In-house inventory supply chain optimization at MST Enschede

Master Thesis

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Management Summary

Context

The goal of this report is to give Medisch Spectrum Twente (MST) advice about how to optimize the in-house inventory supply chain in terms of efficiency. MST wants its in-house supply chain to run as efficiently as possible. The in-house supply chain consists of three main parts, namely the ordering process, picking process, and delivery process. The SKUs are ordered at the different departments in the hospital via electronic order boards, and the SKUs are kept in bins at the department's warehouses, based on a two-bin Kanban system. If a bin of an SKU is empty, the Kanban card that belongs to that specific bin is placed in the electronic order boards. Currently, the electronic order boards are read out at a specific moment every day. At that moment, the SKUs that are linked to the Kanban cards placed on the electronic order board are ordered at the logistics department, which picks these products and delivers them to the specific department. The departments are linked to a specific delivery route based on their position in the hospital. The orange delivery route is the only horizontal (so no elevators) route that delivers the entire 'hotfloor'. The other delivery routes, blue, red, white, green, and yellow, are vertical routes and consist of the department around one of the elevators.

A problem cluster is used to identify the core problems that form the observed problem, which is the feeling of inefficiency in the ordering, picking, and delivery processes. This resulted in finding the following core problems: wrongly timed readout moments, not enough products in the bins, wrong usage of the ordering system at the departments, picking locations and activities in the warehouse, inefficient delivery runs, and the organization of the delivery process. All these core problems lead to the following main research question:

How can MST improve the way of working with the electronic order boards at the departments so as to improve the efficiency of the in-house supply chain?

The data out of the software system that supports the electronic order boards is used to analyze the in-house supply chain. This data shows the status changes of the Kanban cards that belong to the SKUs. In this way, the logistics department tracks whether the status of the SKU is "Op voorraad" (in stock), "Geplaatst" (card placed/posted), "Besteld" (ordered), or "Besteld, van bord" (Ordered, the card is taken from the board). This data gave insights into where the core problems came from, and how these can be tackled.

Methods

The literature study found methods to tackle the mentioned core problems. First, the core problems considering the ordering process are tackled. The fact that the bin quantities are not correctly managed is solved by calculating the Economic Bin Quantity (EBQ). Using this EBQ method should decrease the standard deviation of the average days before a bin is empty, which means that there is a greater chance of more SKUs to be ordered at once and that for a lot of SKUs the bin quantities are calculated correctly, which means that they are aligned with their real usage. Next to that, the wrongly timed readout moments of the electronic order board are tackled with the use of a periodic review model. This model optimizes the time between orders, so the costs of the delivery are minimized. This can also be used in combination with the EBQ. For the picking process, the literature shows several methods to optimize the SKU allocation in the warehouses depending on usage or orders for instance. The warehouse at the logistics department is optimized by using interaction frequency heuristics, which checks how many times SKUs are on the same picking list, which is called the interaction frequency. The SKUs are located depending on the interaction frequency and the demand. The delivery process is optimized by using an ABC-analysis method, which classifies departments according to bin usage. Next to that, new delivery routes are developed out of the existing ones to decrease the peak of activity in the picking warehouse, to increase the efficiency of the logistics suppliers, and to increase the number of SKUs delivered per delivery.

Results

The proposed solution to prevent misuse of the ordering system is giving the users of the electronic order boards additional training by the logistics department about how to use and work with the two-bin Kanban order- and delivery system. This results in more knowledge and a better understanding of the way of work, with results in fewer emergency orders and fewer out-of-stock moments. The EBQ shows that the inventory values of the department warehouses reduce significantly, just as the standard deviation of the average days before a bin is empty. This makes sure that more SKUs are taken at once to a department, which makes the delivery runs also more efficient and decreases the chance of a stock-out. The periodic review model shows that, out of a sample of 22 departments, at least 10 departments do not have to be resupplied daily. These departments can be resupplied less frequently, which increases the efficiency of the delivery runs and revises the readout moments of the electronic order boards. The EBQ-tool and periodic review model do not have to be executed in this sequence and can be used the other way around.

The picking process is optimized using the interaction frequency heuristic. Using this heuristic to allocate the SKUs to a more efficient location reduces the distance that a picker has to walk with 33.30% which means that the picking time is reduced with the same percentage too. SKUs that are commonly used together are closer together, which makes the distance that an order picker walks shorter.

The core problems of the delivery process can be tackled by using an ABC-analysis on the bin usage per department, which is used to develop a new delivery scheme with a new readout moment for every department. This can be used to compare with the periodic review model and verify whether the solutions are in the same region. Next to that, new delivery routes are developed, based on the existing ones. For the first alternative, the departments that are in the orange delivery route are linked to the other delivery routes. This means that the orange delivery route itself is no longer used. This is since the horizontal movements (walking) take more time than vertical movements (with elevators), so the departments of the orange delivery route are added to the other existing routes. The second alternative creates an additional route for the outpatient clinics since their day ends at 4:30 PM, which does not hold for all the nursing wards. Therefore, no additional Kanban cards are placed on the electronic order boards after 4:30 PM. The ABC-analysis on bin-usage departments saves 9.25 hours per week, which is more than one working day for an FTE. If the departments of the orange delivery route are divided over the other delivery routes and, in combination with using the ABC-analysis on bin-usage of departments, this saves 6 hours per week. However, since the ABC-analysis and the periodic review model cannot be used together, the outcomes of the periodic review model should be used to base the delivery on. However, the results of the ABC-analysis can be used to compare the schedules to each other.

Recommendations

The first solution that I would recommend is to give additional training to the users of the electronic order boards, to improve the use of the electronic order boards together with the two-bin Kanban inventory system. Next to that, I would recommend the logistics department using the periodic review tool to determine the optimal time between readout moments, based on the current bin quantities. After that, the EBQ-tool should be used to calculate, and after a while revise, the bin quantities to keep them based on the demand pattern for the new readout moments and the new lead times. Another improvement that I would recommend is using the new warehouse design for SKU allocation since this reduces the picking time by 33.30%. Lastly, the outcomes of the periodic review model should be used in combination with the outpatient clinic route since this saves 9.25 hours and increases the efficiency of the logistics suppliers.

The proposed solutions are shown in table 1. The implementation number shows in which sequence the implementations should take place. If the implementation numbers are equal, the actions can be carried out at the same time.

Implementation number	Priority	Actor	Action
Ordering process			
1. Training	High	Head of logistics together with logistics employees	Assign coordinators to departments to explain the way of working at the logistics department.
1. Periodic review	High	Logistics employee	Recalculate the time between two ordering moments of all departments. Revise this after 3 months.
2. EBQ calculations	High	Logistics employee	Recalculate the bin quantities of the SKUs at all departments. Revise this after 3 months.
Picking process			
1. New warehouse design	Medium	Head of logistics together with logistics employees	Make sure the SKUs get to their newly assigned storage location in the unsterile warehouse.
Delivery process			
3. Outpatient clinic route	Medium	Logistics employee	Make sure the electronic order boards of the departments that are assigned to the outpatient clinic route are read out at different times.

TABLE 1 – ROADMAP WITH IMPLEMENTATIONS

If certain implementations have the same implementation number, these actions can be executed at the same time. If not, the implementations have to wait before the lower implementation numbers are executed.

Preface

It is a pleasure to present my master's thesis to you. This thesis finalizes my half a year of research at Medisch Spectrum Twente (MST) in Enschede. I am very thankful for the opportunity to perform my graduation assignment at MST. In face of the pandemic, they took time for me and helped me along the way as much as was needed. That is why, in the first place, I would like to thank Ton Feringa, Maarten Teutenberg, and Herman Krabbenbos for the opportunity to graduate at MST, for supporting me, and helping me with alternative views on problems and solutions. I also would like to thank Bibian Brunnekreef for her practical insights during this half a year, and of course for the laughs during my graduation period.

Secondly, I would like to thank my supervisors from the University of Twente, Peter Schuur and Sipke Hoekstra, for their time and feedback during my graduation period. As sparring partners, they helped me to improve my thesis with constructive feedback during video calls.

Finally, I would also like to thank my girlfriend, family, and friends for their mental support, enthusiasm, and motivation during my graduation period. They kept me positive and supported me, which kept my eyes on the goal.

Enjoy reading this report!

Lars Bergman

Wierden, May 17, 2021

Glossary

Word	Explanation	Introduced at page
Alltrack	Database of the electronic order boards which coordinates the order moments and saves the status changes.	10
Backorder	If a product that is on the order list is not in stock in the warehouse, a backorder is made, and the product is delivered when it is in stock again.	5
Bin	A small basket at a department warehouse where the products are in.	2
Central warehouse	Warehouse at the logistics department where all the goods are stored.	13
Department Warehouse	Warehouse at a (nursing) department of the hospital.	2
Double cards	Both product cards of a product are placed on the electronic order board, which means that the product is out-of-stock at the department.	15
Electronic order board	Board where the product cards are placed on. The board registers which product is linked to the card and reads out all product cards once a day. All of the cards that are on the board are on the order list that is released later that day.	2
FIFO	First-in-first-out, a principal in inventory/asset management which means that the first product that was on the shelf is also the first product that is used.	11
I/O-point	Input/Output-point, this is the point where the picker enters the warehouse and where he or she delivers the picked orders.	38
Kanban	A Japanese manufacturing system in which the supply of components is regulated through the use of an instruction card sent along the production line. In MST, the Kanban card that is used is the product card, which is the push action that starts the restocking process	2
KPIs	Key Performance Indicator(s), a measurable variable that indicates how a company is performing on its key objectives.	6
Logistics department	Department where all logistic activities take place and are coordinated from	1
MST	Medisch Spectrum Twente, name of the hospital.	1
Oracle	Enterprise Resource Planning (ERP) system of MST, coordinates all logistics activities for MST, for instance in terms of inventory positions.	10
Order line	A line on the order that indicates which product is ordered and how many units should be delivered. An order can consist of multiple order lines.	19
Order list (or picklist)	List of all the products that are ordered per department for a specific day	10
Product card	A card that indicates which product is in the bin, what the number of units of the product should be after restocking, and where the bin is in the department warehouse.	3
Readout moment	A daily moment in time when the cards on the electronic order boards are read out and the order list is made per department.	3
Release time	The time that the orders are ready and released to the order pickers.	14
Sales products	Products with low demand and not commonly used in a lot of departments.	9
SKU	Scannable barcode for one unique item, in order to track the movements of inventory	12
Sterile warehouse	The warehouse where all the products that need to be completely free of bacteria or other living microorganisms are located.	13

Transferium	The department that used to do the delivery of the products at the departments linked to the orange route.	14
Two-bin system	A system where there are two bins in a warehouse with the aim to minimize the out-of-stock moment.	7
Unsterile warehouse	The warehouse where all the products that do not necessarily need to be free from bacteria etc. are located.	13
Warehouse products	Fast-movers, products with a high demand throughout the whole hospital.	9

Table of contents

1. Introduction

This master thesis is written for the graduation assignment of the master study Industrial Engineering and Management, followed at the University of Twente. The graduation assignment took place at the logistics department of Medisch Spectrum Twente (MST) in Enschede, intending to improve the in-house inventory supply chain.

In this introductory chapter, background information is provided in section 1.1, together with a brief description of the problem in section 1.2. Next to that, research questions are asked in 1.3, together with the content of the chapters and the deliverables per chapter. The research objective and scope are provided in sections 1.4 and 1.5.

1.1 Background information

MST is a Dutch hospital, located in Enschede and is one of the largest non-academic hospitals in the Netherlands. MST originated from a merger between different regional hospitals in 1990.

MST is, together with six other hospitals, part of Santeon. Santeon, founded in 2007, is a group of seven top clinical hospitals in the Netherlands which work together to improve the quality of care, achieve greater medical results, and improve patient satisfaction. MST has, next to the location in Enschede, two other locations in Oldenzaal and Haaksbergen, which are outpatient clinics. The current location in Enschede, where the graduation assignment takes place, consisted of two separate buildings called Ariënsplein and Haaksbergerstraat, connected by a bridge between them, until the start of 2016. Nowadays, there is a single large location in Enschede in the center of the city, with a capacity of 620 beds. The current building is called Koningsplein and consists partly of the old location Haaksbergerstraat. This new hospital has got, among others, a state-of-the-art operation room (OR) complex. While developing the new building, the infrastructure of the hospital had a significant impact on the current layout. This is also an aspect that returns later on in the graduation assignment.

The logistics department is located in the part of the hospital that was already there, namely Haaksbergerstraat. This is also where the warehouses are located. All the goods that are used at all the different departments, except for the medicines, are located in the warehouses at the logistics department. The logistics department takes care of (re-)supplying all other departments, who are called clients by the logistics department, with goods that they need to treat patients. They take care of the full in-house supply chain considering goods, which consists of receiving, picking, and delivering the orders with goods to clients. Next to that, the logistics department also collects all the garbage and waste from the other departments and makes sure that the recycling company picks it up.

1.2 Problem description

The logistics management is not satisfied with the current efficiency of the in-house supply chain of MST and is experiencing difficulties to keep the current efficiency at the same level. Since different processes affect the efficiency of the in-house supply chain, these different processes are split and researched independently. The core processes of the logistics department that influence the efficiency of the in-house supply chain are:

- Receiving products
- Picking products and consolidate them to orders per department
- Delivery of the orders

Another core process in the in-house supply chain is the ordering process. This is not done by the logistics department, but by the employees who work at/with the department warehouses that receive the products. The employees at the warehouse departments can order products by putting Kanban cards that belong to a bin (where the products are in) on an electronic order board. The databases and ERP-systems that operate this board send the orders to the logistics department. This process is explained in more detail later on in this thesis.

The problem cluster shows the core problems which need to be solved to improve the efficiency of the in-house supply chain process at MST. A problem cluster is a visual representation of what causes the problems, and which effects these problems have, as can be seen in figure 1.1. The observed problem had different causes, which lead to the core problems that are tackled in this thesis. The core problems are the deepest causes and need to be solved in order to improve the efficiency of the in-house supply chain process at the MST. All these problems and causes are summarized in the problem cluster.

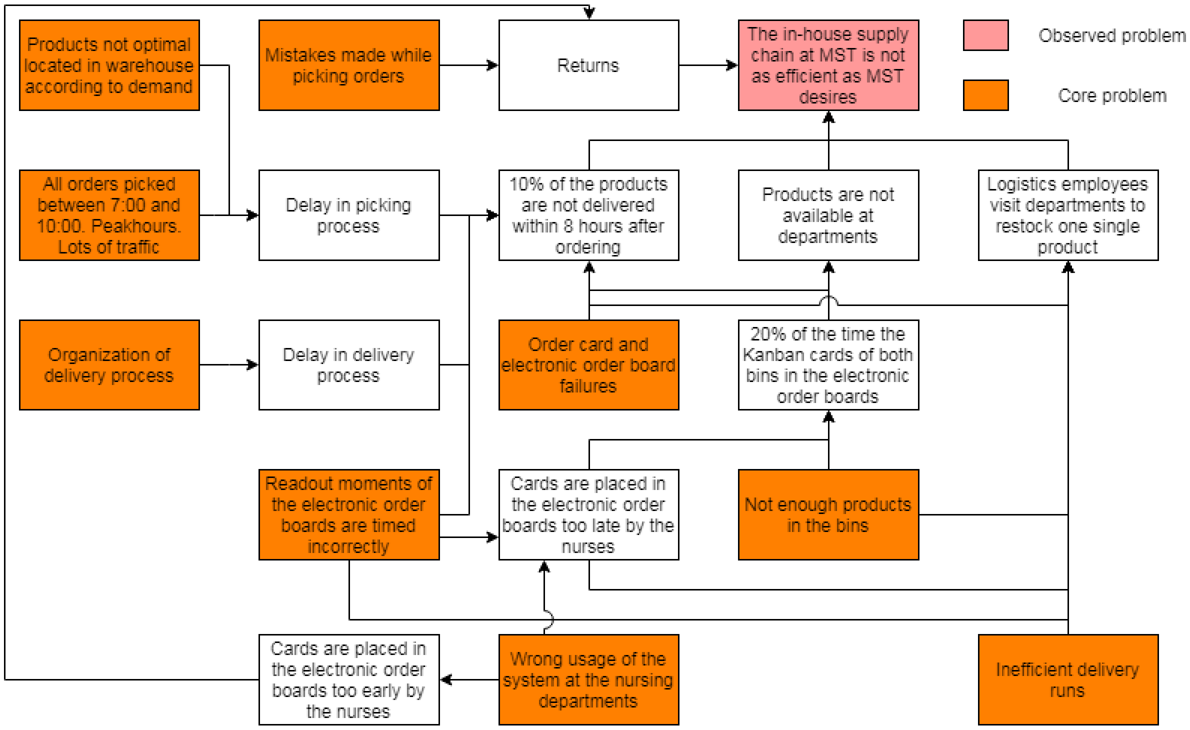


FIGURE 1.1 – PROBLEM CLUSTER

The next paragraphs explain the core problems briefly, ordered by their process.

1.2.1 Ordering

Not enough products in the bins

The presence of products at departments is important for the treatment of patients. If these products are out of stock, the nurses at the departments might have trouble treating patients quickly and to the patients' satisfaction. This can very well decrease the quality of care for the patients. If products are out of stock and nurses need these products immediately, they move to the department that is the closest to their department. This results in movements that decrease the efficiency of the nurses at the departments because the products are not available in their department. This is an additional problem that MST wants to prevent from happening. Next to that, MST also wants to minimize out-of-stock moments, since out-of-stock moments also decrease the efficiency of the supply chain. It happens often (12.88% of all cards placed on the electronic order boards) that both cards of one product are on the order board, which shows that it could be that the number of products in the bin is too low. This could also be due to misuse of the system, which is the next core problem. Next to that, a lot of bins are ordered very often and represent a significant amount of the total ordered products over the period of January 2020 until the 28th of October 2020, which indicates that there might not be enough products in the bins.

Another indication that gives signs of a too low number of products in the bins is the fact that 50% of all the bins are ordering 95% of all the products, as shown in figure 1.2. This directly means that the other 50% of the bins order just 5% of the products. If the minimum number of products in the bins that are ordered very rarely is decreased or changes to just one bin, there is more space for fast-movers. In this way, there are more inventory locations for the fast-movers. If more products of the fast-movers are available at the departments, it should be the case that it is ordered way less often, which leads to fewer movements to the departments and a more efficient spread of products over the departments.

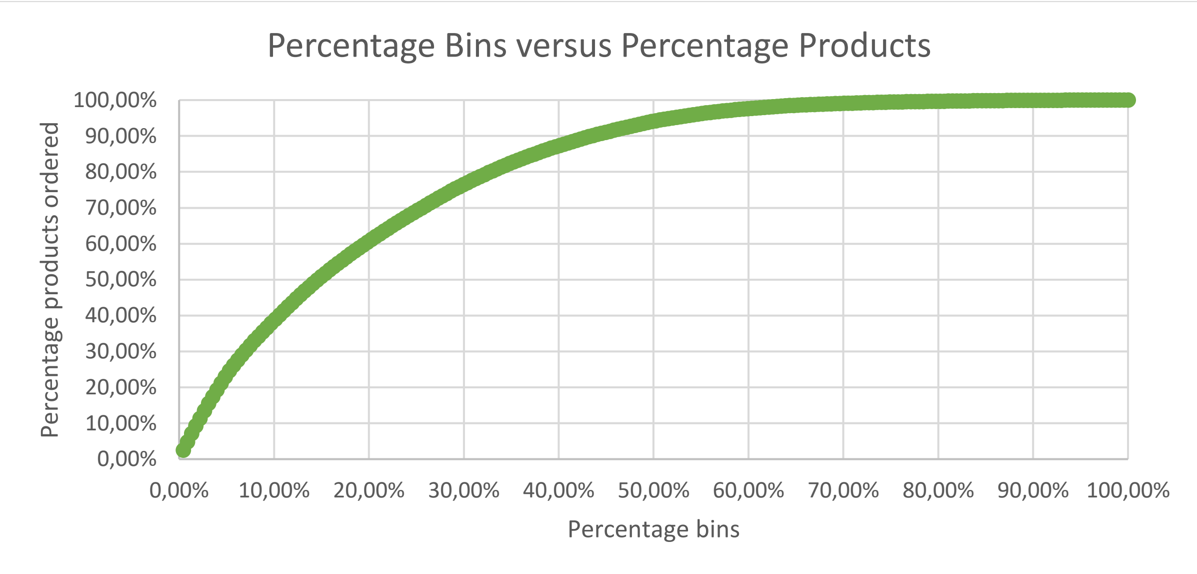


Figure 1.2 – Percentage of the number of bins versus the percentage of products ordered by the departments via the electronic order boards.

Wrong usage of the system at the nursing departments

12.88% Of the products that are ordered by the department warehouses are the same products that are also ordered seconds after each other. This can be due to misuse of the system. This does not have to be on purpose since it could also be that they are instructed in the wrong way. Next to that, the electronic order boards do not show when the next readout moment is, which is the most important information for the nurses to know since all the product cards of the empty bins should be in the electronic order board by then.

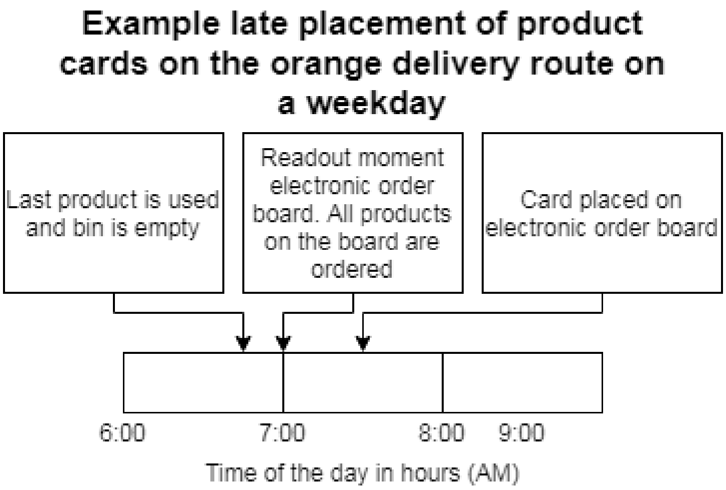


Figure 1.3 – Visual representation of late placement of cards

Another way of misuse is the late placement of cards in the electronic order board. Every electronic order board has a specific readout moment on a day. 9.23% of all cards placed are placed shortly (90 minutes) after the readout moment. Of course, some of the products might be needed in that time interval, but a significant number of times the cards are not placed after the last product is used and not delivered 24 hours. A visual representation of this situation is shown in figure 1.3.

The wrong usage is also related to the number of returns since cards are placed too early. This means that the bin is not empty (yet), but the product card is already placed. Since the suppliers have to take the products back to the logistics department, which in the end is decreasing the efficiency of the supply chain since extra movements and actions need to be done which are normally not necessary.

Readout moment of electronic order boards are timed incorrectly
As already mentioned in the first core problem, the readout moments of the electronic order boards are currently all between 7:00 AM and 10:00 AM. For some of the departments, these are the rush hours of the day. When humans are in a hurry, they tend to forget things (Joosten, van den Berg, & Teunisse, 2008). This also happens at the hospital. If there are a lot of tasks or patients to be treated, nurses might forget to put the Kanban card of an empty bin in the electronic order board. If the readout moment passes, and the nurse checks the bins after the rush hours, it takes more than 24 hours to deliver the product to the department. If the readout moments are spread over the day, and then specially set at moments that the departments have more time to take care of the supplies, the nurses are not stressed and can check the empty bins and put the Kanban cards in the electronic order board. The readout moments need to be aligned with the picking and delivery process. Next to that, the readout moments also have an impact on the fact that logistics employees walk to a department to restock one single product.

1.2.2 Picking

All orders picked between 7:00 AM and 10:00 AM
All orders for all departments need to be picked in three hours, which results in a lot of activity in the warehouse. Every order picker picks his or her order in this time frame. This means that it is busy in the warehouse between 7:00 AM and 10:00 AM. When the new order method was introduced MST chose to read out every electronic order board between 7:00 AM and 10:00 AM, to restock every department early on the day. But, if these readout moments are more spread over the day, the picking process is more spread over the day and the peak of activity is decreased. This flattens the curve of activity. This core problem is in this way related to the incorrectly timed readout moments of the electronic order boards.

Products not optimally located in the warehouse according to demand
Since there is no specific reason for the way the warehouses are equipped and the picking takes a lot of time in the whole in-house supply chain, this problem can decrease the delivery time significantly. Since there are a lot of theories on how to furnish your warehouse and about how to locate the product according to demand, pickers can easily save time by only changing the locations of the product on the shelves.

Mistakes made while picking orders
Since picking is done by humans, picking mistakes are likely to be made and wrong products are picked out of the warehouse. These mistakes lead to returns, for which extra movements and actions need to take place. In order to increase the efficiency of the supply chain, fewer picking mistakes lead to fewer unnecessary movements and actions, which finally leads to an increased supply chain efficiency. The same

holds for the fact that too many units of products are picked. This means that, in most cases, there is not enough space in the bin to fit them in and the inventory position is not correct. If more products are delivered than ordered, there is a difference between the inventory that is really in the warehouse and the inventory position in the ERP system. Eventually, a department might order a certain product that is still in stock according to the ERP system but not in stock in the warehouse. This means that the back office makes a backorder for that product and it is not delivered in 8 hours. This also decreases the efficiency of the supply chain.

1.2.3 Delivery

Organization of the delivery process

The delay in delivery time is caused by the wrong organization of the delivery process. According to Voort (2016), the delivery time of a certain delivery route in the hospital has a high median and variance, which indicates that there are a lot of different delivery times. This means that the person who is delivering on that floor is taking a lot of time to deliver all the products, and these times do differ also significantly which causes the high variance. This means that the delivery is not always as efficient as it should be. This core problem can be solved but is also dependent on other core problems like the number of products per bin. If the number of products per bin is increased, the delivery changes because the logistics employee visits departments less often for a specific product because of the increased bin size. Another possible cause is the way that the departments are spread over the delivery routes. The delivery route scheme is in appendix 1. If the departments are spread differently over the routes or if routes are spread more over the day, the logistics department maybe does not have to visit a certain department for one product, which is the next core problem.

Inefficient delivery runs

It happened almost 700 times in the last 10 months that a supplier had to move to a department to restock one single product, as can be seen in table 1.1. This is not very efficient since the supplier moves to a department with an almost empty cart. This indicates a low number of products delivered per route and per hour, which decreases the efficiency of the supply chain.

Number of Products delivered	Number of times a specific number of products is delivered between January and July	Number of times a specific number of products is delivered between August and October	Total
1	478	208	686
2	515	238	753
3	503	219	722
4	477	219	696
5	555	223	778
6	485	225	710
7	510	220	730
8	510	235	745
9	537	193	730
10	475	170	645

TABLE 1.1 – NUMBER OF TIMES THE SUPPLIERS DELIVERED A SPECIFIC NUMBER OF PRODUCTS.

1.2.4 Other

Order card and electronic order board failures

According to the thesis of Voort (2016), the 492-order card and electronic order board failures happened between November 2016 and January 2017. These failures are of course problematic, but not part of this research because this is due to technical failure of (the hardware of) the products that MST uses.

To conclude this paragraph, the graduation assignment focuses on these core problems, except for the order card and electronic order board failures, and tries to find a suitable solution by which the core problems are solved.

1.3 Research questions

The research questions support achieving the main goal of this research, which is improving the efficiency of the in-house supply chain. To achieve this goal, the main research question has to be answered. The main research question that follows from this problem is:

How can MST improve the way of working with the electronic order boards at the departments so as to improve the efficiency of the in-house supply chain?

The main research question is split into 5 different research questions. To be able to answer the main research question, the following research questions are formulated, which are all specific chapters in the thesis:

1. **How is the in-house supply chain at MST organized?**
   1.1. How is the ordering process organized and which problems are identified?
   1.2. How is the picking process organized and which problems are identified?
   1.3. How is the delivery process organized and which problems are identified?
   1.4. What are the main differences with other hospitals, how does MST perform compared to other hospitals and how did other hospitals optimize their supply chain according to the literature?

The answers to research question 1 and the sub-questions 1.1 until 1.3 are provided in chapter 2. A clear overview of the processes is needed to identify where the problems come from and what needs to be done to solve the main research question. The processes were analyzed by working together with the logistics employees and observing how the materials flow through the hospital. The problems were identified mainly by big data analysis and by observations done at the work floor. The answers to sub-question 1.4 are provided in the literature study, which is the third chapter of this thesis. This chapter results in an overview of the processes and the problems per process.

2. **What is the current efficiency of the supply chain?**
   2.1. Which KPIs are currently in place?
   2.2. How do the supply chain and the different processes perform on these KPIs?
   2.3. Which processes influence which KPIs?
   2.4. Which KPIs need the most attention (the bottleneck) and which KPI can be improved the most?

The answers to research question 2 and sub-questions 2.1 until 2.4 are also provided in chapter 2. The second half of this chapter is about the Key Performance Indicators (KPIs). A KPI is a measurable variable that indicates how a company is performing on its key objectives. To measure the efficiency of the in-house supply chain, there is a need to know which KPIs play a role in the efficiency and how the in-house supply chain performs on these KPIs. Together with the logistics management are several KPIs determined that are important to the hospital. The current value of the KPI is calculated by the use of the big data out of the ERP systems. Next to that, it is important to know which KPIs are affected by which processes. In this way, looking for a solution is more effective. The KPI(s) that can be improved the most need to be researched. Which process(es) affect(s) this/these KPI(s) and how can they be improved? This is determined by splitting the process into several steps and checking per process step which core problems are influencing that step, and which effect this has on which KPIs, based on the opinion of the logistics employees.

Chapter 3 is a literature study. Several research questions need to be solved by the literature study, because of the knowledge gap. More (external) knowledge is needed to solve these questions. The literature study goes in-depth about what the main differences are between the in-house supply chain of MST and the in-house supply chain of other hospitals/firms. If these main differences are identified, it is possible to check why these differences are there and verify whether these are useful for MST (question 1.4). Next to that, it is important to know how other firms work with electronic order boards, how they (re-)design their processes to use the electronic order boards to their full capacity, and what MST can learn from them (questions 3.1, 3.2, 4.1). Several models about reorder frequencies, which are the readout moments for MST, are discussed. Next to that, it is important to know how the number of products in a bin is calculated since this determines how many times a department is visited (question 3.6). The product allocation into storage space in warehouses is another part of the literature study. There will be found out which models are useful to assign products to storage locations. The last part of the literature study is how delivery schedules are designed. Relevant knowledge can be acquired to improve the delivery schedule of the orders (question 5.2). The literature study is done by searching for specific keywords that mark result in papers about the subject of the research question.

