not ordered anymore due to the lack of time.

Accuracy 3: The materials are picked on time. It does not say that the mechanics get suitable materials.

Efficiency 4: timely material picking decreases downtime for mechanics.

Decreased stock deviations 4: Fewer stock deviations exist without mechanics in the warehouse. It could be that the wrong material is booked in 4PS.

- The work preparers must always look at the project stock before ordering new materials.

Cost 3: It will cost money when the work preparers should be doing other activities.

Feasibility 5: There is no problem doing this as the warehouse is nearby.

Accuracy 3: There is no accuracy change because if the work preparer does not look: the material will still be ordered.

Efficiency 4: Looking at the already available project stock will result in a clearer warehouse, which can be suitable for efficiency.

Decreased stock deviations 3: The project stock does not have a stock.

- Have the material brought to the construction site.

Cost 4: It could increase costs when new logistics systems must be set up.

Feasibility 2: There is not always someone present for smaller projects, which makes this hard to do.

Accuracy 4: Materials brought to the construction site are suitable for accuracy, except if the wrong material is delivered.

Efficiency 4: Letting materials go to the construction site saves time in the warehouse, which is suitable for efficiency.

Decreased stock deviations 3: These materials are often project stock which does not have a stock level.

- Closed warehouse with a counter.

Cost 4: The only cost is for the counter.

Feasibility 5: There is no problem implementing this.

Accuracy 3: It could be that the warehouse workers picked up the wrong materials.

Efficiency 5: For mechanics, this will save time.

Decreased stock deviations 4: Without mechanics in the warehouse, there are fewer stock deviations. It could be that the wrong material is booked in 4PS.

- Have warehouse workers with material knowledge.

Cost 2: This may incur training costs or a new full-time employee.

Feasibility 4: Getting someone for this task should be fine, but the market for new personnel is tight.

Accuracy 5: It will mean that the mechanics always get suitable materials.

Efficiency 4: Warehouse workers with material knowledge can streamline the processes in the warehouse, such as ordering.

Decreased stock deviations 4: It will mean that there can be more inventory management as there is a new employee.

- Unit and shelf locations must match between Appeee and 4PS.

Cost 4: It will take a few workdays to locate all these errors, which will cost money.

Feasibility 4: In general, it should be feasible to do this: but it is quite some work.

Accuracy 4: There are fewer errors in picking the materials.

Efficiency 4: This can streamline picking processes and reduce search time.

Decreased stock deviations 4: This can reduce stock deviations because everything is in the right place.

- All SKUs are only available for warehouse workers.

Cost 5: There are no costs incurred.

Feasibility 4: It is generally feasible as long that the rule is maintained and well communicated.

Accuracy 3: It can still be that warehouse workers pick up the wrong materials.

Efficiency 3: Efficiency will stay the same as not much time is saved.

Decreased stock deviations 4: Without mechanics in the warehouse, there are fewer stock deviations. It could be that the wrong material is booked in 4PS.

- All project stock is available for mechanics and warehouse workers.

Cost 5: There are no costs incurred.

Feasibility 4: It is generally feasible as long that the rule is maintained and well communicated.

Accuracy 4: The mechanics know the materials and pick the suitable materials.

Efficiency 3: There is not much time saved.

Decreased stock deviations 3: Project stock does not have a stock level.

- A dedicated place for returned and picked materials.

Cost 4: some cost for space allocation.

Feasibility 5: There is enough room to do this.

Accuracy 3: The accuracy will be the same.

Efficiency 4: The processes enhance efficiency by streamlining the picking and returning of materials.

Decreased stock deviations 4: The warehouse workers have a better overview of what to book.

- Booking and documenting project stock.

Cost 4: Implementing a system may take time, and time costs money.

Feasibility 4: A documentation system must be thought out.

Accuracy 5: The work preparer knows precisely what is in the warehouse and what to order.

Efficiency 3: It saves time for the work preparer but costs time for the warehouse worker.

Decreased stock deviations 3: Project stock does not have a stock level.

- Project stock in a fixed place together.

Cost 5: It will not cost money only to replace materials elsewhere.

Feasibility 4: There must be an assigned place for this.

Accuracy 4: All materials are together.

Efficiency 4: There is less search time for the mechanics.

Decreased stock deviations 3: Project stock does not have a stock level.

- A separation between tubes.

Cost 4: Someone needs to come and build these separations.

Feasibility 5: It is easy to build these separations.

Accuracy 4: Reduce the chance of mix-ups.

Efficiency 4: It is faster if you do not have to look for materials.

Decreased stock deviations 4: There are fewer deviations if the materials do not mix up.

- A warehouse management system with a scanning system.

Cost 1: It will be a costly investment.

Feasibility 4: There are enough suppliers of warehouse management systems, but there must be a well-thought-out plan.

Accuracy 5: A WMS enables the warehouse worker to pick the right amount of suitable material.

Efficiency 5: A WMS will streamline processes.

Decreased stock deviations 5: A WMS shows real-time inventory levels: which enables the warehouse worker to conduct management control.

- Periodic material countings.

Cost 3: It can potentially disrupt other processes: resulting in some cost.

Feasibility 5: It is not hard to conduct these countings.

Accuracy 4: It can identify discrepancies between physical and recorded inventory.

Efficiency 3: can influence other processes which cannot be efficient.

Decreased stock deviations 5: It can reduce deviations by regular checking and maintaining inventory levels.

- One extensive material list on 4PS with all the departments.

According to the ICT department, this is impossible as these departments are their own companies.

- New slotting for T and U racks.

Cost 4: New slotting cost money to implement.

Feasibility 5: In this thesis, it is proven feasible.

Accuracy 5: It is well documented where everything is so that the warehouse worker does not pick up the wrong materials.

Efficiency 5: Travel time is decreased by 14:7%

Decreased stock deviations 4: The fast-moving materials are easier to track for inventory management.

- New slotting for V racks.

Cost 4: New slotting cost money to implement.

Feasibility 5: In this thesis, it is proven feasible.

Accuracy 5: It is well documented where everything is so that the warehouse worker does not pick up the wrong materials.

Efficiency 4: Travel time is decreased by 4:72%

Decreased stock deviations 4: The fast-moving materials are easier to track for inventory management.

- Use 4PS advice orders instead of Appeee.

Cost 5: There are no costs incurred.

Feasibility 4: The change must be well communicated and maintained.

Accuracy 4: Accuracy will increase because all the locations are correct.

Efficiency 4: It is faster to book these materials, saving time.

Decreased stock deviations 4: The warehouse workers cannot accidentally book the wrong materials.