3. **How can the ordering process be optimized?**
   3.1. What is in the literature about readout moments and ordering via electronic order boards? How do other firms deal with this?
   3.2. What is in the literature about the use of two-bin systems in hospitals? How do other firms deal with this?
   3.3. What are the most prominent reasons that cause a lack of efficiency?
   3.4. How does the readout moment affect the in-house supply chain of MST and how does it affect the workday of the nurses at the departments?
   3.5. To what extent is the number of products per bin correct according to the calculations of the Kanban and two-bin system?
   3.6. How can the readout moments be changed with the use of the models found in literature and which changes increase the efficiency?

The answers to research question 3 and sub-questions 3.1 until 3.6 are provided in chapter 4. How other firms deal with the ordering process is also discussed in the literature study, and this is transformed into the MST situation in chapter 4. Next to that, this chapter describes how the users of the electronic order boards (nurses at the department warehouses) experience the use of the order boards and what they think can be changed to improve patient satisfaction and eventually the efficiency of the in-house supply chain. This is done by conducting interviews and a questionnaire and asking the hospital employees how they experience working with the current ordering and delivery system. Another part of this chapter is the calculation of the review period, by using the mathematical model found in the literature study. This mathematical model calculated the optimal review time between the readout moments. Next to that, the Kanban min/max calculations are investigated and compared to the intended number of products by the economic bin quantity (EBQ) model, which optimizes the bin quantities. The goal of this chapter is to provide insight into how to optimize the ordering process of the in-house supply chain. Tools to determine the bin quantities per SKU per department and the optimal time between two ordering moments are provided. Just as recommendations on how to optimize the way of working with the electronic order boards.

4. **How can the picking process be optimized?**
    4.1. How do other firms organize their picking process in combination with electronic order boards?
    4.2. What are the current problems at the picking?
    4.3. How can the products in the products in the warehouses be optimally allocated to a storage place?
    4.4. To what extent are the products optimal located to minimize the picking time in the warehouses?
    4.5. What is the relationship between the changes in readout moments and the new picking times?

The answers to research question 4 and sub-questions 4.1 until 4.4 are provided in chapter 5. A picking process is a very common process throughout different industries. A lot of companies have warehouses where they need to pick products. This is why it is smart to look at the way different firms design their picking process and the activities around it. They encounter comparable problems, from which MST can learn. The placement of the products in the warehouses is also important since walking between products takes the most time while picking products. If the products in the warehouses are placed according to demand, for instance, time can be saved, the picking time can be decreased, and the in-house supply chain efficiency is improved. Several models, found in the literature study, are discussed here and compared to each other in terms of how good the solution is and computation time for instance. The goal is to optimize the storage of products in the warehouse, to minimize the picking time per order line. This chapter results in a new warehouse design where the SKUs are located more optimally.

5. **How can the delivery process be optimized?**
    5.1. What changes can be made to the current delivery process to increase efficiency?
    5.2. Which methods are there to develop the delivery schedules?
    5.3. Which alternatives are there to the current delivery schedules?
    5.4. What are the pros and cons of the different alternatives?
    5.5. What is the best choice to make when trying to optimize the efficiency of the whole delivery process?

The answers to research question 5 and sub-questions 5.1 until 5.5 are provided in chapter 6. The delivery process is the process that takes the most time throughout the in-house supply chain. So, the organization of this process is very important to maintain the high efficiency of the in-house supply chain. The efficiency of the delivery runs is therefore discussed and investigated. Next to that, several methods to develop an alternative delivery schedule are applied to check whether there are more efficient and/or faster delivery routes. One of the methods is found in the literature was delivery based on the classification of departments. This results in delivery with fewer half-empty carts. This chapter results in recommendations about newly developed delivery routes, which can be used to improve the efficiency of the deliveries.

The results of all the previous chapters are presented in chapter 7. The results are combined if necessary and are verified to check whether they improve the efficiency of the in-house supply chain. An overview of conclusions and recommendations for MST to improve the efficiency of the in-house supply chain and answer the main research question is provided in the last chapter, namely chapter 8. This report is used to give MST advice on how to improve the in-house supply chain. Next to that, tools to determine to optimal bin quantity and the time between two ordering moments are provided, just as a proposed design for the picking warehouse. Next to that, newly developed delivery routes are advised to MST to increase the efficiency of the deliveries.

1.4 Research Objective

The research objective is to investigate how MST can improve its current in-house supply chain process. As already has been proven in the graduation thesis by Voort (2016) there are still aspects in the ordering, picking, and delivery processes that can be improved. These aspects are the core problems shown in figure 1.1.

This problem contains a research problem because the organization wants to gain new knowledge and insights in how to improve their current process, where they can improve their process the most, and how much they can improve their process.

1.5 Scope

The scope of the assignment is based on the workload of the assignment, the interest of the management of the logistics department, and the core problems.

When the warehouse products are ordered again to resupply the warehouse, they are delivered at the receiving dock to check the warehouse products and make them ready to distribute them to the corresponding warehouse. The receiving goods activity is out of the scope of this assignment since this is not the priority of the logistics manager, who is more focused on gaining time and saving money on the other in-house processes. That is why the following assumption was made:

For this research, the assumption was made that the products are always available at the warehouse, so reordering the products at the suppliers is out of scope. This also holds for the sales products, which are ordered by the procurement department.

2. Context analysis

This chapter describes the context of the assignment and the way of work at the logistics department. Next to that, the problems that occur in the different processes are addressed, which leads to the core problems that should be solved. In the end, this chapter should give the answers to research questions 1 and 2, which give an overview of all the activities that are involved in the in-house supply chain and make the efficiency of the in-house supply chain measurable. Sub-questions 1.1 until 1.3 and 2.1 until 2.4 help with answering the research questions. Question 1.4 is answered in the literature study of chapter 3.

1. **How is the in-house supply chain at MST organized?**
   1.1. How is the ordering process organized and which problems are identified?
   1.2. How is the picking process organized and which problems are identified?
   1.3. How is the delivery process organized and which problems are identified?

2. **What is the current efficiency of the supply chain?**
   2.1. Which KPIs are currently in place?
   2.2. Which processes influence which KPIs?
   2.3. How do the supply chain and the different processes perform on these KPIs?
   2.4. Which KPIs need the most attention (the bottleneck) and which KPI can be improved the most?

The first two sections of the chapter should answer sub-questions 1.1 until 1.3. Firstly, all processes are described in section 2.1. After that, the processes are analyzed and the identified problems per process are explained in section 2.2. Section 2.3 until section 2.6 answer sub-questions 2.1 until 2.4. The KPIs that are important for MST to measure efficiency are described in section 2.3. Next, the KPIs are measured and linked to processes. Lastly, the bottlenecks are described and located. The last section of this chapter, section 2.7, summarizes this chapter and highlights the most important problems that are going to be tackled.

2.1 Main activities of the logistics department

As already mentioned, the logistics department has got several different activities. The main activities of the logistics department that are part of their in-house supply chain and from which some are also part of this assignment are:

- Picking (individual) products and consolidate to complete orders
- Delivering orders to the department warehouses

Before the logistics department moved into their new location, they also had to make the picking lists themselves. Nowadays, the order lists are generated by Oracle, the ERP system of MST. Oracle receives its data from the electronic order boards database system, called Alltrack. Alltrack coordinates the readout moments of the electronic order boards and the statuses of the product cards. How the ordering, picking, and delivery processes are executed are roughly explained in the next paragraph. Currently, the products are ordered, picked, and delivered six days per week (not on Sunday, only when there is an emergency). Receiving the products and storing them in the warehouses only happens on workdays and not on the weekends.

2.1.1 Old and new ordering method

From the moment the new hospital was ready to use, a new order method was introduced. There were several reasons for introducing this order method, and one of them was the fact that the storage space in the warehouses got smaller after moving into the new building in comparison to the older warehouse location. This means that the inventory levels of the warehouse had to be reduced to fit the inventory of every product in the warehouse. However, the main reason was the lack of efficiency of the old method. Before this new method was introduced, the logistics employees had to visit every single department two or three times a week on foot to keep track of which products were (almost) out of stock at the departments. The products are in bins. A bin is a small basket located at an inventory location at a department. They had to scan a card with a barcode, which indicates which product is in the bin and how many items (min/max of the bin) of that specific product had to be restocked. After all departments were visited, the logistics employees went back to the logistics department and released the picking lists for the order pickers. The orders were picked and delivered to the departments. Since this method is prone to errors, visiting all departments on foot took a lot of time and it frequently occurred that different departments were lacking different products, the head of the logistics department recognized that there had to be a more efficient and effective way of restocking the departments. That is why a new order method was introduced, which uses electronic order boards to digitally order products at the logistics department. In this way, the logistic employees do not have to visit every single department again on foot. The order lists are sent to the logistics department and are automatically generated.

Currently, MST is working with a combination of the so-called 'two-bin system' and the Kanban method to keep track of their inventory at the departments. The combination of these methods with the electronic order board removes the time needed for the logistic employees to visit all the departments. These changes for the ordering method made the new ordering and restocking processes look quite different. The current way of resupplying products at a department goes as follows:

For one specific product, there are two bins in one larger basket, within each bin the same number of products most of the time. Sometimes departments choose to work with one bin for certain products, but this does not happen frequently. In the two-bin situation, each of these bins is linked to a Kanban card. This card contains information about which product should be in the bin and the number of products that were in the bin after restocking. The Kanban cards are located in a small cardholder on the front of the basket in which the bins are. When this product is needed by a nurse, they take the product out of the first bin until this bin is empty. If the bin is empty, the nurse has to post the card into the electronic order board. This board scans the card and recognizes which product, and in which amount it is needed at a department. The products in the second bin are used while the first bin is replaced/restocked. If the second bin is empty, the same procedure is used as when the first bin was empty, and the restocking process repeats itself. This is called First-in-First-Out (FIFO). Normally, the number of products in the second bin should be enough to bridge the time to restock the first bin. In this way, the chance of being out of stock is minimized. This is how the combination of the two-bin system and the Kanban method works.

The electronic order boards generate significant amounts of data about the changes in the state of the products at the departments, which is saved in Alltrack. For example, when a product card is placed into the electronic order board, the state of the product changes from "Op voorraad" (in stock) to "Geplaatst" (card placed/posted), which means that the bin is empty, and the product card is placed into the order board. Every electronic order board has a specific readout moment, where the status of all the cards that are on the board is changed to "Besteld" (ordered). This means that all the products that are connected to the cards are ordered for that specific department. When the products are resupplied, and the so-called ''delivery mode'' of the electronic order boards is turned on, the status of every card changes to "Besteld, van bord" (Ordered, the card is taken from the board) when the card is taken from the board and placed in the bin that belongs to the card. When the ''delivery mode'' ends, the status of the cards that are not on the electronic order board anymore changes back to "Op voorraad" (in stock). All these changes in the status of the product cards are saved in Alltrack, and this data is useful later on in the assignment to argue the mentioned core problems. The chain of statuses is also visible in figure 2.1. Next to that, figure 2.2 gives a visual representation of an example of the status changes on a timeline.

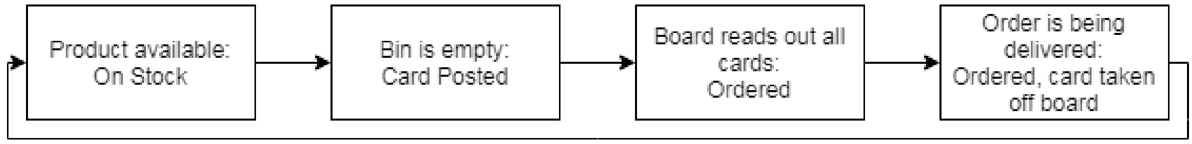


FIGURE 2.1 – STATUS CHANGES OF THE CARDS ON THE ELECTRONIC ORDER BOARDS.

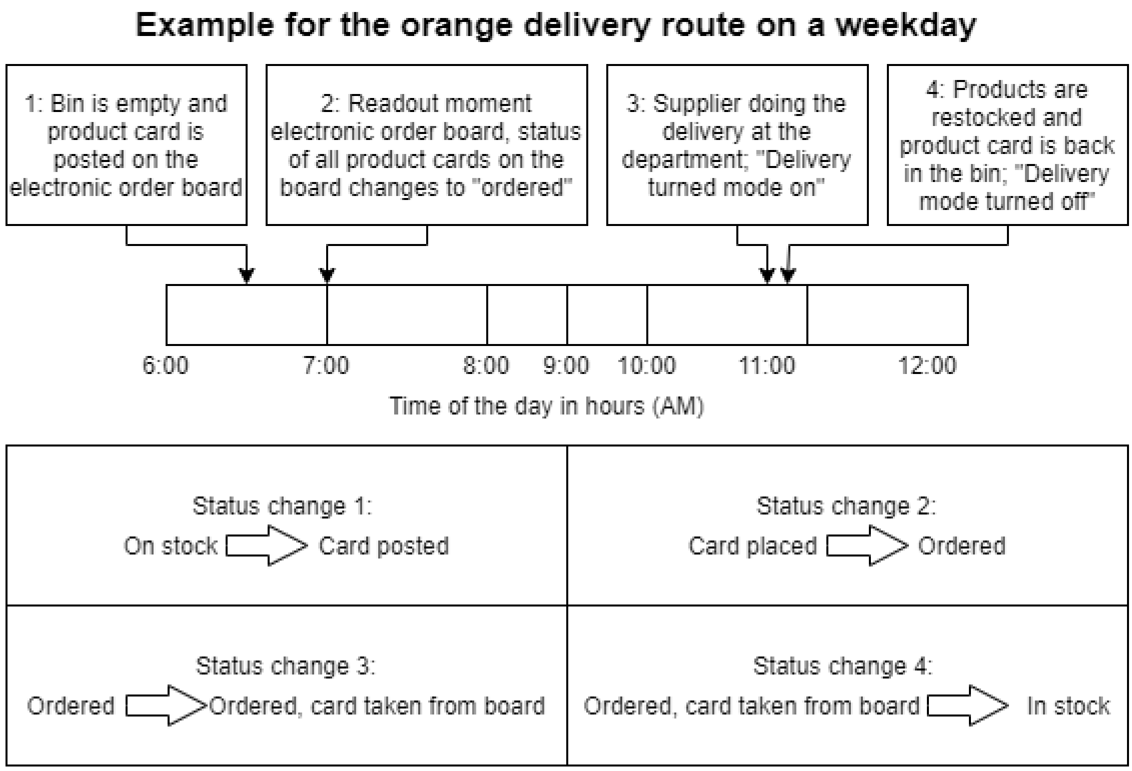


FIGURE 2.2 – TIMELINE OF AN EXAMPLE FOR THE STATUS CHANGES ON A DAY FOR THE ORANGE DELIVERY ROUTE.

Once a day (in the morning), the electronic order board is read out and the order is sent to the logistics department. The readout times per route are shown in table 2.1 and table 2.2. Appendix 1 shows which departments belong to which delivery route. At the logistics department, the order is printed and is passed to the pickers in the warehouses. The next paragraphs roughly explain the following steps in the supply chain.

Route	Readout Time
Orange	7:00 AM
Blue	7:45 AM
Red	8:30 AM
White	9:30 AM
Green	10:00 AM
Yellow	10:00 AM

TABLE 2.1 - READOUT MOMENTS PER ROUTE FROM MONDAY UNTIL FRIDAY.

Route	Readout Time
Orange	8:15 AM
Blue	7:00 AM
Red	7:30 AM
White	8:00 AM
Green	8:00 AM

TABLE 2.2 – READOUT MOMENTS PER ROUTE FOR SATURDAYS.

Not all departments make use of electronic order boards. Some departments have a few Stock-Keeping Units (SKUs) in stock, so they manually enter their order in Oracle. An SKU is a scannable bar code for one unique item, in order to track the movement of inventory. In this way, it is not possible to see the changes in the status of the bins, so we have to assume that the orders are correct, daily, and placed as soon as one bin is empty. The list of departments that do use electronic order boards and the departments that do not use electronic order boards is in appendix 1.

2.1.2 Receiving, picking, and delivery

Receiving, picking, and delivery are the three main activities of the logistics department. Before the products can be picked and delivered to the departments they are stored in the warehouses. MST makes a distinction between two different kinds of products, namely warehouse products, and sales products. Warehouse products are ordered by the logistics department and are, after receiving, placed in the central warehouses at the logistics department. These are fast-movers and/or products with high demand in the hospital. Furthermore, the warehouse products are divided into sterile and unsterile products, for which there are separated sterile and unsterile warehouses to store them. Sterile products are products that need to be clean and free of bacteria when doctors and nurses use them to treat patients. Unsterile products do not have to be free of normal bacteria and need to protect the doctors and nurses from infected micro-organisms. Sales products are slow-movers and/or products with low demand in the hospital. They are ordered by the departments that use these products. When the products arrive at the (un)load docks, they are separated by the characters whether they are warehouse products or sales products. If the number of received warehouse products indeed is equal to the ordered number of warehouse products, the products are stored in the correct warehouse (sterile or unsterile) and are ready for picking. The sales products are made ready to deliver them at the next delivery moment to the department that ordered them.

Every electronic order board has a specific readout moment. At this specific readout moment, every Kanban card that is on the order board is scanned by the order board itself and put on the order list of the department that ordered it. The order lists are firstly separated by the fact of whether the products are sterile or unsterile since these products are in different warehouses. Next to that, the orders are also separated per bin number per department. The list of ordered products is printed and given to the order pickers of the sterile and unsterile warehouses. They pick the list of products in the warehouse where the products are located for every customer and place the products in a bin on a cart. The readout moments are currently between 7:00 AM and 10:00 AM (see table 2.1 and table 2.2), after which the picking finds place. If it fits, the order for one department is in one bin and there are several orders on one cart most of the time. These carts are made ready for delivery and put in front of the elevators that indicate a certain delivery route (which is given the colors orange, blue, red, white, green, and yellow) and delivered to the specific departments. Every delivery route is linked to specific departments that are close to the elevator that indicates a specific color. A list of which departments belong to which route is in appendix 1, including all ordering times and release times of the orders from the back office of logistics to the order pickers. When the logistics employee arrives at the department, the so-called 'delivery mode' is selected on the electronic order boards, the bins are restocked for which the Kanban cards are on the electronic order boards if the products are available and the Kanban cards are put back into the bins. The orange route is delivered by Transferium. Transferium is the department that did safety checks on the goods that were delivered to restock the inventories on the third floor, which is called the 'hotfloor' in MST. This is the floor where all the operations take place and with all the intensive care units. Transferium had to make sure that the ordered goods were placed in the right bins at the right departments, while the logistics department just had to make sure that the goods are placed in front of the elevator that takes the goods to the third floor. For the other routes, the logistics department does deliver the goods at the right bin at the right department. The orange route is the busiest of all delivery routes. This is since most of the departments there are running 24 hours per day. The blue and red routes are also quite busy since these routes include a lot of large departments of the hospital. Since the white and green delivery routes include smaller departments, they are a little less busy. The yellow route is the smallest and includes only departments at the Haaksbergerstraat. Since the Haaksbergerstraat does not have a lot of departments left where patients are treated, this route is not very busy.

2.2 Analysis of the problems per process

The three different processes are analyzed based on data out of Alltrack. The problem description is divided into the three main process parts of the in-house supply chain, namely the ordering process, the picking process, and the delivery. This paragraph describes which problems occur, how important these problems are, and how often these occur.

2.2.1 Ordering process

The transition from the old to the new order method was in 2016, which means that the logistics department is working with it for four years right now. Since the new order system is fully automatic and the logistics employees do not have to visit every department on foot, it is fair to assume that this system is already more efficient than the old order method, mentioned in paragraph 2.1.1. Nevertheless, the logistics management thinks that there is still improvement possible, which was confirmed by an earlier graduation project at MST. End 2016, S. van der Voort (2016) did her master's degree graduation assignment at MST and looked at the overall performance of the supply chain was and how the new order method affected the overall performance. She found out that more than 90% of the products are delivered within 8 hours after the ordering moment and that the 10% that is delivered too late (8 hours after the ordering moment) is caused by delay in the ordering process or backorders. Nowadays, 2% of all the orders are delivered more than 8 hours after the ordering moment. According to Voort (2016), the delay in delivery is mainly caused by the readout moments of the order boards, the way the system is used, the picking process, and the delivery process. If the readout moment for a department is on a busy part of the day, the nurses might forget to put the product card in the electronic order board or just ignore the fact that the bin is empty since they are busy with another task and leave the product card in the bin. In this way, several products might be out of stock and are not restocked within 8 hours. This is one of the first aspects to investigate. Which times are more ideal to read out the electronic order boards? If the readout moments are spread more over the day, will the peak in picking activity decrease so there will be more products delivered within 8 hours?

Since misuse of the system was already one of the problems back in 2016, this could still be an issue. After researching data out of Alltrack from January until October 2020, the number of times that both the product card for bin one and the product card for bin two were in the electronic order board, which means that both bins of this product are empty and there is no stock left at the departments' warehouse, was 15826 (which indicates 31652 cards), which comes down to more or less 50 times each day and 12,88% of the cards posted in the electronic order boards. This might again be due to both misuse of the system by the nurses or due to a too low number of products in the bins. Table 2.3 shows the 20 departments that post the most double cards in the electronic order boards, compared to their total posted cards. Appendix 2 shows the total double cards and cards placed per department from January 2020 until 28th October 2020, together with their percentage double cards placed of the total cards placed.

Department	Total cards placed	Total number of double cards	% Double cards of total cards placed per department
P-Reuma	487	210	43.12%
V-Kraam S	2087	562	26.93%
V-B4 AS	686	178	25.95%
V-Verl O	62	16	25.81%
P-MDL O	2083	534	25.64%
AOK ANES	7952	2004	25.20%
V-Ortho O	2094	508	24.26%
V-CCU O	2766	652	23.57%
PACU/VERK	7557	1590	21.04%
V-Ortho S	2632	534	20.29%
V-Kraam O	4841	982	20.29%
V-MDL S	3382	680	20.11%
V-B4 AO	1199	216	18.02%
V-MDL O	1797	320	17.81%
P-Behan	5259	870	16.54%
P-Intg	109	18	16.51%
P-MOKA	1715	278	16.21%
TOK O	1123	180	16.03%
TIC	8058	1248	15.49%
AOA A6 O	2674	412	15.41%

TABLE 2.3 – TOP 20 DEPARTMENTS WITH THE LARGEST PERCENTAGE DOUBLE CARDS PLACED OF TOTAL CARDS PLACED.

If we look at the double cards per route, we can state that the red delivery route posted the most double cards shortly after the readout moment. 7.72% of all the double cards posted at the red route (425 out of 2754) are placed shortly after the readout moment. In the first 30 minutes after the readout moment, it even happened 151 times over the last 300 days, which comes down to 3 times a week. On average, 9.27% of all double cards are placed shortly after the readout moment. This should be prevented from happening since this causes out-of-stock moments. The whole table of the double cards per interval is shown in appendix 3.

It is clear that there are also other signs of misuse of the system since data shows that nurses at departments place product cards short (within 90 minutes) after readout moments several times. This means that cards are not immediately placed after a bin becomes empty, but when a nurse, for instance, checks whether there are still bins empty without the card being placed. For example, table 2.4 and table 2.5 show the number of times a product is ordered at a department that is in the orange delivery route. The red marked lines show the number of products that were ordered shortly after the readout moment. This shows that more than 2700 products are ordered shortly after the readout moment, which means that the department has to wait more than 24 hours before they actually receive the product. If the system is used in the way that it should be used, these late placements are decreased. Tables for the other delivery routes are shown in appendix 4.

Orange	Times ordered
00:00:00-00:59:59	621
01:00:00-01:59:59	245
02:00:00-02:59:59	142
03:00:00-03:59:59	70
04:00:00-04:59:59	109
05:00:00-05:59:59	77
06:00:00-06:59:59	139
07:00:00-07:29:59	308
07:30:00-08:29:59	2402
08:30:00-08:59:59	2363
09:00:00-09:59:59	4111
10:00:00-10:59:59	4570
11:00:00-11:59:59	7031
12:00:00-12:59:59	3769
13:00:00-13:59:59	7471
14:00:00-14:59:59	15003
15:00:00-15:59:59	5161
16:00:00-19:59:59	2545
20:00:00-23:59:59	1771
Percentage Red	4.68%
AVG Percentage Red of all delivery routes on Weekdays	9.23%

TABLE 2.4 – PRODUCTS ORDERED IN A CERTAIN TIME INTERVAL FOR THE ORANGE DELIVERY ROUTE FOR ALL WEEKDAYS.

Orange	Times ordered
00:00:00-00:59:59	177
01:00:00-01:59:59	63
02:00:00-02:59:59	64
03:00:00-03:59:59	13
04:00:00-04:59:59	53
05:00:00-05:59:59	13
06:00:00-06:59:59	53
07:00:00-07:59:59	46
08:00:00-08:14:59	70
08:15:00-08:59:59	823
09:00:00-09:59:59	1019
10:00:00-10:59:59	438
11:00:00-11:59:59	1014

12:00:00-12:59:59	950
13:00:00-13:59:59	549
14:00:00-14:59:59	1029
15:00:00-15:59:59	341
16:00:00-19:59:59	501
20:00:00-23:59:59	554
Percentage Red	10.59%
AVG Percentage Red of all delivery routes on Saturdays and Sundays	9.45%

TABLE 2.5 – PRODUCTS ORDERED IN A CERTAIN TIME INTERVAL FOR THE ORANGE DELIVERY ROUTE FOR ALL SATURDAYS AND SUNDAYS.

Next to that, the moments that the double cards are placed are also interesting, since this indicates misuse of the system. The data shows that 9.16% of all the cards are placed shortly after the readout moments. The red route is placing most of the cards shortly after the readout moment. This is interesting since the red route should have employees available by then since the departments in the red route are all outpatient clinics where the employees work from 8 AM until 4:30 PM or 5 PM. So, if they start working at 8 AM, they must have enough time to do a last check at the bins and put the cards of the empty bins in the electronic order board. This could, of course, also be due to the fact that the products were needed to treat patients, but this is most of the time due to misuse of the system.

Normally, the time to replenish the first bin should be shorter than the time it takes for the nurses to use all the products that are in the second bin. If this does not hold and the products that were in the second bin are used before the first bin is restocked, this could be an indication that the number of products in one bin is too low. If the number of products in one bin is doubled, the number of times that the bin is restocked halves, if everything goes as it should. If the number of products is too low indeed, it could be the case that the number of replenishments might stay the same, but the number of products that are in one bin might be increased. There are more products in stock, so the chance of running out of stock within the delivery window decreases.

Another possible cause could be, as already mentioned, the misuse of the system. The data shows that 10% of all the bins are for ordering already 40% of all the products. This is also visible in figure 2.5, which shows the percentage of the number of bins versus the percentage of ordered products. 40% of all the bins are also ordering almost 90% of all the ordered products. This also shows that almost 50% of all the bins are ordering 5% of all the ordered products, which is more or less equal to 13000 products ordered. This is a low number, compared to the total 245819 ordered products over almost 10 months. This could be an indication that there is a small number of products in a lot of bins since it should be the case that most of the bins should be resupplied the same number of times, especially if they are in the same departments. Another conclusion that can be drawn is that 114 bins (more or less 50% of all bins) just order 5% of all the ordered products. It might be efficient to make the placed smaller or place fewer products in these bins since they are almost not used. These placed for bins can be used for fast-movers from which the bins are too small, compared to other bins, and more products or units of the products are used in a shorter time. Almost 2000 products are ordered at least once a week and almost 500 products are ordered twice a week. This could be since the maximum bin size is not large enough to restock the product less frequently. But it could also be the case that the maximum number of products in the bin is not reached, which means that the number of products in the bin should be increased.

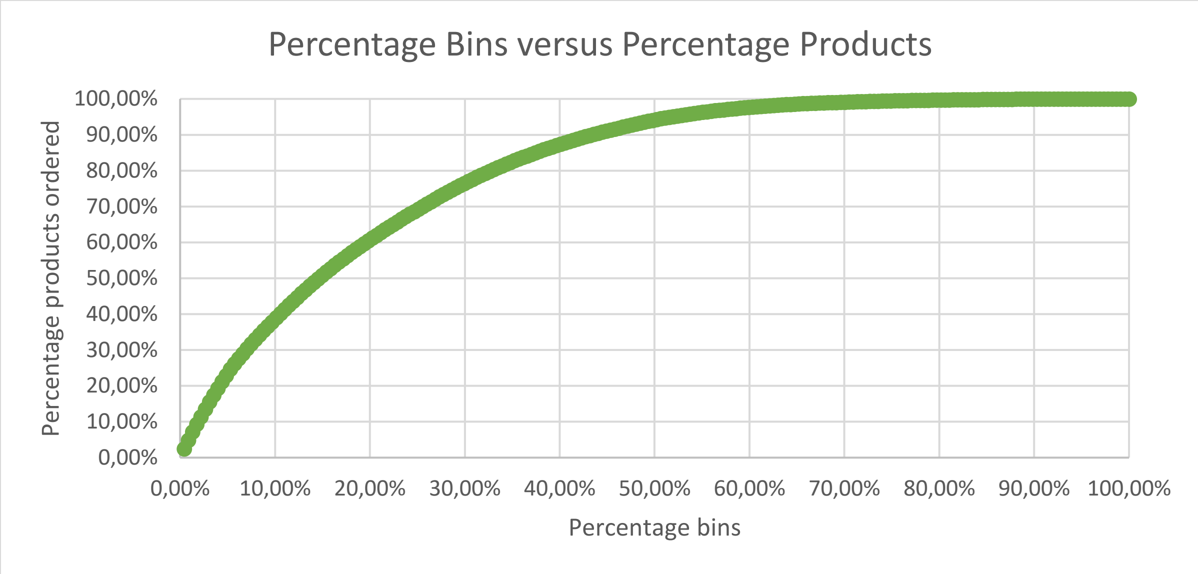


FIGURE 2.5 PERCENTAGE OF THE NUMBER OF BINS VERSUS THE PERCENTAGE OF PRODUCTS ORDERED BY THE DEPARTMENTS VIA THE ELECTRONIC ORDER BOARDS.

2.2.2 Picking process

There are also chances to increase efficiency while looking at the picking process. Next to that, since all readout moments are between 7 AM and 10 AM, there are a lot of order pickers in the warehouses in between these times. Because of that, the order pickers might be in each other's way, since the aisles in the warehouses are too small to pass each other in there. Will the time to pick one order improve, if the picking times are spread more over the day and for instance fewer pickers are needed at the same time? If there are fewer people in the warehouse, the picking process might run smoother since pickers do not have to wait for each other while picking an order list. The location of the products in the warehouse is also an important subject when looking at the picking process. There are a lot of theories about how the products should be located in a warehouse since picking (and in special the time that it takes to walk from product to product) is a very common and time-consuming activity. Since the products are not stored according to demand, a lot of time is lost while picking the products and this decreases the efficiency of the picking process and so the whole supply chain. Another possible solution can be to change the way of picking. Currently, the picking is done by order list, so for every department, the whole picklist is picked in the warehouse. But how would the process change if the picking would be done per product, per pathway, or segment in the warehouse? Would this maybe decrease the picking time and improve efficiency? The proposed ways of picking need, after all the picking is done, some extra time to consolidate the orders per department per route.

Another conclusion that can be drawn out of the data is that there is a significant number of wrong picks. A wrong pick means that a wrong product is picked, which is not on the order list. This means that a department receives a product that they did not order. When this happens, the product that was brought to the department but not ordered is switched for the product that was initially ordered by the client. The wrongly picked product needs to be returned to the warehouse and should be reversed in the ERP system, to keep the number of items per SKU in stock up to date. Another common mistake is that pickers pick too many units of the products. When the suppliers deliver the products to the departments, they have to count the products and if there are too many units of the products picked, the suppliers have to take the products back to the logistics warehouses.

2.2.3 Delivery

The last process where we should take a look at is the delivery process. A finding, by doing research on the data, was that the logistics employees visit departments, sometimes on the other side of the hospital, to restock just one product. From January until October 2020, it happened 686 times that the suppliers had to move to a department for just one product. Table 1.1, in section 1.2.3, shows how many times a supplier had to walk to a department for a specific number of products. Visiting departments to restock one specific product is way less efficient than visiting departments to restock multiple products, especially when certain departments are on the other side of the hospital. If the reorder quantity is larger, the logistics employees do not have to walk to the other side of the hospital for one product, but they can align the reorder quantity with the use and restock moments of other products. In this way, logistics employees can restock multiple products at once for the departments, which makes the process more efficient.

Another aspect that needs to be researched is the delivery times. How much do they vary in terms of time and order lines? If there are a lot of order lines on certain days, it takes more time to deliver the products to the departments. But if it consequently takes more time for certain employees to deliver the same number of goods than other employees do in less time, this employee might need some help to understand the process and learn faster ways to deliver the products.

Data shows that the orange delivery route has the most order lines on average. This was also expected, since (a lot of) the departments in the orange delivery work 24 hours a day. The blue and red delivery routes include outpatient clinics, which are open until 4:30 PM and 5 PM. The yellow delivery route is the route with the least order lines on average. This route is normally only restocked on Mondays and Thursdays. However, the data shows that this route is sometimes also delivered on other days, but often in very small batches of less than 10 products.

The following graph, figure 2.6, shows the average number of order lines per route per day:

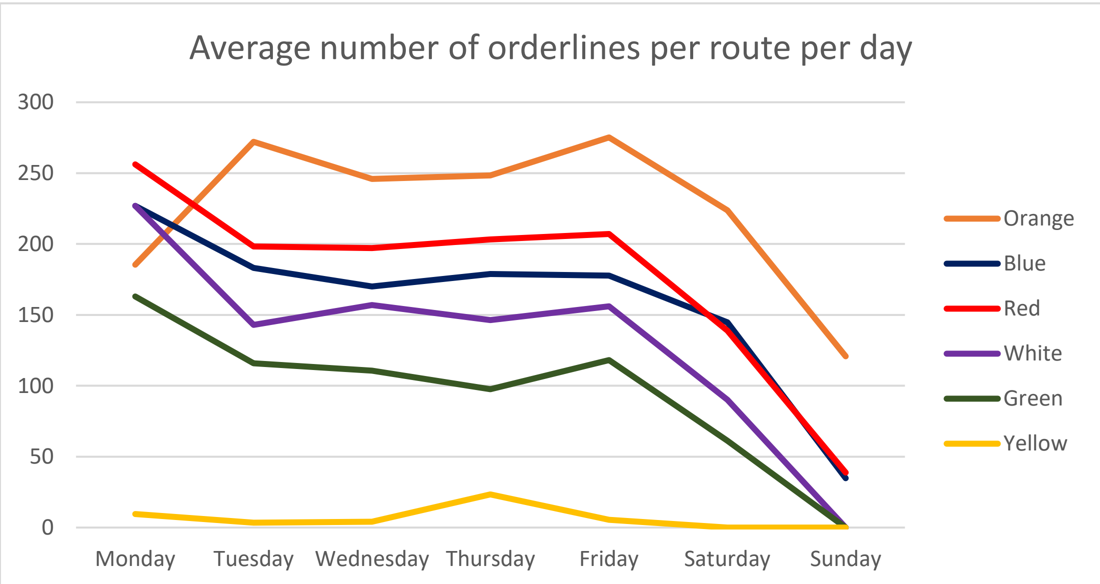


FIGURE 2.6 – AVERAGE NUMBER OF ORDER LINES PER ROUTE PER DAY.

Figure 2.6 shows that the orange route is indeed the busiest route with the most order lines on average. On Mondays, the departments on the red, blue, and white routes are ordering more products than the departments on the orange route, in terms of order lines. However, the orange route is the busiest route by far on the other days. Next to that, Monday is the busiest day of the week for every route, except for the orange route. Dependent on the week, Tuesday or Friday is the busiest day for the orange route. But, if the average number of order lines per day of the orange route is compared to the delivery time, which is the time between the first delivery of the day and the last delivery of the day, the average number of order lines increases from Monday to Tuesday, but the average delivery time decreases. This is also visible in figure 2.7. This means that they deliver more goods on Tuesday in a shorter time. The comparison between the order lines and delivery times and the time of the last delivery after ordering the products for the other routes are in appendix 5.

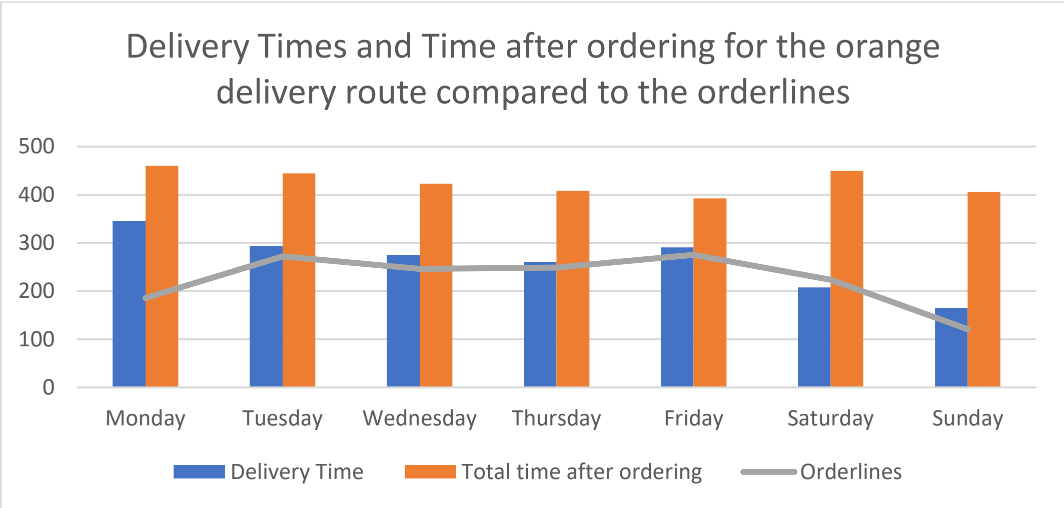


FIGURE 2.7 – DELIVERY TIMES AND TIME AFTER ORDERING FOR THE ORANGE DELIVERY ROUTE COMPARED TO THE AVERAGE ORDER LINES PER DAY.

Another finding is that the delivery times for the orange route are fluctuating. This conclusion can be drawn from figure 2.8. If we compare this to figure 2.9, we can see that the spread in delivery times of the blue delivery route is way smaller than the spread of the orange delivery route. The box plots of the delivery times of all routes are in appendix 6. As can be seen, the spread of the box plots of all delivery routes is smaller than the spread of the box plot for the orange delivery route, which means that the delivery times of all routes, except for the orange one, have less variation in their delivery times. The outliers are caused by errors in the data, which are again caused by the electronic order boards. The boxplot for Sunday is also not representative, since the delivery should not take place on Sunday and this is most of the time emergency, which causes a large variety of times.

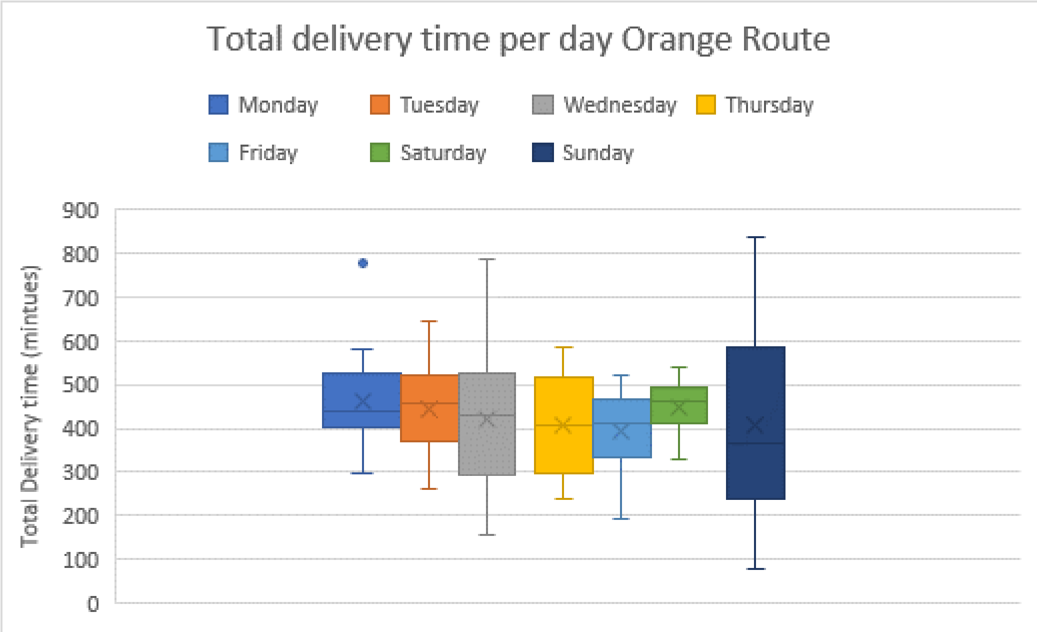


FIGURE 2.8 – BOX PLOT OF THE TOTAL DELIVERY TIME PER DAY FOR THE ORANGE DELIVERY ROUTE.

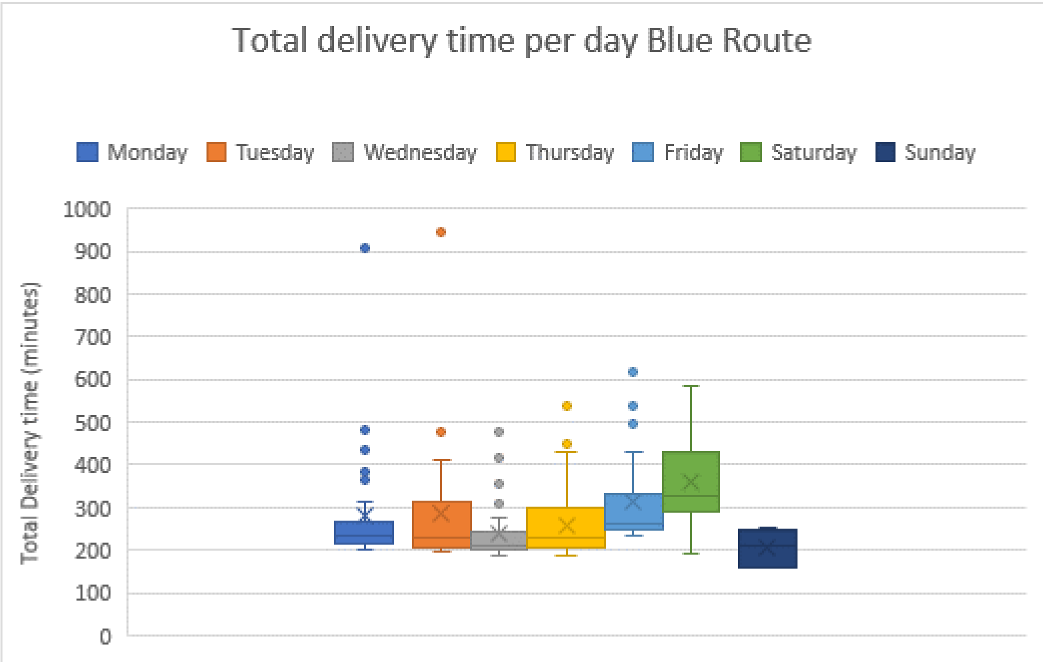


FIGURE 2.9 - BOX PLOT OF THE TOTAL DELIVERY TIME PER DAY FOR THE BLUE DELIVERY ROUTE.

The same holds also for the time between the first and last restock of a route. There is a lot of spread in the box plot for the orange route, which can be seen as a large variety of the times between the first and the last restock of a product at the orange route, especially if we compare the box plot of the orange route (figure 2.10) to the box plot of the blue delivery route (figure 2.11). This is not due to the order lines, since the variance (table 2.6) shows that the spread of order lines is more or less the same for every delivery route, except for the orange route. Another large difference between the orange route and the other delivery routes is the difference between the minimum and the maximum number of ordered products per day, since twice as much for the orange route as for the second-largest route in terms of ordered products.

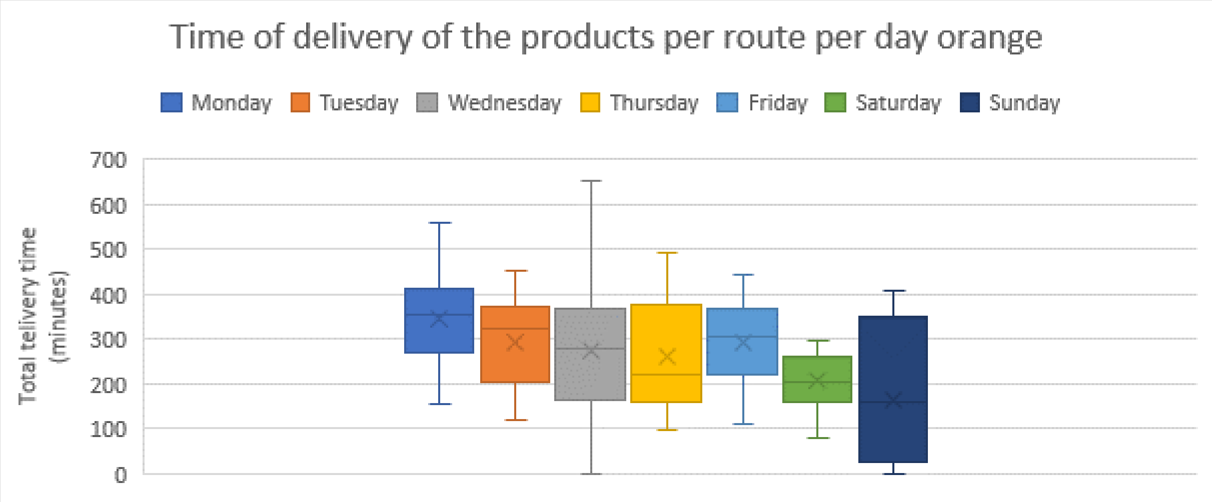


FIGURE 2.10 – TIME OF DELIVERY OF THE PRODUCTS PER ROUTE PER DAY FOR THE ORANGE DELIVERY ROUTE.

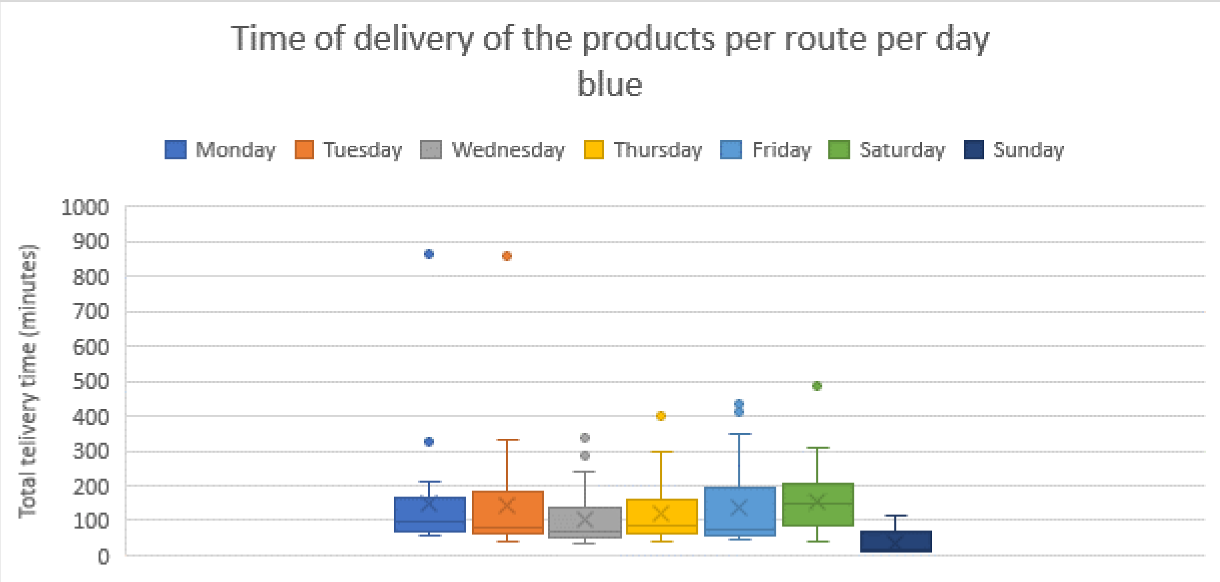


FIGURE 2.11 - TIME OF DELIVERY OF THE PRODUCTS PER ROUTE PER DAY FOR THE BLUE DELIVERY ROUTE.

Variable\Route	Orange	Blue	Red	White	Green	Yellow
Average order lines	239.387	177.4828	197.0345	153.3555	111.1563	9.652632
Variance order lines	3555.394	1984.587	2986.187	2612.346	1822.187	97.6267
Standard Deviation order lines	59.62713	44.5487	54.64601	51.11112	42.68708	9.880623

TABLE 2.6 – AVERAGE, VARIANCE, AND STANDARD DEVIATION OF THE ORDER LINES PER ROUTE.

The data also shows that the percentage of deliveries that take more than 8 hours is the largest for the orange route, namely 5.92% of all delivered products on weekdays and 3.95% on Saturdays and Sundays. In comparison, all the other routes have less than 1% of their products delivered too late on weekdays and less than 1.5% on Saturdays and Sundays. The average delivery time per order line is also the largest for the orange route. On average, the delivery time per order line is between 45 and 60 seconds per order line. This does not hold for the orange delivery route. The average delivery time per order line is between

80 and 90 seconds. The fact that the average delivery time is larger for the routes from which the readout moments are later on the day seems to be normal since the delivery time is calculated by subtracting the readout moment from the last delivery moment. Since picking and consolidating all orders for, for instance, the white and green route takes place later on the day, the average delivery time also is larger due to the way of calculating the variables.

There are also a lot of products that return after resupplying the departments. This can have several issues. Firstly, and already mentioned in paragraph 2.2.2, it can happen that the pickers took the wrong products out of the warehouse. This is called a wrong pick. Another possible issue could be that the nurses already place the product card before the bin that belongs to the product card is empty. This means that there is no place for the products in the bins and the product and are taken back to the warehouses at the logistics department.

2.3 KPIs for the in-house supply chain processes of MST

KPIs are needed to make efficiency measurable. Every process in the in-house supply chain has its own KPIs to measure how the process performs. The KPIs are sorted per process that influences them and in which they occur plus within the brackets the measurement unit of the KPI.

The following KPIs are used for the ordering process:

- *Out-of-stock moments (% of total delivered goods)*
  The presence of products like syringes and medical gloves is necessary to treat patients at the departments. If these products are out-of-stock, nurses and doctors cannot treat patients to their satisfaction and therefore these kinds of medical products should never be out of stock. This is why this KPI, and therefore the number of double cards placed, should be minimized. Multiple factors can influence this KPI, for instance, the wrong usage of the system at the departments and a too low number of products in the bin.

- *Late placements (% of all cards)*
  As already mentioned, the way of work with the ordering system is very important for the further course of the processes that follow in the supply chain. If the cards are placed, whether or not short, after the readout moment, the department that placed the card on the electronic order board has to wait until the next day before the product is delivered. To improve the efficiency of the in-house supply chain, the late placements should be minimized.
- *Returns due to cards placed too early (% of total delivered goods)*
  Another possible consequence of misuse of the system is that the product cards are placed on the electronic order board preventive, just to be sure that they do not lack any products the next day. But since other departments also use the same products, the logistics employees do not refill a bin when it is not empty. If other departments also asked for this product when
  they are out-of-stock, they might not receive it when other departments ask for the same product while they still have certain units left. If a department places a card in a bin too early, the products are returned to the central warehouse. Therefore, the number of cards placed too early should be minimized since this only causes extra actions that do not add any value.

The following KPIs are used for the picking process:

- *Picking time (per order line) (minutes)*
  To indicate how efficient the pickers work, the picking time (per order line) needs to be measured. Differences in picking time per order line per day can give indications about logistics employees who need some extra education or tips and tricks about order picking to work faster and more efficiently for example. The goal is to minimize the picking time.

- *Returns due to picking mistakes (% of total delivered goods)*
  Since picking is done by humans, it happens that the wrong products or too many units of a certain product are picked. However, this decreases the efficiency of the in-house supply chain since extra actions are needed to take the products and place them back in the warehouse for instance. These extra actions are unnecessary and do not add any value to the users of the products. Therefore, the returns due to picking mistakes need to be minimized.

The following KPIs are used for the delivery process:

- *Average delivery time per order line (seconds)*
  Like the picking time for the picking process, the delivery time per order line is also an indication of the efficiency of the delivery process. It could be the case that several employees 'outwork' others due to better knowledge or tips and tricks about the delivery process. Therefore, more experienced suppliers can teach other (new) suppliers these tips and tricks to improve their skills and decrease the delivery time per order line. The delivery time per order line can also be decreased by developing another delivery schedule.

- *Total average delivery time (minutes)*
  This KPI is more or less the same as the previous one, but in this case, the total time of the delivery per route is checked. This should be less than 8 hours since MST is aiming to deliver all the orders in less than 8 hours.

- *Products delivered per department (% orders containing 10 products or less)*
  The KPI about the number of products per delivery route and/or department is more or less the same. As stated in paragraph 2.2.3, it happens frequently that suppliers go to departments with just one or two products. These products might very well be non-medical products, for which the need is not urgent, like for medical products. This is not efficient, since suppliers move through the large hospital with a large cart to a department for just one product. Therefore, the products delivered per route or department indicate the fill rate of the carts of the suppliers.

2.4 KPIs measured and bottleneck KPI(s)

The KPIs mentioned in section 2.3 are measured in this section. After that, it is possible to check which KPIs are the most important for MST to improve. The KPIs are discussed the same way as done in section 2.3, namely per process. All KPIs are calculated based on the status changes that were saved by Alltrack from 1 January 2020 until 28 October 2020.

Ordering process:

- *Out-of-stock moments*
  The out-of-stock moments are measured by the number of double cards on the electronic order board. If both cards are placed on the electronic order board on the same day, it means that the product is out-of-stock. The total number of out-of-stock moments over the period January until the end of October was 15826 times, which comes down to on average, 52 times per day and 12.88% of all cards placed in that period.

- *Late placements*
  The calculation of the late placements is done by checking how many product cards are placed shortly, in this case within 90 minutes, after the ordering moment. This is checked per delivery route since every delivery route has its specific ordering moment of the electronic order boards. 9.10% of all the ordered goods are ordered within 90 minutes after the ordering moment during weekdays, and on the weekend even more, namely 9.63%. Especially the departments that are in the red delivery route place their cards shortly after the ordering moment a lot, namely 14.63%. The percentage of late placement over all the ordered goods is 9.19%.

- *Returns due to too early placed cards*
  The returns are kept in Oracle, the ERP-system that is used, and shows which products in which amounts are returned and placed back in the warehouse. In this way, it is easy to trace how many times product cards are placed too early and the products should be taken back to the logistics department. According to Oracle, 738 times did the nurses place a card too early over the past period, which comes down to 2.5 cards per day. However, since January 2, the new head of the logistics department determined that the logistics employees do not have to take their supplies back when they arrive at the department and there are still products in the bin. Therefore, this KPI is not one of the priorities of MST and this assignment.

Picking process:

- *Estimated picking time (per order line)*
  An estimate of the picking time can be made by checking the time between the release of the orders and the first product that is delivered. The release times and delivery time per product can be checked, so this can be used to calculate the picking time per route. The number of minutes that indicates the picking time can be divided by the number of order lines per delivery route. This gives the picking time per order line, as can be seen in table 2.7.

Route	Estimated picking time (minutes)	Estimated picking time per order line (seconds)
Orange	102	26
Blue	91	31
Red	97	30
White	82	35
Green	87	47
Average	93.4	33

TABLE 2.7 – PICKING TIME ESTIMATION PER ROUTE

- *Returns due to picking mistakes*
  The same holds for the returns due to picking mistakes as for the returns due to too early placed cards. The ERP-system shows which products are returned and in this way, it is possible to check which return is due to a picking mistake. Oracle shows that there were 1214 inventory corrections due to picking mistakes, which comes down to more or less 4 products per day However, the introduction of scanners at the picking department since January 2 made it more difficult to pick the wrong SKUs, since every SKU has to be scanned. Therefore, this KPI is not one of the priorities of MST and this assignment.

Delivery process:

- *Average delivery time per order line (seconds)*
  The delivery time can be calculated by checking the interval in which the first and the last product of a route are delivered. This shows the delivery time. It is possible to check the delivery time per department, floor, and delivery route. The delivery time that is chosen for the purpose can be divided by the number of order lines that match the specific unit of measurement.
  The average delivery time per route is shown in table 2.8, below.

Route	Average delivery time per order line (seconds)	Total average delivery time (minutes)
Orange	74	426
Blue	42	277
Red	49	320
White	50	342
Green	54	344
Average	53.8	341.8

TABLE 2.8 – AVERAGE DELIVERY TIME PER ORDER LINE (SECONDS) AND TOTAL AVERAGE DELIVERY TIME (MINUTES)

This shows that the orange route is the route with the largest number of products and most busy departments. The average delivery time per order line should be decreased since this also influences the total average delivery time, which also should be deceased. Another reason why this should be lower is that the average delivery time per order line also included the time it takes while walking between departments. If a supplier only delivers one product per department, the movement time between the departments is relatively very high compared to the time to resupply the bins, which increases the average delivery time per order line. If a supplier restocks fewer departments but takes more products with him, the average delivery time per order line decreases, which leads to an increase in efficiency.

- *Total average delivery time*
  The total delivery time is the time it takes before the last product of a delivery route is delivered. This should be less than 8 hours (480 minutes) since MST sets this goal for themselves. The current total average delivery times are also shown in table 2.8. Since the averages of the total delivery times are all below 480 minutes MST can state that they are performing according to their standard. However, almost 35% of the days the delivery at the orange delivery route takes longer than 480 minutes. This is relatively high, especially we compare this to for instance the blue route, on which 7% of the days the order arrives too late (after 8 hours).

- *Products delivered per delivery per department*
  The number of products that are delivered per department indicates how efficient the delivery run is. If the supplies always deliver a small number of products to the departments, it might be smart to consolidate the orders for several days and deliver a full cart to a department. The number of products that are delivered per day per department can be calculated by the data out of Oracle.
  Over the whole period, on average 4 departments per day receive just one product. 50% of all orders have 10 or fewer products on the picking list and 90% of all orders have 28 products or less on their picking list. The most common amount of delivered products per department is just one single product. Almost 7% of all orders contain just one product, which is not efficient and too high. Table 1.1 also shows how many times a specific number of products is picked over from January 2020 until the end of October 2020 This number should be decreased to improve efficiency and is one of MST's priorities.

The goal of MST is to minimize the deliveries with just one or two (and maybe not even critical) products. Therefore, the bottleneck KPI is *the number of products delivered per delivery per department*. If this KPI is improved, several other KPIs, like the average delivery time per order line, the total average delivery time, and the picking time is also improved. This has a positive effect on the efficiency of the in-house supply chain at MST. Next to that, the out-of-stock moment should be minimized, especially for several critical SKUs at the departments. Since the main goal in the hospital is to treat patients well and provide good quality of care, several critical SKUs can never be out-of-stock. Therefore, this KPI should also be improved significantly.

2.5 Conclusion

This chapter explained in which context the assignment takes place, which core problems should be tackled and which KPIs measure the efficiency, and how the KPIs should be changed.

The following research questions were addressed and answered:

1. **How is the in-house supply chain at MST organized?**
   1.1. *How is the ordering process organized and which problems are identified?*
   The ordering process is organized by the use of electronic order boards. The nurses at the departments work with a Kanban two-bin system. When a bin is empty, the product card belonging to that bin is placed on the electronic order board. Every day, at a fixed moment, the electronic order board is read out and the orders are sent to the back office at the logistics department. They print the orders and hand them over to the order pickers.

   1.2. *How is the picking process organized and which problems are identified?*
   The order pickers receive the orders from the back office of the logistics department. The orders are separated by the fact if the SKUs on the list are sterile non-sterile since these SKUs are in different warehouses. The pickers take the orders with them to the right warehouse, pick the products and hand them over to the suppliers.

   1.3. *How is the delivery process organized and which problems are identified?*
   The suppliers take a cart with goods, that are packed in crates, of a specific floor. When they arrive on the right floor with the cart, they go to the departments that ordered products. When they arrive at the departments, they activate the "delivery mode" of the electronic order boards. When the delivery mode is activated, the cards from which the products are restocked can be taken from the electronic order board and placed back in the bin. When the delivery mode is deactivated, the current status of the bins is reviewed and updated in the system.

2. **What is the current efficiency of the supply chain?**
   2.1. *Which KPIs are currently in place?*
   2.2. *Which processes influence which KPIs?*
   - **Ordering process**
     - Out-of-stock moments
     - Late placements
     - Returns due to too early placed cards
   - **Picking process**
     - Picking time
     - Returns due to picking mistakes
   - **Delivery process**
     - Average delivery time per order line
     - Total average delivery time
     - Products delivered per department

These are the KPIs that measure the efficiency of the supply chain. The following research questions show their values and which KPIs should be improved as soon as possible.

2.3. *How do the supply chain and the different processes perform on these KPIs?*
2.4. *Which KPIs need the most attention (the bottleneck) and which KPI can be improved the most?* MST is performing quite adequately on several KPIs. However, improvement is always possible and several KPIs need attention, to increase the efficiency of the supply chain. Table 2.9 shows the measured values of the KPIs.

Process	KPI	Measurement unit	Value	Priority for MST (High/Medium/Low)
Ordering process	Out-of-stock moments	% of all placed cards	12.88%	High
	Late placements	% of all placed cards	9.19%	Medium
	Returns due to too early placed cards	# times it happened (Jan 2020- Oct 2020)	738	Low
Picking process	Estimated picking time per order line	seconds	33	Medium
	Returns due to picking mistakes	# times it happened (Jan 2020- Oct 2020)	1214	Low
Delivery process	Average delivery time per order line	Seconds	53.8	High
	Total average delivery time	Minutes	341.8	Medium
	Products delivered per department	% orders containing 10 products or less	50%	High

TABLE 2.9 – SUMMARY OF KPI VALUES

The bottleneck KPIs which need attention are *Products delivered per department* and *Out-of-stock moments*. These KPIs need improvement, which eventually leads to improvements in the in-house supply chain.

3. Literature Study

The literature study is used to obtain information about parts of your research that might already be investigated or researched by others. This literature study is aimed at finding models and methods that can be to improve the efficiency of the processes in the in-house supply chain at MST.

The literature study should at least answer the following sub-questions:

- *What are the main differences with other hospitals, how does MST perform compared to other hospitals and how did other hospitals optimize their supply chain according to the literature?*
  The stated question is sub-question 1.4. This question should help to point out the differences between the design of the in-house supply chains at different hospitals.

- *What is in the literature about readout moments and ordering via electronic order boards? How do other firms deal with this?*
  Sub question 3.1 should give insights into how other firms determine the order moment. Which ways are there to determine this and how to apply this knowledge to the process at MST.

- *What is in the literature about the use of the two-bin system in hospitals? How do other firms deal with this?*
  This question, 3.2, should give insights about different designs of supply chains that use electronic order boards or order with, for example, RFID chips in product cards. This can be very useful since there MST is the only hospital in the Netherlands that works with the electronic order boards and the knowledge about working with these electronic order boards can only be gained out of other industries and branches. This newly obtained knowledge should be used to improve the in-house supply chain at MST.

- *To what extent is the number of products per bin correct according to the calculations of the Kanban and two-bin system?*
  In order to determine to what extent the number of products in the bin is correct, there is a need for knowledge out of the literature that gives insights in the way of calculating the number of products per bin. This is dependent on the inventory policy of MST. This is sub-question 3.6.

- *How do other firms organize their picking process in combination with electronic order boards and how are the products located in the warehouses?*
  Sub-question 4.1 is about the picking process at other companies that use electronic order boards, if there are differences. Next to that, how are the warehouses designed and how are the products allocated in the warehouses.

- *Which methods are there to develop the delivery schedules?*
  The last question that is solved, based on the literature, is sub-question 5.2. This question provides several methods that help develop an improved delivery schedule for MST.

Section 3.1 provides an overview of the different internal supply chains of hospitals. Optimization strategies for ordering and storing the goods at the point-of-use are described in section 3.2 since there are a lot of different techniques and strategies to optimize different parts in the supply chain. Sections 3.3 and 3.4 describe optimization techniques for storing the products in the central warehouse and the delivery of the orders. A conclusion of this chapter is drawn in 3.5, which describes which models are used to optimize the efficiency of the in-house supply chain in the following chapters.

3.1 In-house supply chains and supply chain management at other hospitals

The past decades have seen an increasing amount of research on the healthcare supply chain (Elmuti, Khoury, Omran, & Abou-Zaid, 2013; Kim & Kwon, 2015; Narayana, Pati, & Vrat, 2014; Volland et al., 2017). Furthermore, the healthcare sector stands out because of its many internal supply chains required to get a wide range of products to different users (Bélanger, Beaulieu, Landry, & Morales, 2018; Landry & Beaulieu, 2013). The distribution of all the different medical and non-medical supplies has become a complex network of support services (Bélanger et al., 2018). Therefore, inventory management at hospitals has become more important for healthcare organizations. There are different ways in the distribution of supplies in hospitals to the point-of-use. In most hospitals, among which MST, goods distribution is designed as a multi-echelon inventory system, where the central warehouse delivers goods to the point-of-use (the departments) locations, which are closely located to the patient care units, as can be seen in figure 3.1 (Volland et al., 2017). Another common distribution method is the 'semi-direct delivery', where suppliers skip the central warehouse and go directly to the point-of-use location. Another distribution method is 'direct delivery', where suppliers deliver the goods Just-In-Time (JIT) according to patient demand. It could also be the case that the warehouse at the point-of-use is there to replenish a second warehouse, also called a secondary stockroom, at the point-of-use, but this distribution method is not used very often (Bélanger et al., 2018). It is hard to keep track of inventories if hospitals make use of these secondary stockrooms, but the new RFID technologies can break down these barriers (Bélanger et al., 2018; Landry & Beaulieu, 2013). Studies show that replenishments from department warehouses are superior to direct delivery (Bélanger et al., 2018). This means that the current situation at MST with the use of warehouses at the departments is, according to studies, potentially one of the best distribution systems if used properly.

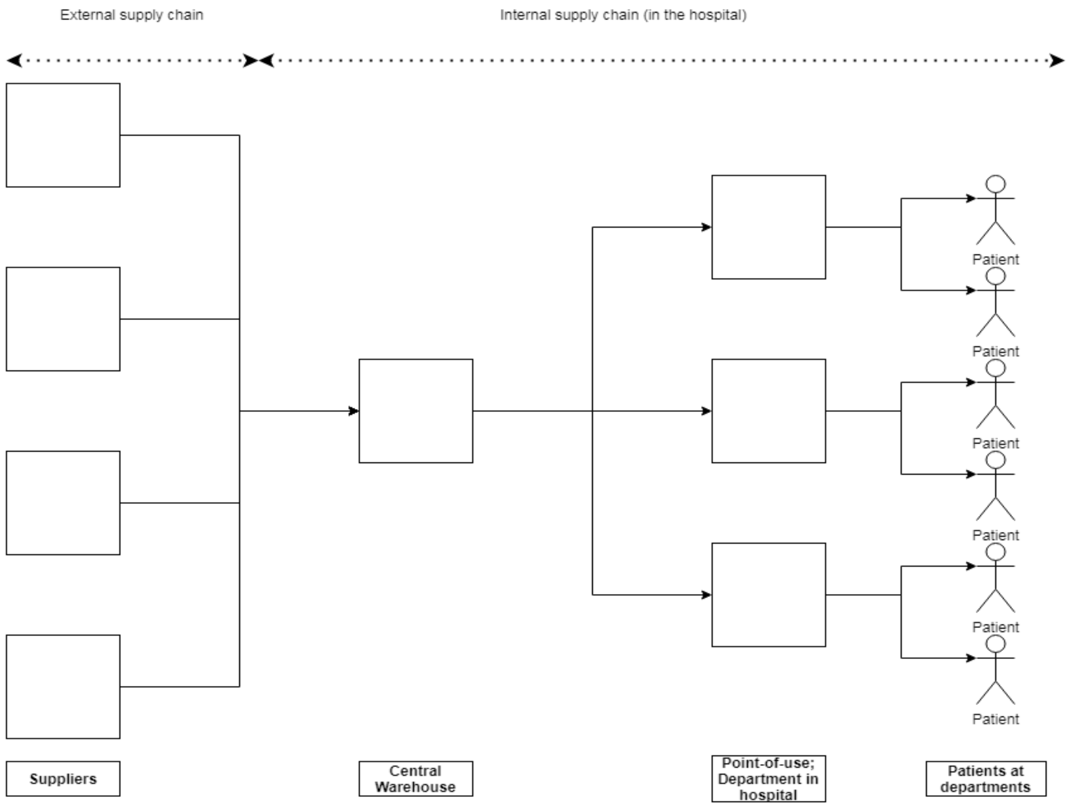


FIGURE 3.1 – THE SUPPLY CHAIN OF GOODS FOR THE HOSPITAL.

The setup of hospital inventory systems and inventory management is to some extent comparable to other industries (Volland et al., 2017). Due to the storage space constraints at point-of-use and the point-of-use data of the inventories at the department, respective inventories are comparable to retail and production environments (Little & Coughlan, 2008; Varghese, Rossetti, Pohl, Apras, & Marek, 2012). Therefore, Lean is also widely used in the healthcare sector. Currently, Lean is a trending topic in healthcare management and the management of the internal supply chain optimizations in hospitals (Gayer et al., 2020). Hospitals have been investing in lean management techniques and principles that made their supply chains more efficient reached considerable savings in terms of costs, and reduced inventories by nearly 80% (Rivard-Royer, Landry, & Beaulieu, 2002). The use of Kanban in hospital inventory management had, for instance, a large impact on the reduction of decentralized inventories in hospitals and is used later on in combination with the two-bin system (Landry & Beaulieu, 2010; Rivard-Royer et al., 2002). A large university hospital, located in southern Brazil, managed to improve its logistic processes by looking at the 7 wastes, which are defined by Ohno (1988) and described by Sutherland and Bennett (2007) in a logistics perspective. They adjusted the descriptions of these wastes to their hospital environment, as can be seen in table 3.1 (Gayer et al., 2020). These wastes need to be minimized to increase the efficiency of the supply chain. Gayer et al. (2020) developed a model that improved the identification of the logistical problems, which in the end lead to waste reduction. Lean logistics in healthcare settings can significantly contribute to hospitals (Gayer et al., 2020; Waring & Bishop, 2010).

7 Wastes in lean logistics	Description of each waste
Overproduction	It is the delivery of materials before they are needed.
Delay/Waiting	It is any delay between the end of one activity and the start of the next activity.
Transportation/Conveyance	Unnecessary transport that results in added costs.
Motion	Unnecessary movement of people.
Inventory	Any logistics activity that results in more inventory being positioned than needed or in a location other than needed.
Space	Use of space that is less than optimal.
Errors	Any activity that causes rework, unnecessary adjustments, or returns.

TABLE 3.0.1 – 7 WASTES BY OHNO DESCRIBED IN A HOSPITAL ENVIRONMENT, ADAPTED FROM GAYER (2020)

This table should also be considered when developing a solution since these wastes should be minimized to increase the efficiency of the supply chain. Several of these wastes are also described in the core problems that were stated in section 1.2.

3.2 Optimization strategies for ordering goods and storing them near the point-of-use in hospitals

Optimization strategies and techniques are useful further in this research to tackle the core problems. The policy that is used when storing the goods at the point-of-use is important to prevent stock-outs at the point-of-use and to keep track of the costs to hold the inventory. Next to that, this model can also be used to determine the optimal interval between two readout moments. These topics are described in 3.2.1. Another important model is the economic bin quantity model, to calculate the desired number of products per bin. Since the current bin quantities are not optimal and these bin quantities determine eventually when SKUs are restocked, the bin quantities need to be optimized. This is explained in 3.2.2.

3.2.1 Inventory policies at department warehouses near point-of-use

One of the most discussed topics in hospital inventory management is the choice of inventory policy (Bijvank & Vis, 2012). Most publications about inventory policies apply a periodic inventory review policy since this is in line with the current practice in hospitals (Volland et al., 2017). However, by the ongoing modernizations and development of new technologies, newly introduced hybrid policies (a combination of periodic reviews and continuous reviews) make their way into hospital inventory management since these are based on a cost-efficient periodic review and are possible since, for instance, RFID chips can give a more up to date status of the inventory at the departments (Volland et al., 2017). MST is working with a combination of Kanban cards and the two-bin system, and that is why the inventory replenishment policies for these subjects are analyzed. Several models are described in this section. The models that are used for the research are explained in the section where they are used to optimize the process step.

MST is currently working with a two-bin system, which is commonly used in practice in hospitals. The two-bin replenishment system applies two equally sized bins in the care unit. If one of the bins is empty, replenishment is triggered, which is mostly relying on Kanban logic (Rosales, Magazine, & Rao, 2015). The paper of Rosales et al. (2015) describes how to optimize the two-bin replenishment system. The difference between working with the two-bin system and the traditional inventory replenishment policies is that the traditional policies are on unit level, which requires unit-level demand tracking and inventory control parameters per SKU, as the order-up-to-levels and reorder (Khouja & Goyal, 2008; Rosales, Magazine, & Rao, 2014). The number of SKUs per bin should be based on the number of desired inventory turns per year. However, Inventory par levels often reflect the desired inventory levels of nurses and physicians and are not calculated with the use of data. The reorder quantity, for instance, is most of the time based on experience and not on data (Dubey, 1991). This is one of the typical obstacles when implementing an inventory policy. Therefore, the number of SKUs per bin should be recalculated. Since the inventory is tracked and reordered with RFID-tags in Kanban cards that are triggered when placed on the electronic order boards, the challenge is how to determine the right time to replenish the warehouses at the departments without decreasing the quality of care (Bélanger et al., 2018).

Traditionally two-bin inventory systems used in hospitals are replenished using periodic reviews (Landry & Beaulieu, 2010), with empty bin replenishments carried out at the beginning of every review cycle, usually once a day. This situation also holds at MST. Therefore, MST is one of the hospitals that, while still using their traditional two-bin system, can improve their inventory management practices by parameter optimization or policy improvement (Rosales et al., 2015). If a two-bin system is used, the inventory policy that is used for the replenishments can be mapped in different ways. Inventory models that are the closest to the periodic review of the two-bin systems are the (nQ,r,T) replenishment policies (Hadley & Whitin, 1963). This means that after every period T an order is placed whenever the inventory position of the products in the bin falls below the reorder point (r). The number of products that are ordered is always a multiple of Q, such that the inventory position (IP) after restocking is greater than the reorder point. Another way that the two-bin system inventory policy for replenishments can be mapped is the (s,Q) policy, which is more recently developed (Mustafa Tanrikulu, Şen, & Alp, 2010). In this policy, where $s = \{s_1, s_2, \dots, s_N\}$ representing a vector of reorder levels for each SKU in the system (N is the total number of SKUs in a department's warehouse using the two-bin system) (Elmuti et al., 2013). In an inventory position that falls under any s_i, the replenishment is triggered, and the bin is refilled with quantity Q_i. However, these inventory policies do not deal with the Kanban-type two-bin inventory system that MST uses (Rosales et al., 2015).

Rosales et al. (2015) studied data out of a hospital that works similar to MST and developed a model to optimize the inventory policy at hospitals. These models aim to find the optimal review cycle, together with the optimal costs for the periodic review cycle and the model minimizes the steady-state average cost per unit time together with the optimal value of empty bins before replenishment should be done. The unit of analysis is on bin level and not on unit level (per piece) since the hospital that was studied works with the two-bin system captures the demand also on bin level. Next to that, the hospital uses a replenishment trigger that when a certain number of primary bins is empty or whenever the primary bin and secondary bin of an SKU are empty, they are replenished.

Periodic review

Periodic review means that the inventory status of products in a departments' warehouse is checked after a certain period (T). The periodic review model formulates the expected stock-out costs for one representative SKU and then scales this cost using the number of SKUs in the system. This is valid since we assume that every bin has an equal consumption rate. This model tries to obtain the stock-out cost for one representative SKU by first understanding the inventory profile. The inventory status is checked periodically every T time units, which is T = 24 hours for MST. After a delivery lead time L (the time between the ordering and delivery moment), the order of one bin is received, and the on-hand inventory and the inventory position are equalized to two bins. Before the next review period ends, this bin should be replenished. Figure 3.2 shows the inventory profile at MST after T+L.

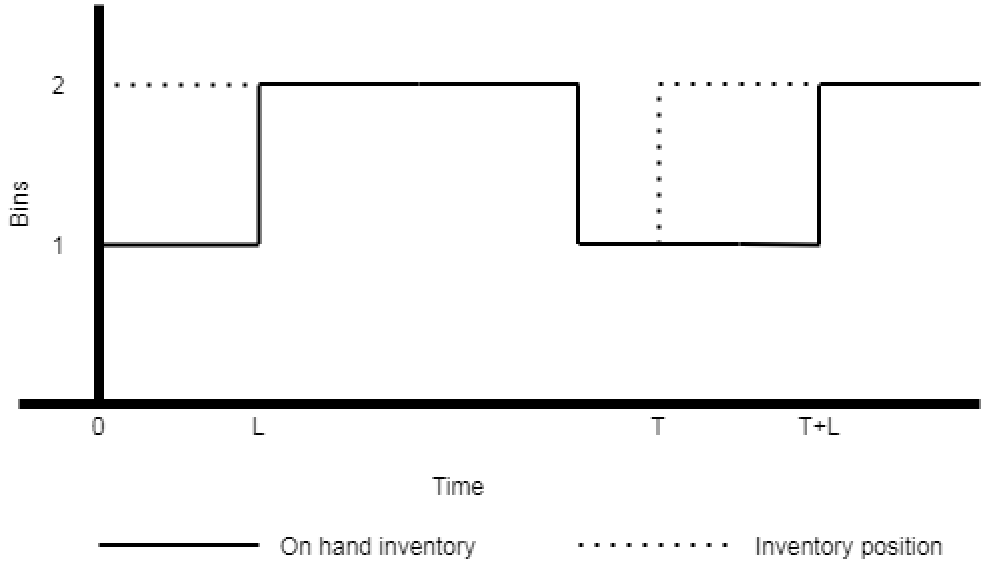
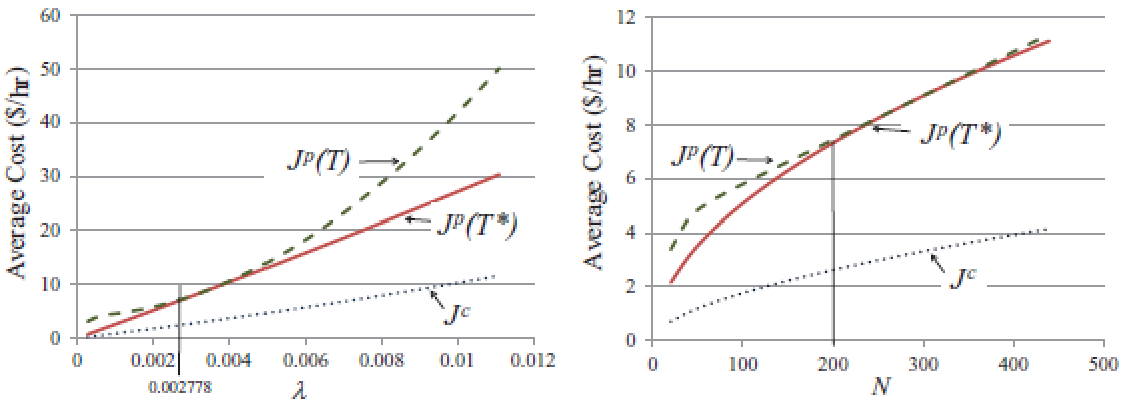


FIGURE 3.2 – VISUALIZATION OF THE INVENTORY PROFILE FOR PERIODIC REVIEW OF THE TWO-BIN SYSTEM

The average cost per unit time for one renewal cycle of the periodic two-bin system is used to estimate the long-run average cost per unit time. This model first calculates the total stock-out costs over the interval t, which is again used to calculate the expected stock-out costs of a single SKU during interval t = L and t = T – L. Since this is first calculated for one item, it is scaled to multiple items after the last step. After that, the expected ordering costs per replenishment cycle are calculated, which are necessary to calculate the total shortage costs. All these formulas combined are needed to find the optimal review cycle T*, with the incurring optimal costs for the periodic review interval.

This model yields, according to Rosales et al. (2015), lower average costs for the optimal periodic review time T* than for the T that they have already worked with for a long time. They show the difference in terms of cost against the changes in bin consumption, changes in the number of unique SKUs per department warehouse, changes in stock-out cost, changes in replenishment cost. Examples are shown in figures 3.3a and 3.3b, where $J^P(T)$ denotes the cost for a review period T and where $J^P(T^*)$ denotes the optimal cost for the optimal review period T*. The explanation of the parameters in figure 3.3 can be found in section 4.4. For (almost) every value of these different parameters, the optimal periodic review time T* is always less expensive than the T used before in real-life. Therefore, this model is quite interesting to use for MST since they work in a comparable environment with more or less the same process steps.



(a) Impact of changes in λ (b) Impact of changes in N

FIGURE 3.3 – THE IMPACT OF CHANGES IN THE BIN CONSUMPTION AND NUMBER OF SKUS ON THE AVERAGE COSTS PER HOUR (ADAPTED FROM ROSALES ET AL. (2015))

Continuous review

The difference between the periodic and continuous review is that under periodic review, every empty bin is replenished at the start of a replenishment period, while under continuous review the bins are replenished when a certain number of primary bins is empty or when an SKU has an empty primary and secondary bin. An advantage of the continuous review is that it has larger benefits, namely over 50 percent reduction of the costs, than the periodic review. However, it is harder to implement, since the tasks for material management are more difficult to plan since you never know when a certain department needs to be replenished (Rosales et al., 2015). This continuous review model is not explained extensively since it is very hard to implement in practice, and MST would like to have a solution that can be used in practice.

3.2.2 Bin quantity two-bin replenishment system

The bin quantity, which means the number of products per bin, is important since it has a lot of influence on the number of replenishments that should be done for a department. There are a lot of techniques that can optimize the quantity to be ordered, but since MST is working with a two-bin system these economic order quantity (EOQ) techniques cannot be used directly (Kanet & Wells, 2019). The two-bin system requires, as the name also says, two bins with the same product. The number of items of an SKU that are in the bin needs to be determined. The scientific literature sometimes describes the two-bin system as a system with two unequal-sized bins. However, MST chose to have an equal quantity of SKUs per bin since there is empirical evidence that shows the prevalent simplification found in practice that both bins contain the same number of products (Bélanger et al., 2018; Kanet & Wells, 2019; Rosales et al., 2015)

The economic two-bin Kanban model by Kanet and Wells (2019)

To calculate the desired number of products in a bin, Kanet and Wells (2019) developed a formula that selects the number of products in a bin that minimizes the total costs. Several parameters are needed to calculate this economic bin quantity (EBQ). Normally EBQ is calculated for situations that monitor the bins continuously, which means that the EBQ works best for the continuous review policy. However, the two-bin system used at MST is using a periodic review policy. This means that the results are not as optimal as for the continuous review, but are still useful. The initial setting for two bins is *2B* units, where *B* is the number of units in a bin. The nurses take products from the bin with demand rate *D*, and when that demand rate reached level *B*, an order is placed, which is expected to arrive L time units later.

First, the average inventory level is calculated, which again is needed to calculate the total relevant costs. The total relevant costs consist of the average inventory costs and the costs to replenish a bin.

To assure that the customer service level (CSL) is met the following constraint holds: $B \geq DL + Safety\ Stock$. Assuming that the demand is normally distributed with a standard deviation σ, z_α is the point on the standard normal distribution such that $P\{Z > z_\alpha\} = \alpha$. Recalling that L is the lead time until the products are delivered, results in $ss = z_{CSL}\sigma\sqrt{L}$. Thus, when $B > DL + ss$, the two-bin Kanban approach affords the added stock-out protection of $B - DL - z_{CSL}\sigma\sqrt{L}$ units of safety stock. These terms are used to calculate the expected total periodic cost. The Economic Bin Quantity (EBQ) can be calculated by taking the derivative of the formula for the total relevant cost and setting it to 0.

The paper of Kanet and Wells (2019) explicitly states and shows that the use of the normal EOQ formula results in higher costs than the EBQ formula. The optimal bin size yields the minimized average total relevant costs and would therefore be interesting for MST to use when calculating the bin quantities. This is shown in figure 3.4, where the EBQ(2) yields the lowest total relevant cost for the 2-equal bin system, TC_2, according to the black line in figure 3.4. The explanation of the parameters and variables in figure 3.4 can be found in section 4.3. The red dotted line shows the expected total periodic costs. This model is relatively easy to use and the results can be immediately implemented in the MST environment and are therefore very interesting to use.

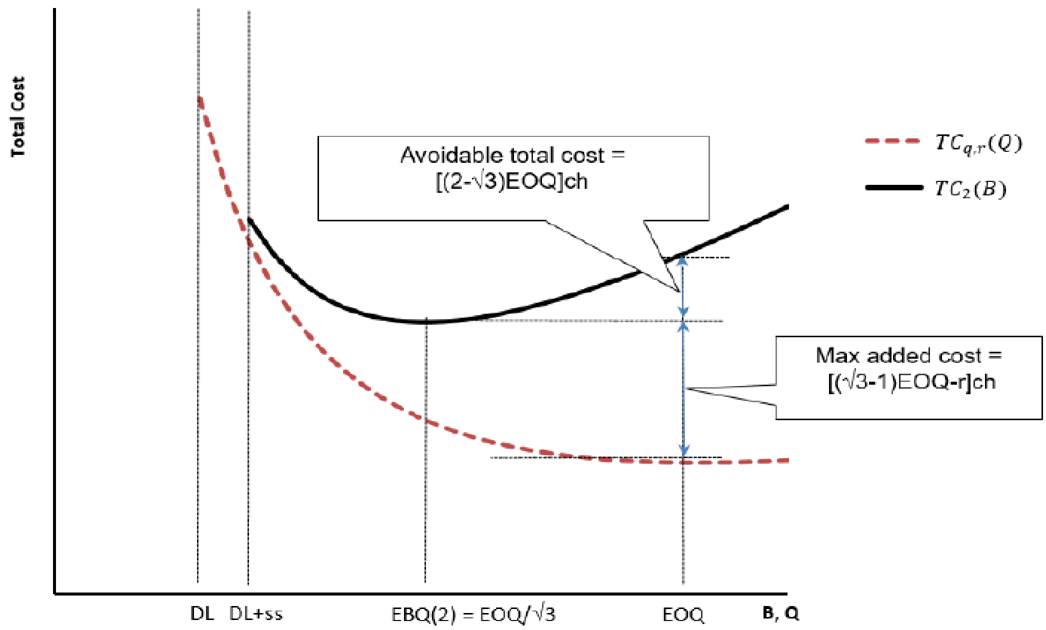


FIGURE 3.4 – THE ECONOMIC BIN QUANTITY (EBQ) COST MODEL (ADAPTED FROM KANET AND WELLS (2019))

3.3 Optimization strategies for the storage of goods in the central warehouse and the picking process

The picking process is one of the most time-consuming activities in the supply chain, the most labor-intensive activity in the warehouse, and contributes most to the operational costs in a warehouse (De Koster, Le-Duc, & Roodbergen, 2007; Roodbergen & Vis, 2006). The time it takes to walk between two products in the warehouse is the most time-consuming activity while picking, as can be seen in figure 3.5 (Tompkins, 1997). To minimize this, the locations of products in the warehouses need to be optimized, according to demand for instance. The allocations of products to storage locations in warehouses are discussed in 3.3.1 until 3.3.3. Different methods are to allocate products to storage locations are examined, summarized, and compared to each other. Next to the fact that the picking time should be minimized, the number of wrongly picked SKUs is also a problem since they result in invaluable extra actions. However, since the KPI that measures the wrong picks has low priority now for MST, this is not part of the literature study.

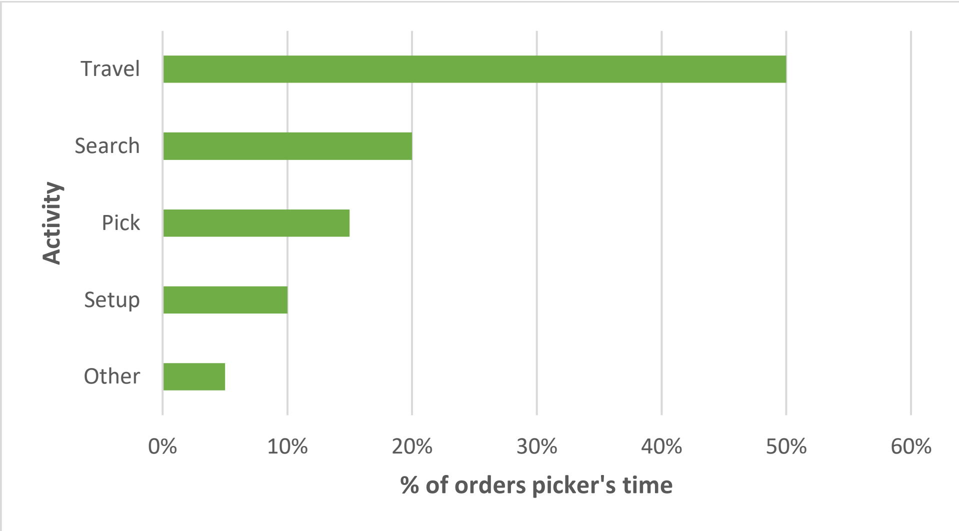


FIGURE 3.5 – DISTRIBUTION OF AN ORDER PICKER'S TIME

3.3.1 Cube per Order Index

The Cube per Order Index (COI) rule is the most well-known example in literature and was first introduced by Heskett (1963). This slotting strategy is one of the most implemented strategies in practice since it is easy to use and generates an adequate solution relatively fast. However, several papers, like the paper of de Ruijter, Schuur, Mantel, and Heragu (2009), state that the COI is one of the least improving slotting strategies. In special when it is compared to for instance Order Oriented Slotting (OOS) and interaction frequency (QAP) heuristics. The difference between the COI and OOS for instance is that the COI is SKU oriented, and the OOS order oriented. The COI does not look at the correlation between products, but just at the popularity of the products. However, COI can perform adequately when there are a lot of orders with a small number of SKUs on them (Mantel, Schuur, & Heragu, 2007).

The COI rule allocates the fast movers close to the Input/Output-point (I/O-point). This is the point where the pickers enter the warehouse and deliver the picked orders to. As already mentioned, the COI does not even find a near-optimal solution, but it does find a solution that is, in most cases, better than random storage allocation.

3.3.2 Order Oriented Slotting ILP model and interaction frequency heuristics

Order oriented slotting is a dedicated storage strategy introduced by Mantel et al. (2007) and is based on earlier work by Frazele and Sharp (1989) on correlated storage of SKUs. All storage strategies described in this section are from the paper of Mantel et al. (2007). OOS is about multi-SKU orders instead of individual location visits and is the only slotting strategy for which the way of allocating SKUs to storage locations is directly related to the way of calculating the traveling times. Currently, the pickers receive a lot of orders with a small number of SKUs. However, that is one of the core problems that is tackled, which means that there are larger orders in the future, and therefore OOS is useful.

OOS assumes that an empty warehouse is given, there is a set of orders to be picked and a routing policy applied. OOS stores the ordered items in the warehouse in such a way that the total routing time needed to pick all the orders are minimized (Mantel et al., 2007). Another assumption made is that the orders are not batched, so the pickers pick single orders. The OOS is solving two sub-problems simultaneously, namely the allocation of SKUs to storage locations, and the execution of the order picking tours for all the orders. Another advantage of using the OOS is that it is by no means restricted to the shape of the warehouse.

The goal of the OOS is to minimize the distance traveled to pick all orders and is solved by the means of an Integer Linear Programming (ILP) model. For small to moderate size warehouses, the ILP formulation can solve this allocation problem to optimality. However, for real and large size warehouses it is better to use heuristics since the OOS is an NP-hard combinatorial optimization problem, which is generally hard to solve and takes a lot of computation time. These heuristics can solve the problem close to optimality (between 2% and 6% above the optimum), and a significantly smaller computation time.

OOS works with a simulated annealing algorithm. The idea of simulated annealing is that you accept solutions that are slightly worse than the best solution. In this way, you search in a larger solution space, which improves the chance of finding the optimal solution. The OOS needs a starting solution, with a certain traveling time which does not have to be the best solution. After that, in each iteration, the simulated annealing swaps two SKUs and recalculates the difference in total travel distance. Improvements in traveling time are always accepted, and slightly worse solutions are also accepted with a specific chance. As already mentioned, if you have to work with a lot of products, the computation time is very large, and heuristics would approach the optimal solution.

One of these heuristics is the Interaction Frequency-based quadratic assignment (QAP) heuristic. These heuristic forces items that frequently occur in the same order to be close together, while at the same time the fast movers are not allocated too far from the I/O-point. The QAP is another NP-hard combinatorial optimization problem, for which it is extremely difficult to obtain exact solutions. This heuristic finds a near-optimal solution, but it again takes a significant computation time. This heuristic can also approximate an optimal solution by using simulated annealing the same way as used for the OSS, but with significantly less computation time, which makes this heuristic interesting.

The second heuristic is the Interaction Frequency heuristic. This heuristic first allocates all SKUs that never share an order with other SKUs, in such a way that their distance to the I/O-point is in line with their demand. The Interaction Frequency heuristic is also used as a good starting solution for the Interaction Frequency QAP. Next, the nonnegative interaction frequencies are ranked in decreasing order. The heuristic processes the sequence of interaction frequencies, dependent on the fact whether the two next SKUs are both allocated to a storage space or not. If they are both not placed, they are allocated to two free locations as close together as possible, and as close to the I/O-point as possible. If only one SKU needs to be placed, this SKU is placed as close to the other SKU such that its distance to the I/O-point is in accordance with its demand. If there is no suitable location, go to the next interaction frequency. This heuristic does find an adequate solution in a relatively short time, compared to the other methods in this section.

Figure 3.6 shows the difference in reductions for the COI, OOS, Interaction Frequency Heuristic, and the Interaction Frequency-based QAP heuristic. This shows indeed that the OOS is the method that reduces the travel distance the most, however against large computation time.

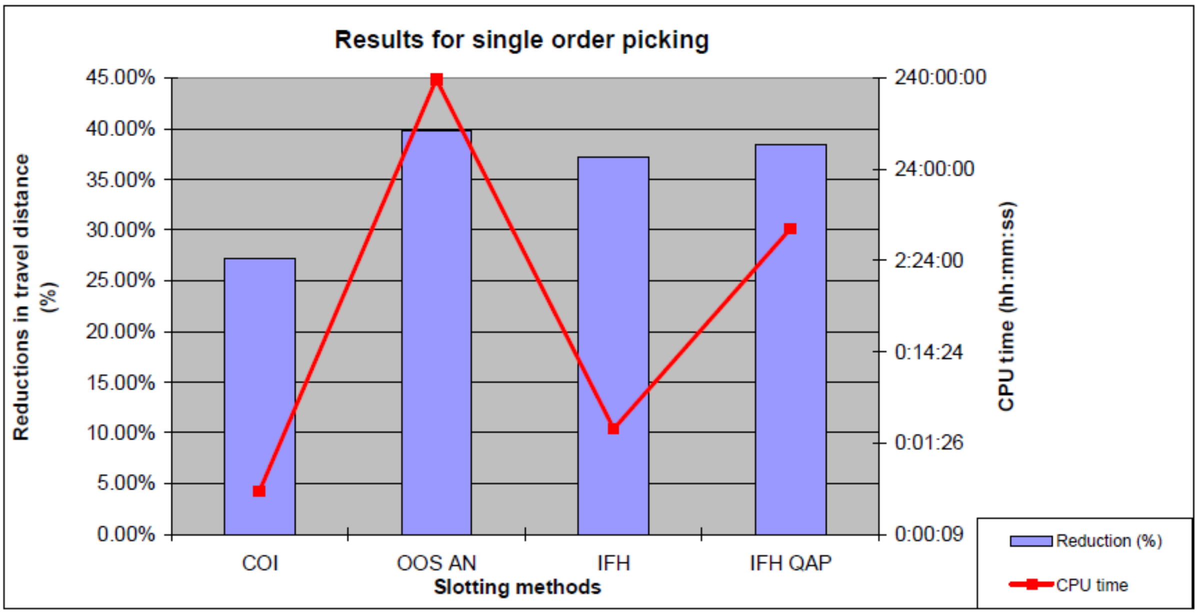


FIGURE 3.6 – REDUCTIONS IN TRAVEL DISTANCE AND COMPUTATION TIME PER STORAGE STRATEGY (ADAPTED FROM DE RUIJTER ET AL. (2009))

3.3.3 Class-Based Storage

The last slotting strategy is a mix of a random and dedicated storage strategy. This one is called Class-Based Storage (CBS), where the SKUs are grouped into classes. Each class is assigned to a dedicated storage area, but within that class, every SKU is randomly assigned to a location. One of the reasons that CBS can work well is that it is based on the principle that 20% of the items are 80% of all the order lines. This is also the case at MST, and therefore can be a fast and adequate strategy to redesign their warehouse.

The SKUs are partitioned by the CBS into several storage classes by demand and randomly assigns warehouse locations within the storage class area (Petersen, Aase, & Heiser, 2004). The storage class containing the largest volume of SKUs is located nearest to the I/O-point. There are several ways to divide the SKUs into classes. One proposed method is to use the ABC-analysis to classify the SKUs into storage classes (Kee, 2003). ABC-analysis ranks the SKUs according to for instance demand and divides the SKUs into three classes. When the SKUs are assigned to classes, the SKUs need to be located on the shelves. There are two common ways to do this, namely within-aisle storage or across-aisle storage (De Koster et al., 2007). Examples of these ways to implement CBS are shown in figure 3.7. The paper of Yu, De Koster, and Guo (2015) calculates and optimized the number of classes needed for a finite number of products in a warehouse. They find that the optimal number of classes is commonly between 2 and 5.

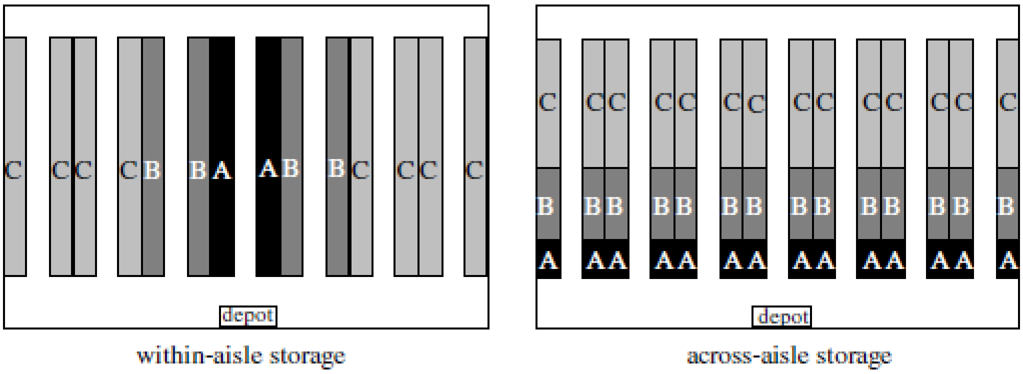


FIGURE 3.7 – TWO COMMON WAYS OF IMPLEMENTING CLASS-BASED STORAGE (ADAPTED FROM DE KOSTER ET AL. (2007))

The study of Petersen et al. (2004) compares CBS to random assigning SKUs to slots. This shows significant savings from at least 12% up to 26% in terms of picking time, as can be seen in figure 3.8.

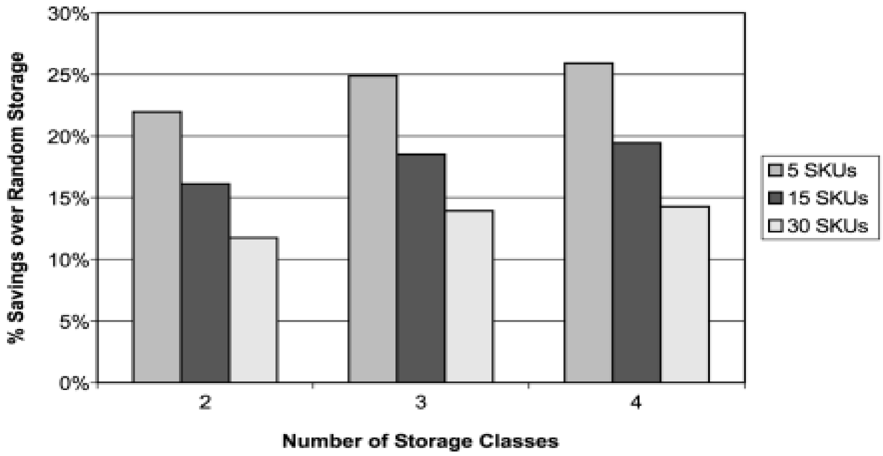


FIGURE 3.8 – COMPARISON OF CLASS-BASED STORAGE AND RANDOM STORAGE (ADAPTED FROM PETERSEN ET AL. (2004))

3.4 Optimization strategies for the delivery of goods to the departments in a hospital

The optimization of the delivery process is one of the priorities of the logistics management board. They aim at a more efficient supply chain, where delivery plays an important part.

3.4.1 Delivery based on classification of departments

One lever to efficiently manage deliveries is to categorize departments based on bin usage. Departments can be classified in several ways. Classification can, for instance, be based on four dimensions, namely patient treatment criticality, supply characteristics, inventory problems, and usage rate (Al-Qatawneh & Hafeez, 2011). They did a multi-criteria classification based on criticality, cost, and usage value. Of course, SKUs can also be classified. SKU classification is a commonly used method to base the delivery schedule on. However, this is not used in combination with the two-bin Kanban inventory system.

Classification of departments (or SKUs) based on demand and value can easily be done by ABC analyses, while classification based on the criticality of the SKUs is commonly done with a VED (Vital, Essential, and Desirable) analyses (Volland et al., 2017). The studies of Khurana, Chhillar, and Gautam (2013), Gupta, Gupta, Jain, and Garg (2007), Nigah, Devnani, and Gupta (2010), and Danas, Roudsari, and Ketikidis (2006) combine ABC and VED classification and use these on hospital inventories, with the idea to classify each SKU along a classification tree to determine its stock and inventory strategy. However, since SKU classification in combination with the two-bin Kanban inventory system is not favorable, SKU classification is not used. The use of the ABC-analysis is nevertheless explained in terms of SKU classification, but can also be applied to categorize the departments.

(Multi-criteria) ABC-analysis

ABC-analysis is a commonly used and well-developed classification method based on the Pareto Principle to determine the priority of SKUs in a company's inventory (Ravinder & Misra, 2014). Products in inventories are categorized into three classes, namely A, B, and C. The most effort should be expended on the A SKUs, which are the most important SKUs for this specific company. C SKUs often get the least attention, and the B SKUs are in-between the A and C SKUs. Traditionally, the ABC-analysis was based on the criterion of dollar volume and the principle that just a few SKUs that were in category A represented most of the dollar volume. At the other extreme, there are a lot of SKUs in category C which represent a very small part of the dollar volume. Again, the category B SKUs are in-between these extremes. The category A SKUs are usually the high-demand and high-value SKUs, whereas the category C SKUs are at the other extreme of low-demand and low-value SKUs. For the hospital, the most common practice is to categorize based on the cost per unit of the SKU.

An extension of the ABC-analysis is the multi-criteria ABC-analysis, where the categorization is not only done on the cost per unit for instance but also demand, criticality, obsolescence, etc. (Ravinder & Misra, 2014). In this way, the analysis of the SKUs is viewed from more perspectives. This results in different outcomes than the ABC-analysis that was done on one criterion since more criteria show different aspects of this SKU. Nowadays, a single criterion is no longer adequate to manage your inventories and multiple criteria have to be considered (Ravinder & Misra, 2014). A multi-criteria ABC-analysis can be done based on an AHP-analysis, which indicates the importance of every criterion and weights the importance of all the criteria compared to each other.

Normally, a multi-criteria ABC-analysis would be a fair way to classify the SKUs in inventory. Several criteria that would also be useful in hospitals like MST would be:

- (Variability of) Demand
- (Variability of) Unit Price
- Lead time (from supplier to the hospital)
- Obsolescence

These kinds of classification tools can also be used in more or less the same way to classify departments. These departments can be classified in terms of bin-usage or 'involvement in patient care', which can be seen as patient contact. Since the goal of the total hospital is to maintain high patient satisfaction and good quality of care. For instance, there is a clear difference between the patient contact of the "Thorax" department, where all the heart-related operations and consults take place, and the board of directors. It is, for instance, possible to say that the replenishments at the board of directors only take place once a week since they do not directly improve patient satisfaction or quality of care.

3.5 Conclusion

This literature study gave insight into different subjects about supply chain optimization in hospitals. The goal of the literature study was to find key insights about how to optimize the in-house supply chain. The following sub-questions should be answered:

- *What are the main differences with other hospitals, how does MST perform compared to other hospitals and how did other hospitals optimize their supply chain according to the literature?*
- *What is in the literature about the use of the two-bin system in hospitals? How do other firms deal with this?*
  The main difference with other hospitals is the use of the two-bin Kanban system at MST. A lot of hospitals work with order-up-to-levels and just one bin. However, literature shows that effective use of the two-bin Kanban system is the most efficient.

- *What is in the literature about readout moments and ordering via electronic order boards? How do other firms deal with this?*
  The literature shows several models to optimize the readout moments (reorder frequencies) of the electronic order boards. These models can be solved for periodic reviews or continuous reviews. For this thesis, the periodic review is used.

- *To what extent is the number of products per bin correct according to the calculations of the Kanban and two-bin system?*
  The EBQ can be calculated, based on the model presented in 3.2.3. This results in the optimal bin quantity based on several factors. This new bin quantity can be used to review the readout moments of the electronic order boards.

- *How do other firms organize their picking process in combination with electronic order boards?*
  There is no specific information about optimizing the picking process in combination with the electronic order boards since the picking process does not change dependent on the way of ordering. Only if the orders are placed on the electronic boards in continuous time, the picking process changes.

- *How can the products in the products in the warehouses be optimally allocated to a storage place?*
  The products can be allocated to a place in the warehouse by using the models found in the literature and stated in sections 3.3.1 until 3.3.3. With the use of these models, the products can be allocated according to several factors, which could decrease the picking time per order line in the warehouses.

- *Which methods are there to develop the delivery schedules?*
  One method to improve the efficiency of the delivery runs is to deliver based on the classification of departments. This means that all departments are not visited daily anymore but are visited depending on the number of bins used per day in the current situation.

The answers found in the literature study can be used to optimize the in-house supply chain. The next chapters go into detail about how to use the information found in the literature, and which changes need to be made to improve the efficiency of the in-house supply chain.

Table 3.2 shows which models are discussed in the literature study, and how they score on certain criteria. This table is meant to choose between all the models that are discussed on aspects that are important for this research and MST. The models that are chosen are used in the next chapters. To explain the table: '++' means that the model scores very positively on that criterion, whereas '--' means that the model is not doing well on that criterion according to the author. The models that are used are explained extensively in the chapter where there belong.

Model	Author	Process	Lowly data intensive	User friendly	Computation speed	Optimal solution	Practical significance for MST	Applicability in the current process
Periodic review inventory policy	Rosales et al. (2015)	Ordering	++	+	+	+	+	++
Continuous review inventory policy	Rosales et al. (2015)	Ordering	+	--	-	++	++	--
EBQ-model	Kanet and Wells (2019)	Ordering	++	++	++	+	++	++
Cube per Order Index	Heskett (1963)	Picking	+	+	++	--	++	+
Order oriented slotting	Mantel et al. (2007)	Picking	+	-	-	++	++	+
Interaction frequency based on QAP	Mantel et al. (2007)	Picking	+	-	+	++	++	+
Interaction frequency heuristic	Mantel et al. (2007)	Picking	+	+	++	+	++	+
Class-Based Storage	(Yu et al., 2015)	Picking	+	+	++	-	++	+
ABC-analyses	Multiple authors	Delivery	+	++	++	+	++	++

TABLE 3.2 – SCORES OF ALL MODELS DISCUSSED IN THE LITERATURE STUDY ON CERTAIN CRITERIA

The models that are used to optimize the in-house supply chain process are based on the criteria above. The choice between which inventory policy model to use is in this case based on the fact that the continuous review policy is very hard to implement in real-life. Therefore, the periodic review model is used to calculate the optimal time between two readout moments. This periodic review model can be combined with the EBQ-model of Kanet and Wells (2019). This model calculates the optimal bin size with the incurring optimal relevant costs.

The next step is to choose the model that optimizes assigning products to a storage location. There are, again, several models that can do this. However, not every model has the same outcome and significance. Since the computation time is an important aspect, the OOS simulated annealing is not used. The computation time takes at least several days to a week, which makes them not applicable. Next to that, a model with a short computation time, like the COI, is not the model that is chosen here since this model does not give the results that are expected. Therefore, the Interaction Frequency Heuristic (IFH) (QAP) and the Class-Based Storage are left, since these models yield well-performing solutions in acceptable computation time. Since the solution of the IFH is significantly better according to the literature, this heuristic is used.

For the delivery, the ABC-analysis is used in combination with common-sense methods to develop new delivery routes. The ABC-analysis determines new readout moments, where new delivery routes can improve the efficiency of the delivery itself.

4. Ordering process optimization

The ordering process of products by the nurses at the departments should be improved, in order to increase the efficiency of the in-house supply chain. Therefore, the way of working with the electronic order boards is discussed and solutions are proposed. Next to that, the reorder frequencies, which are also called readout moments, need to be reviewed again and be aligned with the economic bin quantity (EBQ). This chapter should give insights into how to improve the efficiency during the ordering process and how the readout moments can be optimized, together with the EBQ. The following research question, together with several sub-questions was asked to find out how the ordering process can be optimized:

3. **How can the ordering process be optimized?**
   - 3.1. What is in the literature about readout moments and ordering via electronic order boards? How do other firms deal with this?
   - 3.2. What is in the literature about the use of two-bin systems in hospitals? How do other firms deal with this?
   - 3.3. What are the most prominent reasons that cause a lack of efficiency?
   - 3.4. How does the readout moment affect the in-house supply chain of MST and how does it affect the workday of the nurses at the departments?
   - 3.5. To what extent is the number of products per bin correct according to the calculations of the Kanban and two-bin system?
   - 3.6. How can the readout moments be changed with the use of the models found in literature and which changes increase the efficiency?

Research questions 3.1 and 3.2 were already answered in section 3.2. The literature shows that several models can optimize the reorder frequencies, which in the case of MST are the readout moments of the electronic order boards. A model to optimize the periodic review period of the electronic order boards is used to check how the readout moments can be changed, to improve the efficiency of the delivery. Before the new readout moments can be determined, the EBQ should be calculated to check what the optimal number of products at the department is, since the EBQ has an influence on the average bin consumption and this again influences the readout moment. The continuous review inventory policy is usually more efficient, but a lot harder to implement. The literature study also shows that the two-bin Kanban system in combination with the use of electronic order boards is unique and one of the most efficient inventory systems in hospitals. However, the use of the system is very important to reach the full potential of the inventory system. That is why the users, the nurses at the departments, who place orders on the electronic order boards need to be trained in the use of the system. Their feedback and ideas about the use of the system are therefore also important. Sub-question 3.3 is also already answered in chapters 1 and 2 but is shortly repeated in section 4.1, together with the most important KPI that is influenced by the ordering process.

This chapter answers research question 3 and its sub-questions, in the same sequence as noted above. First, the most important KPI that is influenced by the ordering process is repeated in section 4.1, together with the core problems that cause the decrease in efficiency (sub-question 3.3). This is followed, in section 4.2, by the research about how the nurses work with the two-bin Kanban system and how changes in readout moments of the electronic order boards can affect the working way of the nurses (sub-questions 3.4). In section 4.3, the EBQ is calculated for the departments in the red delivery route since a good review of the bin quantities already decreases the probability that a product is out-of-stock (sub-question 3.5). The newly calculated EBQs can be used to determine the new readout moments of the electronic order boards in section 4.4, which will answer sub-question 3.6. The last paragraph of this chapter, namely 4.5, draws a short conclusion about the answers to the sub-questions and also answers the research question 3.

4.1 Core problems and KPIs of the ordering process

This section describes the problems that should be tackled in this chapter, together with the KPI that should be improved, as a result of tackling the problems. Chapter one describes the core problems step by step, whereas chapter two dives into detail about the causes. The core problems that are linked to the ordering process are:

- Wrong usage of the ordering system at the departments
- Not enough products in the bins
- Readout moments are too close to each other

The first problem is tackled in section 4.2 where methods are described to let the users think about the correct way of using the electronic order boards. The second core problem is the number of products per bin. This core problem is researched in section 4.3 and can be tackled by calculating the EBQ for every bin. This causes a different optimal review policy. The optimal review policy influences the readout moments of the electronic order boards. It is, for instance, possible for certain departments to receive the delivery of new goods every two or three days, instead of daily. This is reviewed in section 4.4.

The KPIs attached to the ordering process should also be improved after these optimization steps are implemented in real life. These are the following KPIs:

- Out-of-stock moments
- Late placements
- Returns due to the too early placement of cards

These KPIs are also related to the core problems in the following way:

- Wrong usage of the ordering system at the departments
    - Out-of-stock moments
    - Late placements
    - Returns due to the too early placement of cards
- Not enough products in the bins
    - Out-of-stock moments
- Readout moments are too close to each other
    - Out-of-stock moments
    - Late placements

This shows why the KPI about the out-of-stock moments is an important KPI for MST. All the core problems influence that specific KPI. More information about the KPIs is in sections 2.3 and 2.4.

Another conclusion that can be drawn is that the wrong usage of the ordering system at the departments is also influencing all KPIs, and more urgent all the processes that follow after the ordering process.

4.2 Working method of the nurses at the department warehouses

The working method of the nurses at the department warehouses is essential for the further course of the subsequent processes since the ordered products should be picked and delivered to the departments. If the nurses do not place the cards (on time) they do not receive the product (on time). To make the ordering process as efficient as possible, the flaws in the way of working with the electronic order boards at the departments need to be changed and solved. As already mentioned in section 2.2.1, the nurses at the departments have a lot of influence on the process that is executed at the logistics department. The nurses trigger the start of the picking and delivery process since they place the Kanban cards in the electronic order boards. However, when nurses do not place the cards on time, there is a large chance that the logistics department receives an emergency order for the same product that was placed too late by the nurses. These additional actions are costly and should be prevented. Next to that, if nurses do not place a card immediately after using the last product in a bin, it could very well be that they forget to place the card and notice it when the second bin becomes empty too. This will also result in an emergency order since all the units of this SKU are used.

There are several ways to change the mind and the way of working of the nurses. One of the solutions is to give the nurses training by a logistics employee once. The nurses do not know and do not think about the additional actions that the logistics department has to take before they can deliver a certain emergency order. After that, appoint the head of the department as a point of contact and let this person explain to every new employee how the ordering and delivery system works. This will result in a lot fewer emergency orders, which yields more time for the logistics employees to work on their process.

Another change that is proposed to be made is changing the readout moments of the electronic order boards. The nurses will not directly notice this, since their working day is not relying on the logistics departments stopping by. However, the other way around, readout moments can be changed based on the working day of the nurses. Since several outpatient clinics work from 8:00 AM until 4:30 PM or 5:00 PM. This is where several opportunities are for the logistics department. If, for instance, the readout moments of the order boards changed to the end of the working day at the outpatient clinics. Currently, 4 logistics suppliers are starting their working way at 8:00 AM at the logistics department. Their first hour is also their least efficient hour since they have to wait before the order pickers have the first orders of the day ready. If two of the logistics suppliers start their day at 9:00 AM and work until 5:30 PM, they could start picking the orders of the outpatient clinics and make prepare these for the other two order pickers that start at 8:00 AM the next day. This makes the first hour of the logistics suppliers more efficient and will make sure that the outpatient clinics receive the ordered products at the start of their working day, which decreases the chance of a stock-out.

4.3 Economic bin quantity of the products at the department warehouses

To calculate the optimal review policy for the electronic order boards, the optimal bin quantities should be calculated for every product with two bins at a department. This optimal bin quantity is called the economic bin quantity (EBQ). The EBQ should satisfy the demand for a specific number of weeks, where the number of weeks is determined by the management. The model of Kanet and Wells (2019) is used to determine the EBQ for all the products at several departments, among which the whole red delivery route. The parameters needed to calculate the EBQ are:

- *D → Demand over a certain time*
- *L → Lead time, the time it takes to deliver the products after a Kanban card is placed*
- *S → Fixed cost to replenish a bin, ordering costs*
- *c → Unit cost*
- *h → Periodic percent inventory holding cost*

The number of units per bin, which is defined by the letter B, varies per SKU per department and is recalculated in the end. The order quantity Q is also used to calculate the total periodic costs. The order quantity Q and the number of units per bin B are the same per SKU.

If the system is in steady-state, the expected minimum inventory is $MinI = B - DL$ and the expected maximum inventory is $MaxI = B + B - DL = 2B - DL$. This means that the average inventory is:

1. $Average\ inventory = \frac{(MinI+MaxI)}{2} = \frac{(3B-2DL)}{2}$

S denotes the fixed replenishment costs per bin, which consists of labor costs for the logistics employees who replenish the bin. The parameter for the unit cost is *c* and the periodic percent inventory holding costs are represented by *h*. Given these parameters, the expected value of the total relevant costs for the 2-equal-bins system, TC_2, as a function of *B* is:

2. $TC_2(B) = \frac{(3B-2DL)}{2}ch + \frac{DS}{B}$

The first term on the right-hand side (RHS) defines the average periodic inventory holding costs, whereas the second term describes the average periodic fixed replenishment costs. To assure that the customer service level (CSL) is met the following constraint holds: $B \geq DL + ss$. Assuming that the demand is normally distributed with a standard deviation σ, z_α is the point on the standard normal distribution such that $P\{Z > z_\alpha\} = \alpha$. Recalling that L is the lead time from the moment that a Kanban card is placed until the products are delivered, results in $ss = z_{CSL}\sigma\sqrt{L}$. Thus, when $B > DL + ss$, the two-bin Kanban approach affords the added stock-out protection of $B - DL - z_{CSL}\sigma\sqrt{L}$ units of safety stock. The expected total periodic cost is:

3. $TC_{Q,r}(Q) = \frac{Q}{2}ch + \frac{DS}{Q} + (ss)ch$

Taking the first derivative of (2) and setting it equal to zero results in the formula for the economic bin quantity for the two-bin Kanban system, EBQ (2) (the 2 between brackets stands for the number of bins):

4. $EBQ(2) = \sqrt{\frac{2DS}{3ch}} = \frac{EOQ}{\sqrt{3}}$

The paper of Kanet and Wells (2019) explicitly states and shows that the use of the normal EOQ formula results in higher costs than the EBQ(2) formula. $TC_{Q,r}$ is only relevant when $Q \geq DL$ and TC_2 is only relevant for $B \geq DL + ss$. Because of the convexity of $TC_2(B)$, whenever $EBQ(2) < DL + ss$, the lowest cost choice for *B* is $DL + ss$. This means that the optimal bin size B is the largest number of either the EBQ or the demand over lead time and the safety stock. This results in the following formula for selecting the optimal bin size *B:*

5. $B = max\{EBQ(2), DL + ss\}$

The optimal bin size yields the minimized average total relevant costs and is therefore used to calculate the optimal bin quantities.

Before the EBQ can be calculated, several (fixed) parameters like for instance the ordering costs (S), need to be estimated. The ordering cost is estimated by timing how long every step takes to deliver one product to a department on average. The following times are checked for every step in the process:

Process step	Time (minutes)
Ordering	1
Batching	3
Picking	8
Walking time to department	10
Resupply bin and place cards back	3
Total	25

TABLE 4.1 – TABLE OF TIME PER ACTIVITY ORDERING PROCESS UNTIL DELIVERY

As the table shows, it takes more or less 25 minutes to resupply a bin at a department. The 25 minutes it takes to resupply the bin can be translated to cost by multiplying this with the earnings per hour of a logistics employee. This results in ordering costs (S) of €8 per order. The second parameter that is estimated is the % periodic holding cost *h*. For this parameter, the average holding costs in inventory management at hospitals are used, which comes down to *h* = 20% of the unit price. The lead time *L* is dependent on the number of readout moments (reorder frequencies) per week. Since the readout moments are currently daily for almost every department, the lead time *L* after placing the Kanban card until the bin is resupplied is, on average, 8 hours. The unit costs *c*, bin quantity *B*, and demand per unit time *D* differ per item.

The EBQ should take the multiple in which the product is issued to the departments into account. An example is that certain syringes can only be ordered in multiples of 5 since this makes the life of the pickers easier. This results in, for instance, that when the EBQ of a product that only can be delivered in multiples of 5 yields 23, the EBQ will be adjusted to 20 or 25, depending on the lowest total relevant cost. The tool that is developed needs input about the non-fixed parameters, and it is possible to fill in other information about the product. The tool itself calculates the number of days over which the demand is known, the number of times that the SKU is ordered, the estimated lead time depending on the number of delivery moments per week, and of course the EBQ per bin of an SKU.

The EBQs are calculated for the several departments at the blue delivery route and the whole red delivery route. An example of how the dashboard looks and which changes can be made to the bin quantities can be found in appendix 8. This is an example of the EBQ calculations for the nursing ward of all gastrointestinal and liver diseases. A lot of bin quantities stay the same, namely 70. 22 Bin quantities should be increased and 61 bin quantities need to be decreased. This is in line with the literature since the literature says that most of the time the inventory at the department warehouses is too high since the inventory levels are based on the thoughts and experience of the nurses at the department, and not on the actual demand. There are bin quantities for several SKUs that cannot be calculated correctly since these SKUs are 'free'. These SKUs are donated by the laboratory of MST to the departments and therefore no costs are incurred. These SKUs are calculated based on the safety stock and demand over lead time, as stated in formula 5.

The use of the EBQ lowered the average number of days that it takes to empty a bin of an SKU. Next to that, the total inventory value decreased as well by 25% for only the nursing ward of all the gastrointestinal and liver diseases. Besides the fact that this is mostly an advantage for the department, the logistics department also has an advantage of the use of the EBQ, since a significant number of SKUs had to be increased, which means that they are resupplied too frequently compared to the cost. Next to that, when several departments lower their stock at the warehouses, there will be more products at the central warehouse to distribute to the other departments. Therefore, the logistics department also benefits from this situation. Another benefit is that the standard deviation of the expected number of days that it takes before all products in one bin is used is decreased. This 11.7% decrease in standard deviation means that the expected number of days before a bin is empty is closer to the average for all products, which again means that there is a larger chance of delivering multiple products in one run.

Department	Nr of unique SKUs per department	The standard deviation of average days before a bin is empty before EBQ	The standard deviation of average days before a bin is empty after EBQ	Average number of days in inventory per bin before EBQ	Average number of days in inventory per bin after EBQ	Change in inventory value (%)
V-MDL S	153	78.46	67.08	51.73	37.61	-37%
V-MDL O	49	79.49	77.59	44.71	42.20	-25%
V-A5 S	129	72.55	60.66	38.82	25.37	-49%
V-A5 O	85	72.92	72.81	40.25	36.81	-37%
V-E6 HIC	86	61.32	54.20	43.34	30.66	-25%
V-E61 S	164	69.59	65.00	40.47	33.51	-26%
V-E61 O	74	44.03	43.82	22.26	20.45	-19%
V-Neuch S	220	90.82	71.98	73.98	48.18	-56%
V-Neuch O	94	84.25	75.11	59.06	47.67	-58%
V-E4 S	179	58.11	53.27	33.00	26.78	-36%
V-E4 O	100	65.21	54.43	39.73	31.34	-28%
P-MDL S	154	82.39	77.56	76.16	63	-32%
P-MDL O	38	59.81	60.97	38.12	35.36	-35%
P-Dagb LS	34	71.57	56.90	47.20	34.45	-56%
P-Dagb RS	66	95.39	82.42	64.62	45.30	-55%
P-Dagb O	71	87.26	87.21	68.28	59.71	-23%
P-Reuma	26	78.54	80.26	56.20	45.94	-54%
P-Rontg	116	55.15	44.49	34.43	27.01	-43%
P-Intg	19	101.10	111.89	112.42	102.93	-27%
P-Hemo S	189	79.41	72.42	60.85	47.06	-39%
P-Hemo O	5	20.18	2.88	21.87	2.62	-87%
0-KEUKEN	62	111.50	101.92	163.31	126.98	-35%

TABLE 4.0.2 – RESULTS OF EBQ CALCULATIONS PER DEPARTMENT

Table 4.2 shows that, especially for the departments that keep many different SKUs in their inventory, the standard deviation of the average days before a bin is empty also decreased significantly. This indicates that the estimated number of days before a bin is empty is closer to the average number of days before a bin is empty for all products. Therefore, there is a significantly higher chance that more products will be delivered every time the suppliers will deliver the SKUs at the department. The average reduction in standard deviation is 11.7%, which means that the expected bin consumption is closer to the average bin consumption than it was. Next to that, the average number of days before a bin is empty also decreased by 21%. All these calculations are based on the current delivery schedule. The average number of days before a bin is empty decreased significantly for every department. Since the standard deviation is decreased significantly, together with the decreasing inventory value, we can state that the bin quantities of all the SKUs are more in line with each other. The fact that the inventory value decreased for every department, together with the average days before a bin is empty, indicates that daily delivery is too frequent for the current bin quantities. The calculated EBQs are also necessary for the following steps of the research since these can be used to optimize the time between two ordering moments. The time between two ordering moments is dependent on the bin quantities since these need to be resupplied after they become empty. Therefore, the newly calculated bin quantities are used in the next section, where the periodic review period is calculated.

4.4 Periodic review inventory policy model to revise the readout moments

As already mentioned, the calculated EBQs can be used to optimize the periodic review policy of several departments. Currently, every order board is read out 6 times per week (not on Sunday). If the number of readout moments can be decreased for departments since it seems that the periodic review time is currently too short, it might result in more efficient delivery runs since the suppliers deliver more products per delivery. This eventually leads to a more efficient in-house supply chain.

The periodic review model of Rosales et al. (2015) is used to calculate the optimal review period T* with incurring minimized average costs. In this model, N denotes the number of SKUs stored in a particular storeroom, while using the two-bin system. The delivery lead time L is defined as the time it takes from the moment that the SKU in an empty bin is ordered until it is resupplied since we use the periodic review model. For the remainder of this model, the following assumptions are used:

Assumption 1: *Bins become empty following a Poisson process, having probability mass function p(), cumulative distribution function $\overline{P}$(), and upper tail probability P() with equal bin consumption rates λ, for each SKU.*

The bin consumption is assumed to be the same for every bin since Rosales et al. (2015) experienced that hospitals determine the number of units stored to achieve a target number of inventory turns. Therefore, they state that bins contain different quantities of items, but will on average have similar bin consumption rates. Rosales et al. (2015) analyzed data out of several hospitals and concluded that the interarrival times for bin demand for several SKUs is exponential, which means that the Poisson distribution fits very well. Since section 4.3 influences the average bin consumption per SKU, the new average bin consumption per department after the EBQ is calculated is also used.

Assumption 2: *The probability that the demand for a particular SKU during the delivery lead time L exceeds the quantity stored in both primary and secondary bins is negligible.*

The lead time for delivery is on average a few hours. If the average bin consumption is larger than two days, the probability that both bins of one SKU are used in the replenishment period is negligible. This assumption, although indirectly, also says that the predicted demand between two replenishment cycles is not larger than the number of units in one bin.

Next, they obtain estimates for the fixed replenishment costs (*K*) and the stock-out costs (ρ or $\hat{\rho}$), for which a cost-based analysis was performed. The replenishment costs were based on the time it takes to process, refill, and deliver full bins to the storage locations. The stock-out costs were calculated by estimating the time nurses spent on requesting and obtaining stock-out SKUs. Whenever there is a bin demand while the secondary bin is empty, there is a stock-out cost ρ. Furthermore, the time-weighted shortage cost ($\hat{\rho}$) is added for each unit of time that both bins are empty. Holding costs of point-of-use inventory are not incurred in the total costs since these costs are already made when the hospital bought the SKUs and put them in the central warehouse. The number of products per bin is pre-specified in the model of Rosales et al. (2015), so this can be another optimization step. The number of units per bin should be calculated before this model is used to optimize the cycle time and costs.

The periodic review model formulates the expected stock-out costs for one representative SKU and then scales this cost using the number of SKUs in the system. This is valid since the assumption was made that every bin has an equal consumption rate. This model tries to obtain the stock-out cost for one representative SKU by first understanding the inventory profile.

The average cost per unit time for one renewal cycle of the periodic two-bin system is used to estimate the long-run average cost per unit time. The total stock-out costs include the stock-out cost per occurrence at rate ρ and the time-weighted stock-out cost at rate $\hat{\rho}$. For a representative SKU, the stock-out costs during interval t depend on the number of non-empty bins at the beginning of the time interval, denoted by $m \in \{0,1,2\}$ as there are only two bins per SKU. If m = 0, products may be in backorder, with corresponding shortage costs at the rate ($\rho + \hat{\rho}$t). When m = 1 or m = 2, the total stock-out cost over the interval t is denoted as $C(m, t)$ which is used to calculate the expected stock-out costs of a single SKU during interval t = L and t = T – L. In the $C(m, t)$ expression, $x(t)$ denotes demand for one single SKU during interval t. The stock-out costs are only incurred if the secondary bin becomes empty, which means that there are no SKUs of that product left at that department at all. Therefore, any demand $x(t) \geq m$ implies an empty secondary bin and potentially a stock-out. All these variables and parameters are used in formula 1. To give a clear overview of the parameters:

- K → Fixed replenishment costs
- ρ → Stock-out costs
- $\hat{\rho}$ → Time-weighted stock-out costs
- L → Delivery lead time from the moment that a Kanban card is ordered until the bin is resupplied
- λ → Bin consumption rate
- N → Number of SKUs per department

The distribution functions are explained in assumption 1. The formula that Rosales et al. (2015) used for the total stock-out cost over interval t look as follows:

1. $$C(m,t) = \rho[\lambda t p(m-1,\lambda t) + (\lambda t - m + 1)P(m,\lambda t)] + \hat{\rho}\left[\frac{\lambda t^2}{2}P(m-1,\lambda t) - \frac{m(m-1)}{2\lambda}P(m+1,\lambda t) + (1-m)\left[tP(m,\lambda t) - \frac{m}{\lambda}P(m+1,\lambda t)\right]\right]$$

The first part of formula 1, which is multiplied by ρ, is the costs per stock-out occurrence. The second part of the formula, which is multiplied with $\hat{\rho}$, shows the costs for every unit of time t that the bin(s) is/are not resupplied yet.

As already mentioned, this formula calculates the stock-out costs for one SKU, but the goal is to calculate it for all SKUs. Therefore, to scale the costs to all N SKUs, the following is defined: η_L denotes the expected number of primary bins empty after delivery lead time L. η_1 denoted the expected number of SKUs with at least the primary bin consumed during the period between two reviews. η_2 denotes the total number of secondary bins consumed plus any additional unmet bin demand across all SKUs, representing total stock-outs during the periodic review interval.

Expressions for η_L, η_1, and η_2 are provided below.

2. $\eta_L = N\lambda L$
3. $\eta_1 = N(1 - p(0,\lambda T))$
4. $\eta_2 = N(\lambda t - p(1,\lambda T))$

Note that by assumption 2, all the primary empty bins immediately after delivery lead time L must have been demanded during this lead time. Hence $N\lambda L$ represents the expected number of bins depleted during the delivery lead time.

The expression for the long-run average cost per unit time is based on formulas 1 until 4. This is denoted by $J^p(T)$ and includes fixed order and stock-out costs for all N SKUs. The fixed order costs are incurred when at least one bin is empty during that time interval. This gives the following expected order cost per replenishment cycle:

5. $K(1 - p(0,\lambda NT))$

The expected shortage costs are divided into two different time intervals, namely T-L, which is the length of the review period after order delivery, and the delivery lead time L. During interval L, only SKUs with at most one empty bin at the beginning of the review interval (m = 0,1) can incur stock-out costs, since the demand during lead time is 0 or 1, according to assumption 2. The expected stock-out costs during lead time L for a single SKU are given by $C(1,L)$, when m = 1. If m = 0, so there are no non-empty bins, stock-out costs incurred over the interval L are given simply by $(\rho + \hat{\rho}L)$. If these stock-out costs are multiplied by η_2, it results in the total stock-out costs of all SKUs in that storeroom with m = 0. Shortage costs over time interval T – L are obtained by setting t = T – L. Note that m = 1, or m = 2 because the T – L interval starts immediately after the delivery time L, according to assumption 2. Furthermore, note that the expected number of SKUs where m = 1 or m = 2 after lead time L is equal to $\eta_L(N - \eta_L)$. This gives the following total shortage costs over T – L:

$$\eta_1 C(1,L) + \eta_2(\rho + \hat{\rho}L) + \eta_L C(1,T-L) + (N - \eta_L)C(2,T-L)$$

All these formulas together give the expression for the long-run average cost per unit time for the whole system:

6. $J^p(T) = \frac{1}{T}\left[K\left(1 - p(0, \lambda NT)\right) + \eta_1 C(1, L) + \eta_2(\rho + \hat{\rho}L) + \eta_L C(1, T - L) + (N - \eta_L)C(2, T - L)\right]$

Proposition 1: *When* $\lambda T \leq 2 - \delta$*, with* $\delta = (\frac{KNe^{-(N-1)\lambda T}}{\rho + L\hat{\rho}} + \frac{\lambda L\left(\rho + \frac{L\hat{\rho}}{2}\right)}{(\rho + L\hat{\rho})})$*, the long-run average cost per unit time* $J^p(T)$ *for the periodic review two-bin policy is quasi-convex in the cycle length T, and therefore unimodal.*

Based on Proposition 1, the optimal review cycle T* with incurring optimal costs $J^p(T)$ for the periodic review can be found readily by solving:

$$T^* = \arg\min_T J^p(T)$$

Before the model can be solved, certain fixed parameters need to be described. First, the lead time *L*, which is always more or less 4 hours after the ordering moment itself. The stock-out cost per occurrence *ρ* is estimated at €45 every time an SKU is out of stock. For the time-weighted stock-out cost $\hat{\rho}$ the industrial average is taken, namely €0,08. Lastly, the order cost for a replenishment order is estimated at €8 per order, just like in 4.3. These parameters are all fixed. Several other parameters are variable, as the number of SKUs per department *N*, interval *t* which is equal to the lead time *L* and the time between the lead time and periodic review time *T-L*, and the average bin consumption *λ*. The periodic review time *T* for which the total shortage cost has minimized the need to be found.

To find out what the optimal review period is to minimize the shortage cost, the same departments are used for the EBQ calculations, since it is possible to check for a department whether the newly calculated bin consumption is indeed cheaper than the bin consumption before the EBQ was calculated and which difference it shows for the optimal review period.

Department	Number of unique SKUs	Average bin consumption (days)	Optimal review period (T*)(hours)	Shortage Cost (€ per hour)	Rounded review period per 24h (hours)
V-MDL S	153	51.73	27	0,586307407	24
V-MDL O	49	44.71	43	0,376130233	48
V-A5 S	129	38.82	23	0,685282609	24
V-A5 O	85	40.25	29	0,540427586	24
V-E6 HIC	86	43.34	31	0,510741935	24
V-E61 S	164	40.47	21	0,74442381	24
V-E61 O	74	22.26	19	0,853768421	24
V-Neuch S	220	73.98	29	0,527996552	24
V-Neuch O	94	59.06	38	0,415131579	48
V-E4 S	179	33.00	17	0,928717647	24
V-E4 O	100	39.73	27	0,592281481	24
P-MDL S	154	76.16	36	0,434622222	48
P-MDL O	38	38.12	43	0,37834186	48
P-Dagb LS	34	47.20	54	0,299509259	48
P-Dagb RS	66	64.62	49	0,324959184	48
P-Dagb O	71	68.28	49	0,32295102	48
P-Reuma	26	56.20	71	0,227432394	72
P-Rontg	116	34.43	22	0,721368182	24
P-Intg	19	112.42	140	0,116125	144
P-Hemo S	189	60.85	27	0,570614815	24
P-Hemo O	5	21.87	101	0,217627273	96
0-KEUKEN	62	163.31	97	0,163685567	96

TABLE 4.3 – RESULTS OF THE REVIEW PERIOD CALCULATIONS PER DEPARTMENT FOR CURRENT BIN QUANTITIES

Table 4.3 shows the results of the review period calculations per department, with the use average bin consumption for the current quantities per SKU in a bin. This shows that several departments certainly do not have to be visited daily but can very well be visited less in a week. The 'P-Reuma', 'P-Intg', 'P-Hemo O', and '0-Keuken' are examples of departments that were visited many times with just a low number of products to deliver. These review period calculations support the statement that says that several departments do not have to be visited daily. Next to that, this table also shows that several departments maybe should be resupplied more often, although that will not surely result in better overall performance for the supply-chain since this will result in more than one delivery per day. These newly calculated review periods can be used to develop a new delivery schedule, which takes into account how many hours there should be between the deliveries.

The results in table 4.3 are, as already mentioned, based on the average bin consumption with the current bin quantities. In section 4.3, the EBQ was used to find the optimal bin quantities, taking the costs it takes to deliver the products to the department and the costs per unit of an SKU into account. These newly calculated bin quantities can also be used to recalculate the review periods for the departments since these review periods change dependent on the average bin consumption per day. The results of this experiment are shown in table 4.4.

Department	Number of unique SKUs	Average bin consumption (days)	Optimal review period (T*) (hours)	Shortage Cost (€ per hour)	Rounded review period per 24h (hours)
V-MDL S	153	51.43	21	0,766295238	24
V-MDL O	49	50.79	41	0,394607317	48
V-A5 S	129	34.90	16	1,00113125	24
V-A5 O	85	44.21	27	0,583222222	24
V-E6 HIC	86	47.52	23	0,688273913	24
V-E61 S	164	44.76	18	0,877283333	24
V-E61 O	74	29.84	18	0,92455	24
V-Neuch S	220	62.07	21	0,74207619	24
V-Neuch O	94	58.03	32	0,49325	48
V-E4 S	179	37.24	14	1,122514286	24
V-E4 O	100	40.78	22	0,727822727	24
P-MDL S	154	69.12	31	0,502609677	24
P-MDL O	38	41.61	40	0,403355	48
P-Dagb LS	34	48.11	41	0,390012195	48
P-Dagb RS	66	60.49	37	0,431654054	48
P-Dagb O	71	65.65	44	0,358315909	48
P-Reuma	26	60.76	60	0,267481667	72
P-Rontg	116	41.31	18	0,896127778	24
P-Intg	19	112.34	132	0,12350303	144
P-Hemo S	189	56.01	22	0,702740909	24
P-Hemo O	5	6.70	85	0,67578	96
0-KEUKEN	62	129.90	82	0,193287805	72

TABLE 4.4 – RESULTS OF THE REVIEW PERIOD CALCULATIONS WITH THE EBQ

There is almost no difference between the results of the review period calculations with the EBQ and the current bin quantities. The only difference, which does not emerge from these calculations, is that there is a larger chance that the average bin consumptions will be reached since the standard deviation of the average bin consumption per day is lower for the EBQs. Next to that, these calculations also show that several departments do not have to be visited daily. The readout moments of electronic order boards of several departments can be extended for the time of the review period to deliver more efficiently.

If we look at the departments that are in the sample, most of the departments for which the review period is increased to at least 48 hours, are outpatient clinics. These departments have fewer SKUs in their inventory and use fewer products on average. These departments can be visited two or three times a week, instead of the daily delivery.

Since a lot of readout moments for departments change, we have to check whether these new readout moments also influence the EBQ, calculated in section 4.3, together with the average and the standard deviation of the number of days before a bin is empty. The number of resupplies per week is increased for certain departments, which means that the lead time also increases. The effects of the newly calculated readout moments on the EBQ are investigated. This is done for the departments which are given a different readout period than every 24 hours (daily). The results of the new bin quantities are shown in table 4.5.

Department	Nr of readout moments per week	St. Dev of average days before a bin is empty after EBQ and current delivery frequency	St Dev. of average days before a bin is empty after EBQ and new delivery frequency	Avg. number of days in inventory per bin after EBQ and current delivery frequency	Avg. number of days in inventory per bin after EBQ and new delivery frequency	Change in inventory value compared to current bin quantities (%)	Change in inventory value compared to EBQ bin quantities based (%)
V-MDL O	3	77.59	78.46	42.20	46.87	-6%	13%
V-Neuch O	3	75.11	73.53	47.67	53.07	-40%	11%
P-MDL O	3	60.97	59.90	35.36	37.46	15%	15%
P-Dagb LS	3	56.90	55.44	34.45	41.28	-35%	4%
P-Dagb RS	3	82.42	80.32	45.30	53.48	-27%	21%
P-Dagb O	3	87.21	85.89	59.71	62.37	3%	7%
P-Reuma	2	80.26	76.17	45.94	59.42	-26%	2%
P-Intg	1	111.89	102.59	102.53	118.03	-8%	34%
P-Hemo O	1	2.88	4.90	2.62	7.02	-63%	54%
0-KEUKEN	2	101.92	12.78	126.98	128.65	-32%	14%

TABLE 4.5 – REVISED EBQ CALCULATIONS AFTER NEWLY CALCULATED READOUT MOMENTS

Table 4.5 shows that the inventories of the departments that got new readout moments are increased to prevent stock-outs during the days that they are not resupplied. This makes sense since the EBQ was, at first, calculated based on daily delivery. Since the lead time changes significantly for the different departments, the EBQ changes as well.

To conclude this section, I would recommend MST that the periodic review tool is used before the EBQ tool since the bin quantities are dependent on the deliveries and lead time. Therefore, the optimal readout moments should be calculated before the bin quantities are determined because the lead time and delivery frequencies might change.

4.5 Conclusion

The last section of the chapter is about the solutions to the research questions mentioned in the first section of this chapter, section 4.1. Research question 3 is answered together with the sub-questions that are not answered already. The answers to the sub-questions should at the end help to solve the main research question, which leads to optimizing the ordering process.

The following sub-questions are answered in this chapter:

3.1. *What is in the literature about readout moments and ordering via electronic order boards? How do other firms deal with this?*

3.2. *What is in the literature about the use of two-bin systems in hospitals? How do other firms deal with this?*
These sub-questions are already answered in section 3.2

3.3. *What are the most prominent reasons that cause a lack of efficiency?*
This sub-question is already answered in chapters 1 and 2 and section 3.3.

3.4. *How does the readout moment affect the in-house supply chain of MST and how does it affect the workday of the nurses at the departments?*
The readout moment itself does affect the supply chain directly since the orders are generated immediately after the readout moment. The readout moments do not directly influence the workday of the nurses, but the workdays of several departments, for instance, 8:00 AM until 4:30 PM, can be used to improve the delivery schedule and make the workday of the logistics suppliers more efficient.

3.5. *To what extent is the number of products per bin correct according to the calculations of the Kanban and two-bin system?*
The number of products per bin is too high on average since a significant number of products has a turnover rate of more than 100 days. This happens sometimes since there are, for instance, 100 units in one box. The average number of days it takes before a bin is empty is lower for the EBQ calculations. The same holds for the standard deviation of the number of days it takes before a bin is empty, which means that there is a higher chance of delivering more products at once to a department. Delivering more products at once to a department is more efficient than going multiple times for small orders, which is currently the case. Therefore, we can state that the EBQ calculations will directly impact the efficiency of the supply chain and that the EBQ calculations can also be useful in calculation new readout moments of electronic order boards at the departments.

3.6. *How can the readout moments be changed with the use of the models found in literature and which changes increase the efficiency?*
The readout moment can be changed by reading out the electronic order boards less frequently. As the periodic review calculations also show, 10 to 12 of all the examined departments can be delivered less often than daily, for instance, every 48 hours or maybe only once or twice a week. Most of these departments are outpatient clinics. This means that more products will be used in the review period and more products can be delivered after the review period and lead time passed. This increases the efficiency of the in-house supply chain.

To conclude this chapter, the answer to the main research question is presented. The main research question is:

3. How can the ordering process be optimized?

The ordering process can be optimized by training the nurses at the departments and teach, explain, and show them how the way correct is according to the Kanban principle. Next to that, the EBQ calculation tool decreases the average and standard deviation of the number of days before a bin is empty, which means that, on average, the bins are empty sooner. However, more bins are delivered to the departments at once. The last step is to read out the electronic order boards less frequently. This can be done with the review period model by Rosales et al. (2015), which can be combined with the EBQ calculations. I recommend using the periodic review model first since this model already optimizes the time between the readout moments. The new readout moments can be used while calculating the new lead times for the EBQ calculations. Therefore, I recommend starting with the periodic review model and using the EBQ tool afterward. Optimizing the ordering process will in the end make sure that deliveries will be more efficient.

5. Picking process optimization

Chapter 5 is about the optimization of the picking process. The picking process has several aspects that influence the efficiency of the total supply chain. To increase the efficiency of the supply chain, several core problems should be solved. These core problems are solved in this chapter, which should give insights into improvements in the picking process. To optimize the picking process, a research question was asked. To answer the research question, we should provide a or several solutions to optimize the picking process, solve the core problems and improve the KPIs. The following research question with corresponding sub-questions are asked:

4. **How can the picking process be optimized?**
    4.1. How do other firms organize their picking process in combination with electronic order boards?
    4.2. What are the current problems at the picking?
    4.3. How can the products in the products in the warehouses be optimally allocated to a storage place?
    4.4. To what extent are the products optimal located to minimize the picking time in the warehouses?
    4.5. What is the relationship between the changes in readout moments and the new picking times?

The goal of the chapter is to answer main research question 4, which aims at optimizing the picking process. Sub-question 4.1 is already answered in the literature study. As may be expected, almost every hospital researched in the case studies picked its orders for goods in more or less the same way. The biggest difference between the hospitals was the inventory policy and the storage near point-of-use, which was already discussed in chapter 4. Sub-question 4.2 is also already answered, but in chapters 1 and 2, where the core problems and the causes are explained. A model to answer sub-question 4.3 is also provided in the literature study.

This chapter is divided into four sections, from which the first section briefly discusses the core problems with corresponding KPIs (sub-question 4.2). The second section, which is about sub-questions 4.3 and 4.4, is going to explain how the storage allocation of the picking process is done, and how this could be optimized with the model explained in section 3.3.1 of the literature study. The next paragraph explains the consequences for the picking process if the readout moments of the electronic order boards are changed. This answers sub-question 4.5. Eventually, this chapter is summarized in the conclusion (section 5.4) and the most important findings are shown.

5.1 Core problems and KPIs of the picking process

This section briefly describes the core problems and KPIs of the picking process found earlier in this thesis. Next to that is described when which core problem is solved, and which core problem influences which KPI. The following core problems are addressed:

- All orders picked between 7:00 AM and 10:00 AM
- Products not optimally located in the warehouse according to demand
- Mistakes made while picking

These core problems should be solved to increase the efficiency of the whole supply chain. The second core problem of the bullet points is discussed first, namely in section 5.2, which is the most important part of this chapter, since this changes the locations of the products stored in the warehouses and should decrease the picking time. The first bullet point describes a core problem that starts at the ordering process but causes peaks in the warehouse activities. If the readout moments of the electronic order boards are changed, as already mentioned in section 4.4, this would also impact the picking process. This is described in section 5.3. The last core problem is not addressed since MST is changing the picking process since the pickers work with scanners from January 2 and their priority is not anymore on the picking mistakes. These scanners show whether the pickers pick the right product, and it warns the picker when he or she picks the wrong products.

The KPIs that are influenced by the picking process are the following:

- Picking time per order line
- Returns due to picking mistakes

If the picking time per order line can be decreased, the suppliers can start earlier with restocking the bins at the departments and are done sooner.

The relations between the core problems and the KPI look as follows:

- All orders picked between 7:00 AM and 10:00 AM
    - Picking time per order line
    - Returns due to picking mistakes
- Products not optimally located in the warehouse according to demand
    - Picking time per order line
- Mistakes made while picking
    - Returns due to picking mistakes

More information about the KPIs is in sections 2.3 and 2.4. Since the picking mistakes are, as already mentioned in section 2.5, not a high priority anymore, the full focus of this chapter is on decreasing the picking time per order line. Therefore, the allocation of the products in the warehouse should be researched and the changes for the picking process due to the new readout moments of the electronic order boards should be discussed.

5.2 Product allocation in the warehouses

As already mentioned in the literature study, traveling between products while picking orders is the most time-consuming activity for pickers. Therefore, the products should be optimally allocated to minimize the picking time. Since the allocation of products to storage locations in the warehouse does not change the other processes directly, this is an improvement that is not hard to implement in terms of changes in other processes. On the other hand, the whole warehouse needs to be redesigned and products need to be re-allocated, which takes a lot of time.

The heuristic that is used to redesign the unsterile warehouse is the Interaction Frequency Heuristic. As the name already reveals, the Interaction Frequency Heuristic (IFH) looks at the interaction of an SKU with other SKUs that are in the same warehouse. These interactions are based on the number of times that these SKUs are in the same order together. The execution of the IFH is explained next, according to the paper of Mantel et al. (2007). The IFH can be used since MST works according to the single order picking principle, and they do not pick in batches. The IFH cannot be used if the orders are picked in batches, since batching implies longer order sequences that occur less frequently and the IFH does not make sense anymore.

First, this heuristic allocates the singles (i.e., the SKUs that never share an order with the other SKUs) in such a way that their distance to the I/O-point is in accordance with their popularity f_{i0}, which means the number of orders that require SKU i. Next, the heuristic ranks the nonnegative interaction frequencies in decreasing order. The interaction frequency f_{ij}, which is the number of orders that require both SKU i and SKU j. The heuristic then processes the sequence of interaction frequencies in the following way:

Let f_{ij} be considered in the current step. If SKU i and SKU j have already been allocated, then process the next interaction frequency; otherwise, proceed as follows:

Case ALLOCATION_OF_TWO: neither SKU i nor SKU j has been allocated so far. Allocate the SKUs to two free locations that are as close together as possible (relative to the routing-policy-specific distance) and such that the individual distances to the I/O-point are in accordance with their popularity

Case ALLOCATION_OF_ONE: only one SKU has been allocated so far. Allocate the other SKU as close as possible to the SKU that has already been allocated such that its distance to the I/O-point is in accordance with its popularity. If no suitable location exists, then process the next interaction frequency.

The distance between SKU i and SKU j is called d_{ij}, whereas the distance between the I/O-point and SKU i is called d_{i0}.

The unsterile warehouse at the logistics department counts 566 unique SKUs, which are located over 15 aisles and a small refrigerator. In order to reallocate the SKUs in the warehouse, the interaction frequencies of the SKUs need to be determined. These interaction frequencies are determined based on the orders placed from January 2020 until the end of July 2020. After these interaction frequencies are determined, the distance matrix is developed. This distance matrix gives the distance from the I/O-point to all the SKU locations and the distance between all SKU locations in terms of units of distance. One unit means in this case that the picker moves from one storage location to the storage location next to it. Additional units are added if the picker walks from aisle to aisle for instance. This is used to determine the location for the SKUs from the I/O-point in order to minimize the distance that an order picker travels. Next to that, the distance matrix is used to locate SKUs that never share an order with other SKUs according to their popularity. A location can be assigned based on the distance from the I/O-point.

Several SKUs cannot be placed differently, since these SKUs need to be placed in a refrigerator since these SKUs need to be kept cool. This means that the locations for SKUs that are in the refrigerator are fixed and stay the same.

The SKUs that are linked to a warehouse location, but never ordered are located in the aisles that are the furthest away from the I/O-point. This holds for 104 SKUs, which are for just one or two departments and very slow-moving. Since these SKUs are not ordered in the first 200 days of 2020, MST can consider removing these SKUs out of the warehouse and order them when needed, since these SKUs are using locations in the warehouse that can easily be filled by other SKUs. For the new design, the SKUs that are not used between

As already mentioned earlier in this section, the first step in allocating the SKUs to locations, following the interaction frequency heuristic, is to allocate single SKUs that never share an order with other SKUs, according to their popularity. In the case of the unsterile warehouse of MST, two SKUs never share an order with other SKUs. These SKUs are both only ordered once, which means that these SKUs are also located far from the I/O-point since their popularity is the lowest of all the SKUs.

If all these SKUs with exceptions are located, the heuristic can start in the way mentioned earlier. The heuristic sorts the nonnegative interaction frequencies in decreasing order. Next, it checks whether, one, both, or none of the SKUs are already assigned to a new location. If both SKUs are already assigned to a location, the heuristic goes to the next iteration. If one SKU is already assigned to a location, the heuristic finds a location that is as close as possible, considering the locations that are still free and the ones that are already assigned to other SKUs, to the other SKU, in accordance with the popularity of the SKU. If no suitable location exists, the heuristic proceeds to the next iteration. If both SKUs are not assigned yet, the first of the two SKUs that are assigned is the SKU with the highest popularity. This SKU is assigned to a free storage location, as close as possible to the I/O-point. The other SKU is assigned to a free storage location as close as possible to the storage location of the SKU that was just assigned. The heuristic ends when all the SKUs are assigned to a storage location.

This heuristic is extended with the feature that it recognized which SKUs should be placed at a pallet storage place, which are locations 1.1.A.A until 1.31.A.A. These SKUs that more surface since these are large in terms of size and/or demand. The SKUs that are currently stored at these locations are only moved over these pallet storage locations, and not to locations 2.1.B.A until 17.1.E.A., which are storage racks.

After the heuristic assigned every SKU to a new storage location, a comparison with the old locations is made to verify whether the new design of the warehouse indeed reduces the average distance walked while picking and so the average picking time. The distance for every order made is calculated for the current and proposed warehouse design. The current and (proposed) new storage locations of SKUs are in appendix 10. This resulted in the following differences in distances:

	Total distance walked (units)	Average distance per day (unit)
Current warehouse design	805537	83.00
New warehouse design	537324	55.37
Reduction in distance	33.30%	

TABLE 5.0.1 – WALKING DISTANCE FOR ORDER PICKERS FOR THE CURRENT AND (PROPOSED) NEW WAREHOUSE DESIGN

Table 5.1 shows the differences between the current warehouse design and the proposed warehouse design. The total distance that the order pickers walked when picking the orders could have been reduced by 33.30%, which means that the picking time can be reduced by the same percentage. Next to that, the average distance walked per day can be decreased with the same percentage.

If we look at the changes in location of SKUs (appendix 10), almost every SKUs, except for the SKUs that are kept in the refrigerator and three other SKUs, are assigned to another storage location. This means that moving all SKUs to their proposed new location takes quite some time. On the other hand, the SKUs can be kept at their new storage location for a long time. Next to that, the time that it takes to move the SKUs to a new storage location does not outweigh the reduction in picking time and distance that an order picker has to walk.

5.3 Changes in picking process due to new readout moments

Since the readout moments of several departments should be changed to increase the efficiency, as can be concluded out of section 4.4, the picking process therefore also notices small changes in workload and departments per day. The periodic review model shows that a significant number of electronic order boards of the departments that were examined are read out too frequently, namely every 24 hours. This means that a lot of department warehouses can be resupplied less often, which leads to fewer deliveries but with more SKUs at once. Therefore, the largest change for the picking process is that the orders that are picked contain more SKUs than they did before. Therefore, the time to pick one order is, on average, going to be longer. However, the average time it takes to pick one item is shorter since the new storage allocation method works better for larger orders. Since decreasing the number of readout moments per department increases the number of order lines per order and per delivery, the proposed changes in readout moments have a positive influence on the picking process.

Another possible change that could be implemented, dependent on the change in delivery schedule, is that picking for several departments can be done at the end of a day, instead of at the start of the day. When several logistics suppliers start their day at 9:00 AM and work until 5:30 PM, several outpatient clinics' electronic order boards can already be read out since these departments work from 8:00 AM until 4:30 PM. If the order boards are read out at 4:30 PM, the logistics suppliers who work until 5:30 PM have 60 minutes to start picking these orders and can prepare these for the start of the next day. This makes the start of the next day already more efficient for the logistics suppliers. Next to that, the peak while picking orders in the warehouse flattens, since at least 13% until 25% of all order lines per day come from outpatient clinics.

5.4 Conclusion

The last section of the chapter is about the solutions to the research questions mentioned in the first section of this chapter, section 5.1. Research question 4 is answered together with the sub-questions that are not answered already. The answers to the sub-questions should at the end help to solve the main research question, which leads to optimizing the ordering process.

4.1. *How do other firms organize their picking process in combination with electronic order boards?*

4.2. *What are the current problems at the picking?*

   Sub-questions 4.1 and 4.2 are already answered in section 2.2.2.

4.3. *How can the products in the products in the warehouses be optimally allocated to a storage place?*

   Sub-question 4.3 is already answered in section 3.3. In this chapter, we use the IFH.

4.4. *To what extent are the products optimal located to minimize the picking time in the warehouses?*

   The IFH changes assigned a new location to almost every SKU if we do not count the SKUs that are kept in the refrigerator since these cannot be moved. The picking time is not minimized, since a heuristic was used instead of an exact model, which means that the solution is improving the current situation. However, this is not the optimal solution. This solution decreases the average distance an order picker has to walk (daily) by 33.30%.

4.5. *What is the relationship between the changes in readout moments and the new picking times?*

   As mentioned in section 5.3, the order frequency of the electronic order boards is decreased, which causes fewer orders of several departments, but when the SKUs of these departments are ordered, the packing list will contain more order lines. This means that the picking time per order is increasing, but the average picking time per SKU will decrease due to the larger picklist and the newly assigned SKU locations in the warehouse.

4. How can the picking process be optimized?

The picking process can be optimized using the IFH to assign SKUs to new storage locations. As already mentioned in section 5.2, the allocation of new locations to SKUs reduced the total distance that a picker walks by 33.30%. Next to that, the average distance that a picker walks per day is also reduced. This means that time that pickers travel between SKUs reduces, which subsequently decreases the picking time per day and per order line, which increases the efficiency of the pickers and the efficiency of the in-house supply chain.

6. Delivery process optimization

This chapter aims at the optimization of the delivery process. To increase the efficiency of the delivery process, the core problems named in the first chapter should be solved. Different aspects influence the efficiency of the delivery process, for instance, the products delivered per department. To optimize the delivery process, a research question was asked together with several sub-questions. To answer the research question, we should provide a or several solutions to optimize the delivery process, solve the core problems and improve the KPIs. The following research question with corresponding sub-questions are asked:

5. **How can the delivery process be optimized?**
   5.1. What changes can be made to the current delivery process to increase efficiency?
   5.2. Which methods are there to develop the delivery schedules?
   5.3. Which alternatives are there to the current delivery schedules?
   5.4. What are the pros and cons of the different alternatives?
   5.5. What is the best choice to make when trying to optimize the efficiency of the whole delivery process?

The goal of chapter 6 is to provide good solutions to increase the efficiency of the supply chain. Several sub-questions are already (partially) answered in the literature study. For instance, sub-questions 5.1, 5.2 are partially answered. The ABC classification techniques in section 3.4.1 can be used to determine when the suppliers should go to a department or even when to read out an electronic order board. This can be aligned with the changes made for the readout moments in the previous chapters.

The first section of this chapter briefly repeats the core problems and KPIs related to the delivery process. Section 6.2 describes a department classification method, and so answers sub-question 5.2. The next section describes more alternatives of the delivery schedule, which includes the combination of for instance the new readout moments, the changes in current delivery routes, and the development of new delivery routes. These methods can change the delivery process but have their pros and cons. These pros and cons are described in section 6.4. Section 6.5 summarizes this chapter and draws the most important conclusions to improve the in-house supply chain related to the delivery process.

6.1 Core problems and KPIs of the delivery process

The following core problems are found and explained in chapters 1 and 2:

- Organization of the delivery process
- Inefficient delivery runs

The core problems found are overlapping since the first bullet point influences the second bullet point. The organization of the delivery process, which also includes the readout moments, is currently not designed efficiently. Therefore, since there are too many readout moments for several electronic order boards, and that causes inefficient delivery runs where the suppliers go to departments to deliver just one product. Solving the core problems should have a positive impact on the KPIs that are influenced by the delivery process.

The following KPIs are important for the delivery process:

- Average delivery time per order line
- Total average delivery time
- Products delivered per department

More information about the KPIs is in sections 2.3 and 2.4. If the average delivery time per order line can be decreased and the number of SKUs delivered per department can be increased, the delivery runs are more efficient. If the relation between the KPIs and core problems is checked, both core problems influence all the delivery process KPIs. Therefore, this can be the most important optimization step to increase supply chain efficiency.

6.2 Classification of department warehouses

As already mentioned in 3.4.1, the delivery can be based on department classification for instance. This means that, for example, the delivery of departments is based on the bin usage per department, which leads to a decrease in delivery frequencies and an increase in the number of products delivered per delivery.

6.2.1 ABC-analysis of departments

Another method to develop an alternative delivery schedule is to deliver based on the average daily usage of products at departments. This is used to prevent the suppliers from going to a department with (half) empty carts. If the number of times a delivery takes place is decreased, the carts will be fuller, and the suppliers will deliver more products to the departments at once. Departments can be classified based on their average daily usage of products and based on that classification they can be delivered. For this ABC-analysis, the departments are classified by intervals of the average usage of bins per week. The intervals are shown in table 6.1.

Usage per day	Number of deliveries per week
More than 10 bins per day	Five or six times per week (daily)
6.01-10 bins per day	Three times per week
3.01-6 bins per day	Twice per week
0-3 bins per day	Once per week

TABLE 6.1 – NUMBER OF DELIVERIES PER WEEK BASED ON MEDICAL SUPPLY USAGE

Several exceptions are made for the departments that are in the orange delivery route and the outpatient clinics, which do only work on weekdays. Departments at the orange delivery route are at least delivered three times per week since stock-outs at these departments are very costly. Next to that, if there are outpatient clinics that are using more than 10 SKUs per day, and so should be delivered daily, they are only delivered on weekdays. This is because they do not work on Saturdays and so do not use any products then. Therefore, the table states that, if they use on average more than 10 bins per day, the number of deliveries will be five or six since several departments do not work on Saturdays and Sundays.

If we apply these intervals to the current bin usage of the departments, 39 departments are classified to be resupplied daily, 15 departments that are resupplied three times a week, 24 departments that are resupplied twice a week, and 14 departments that are only resupplied once a week. However, if the exceptions mentioned earlier are taken into account, the numbers change slightly. This will be visible when the alternative delivery schedules are developed.

If this is compared to the results of chapter 4, where the review period of the departments at the red delivery route are calculated together with several departments that are delivered through the blue delivery route, we can see that there are a lot of similarities. Table 6.4 shows the comparison between the number of deliveries based on the current Min/Max, the EBQ, and based on the categorization by the average usage of bins per day. Out of this sample with 22 departments, the calculated delivery frequencies are the same for 15 departments. This means that all three methods result in the same solution. Next to that, there is no department for which every single method gave a different solution, so at least two of the three methods gave the same solution. The results of the ABC-analysis on the bin usage of departments per day is shown in table 6.2.

Department	The number of products per dept.	Review period without EBQ converted to deliveries per week (CH4)	Rounded review period with EBQ converted to deliveries per week (CH4)	The average usage in bins per day (nr of bins per day)	Deliveries per week based on categorization
V-MDL S	153	Daily	Daily	11.632	Daily
V-MDL O	49	Three times per week	Three times per week	6.3052	Three times per week
V-A5 S	129	Daily	Daily	16.06	Daily
V-A5 O	85	Daily	Daily	13.479	Daily
V-E6 HIC	86	Daily	Daily	10.763	Daily
V-E61 S	164	Daily	Daily	24.506	Daily
V-E61 O	74	Daily	Daily	18.088	Daily
V-Neuch S	220	Daily	Daily	16.82	Daily
V-Neuch O	94	Three times per week	Three times per week	11.444	Daily
V-E4 S	179	Daily	Daily	25.953	Daily
V-E4 O	100	Daily	Daily	15.991	Daily
P-MDL S	154	Three times per week	Daily	7.5242	Three times per week
P-MDL O	38	Three times per week	Three times per week	7.8891	Three times per week
P-Dagb LS	34	Three times per week	Three times per week	7.6464	Three times per week
P-Dagb RS	66	Three times per week	Three times per week	4.6906	Twice per week
P-Dagb O	71	Three times per week	Three times per week	9.5219	Three times per week
P-Reuma	26	Twice per week	Twice per week	1.9085	Once per week
P-Rontg	116	Daily	Daily	16.458	Daily
P-Intg	19	Once per week	Once per week	0.3845	Once per week
P-Hemo S	189	Daily	Daily	17.81	Daily
P-Hemo O	5	Once per week	Once per week	0.6875	Once per week
0-KEUKEN	62	Once per week	Twice per week	1.2074	Once per week

TABLE 6.2 – RESULTS OF CHAPTER 4 COMPARED TO THE CATEGORIZATION BASED ON USAGE PER WEEK

The difference between these methods is that the methods in chapter 4 are also based on different costs that are incurred as the shortage cost and order cost for instance. The latter method about categorization based on daily bin usage just looks at the bin demand at the departments. However, when both methods result in the same solution, we can state that it is a good way to improve the current delivery schedule.

6.3 Alternatives to the current delivery schedule

As already mentioned, there are several options to make changes in the delivery schedule, since delivery can be based on certain aspects. This can be done, for instance, by basing delivery on the ABC analysis on the average usage of products per day of a department, as shown in 6.2.1. Another opportunity is to divide the departments of the orange delivery route over the other routes since this is the only horizontal delivery route and this takes by far the most time. The last section is about developing an additional route for the outpatient clinics since they have different working hours than another department, which might run 24/7. All these methods are discussed in this chapter.

6.3.1 Schedule based on ABC-analysis of usage of bins at departments

The schedule based on the ABC-analysis of the usage of products at departments resulted in different alternatives. For the first alternative schedule, the ABC-analysis based on the average usage of bins per day is used to categorize the departments. This is done for all departments in the same way as explained in schedule 6.2.1. As already mentioned, 39 departments are classified to be resupplied daily, 15 departments that are resupplied three times a week, 24 departments that are resupplied twice a week, and 14 departments that are only resupplied once a week. The departments at the orange delivery route are important for operations to continue, and therefore they need to be delivered more frequently than the other routes and stock-outs should be prevented. The full delivery schedule is in appendix 11. The average bin usage per day is shown in table 6.2.

A second alternative checks whether it is possible to work only on weekdays and stop working on Saturdays. This is very difficult since several departments at the hospital work 24 hours and 7 days a week and therefore use their products also continuously and there are a lot more order lines on Monday since bins are not resupplied on Saturdays anymore. On average, it is possible to deliver the number of products with the current number of suppliers. However, if there is a peak in usage on Saturdays and Sundays, it is almost impossible to deliver all the products. The worst-case scenario is that there are almost 1750 order lines to be delivered on Mondays, which means 900 extra order lines than the current average number of order lines (856) and 200 more than the maximum delivered number of products while working with the current schedule. And since the current schedule is already using the maximum number of delivery moments, there will not be any additional time to deliver the 200 extra order lines. If deliveries do not take place on Saturdays anymore, realizing a high service level very difficult. The only difference between the current schedule and the proposed schedule is that the logistics employees do not work on Saturdays anymore, so the delivery frequencies on weekdays stay the same. The average number of order lines per day is shown in table 6.3.

Order lines per day per schedule	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Average
Current schedule	1061	889	859	872	934	522	856
ABC-Analysis schedule	1052	920	832	916	892	522	856
No delivery on Saturday	1328	1113	1075	1092	1169	0	1156

TABLE 6.3 – AVERAGE NUMBER OF ORDER LINES PER DAY FOR DIFFERENT SCHEDULES.

The average usage of bins per week is the same for the current schedule and the ABC-Analysis schedule. This is also the case since the demand and usage do not change when the delivery schedule is changed. The only thing that changes in terms of order lines is the average demand per day since several departments are not visited daily anymore. Another difference that this method yields over the current schedule is the decrease in the number of departments and floors visited per week. Currently, every on average 73 departments are visited per day and 157 floors are visited per week. If the schedule of the ABC-analysis is used, the average number of departments per day decreases to 53, which means a reduction of 28%. The number of floors visited per week decreases by 18% to 128. We assume that logistics suppliers only take the carts with them that are needed to supply one floor and have to go back to the basement to take new supplies for another floor. Therefore, we estimate that going back to the basement, walk to and grab a new cart with supplies, going back to the elevator, and going to the new floor, takes 10 minutes. Next to that, we estimate that switching between departments on the same floor takes 5 minutes on average. The following table shows the difference between the number of departments visited per day for the current schedule and the alternative:

Departments visited per day per schedule	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Total
Current schedule	64	64	65	67	67	44	371
ABC-Analysis schedule	57	54	55	56	55	41	318
Difference	7	10	10	11	12	3	53

TABLE 6.4 – AVERAGE DEPARTMENTS VISITED PER DAY FOR BOTH DELIVERY SCHEDULES

If the difference between the departments visited is multiplied with the two minutes, so 53*5 = 265 minutes per week are saved with only reducing the movements between the departments. Next to that, logistics suppliers save 29 times 10 minutes by switching floors and taking new carts for departments, which comes down to 290 minutes per week. This makes 555 minutes in total, which comes down to almost 9.25 extra hours per week only by changing the schedule, which is more than one working day for FTE.

6.3.2 Stop with the orange delivery route and divide the departments over the other delivery routes

Since the orange delivery route takes the most time per bin the be replenished, as can be seen in section 2.3, changes in the orange delivery route can significantly improve the efficiency. An option to change and improve the current delivery schedule is to stop with the orange delivery route and add the departments that were in the orange delivery route to the other existing routes. This will decrease the horizontal movements across the departments and will make sure that bins are faster resupplied since the suppliers do not have to walk to all the departments across the whole third floor. This means that several departments that are currently linked to the orange route are rescheduled and added to another route. Since all the other routes are linked to the elevators, the departments on the third floor are also linked to the delivery routes in the same way. This yields the following changes in the delivery schedule:

New Route	Floor	Department that works with order boards
Blue	3	TOK Anesthesie/TOK steriele gang
Blue	3	TOK Anesthesie/TOK steriele gang
Blue	3	TOK Anesthesie/TOK steriele gang
Blue	3	C34 ICC-A (TIC)

Blue	3	C37 EHH
White	3	C37 CCU
White	3	C37 CCU
White	3	C3 OBC
Red	3	C34 ICC-D
Red	3	C34 ICC-E
White	3	AOK Anesthesie
White	3	AOK
White	3	AOK
Blue	3	Perfusie

TABLE 6.5 - NEW ROUTES FOR DEPARTMENTS OF THE ORANGE ROUTE

Spreading the departments of the orange delivery route over the other routes also has consequences for the ordering moments. These change since the orange delivery route is not used anymore. Therefore, the departments at the blue delivery route are read out instead of the orange delivery route. This means that the red delivery route is read out at the time of the blue delivery route, and so on. Table 6.10 shows the ordering moments per delivery route.

Route	Time
Blue	7:00 AM
Red	7:45 AM
White	8:15 AM
Green	9:00 AM
Yellow	9:30 AM

TABLE 6.6 – NEW ORDERING TIMES WHEN THE ORANGE DELIVERY ROUTE IS NO LONGER USED

Of course, the Blue, Red, and White routes will be busier since all the order lines of the orange route are divided over these three routes. However, the horizontal movements that took place while resupplying the orange route are minimized, which leads to an increase of vertical movements and in the end faster delivery of products. Next to that, an extra improvement can be made by applying the ABC-analysis on bin usage per department on this delivery schedule in the same way as it was applied on the current delivery schedule. The combination of these two measures has a direct impact on the in-house supply chain efficiency since fewer departments are visited daily and several departments. The expected average number of order lines per route per day is shown in table 6.11. However, this is when the current schedule is still used.

Route	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sum per route
Blue	245	205	198	201	216	134	1199
Red	346	290	280	284	304	175	1678
White	328	275	266	270	289	141	1568
Green	133	111	107	109	117	73	650
Yellow	24	0	0	20	0	0	44
Sum per day	1075	881	851	884	925	522	5139

TABLE 6.7 – THE EXPECTED NUMBER OF ORDER LINES PER DAY PER ROUTE IF THE ORANGE DELIVERY ROUTE IS NO LONGER USED

If the ABC-analysis is used to change the delivery schedule and decrease the delivery frequencies, the expected order lines per day are distributed over the routes in the following way:

Route	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sum per route
Blue	267	200	177	208	206	141	1200
Red	370	248	310	243	339	174	1684
White	353	271	255	266	292	137	1574
Green	126	121	102	120	111	69	650
Yellow	0	0	39	0	0	0	39
Sum per day	1116	840	884	837	949	522	5147

TABLE 6.8 – THE EXPECTED NUMBER OF ORDER LINES PER ROUTE PER DAY IF THE ORANGE DELIVERY ROUTE IS NO LONGER USED AND THE ABC-ANALYSIS OF BIN USAGE IS APPLIED TO THE SCHEDULE

The small difference of 8 order lines is due to the rounding of several numbers. These tables show that the difference between the average expected products to deliver per day is small. However, the expected number of departments to visit is significantly smaller for the alternative that combined the schedule without the orange delivery route and the ABC-analysis of the bin usage. The expected average number of departments visited per week for just the new schedule without the orange delivery route is the same as for the current schedule, namely 72. If we compare this to the alternative that combines the divided orange delivery route and the new delivery schedule, the expected average number of departments visited decreases to 54, which means an expected decrease of 25%. Next to that, the expected number of floors that are visited per week decreases from 151 to 140, which means that the logistic suppliers weekly visit 11 floors less than normally. If we make the same assumption and estimate the time for a floor switch around 10 minutes, 110 minutes are saved per week.

Departments visited per day per schedule	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Total
Schedule without the orange route	64	64	65	67	67	44	371
Schedule without the orange route + ABC-analysis of bin-usage	61	50	59	52	59	41	322
Difference	7	10	10	11	12	3	49

TABLE 6.9 – AVERAGE DEPARTMENTS VISITED PER DAY FOR BOTH DELIVERY SCHEDULES

Table 6.13 shows the difference in departments visited per day and in total over the whole week. The number of departments visited decreases by 13.2% to 322. The 49 movements between departments that are saved for the logistic suppliers yield 49*5=245 minutes per week. If we add this to the minutes saved for switching floors, 355 minutes, which comes down to almost 6 hours per week, are saved.

6.3.3 Outpatient clinic route

As already discussed in 4.2, the workdays at the outpatient clinics differ from the hours at the nursing wards for instance. The nursing wards work 24 hours a day, 7 days a week, whereas the outpatient clinics do have opening and closing times. The employees at the outpatient clinics work from 8:00 AM until 4:30 PM or 5:00 PM. This means that, after the closing time of the department, no additional Kanban cards are placed. So, in theory, the orders for the outpatient clinics can already be batched and picked around 4:30 PM. On the other hand, the first hour of the suppliers of the logistics department is not efficient since they wait before the first orders arrive to resupply several departments. Hence, there are chances to increase the current efficiency of the internal supply chain, with certain changes in the planning of the suppliers at the logistics department and shifting the readout moment of the outpatient clinics to 4:30 PM. Normally, 4 logistics suppliers start their day at 8:00 AM. As already mentioned, their first hour is not efficient, and that is why the following changes are proposed. Two of the logistics suppliers work their normal hours, which means from 8:00 AM until 4:30 PM. The other two logistics suppliers work from 9:00 AM until 5:30 PM. This shift is made since they can start picking the products for the outpatient clinics, which means that the logistics suppliers who start the next day at 8:00 AM can start immediately with the delivery of the orders that are picked the day before. The readout moments are as follows:

Route	Time
Orange	7:00 AM
Blue	7:45 AM
Red	8:15 AM
White	9:00 AM
Green	9:30 AM
Outpatient Clinics	4:30 PM

TABLE 6.10 – NEW ORDERING TIMES WHEN ADDING THE OUTPATIENT CLINIC ROUTE

Almost every outpatient clinic is added to the route. The only department that is not added to the route is the 'P-SEH', which is the emergency department since this department is also running every hour of every day. Therefore, the electronic order boards at this department are read out at the same moment as already was the case. The list of departments that are added to the outpatient clinic route, together with the other delivery routes, is shown in appendix 12. The number of departments at the red delivery route decreases the most since 11 inventory stockrooms are linked to the red route.

The average order lines per day per route are a bit more spread out over the different delivery routes in this way. The outpatient clinic contains the most departments compared to all the other delivery routes, namely 25. This also results in relatively many order lines per day. However, if we look at the ABC-analysis based on bin usage to this schedule, which results in fewer deliveries and more efficient runs, we can state that a significant number of departments of the outpatient clinic route do not use large numbers of products. Most departments should only be delivered one, two, or three times a week. This is also represented in appendix 12. The following tables show the order lines per day for the outpatient clinic route with the current delivery schedule (table 6.11) and the alternative schedule developed with the ABC-analysis (table 6.12).

Order lines per day per schedule	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sum per route
Orange	286	240	231	235	252	146	1390
Blue	179	150	145	147	158	111	890
Red	144	121	117	119	127	88	716
White	137	115	111	112	120	80	675
Green	103	87	84	85	91	64	513
Outpatient Clinics	211	177	171	174	186	34	954
Sum per day	1061	889	859	872	934	522	5137

TABLE 6.11 – THE EXPECTED AVERAGE NUMBER OF ORDER LINES PER DAY IF THE OUTPATIENT CLINIC ROUTE IS USED

The differences in the totals are because of the rounding of the numbers. Nevertheless, this shows that the variance of the daily number of orders reduced which means that the number of order lines is spread more over the week.

Order lines per day per schedule	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sum per route
Orange	311	213	252	209	274	139	1397
Blue	195	151	131	161	142	112	892
Red	143	120	122	117	126	88	715
White	167	108	105	106	114	80	680
Green	94	94	76	93	83	69	510
Outpatient Clinics	142	234	146	230	154	34	941
Sum per day	1052	920	832	916	892	522	5134

TABLE 6.12 – THE EXPECTED AVERAGE NUMBER OF ORDER LINES PER DAY IF THE OUTPATIENT CLINIC ROUTE IS USED COMBINED WITH THE ABC-ANALYSIS SCHEDULE

If we compare the average number of departments visited per day of the outpatient clinic route and the outpatient clinic route with the ABC-analysis schedule, we can state that this saves the same amount of time as applying only the ABC-analysis schedule. However, the combination of the outpatient clinic route and the ABC-analysis increases the efficiency even more since the first hours of the logistics suppliers is more efficient than before.

6.4 Pros and Cons of the alternative schedules

All the alternatives described in sections 6.2 and 6.3 are useful to increase the efficiency of the delivery process in terms of KPIs. However, the alternatives do not only have advantages of course. All the pros and cons are discussed in this section. Next to that, there is also a discussion about the use of different methods and techniques together. The alternative schedules and methods can be implemented separately but can also be used in combination to strengthen each other. As already described, the outpatient clinic route and the schedule where the orange route vanished can be used in combination with the ABC-analysis of the usage of bins per day to increase the efficiency even more. Another important point is the implementation of the new delivery schedule in the current process. Where is a successful implementation depends on and which measures should be taken before a method actually can be used for delivery in practice.

6.4.1 Pros and cons of the ABC-analysis based on usage of bins per department

If the delivery is based on the usage of bins per day, a lot of deliveries for just a small number of SKUs are saved up until the next readout moment. Normally, every 24 hours an electronic order board sends an order with all the SKUs that are on the electronic order board. This period is too small for a lot of departments since they do not use that many (items of) SKUs, which results in a small number of SKUs to deliver to the departments the next day. If the departments are delivered based on an ABC-analysis on the number of bins used per day, a lot fewer deliveries are done, and more SKUs are delivered to departments at once. This increases the efficiency of the delivery runs. Another advantage is that logistics can easily track the number of bins used daily, which can be used to revise the ABC-analysis after a certain period. Next to that, these changes are easy to implement, since this only changes the readout moments of the electronic order boards and do not need certain algorithms to be developed like for the implementation of the delivery based on certain conditions.

The results of the ABC-analysis can be used in combination with both the delivery schedule without the orange delivery route and the outpatient clinic route. A possible disadvantage can be that, when departments are delivered once a week, they have to wait for their products if two bins are out-of-stock. However, if this happens frequently, the bin size can be adjusted to prevent stock-outs.

6.4.2 Pros and cons of the schedule without the orange delivery route

When the orange delivery route is split and the departments are divided over the other routes, fewer horizontal movements take place, which decreases the overall delivery time and increases the overall efficiency. The number of horizontal movements is decreased by spreading the departments of the orange route over the other routes.

The implementation of this solution in terms of technical changes for the electronic order boards can be done fast since only the routing and readout moments of the electronic order boards need changes. Next to that, all other proposed methods to change the delivery schedule can be combined with this method. However, a possible disadvantage can be that the changes for Transferium, who are currently doing the delivery at the orange route, are huge since they lack work if they do not resupply the departments anymore.

6.4.3 Pros and cons of the outpatient clinic route

If the outpatient clinic route is set up and implemented, first, the peak of activity in the picking warehouse, which is currently between 8:00 AM and 12:00 PM, will be decreased which leads to fewer order lines to pick during the morning hours. Next to that, the first hours of the logistics suppliers are also more efficient, since, at the start of the day, there are several carts with orders for the outpatient clinics ready to directly start resupplying the outpatient clinics. Another advantage is that this new delivery schedule can be applied in combination with all the other methods discussed earlier in section 6.4.

However, this solution is somewhat harder to implement, since there is a need for logistics employees to work from 9:00 AM until 5:30 PM. Changes are needed in the schedule and the employees need to agree with this change.

6.5 Conclusion

To finish this chapter, the main research question and the sub-questions mentioned earlier in 6.1 are answered, if they are not already answered in the literature study. The answers to the sub-questions help in answering the main research question of this chapter.

5.1 *What changes can be made to the current delivery process to increase efficiency?*
Changes to the current delivery schedule can be made on different levels. For instance, deliveries can be done less frequently when the schedule is based on demand. Another possibility is to add new delivery routes and/or change and replace the current delivery routes. This can be based on the current routes that can be improved or the working days of other departments.

5.2 *Which methods are there to develop the delivery schedules?*
A new delivery schedule can be based on certain conditions on department level, namely the delivery frequencies can be based on the bin demand per day, which can be classified with an ABC-analysis. Creating new routes or changing existing routes can be based on common sense since these are unique for every firm that you work for.

5.3 *Which alternatives are there to the current delivery schedules?*
There are several alternative methods to base a new delivery schedule on, where the first alternative described is a delivery schedule on bin usage. This alternative for the current delivery schedule is based on the delivery of the number of bins used per day. When the bin usage per day is between a certain range, an adequate number of deliveries per week will take place to make sure that the service level remains high, but deliveries for a small number of SKUs per department do not take place very often.
It is also possible to change the delivery routes, based on common sense. Another alternative is spreading the departments of the orange delivery route and dividing these departments over the other, already existing, routes. The orange delivery route is no longer used in this way. This makes sure that there are fewer horizontal movements, which take more time than vertical movements. This reduces the delivery time per SKU overall since the orange delivery route currently is the delivery route that takes the most delivery time per SKU.
The last alternative that was described is to create a separate delivery route for the outpatient clinics. This is since the working days of the outpatient clinics end at 4:30 PM. If two logistics suppliers start and end their day one hour later, they can pick the orders for the outpatient clinics, since these departments do not consume any products during the night. Therefore, if the orders are (partially) ready at the start of the next day, the logistics suppliers can immediately start with delivering these orders to the outpatient clinics.

5.4 *What are the pros and cons of the different alternatives?*
There are different pros and cons per alternative. Next to that, we can compare the alternatives on different criteria and check which alternative fits in which situation. Several criteria are for instance the cost, how the alternative can be combined with the other proposed alternatives, the expected efficiency improvement and whether this alternative can be implemented in the short-term. When an alternative receives ‘++’ on a criterion, it means that it performs well, whereas ‘--’ means that it does not perform well on that criterion.

Alternative	Lowly time intensive	Combined with other delivery methods	The expected improvement in efficiency	The expected improvement in product availability for patient care	Short-term implementation	Low implementation cost
Bin usage-based delivery	++	+	+	-	++	++
Schedule without the orange delivery route	+	++	+	-	+	+
Outpatient clinic route	+	++	++	+	-	+

TABLE 6.13 – EVALUATION OF THE PROS AND CONS ON DIFFERENT CRITERIA OF THE PROPOSED ALTERNATIVES

5.5 *What is the best choice to make when trying to optimize the efficiency of the whole delivery process?*
When trying to optimize the schedule in the short-term, apply the schedule achieved from the ABC-analysis on the usage of bins per department. Several departments are delivered less frequently, but with more SKUs at once. Next to that, this can, in the future, very well be combined with the outpatient clinic route. This solution is a solution for the long term since before this solution can be implemented, schedules of logistics suppliers need to be changed and the logistics suppliers have to agree on different working hours than discussed. Dividing the departments of the orange delivery route over the blue, red and, white delivery routes results in faster delivery per SKU.

This chapter aimed at improving the efficiency of the delivery process. So, to conclude this chapter, the following main research question needs to be answered:

5. **How can the delivery process be optimized?**
To optimize the delivery process, the delivery schedule needs to be changed to make the delivery runs more efficient. For a short-term adequate solution, the ABC-analysis on the usage of bins per department can be used to lower the readout frequencies, which makes sure that the logistics suppliers deliver more goods at once. This should be combined with the outpatient clinic route in the future since this extra route cannot be implemented immediately because of the complications before the schedules of the logistics suppliers can be changed. This results in the most savings per week. However, this change in schedule makes the first hour of the logistics suppliers more efficient and decreases the peak in picking activities. The solutions described in this chapter contribute to the improvement of the KPIs mentioned in 6.1. First, the average delivery time per order line and the average delivery time is decreased by dividing the departments of the orange delivery route over the other routes, whereas the number of products delivered per department increased by the new delivery schedule based on the daily bin usage per department.

7. Results per process aligned with other processes and implementation plan

This chapter combines the results of the previous chapters and verifies which proposed changes result in the most savings per process and for the whole supply chain. Next to that, is compared which influence a change in a certain process has on the other processes.

7.1 Ordering process and picking process

The ordering process initiates the picking process since the products that are ordered, of course, need to be picked and delivered to the departments. The first proposed solution was training by logistics for the users of the electronic order boards. This results in a significantly better understanding of how to use the electronic order boards, how the Kanban-two bin principle works, and what the trigger is to deliver for the logistics department. If the users of the electronic order boards know and understand how the order and delivery system work, they do not misuse it, the number of returns decreases, and fewer emergency orders have to be brought to the departments since the users place cards on time and not shortly after the readout moment.

A second improvement in the ordering process which causes small changes in the picking activities is the implementation of the EBQ calculation in the min/max quantities of the SKUs at the department warehouses. Several SKUs have to be picked in other quantities, which match more with the current demand and usage pattern of the SKUs. As already mentioned in section 4.3, the average days that pass before a bin is empty decrease significantly. This means that, on average, SKUs are picked more often. However, this is mostly due to the decrease bin quantities of the SKUs that are rarely resupplied but have a large quantity of the SKU in the bin, which slow-moving stock for a long period. If, for example, a bin with a certain SKU with a min/max of 10 units currently needs 300 days before it is resupplied. This means that, on average, one unit is used every 30 days. Therefore, if the min/max is lowered to, for instance, 2 units, the average number of days it takes before the bin is empty is reduced to 60. These kinds of items are picked more often than before. The solution results, as also stated in section 4.3, that the inventory value reduces significantly, just as the standard deviation of the average days before a bin is empty. The standard deviation of the average days before a bin is empty reduces by 11.7%, which means that the average days before a bin is empty is closer to the average number of days before a bin is empty over all bins. This means that there is more inventory available in the central warehouses, so logistics does not have to order more products for their warehouses and can lower their stock there. Next to that, there is a larger chance that more items are resupplied at once since the averages of the days before a bin is empty are closer to each other.

The third proposed change is the decrease in readout moments of the electronic order boards. Since the order frequency of a significant number of departments decreased and is not resupplied daily but for instance two or three times a week, the orders of these departments only show up after the specific review periods. This means that the average number of order lines of these departments is increasing since order lines are saved for the next day for instance. This means orders contain more order lines per department and that the pickers need more time to pick one order. This has a positive influence on the picking process since the proposed storage allocation of SKUs works significantly better for orders with more order lines than for short orders. As can be seen in section 4.4, out of the sample of 22 departments, the periodic review model shows that at least 10 departments can be resupplied less frequently than daily. Most of these departments are also outpatient clinics. This indicates that these departments can be treated differently from nursing wards for instance, where care takes place 24 hours a day and 7 days per week. This was also a reason to check how a specific route for outpatient clinics (except for the emergency department) would look like and to check whether it is possible to develop such a route.

The proposed change in storage allocation does not have an impact on the ordering process since the picking process is triggered by the ordering process, and not the other way around.

7.2 Picking process and delivery process

Since the delivery process can only start after the picking of orders is done, reducing the average time to pick all orders does influence not influence the delivery process itself directly, but only the makespan. Since the picking can be done faster, the delivery of the SKUs to the departments can start earlier and more SKUs can be delivered in the same amount of time. The proposed storage allocation for SKUs makes sure that the picking of orders runs faster since the SKUs are located closer to the I/O-point of the warehouse. If the pickers need less time to pick the orders, the logistics suppliers can start earlier with the delivery of the medical supplies. This means that more orders can be delivered on a day. As already mentioned in section 5.2, the average distance an order picker has to walk is reduced by 33.30%, which means that less time is needed to do the picking, and eventually more orders and order lines can be picked in a day.

Some of the proposed changes in the delivery process can influence the picking process. The separated outpatient clinic route does certainly influence the picking process since the picking of these goods happens after 4:30 PM when normally the day ends for every logistics employee. If these supplies are picked and the orders are consolidated, the logistics suppliers can start immediately by delivering the supplies to the outpatient clinics.

The other proposed solutions, namely the ABC-analysis on bin-usage per department and dividing the department of the orange delivery route over the other delivery routes, have only a small influence on the picking process. These solutions only change when which department is picking, just as explained in 7.1 for the departments that are not resupplied daily anymore but two or three times a week.

7.3 Ordering process and delivery process

The idea behind the proposed solutions to increase the efficiency of the ordering and delivery process is more or less the same: decrease the order and delivery frequency and increase the average number of SKUs delivered to the departments. Since the delivery process is triggered by the ordering process, decrease the order frequency will in this case automatically decrease the delivery frequency. If the period between the readout moments of the electronic order boards is extended to 48 hours, for instance, SKUs are saved to make delivery runs to the department warehouses even more efficient.

The conclusion from 4.4 is that the review period of a lot of departments can be extended to 48 hours or more. This is also confirmed by the results of 6.3.2, which is the ABC-analysis on bin-usage per day. This gives extra strength to the assertion that the review times are too close to each other. Therefore, we can state that the ordering frequencies, and consequently the delivery frequencies, can be decreased.

Another conclusion from section 4.4 is that the departments for which the review period should be extended mostly are outpatient clinics. Out of the sample of 22 departments, the review period should be increased for at least 10 departments, from which 7 departments are outpatient clinics and 1 department is a kitchen. Therefore, a separate route for the outpatient clinics (and kitchens) is a serious option to improve efficiency since these departments do not work 24 hours a day. Since the outpatient clinics' working day ends at 4:30 PM, no additional Kanban cards are placed. Therefore, as already mentioned in section 6.3.4, if the electronic order boards are read out at 4:30 PM, all orders can be prepared the same day and delivered the next day.

Next to that, dividing the departments of the orange delivery route over the other delivery routes has consequences for the ordering of the departments that are in the orange delivery route. All these departments are linked to the other delivery routes, which means that the ordering times of the departments are changed, as already explained in 6.3.3. This results in more vertical movements instead of horizontal movements, which decreases the overall delivery time.

Since the picking time is decreased by the reallocation of SKUs in the unsterile warehouse, the logistics suppliers can start earlier with resupplying the departments. Next to that, more order lines can be picked in the same amount of time, so, more order lines can be handled in a day.

8. Conclusions and recommendations

The last chapter of this master thesis concludes this research, recommends which proposed changes MST should implement, gives insights in future research, and shows the limitations of this research. Section 8.1 presents an overview of the conclusions and answers the main research question. Next, section 8.2 presents the recommendations to MST using the results of the research. Section 8.3 shows a plan on how to implement the recommended solutions. The next section, namely 8.4 gives the limitations of this research and links these limitations to the conclusion and recommendations. Finally, section 8.5 gives insight into future research that can be done.

8.1 Conclusions

This research has the aim to answer the following main research question:

How can MST improve the way of working with the electronic order boards at the departments so as to improve the efficiency of the in-house supply chain?

Chapter 2 was an introductory chapter and analyzed the context of the organization. This chapter described in which context the research took place and how the current process runs. Next to that, all the core problems are analyzed by big data analysis together with the KPIs about the efficiency of the in-house supply chain. The in-house supply chain is split into the different processes, which are described and analyzed in chapters 4 until 6.

The literature study of chapter 3 resulted in methods and models that were useful in optimizing the processes in the in-house supply chain. Several methods and models were found per process step and can be used to tackle the core problems that occur in that specific process step. Eventually, per process step, one of the models is chosen to optimize it.

The fourth chapter of this thesis describes how to optimize the ordering process of the in-house supply chain. First, the way of working with the electronic order boards is discussed. With additional training for the users of the electronic order boards by the logistics employees, late placements and out-of-stock moments are decreased, which increases the efficiency of the in-house supply chain. The second improvement is done with the use of the EBQ-tool. This tool recalculates the bin quantities to be aligned with the usage of the SKU and to increase the chance of resupplying more products at once to the departments. Next to that, the readout moments are adjusted, based on the periodic review model. This model optimizes the time between two readout moments for every department, based on the cost per order, shortage cost, and the average bin usage of the department.

The fifth chapter optimizes the storage allocation of SKUs in the unsterile warehouse. Since order pickers spend 50% of their time traveling from SKU to SKU, the SKUs should be located optimally based on the demand and interaction frequency of the SKU. This is done with the use of the interaction frequency heuristic (IFH). This reduced the distance that the order pickers walk by 33.30%, which means that the picking time also reduced with the same percentage.

The sixth chapter describes how the delivery process can be changed to increase the efficiency of the in-house supply chain. There are several methods described to optimize the delivery process, among which the ABC-analysis, which is done on the bin-usage per department. This improvement can only be implemented if the changes in the ordering process are not implemented already, since these methods do the same, but have different results. With the use of this ABC-analysis, the delivery frequencies are based on the bin usage per department, which increases the efficiency of the delivery runs since fewer runs for a low number of SKUs are made. Another possible improvement is adjusting current delivery routes or creating new delivery routes. The first alternative that is discussed is dividing the departments of the orange delivery route over the other delivery routes. Since the orange delivery route is the only route that is horizontal, instead of vertical, the departments along this route can be divided over the other already existing routes. In combination with the ABC-analysis on bin usage, this alternative saves 6 hours per week. The other alternative is a special route for outpatient clinics (except for the emergency department) and kitchens. This alternative route is developed since the working days of the outpatient clinics end at 4:30 PM, which means that no SKUs are used after that time. So, the electronic order boards are read out after that moment and already picked. At the start of the next day, the logistics suppliers can already resupply the outpatient clinic and do not have to wait before the first orders of the orange delivery route are picked. This alternative, in combination with the ABC-analysis on bin usage, saves 9.25 hours per week. However, the schedule that was developed by the periodic review model should be used to resupply the departments. However, the ABC-analysis can be used to compare both outcomes.

8.2 Recommendations

After discussing and analyzing several alternatives to the current ordering, picking, and delivery processes, the improvements that are recommended are described in this section. A lot of improvements are proposed, but not it is not possible to implement all the solutions since not all solutions strengthen to other solutions. Therefore, per process an improvement is recommended for the short term, and if available for the long-term.

The first improvement that should be done is the additional training for the users of the electronic order boards by the logistics employees. The logistics employees have the know-how about the two-bin Kanban system and are capable of giving a good explanation of their process and tell them what the desired way of working with the electronic order boards is. If the users of the electronic order boards know what the optimal way of working is with the electronic order boards, the out-of-stock moments due to late placements or double cards decrease. The next improvement that is recommended is the use of the periodic review model. This model optimizes the time between the readout moments, to decrease the order frequencies and spread the picking activities. This model optimes the time between the ordering moments. The outcomes of this model can be used for the EBQ-tool, which is the last tool that should be used to improve the efficiency of the in-house supply chain. The EBQ-tool is used to decrease the inventory value at the departments, which makes sure that more units of an SKU stay at the warehouse, to distribute these to other departments for instance, and prevent stock from getting obsolete for instance. Another advantage of the EBQ-tool is that the standard deviation of the average days before a bin is empty is decreased, which indicates that the chance that the bins of SKUs are empty at the same time is larger, which means that more SKUs are resupplied at once.

The recommended improvement for the picking process is the new design of the warehouse. The SKUs in this warehouse are allocated based on the usage of SKUs and interaction frequencies on orders, which decreases the picking distance that a picker has to walk, and so decreases the time before the picking is done. The average time per order increases, since the improvements in the ordering and delivery process make sure that the picking lists contain more order lines. However, the average time per order line picked decreases since the SKUs are located more optimally. The interaction frequency heuristic allocated the SKUs according to the frequency that they occur together on orders. This heuristic decreases the distance that an order picker has to travel while picking orders by 33.30%. This means that more orders and order lines can be picked in the same amount of time as before.

The recommended changes in the delivery process are done by using the ABC-analysis on bin usage per department. This can be checked and compared to the solutions of the periodic review model used for the ordering process. However, the ABC-analysis itself should not be used, since the periodic review model already optimizes the time between two readout moments. Next to that, the EBQ is used after the periodic review model. If the EBQ is used after the ABC-analysis, the results always change since the EBQ is more or less based on the same values as the ABC-analysis. These improvements can be compared with the new outpatient clinic route. The use of this newly developed delivery route increases the efficiency of the first hour of the logistics suppliers and makes sure that the peak in picking activity decreases. The use of the recommended changes based on the periodic review model together with the newly developed delivery route is expected to save the logistics department 9.25 hours per week.

8.3 Implementation plan

There are many steps to start with and that can be done to increase the efficiency of the in-house supply chain. This section describes how to solve the core problems via an implementation plan that consists of the methods described in this thesis. Several solutions stand by themselves and do not need a complete plan with multiple methods before it can be implemented.

The core problems for the ordering process are solved first. The misuse of the system at the departments is mostly solved by giving additional training by logistics employees/coordinators to the users of the electronic order boards. Of course, several cards can still be placed shortly after the readout moment since SKUs can be used then, but most late placements due to misuse are solved.

The out-of-stock moments due to too few units of SKUs in the bins can be solved by applying the EBQ to the min/max calculations of the Kanban two-bin inventories. The EBQ makes, among others, sure that for SKUs for which the min/max is too low, is increased. This reduces the out-of-stock moments significantly since the inventory is aligned to the usage of SKUs.

The next core problems that are solved are the wrongly timed readout moments of the electronic order boards, the organization of the delivery process, and the inefficient delivery runs. The readout moments are too close to each other, which causes inefficient deliveries of logistics suppliers to the departments. If the readout moments are too close to each other, a lot of departments are visited for just one or two SKUs, which makes a run through the whole hospital not efficient. Therefore, the goal is to visit these departments with more than one SKU, but less often. As mentioned in the recommendations, this should be solved by using a combination of the EBQ, periodic review model, and ABC-analysis on bin-usage per department. The first step is to use the EBQ-tool to revise the min/max of all the SKUs at that department. An instruction manual of how this tool works is shown in appendix 8. This makes sure that all the bin quantities are aligned to each other, which gives a greater chance of making a resupply run for multiple products. Next, the periodic review model is used to recalculate the time between two order moments. An instruction manual about the tool that the logistics department can use to recalculate the periodic review interval is shown in appendix 9. This results in a time interval that should be in between two orders of a specific department. This time interval can be compared with the ABC-analysis done on bin usage at the departments. If there is a difference between the outcome of the ABC-analysis and the periodic review model, I would recommend using the outcome of the periodic review model, since this is based on more parameters than the ABC-analysis. However, the ABC-analysis is a way to compare the result of the periodic review to the bin usage per day. These techniques and readout moments can be combined with the outpatient clinic delivery route. This is implemented by changing the readout moments of the electronic order boards of all the outpatient clinics (and kitchens), except for the emergency department, to 4:30 PM. This also takes care of the peak in the picking process. Not all orders are picked in the morning hours since the orders for the outpatient clinic route are picked in the afternoon, which flattens the curve of activity in the picking process.

The picking time is reduced by the re-allocation of SKUs in the central warehouses since the SKUs are not optimally located in the warehouse. Currently, the SKUs are located on gut feeling. The method used re-allocates the SKUs based on the interaction frequency of SKUs at orders. The re-allocation of SKUs minimizes the picking distance for the pickers to travel, which at its turn decreases the picking time. This works the best for larger orders. These larger orders are also created by the decrease in order and delivery frequencies. Since departments are resupplied less frequently, more SKUs are delivered every time the logistics suppliers go to the departments. Lastly, since the order pickers work with barcode scanners currently, wrongly picked products are not an issue anymore. However, the number of units per SKU is the only mistake that the pickers still can make, which means that they do not count the number of units correctly and pick too few or too many products.

The following solutions are recommended in order to increase the efficiency of the in-house supply chain. The implementation numbers are also the sequence that the solutions that should be implemented. If all solutions with a lower implementation number are not implemented yet, the implementation of the next number cannot be done.

Implementation number	Priority	Actor	Action
Ordering process			
1. Training	High	Head of logistics together with logistics employees	Assign coordinators to departments to explain the way of working at the logistics department.
1. Periodic review	High	Logistics employee	Recalculate the time between two ordering moments of all departments. Revise this after 3 months.
2. EBQ calculations	High	Logistics employee	Recalculate the bin quantities of the SKUs at all departments. Revise this after 3 months.
Picking process			
1. New warehouse design	Medium	Head of logistics together with logistics employees	Make sure the SKUs get to their newly assigned storage location in the unsterile warehouse.
Delivery process			
3. Outpatient clinic route	Medium	Logistics employee	Make sure the electronic order boards of the departments that are assigned to the outpatient clinic route are read out at different times.

TABLE 8.1 – ROADMAP OF THE IMPLEMENTATIONS

8.4 Limitations of this research

A limitation of this research can be that the data is biased since the data that was used was collected during the COVID-19 pandemic. During an average year, several items are used less or more than during a pandemic, like for instance the mouth masks and gloves. Next to that, several departments are treating fewer patients than normal since the regular care is scaled down to treat more COVID-19 patients.

Another limitation is the fact that several parameters are estimated, which means that in real life these costs can fall out differently, which at its turn can cause results that are not as efficient in real life as they seem when the model calculates them.

8.5 Future research

Several aspects are still there to do future research on. An example for future research is the continuous research model of Rosales et al. (2015), which calculates the minimum number of products before an electronic order board should readout and send an order to the logistics department. Literature states that this resupplying method is more efficient and less costly than the current periodic review. However, since the whole planning and in the end, all the processes in the logistics department should be changed, this research takes quite some effort. Therefore, in the future, this can be one of the topics that can be added up to this research. Next to that, the EBQ calculations work better in combination with the continuous review model since the EBQ calculations are based on continuity.

Next to that, the head of the logistics department is currently thinking and talking about taking the flow of goods of the pharmacy with them to the departments, as well as an additional flow of goods for the kitchens. For future research, it can be checked how these different streams can be combined into one flow of goods and how this can be designed efficiently.

Another option for improvement in the future is the use of Order Oriented Slotting (OOS). Literature states that the OOS reduces the distance that a picker walks, and so the picking time, with almost 40%. This is an interesting option to further investigate.

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Appendix

Appendix 1: Use of electronic order boards per department including order time, release time, work floor, and warehouse codes

Departments with an electronic order board with order- and delivery information. This schedule holds from Monday till Friday.

OrderTime	ReleaseTime	Route	Floor	Department that works with order boards	Warehouse code at Dept.
07:00	07:30	Orange	3	TOK Anesthesie/TOK steriele gang	TOK S
07:00	07:30	Orange	3	TOK Anesthesie/TOK steriele gang	TOK O
07:00	07:30	Orange	3	TOK Anesthesie/TOK steriele gang	TOK ANES
07:00	07:30	Orange	3	C34 ICC-A (TIC)	TIC
07:00	07:30	Orange	3	C37 EHH	V-EHH S
07:00	07:30	Orange	3	C37 CCU	V-CCU S
07:00	07:30	Orange	3	C37 CCU	V-CCU O
07:00	07:30	Orange	3	C3 OBC	C3 OBC
07:00	07:30	Orange	3	C34 ICC-D	AIC B
07:00	07:30	Orange	3	C34 ICC-E	AIC A
07:00	07:30	Orange	3	AOK Anesthesie	AOK ANES
07:00	07:30	Orange	3	AOK	AOK SB
07:00	07:30	Orange	3	AOK	AOK OB
07:00	07:30	Orange	3	Perfusie	Perf
07:00	07:30	Orange	3	PACU/VERKOEVER	PACU/VERK
07:45	08:15	Blue	6	A61 VPU MDL	V-MDL S
07:45	08:15	Blue	6	A61 VPU MDL	V-MDL O
07:45	08:15	Blue	6	A61 AOA	AOA A6 S
07:45	08:15	Blue	6	A61 AOA	AOA A6 O
07:45	08:15	Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 S
07:45	08:15	Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 O
07:45	08:15	Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AS
07:45	08:15	Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AO
07:45	08:15	Blue	4	B4 VPU Orthopedie	V-Ortho S
07:45	08:15	Blue	4	B4 VPU Orthopedie	V-Ortho O
07:45	08:15	Blue	2	A25 Poli Cardio/Cardiochirurgie	P-Cardio
07:45	08:15	Blue	2	B23 Poli Longgeneeskunde	P-Longf
07:45	08:15	Blue	1	A17 Poli MondKaak	P-MOKA
07:45	08:15	Blue	1	A14 Poli KNO	P-KNO
07:45	08:15	Blue	0	B01 AOA	AOA BG S
07:45	08:15	Blue	0	B01 AOA	AOA BG O
07:45	08:15	Blue	0	A01 SEH	P-SEH S

07:45	08:15	Blue	0	A01 SEH	P-SEH O
08:30	09:00	Red	6	E61 HIC E6	V-E6 HIC
08:30	09:00	Red	6	E61 VPU Interne Geneeskunde	V-E61 S
08:30	09:00	Red	6	E61 VPU Interne Geneeskunde	V-E61 O
08:30	09:00	Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh S
08:30	09:00	Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh O
08:30	09:00	Red	4	E41 VPU Chirurgie/Oncologie	V-E4 S
08:30	09:00	Red	4	E41 VPU Chirurgie/Oncologie	V-E4 O
08:30	09:00	Red	2	D25 Poli MDL/Endoscopie	P-MDL S
08:30	09:00	Red	2	D25 Poli MDL/Endoscopie	P-MDL O
08:30	09:00	Red	2	E21 Dagbehandeling	P-Dagb O
08:30	09:00	Red	2	E21 Dagbehandeling	P-Dagb LS
08:30	09:00	Red	2	E21 Dagbehandeling	P-Dagb RS
08:30	09:00	Red	1	D17 Poli Reumatologie	P-Reuma
08:30	09:00	Red	1	D15 Poli Radiologie	P-Rontg
08:30	09:00	Red	1	E16 Interne Gen/1-KP	P-Intg
08:30	09:00	Red	0	E01 Hemodialyse	P-HEMO S
08:30	09:00	Red	0	E01 Hemodialyse	P-HEMO O
08:30	09:00	Red	0	Magazijn verdiepingskeuken BG	0 KEUKEN
09:30	10:00	White	6	C61 VPU Longeneeskunde	V-Long S
09:30	10:00	White	6	C61 VPU Longeneeskunde	V-Long O
09:30	10:00	White	6	Magazijn verdiepingskeuken 6E	6 KEUKEN
09:30	10:00	White	5	C51 VPU Neurologie/stroke unit	V-Neuro S
09:30	10:00	White	5	C51 VPU Neurologie/stroke unit	V-Neuro O
09:30	10:00	White	5	Magazijn verdiepingskeuken 5E	5 KEUKEN
09:30	10:00	White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 S
09:30	10:00	White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 O
09:30	10:00	White	4	Magazijn verdiepingskeuken 4E	4 KEUKEN
09:30	10:00	White	2	C21 KNF (ma/wo/vr)	P-KNF
09:30	10:00	White	2	C21 NEUROCHIRURGIE 1 - KP	P-Neuro
09:30	10:00	White	1	C16 Behandelpoli	P-Behan
09:30	10:00	White	1	C13 Poli Dermatologie	P-Derm
09:30	10:00	White	1	C16 Gipskamer	P-GIPSK
09:30	10:00	White	0	C05 Oogheelkunde	P-OOG

10:00	10:30	Green	4	H41 Urologie	P-Uro
10:00	10:30	Green	3	H31 Kinder/tienerafdeling	V-Kind S
10:00	10:30	Green	3	H31 Kinder/tienerafdeling	V-Kind O
10:00	10:30	Green	2	H21 Moeder/kind afdeling	V-Kraam S
10:00	10:30	Green	2	H21 Moeder/kind afdeling	V-Kraam O
10:00	10:30	Green	1	H11 Verloskamers	V-Verl S
10:00	10:30	Green	1	H11 Verloskamers	V-Verl O
10:00	10:30	Green	1	H11 Neonatologie	V-Neo
10:00	10:30	Green	0	H03 Gyn-Pok	P-Gyn
10:00	10:30	Yellow	0	F02 Nucliare Geneeskunde	P-Nucl
10:00	10:30	Yellow	0	Diagnostich Centrum	DCT
10:00	10:30	Yellow	0	Apotheek	Apotheek

Delivery schedule for the weekends.

OrderTime	ReleaseTime	Route	Floor	Department that works with order boards	Warehouse code at Dept.
07:00	07:30	Blue	6	A61 VPU MDL	V-MDL S
07:00	07:30	Blue	6	A61 VPU MDL	V-MDL O
07:00	07:30	Blue	6	A61 AOA	AOA A6 S
07:00	07:30	Blue	6	A61 AOA	AOA A6 O
07:00	07:30	Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 S
07:00	07:30	Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 O
07:00	07:30	Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AS
07:00	07:30	Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AO
07:00	07:30	Blue	4	B4 VPU Orthopedie	V-Ortho S
07:00	07:30	Blue	4	B4 VPU Orthopedie	V-Ortho O
07:00	07:30	Blue	0	B01 AOA	AOA BG S
07:00	07:30	Blue	0	B01 AOA	AOA BG O
07:00	07:30	Blue	0	A01 SEH	P-SEH S
07:00	07:30	Blue	0	A01 SEH	P-SEH O
07:30	08:00	Red	6	E61 HIC E6	V-E6 HIC
07:30	08:00	Red	6	E61 VPU Interne Geneeskunde	V-E61 S
07:30	08:00	Red	6	E61 VPU Interne Geneeskunde	V-E61 O
07:30	08:00	Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh S
07:30	08:00	Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh O
07:30	08:00	Red	4	E41 VPU Chirurgie/Oncologie	V-E4 S
07:30	08:00	Red	4	E41 VPU Chirurgie/Oncologie	V-E4 O

07:30	08:00	Red	1	D15 Poli Radiologie	P-Rontg
07:30	08:00	Red	0	E01 Hemodialyse	P-HEMO S
07:30	08:00	Red	0	E01 Hemodialyse	P-HEMO O
08:00	08:30	White	6	C61 VPU Longeneeskunde	V-Long S
08:00	08:30	White	6	C61 VPU Longeneeskunde	V-Long O
08:00	08:30	White	5	C51 VPU Neurologie/stroke unit	V-Neuro S
08:00	08:30	White	5	C51 VPU Neurologie/stroke unit	V-Neuro O
08:00	08:30	White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 S
08:00	08:30	White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 O
08:00	08:30	Green	3	H31 Kinder/tienerafdeling	V-Kind S
08:00	08:30	Green	3	H31 Kinder/tienerafdeling	V-Kind O
08:00	08:30	Green	2	H21 Moeder/kind afdeling	V-Kraam S
08:00	08:30	Green	2	H21 Moeder/kind afdeling	V-Kraam O
08:00	08:30	Green	1	H11 Verloskamers	V-Verl S
				H11 Verloskamers	V-Verl O
08:00	08:30	Green	1	H11 Neonatologie	V-Neo
08:15	08:45	Orange	3	AOK Anesthesie	AOK ANES
08:15	08:45	Orange	3	AOK	AOK SB
08:15	08:45	Orange	3	AOK	AOK OB
08:15	08:45	Orange	3	C34 ICC-A (TIC)	TIC
08:15	08:45	Orange	3	C34 ICC-D	AIC B
08:15	08:45	Orange	3	C34 ICC-E	AIC A
08:15	08:45	Orange	3	C37 EHH	V-EHH S
08:15	08:45	Orange	3	C37 CCU	V-CCU S
08:15	08:45	Orange	3	C37 CCU	V-CCU O

Departments without an electronic order board.

Code	Descr
AOK GYN	Koopartikelen
AOK	Koopartikelen
AOK 72162	Steriele Berging
AOK 72181	Steriele Berging
CIC SSTAY1	CIC short stay Bin 1
CIC SSTAY2	CIC short stay Bin 2
CIC VAAT	CIC vaatkamer radio Bin 1
CIC VAAT 2	CIC vaatkamer radio Bin 2
COR1 72042	72042 - AOK IMPLANTATEN NEUROCHIR - KP
COR1 72121	72121 - AOK UROLOGIE - KP
COR1 72142	72142 - AOK NEUROCHIRURGIE - KP

COR1 72192	72192 - AOK OOGHEELKUNDE - KP
COR2 72032	72032 - IMPLANTATEN ORTHOPEDIE - KP
COR2 72051	72051 - AOK IMPLANTATEN PLAST. CHIR - KP
COR2 72132	72132 - AOK ORTHOPEDIE - KP
COR2 72151	72151 - AOK PLAST. CHIRURGIE - KP
EFO	BESTELLIJST EFO & ABLATIE
HCK	HCK (PTCA)
HD-Oost	Huisartsendienst oost
HYBR	AOK 72012
H4 Pan O	Magazijn H4 Pandemie Onsteriel
H4 Pan S	Magazijn H4 Pandemie Steriel
Logistiek	MFR Logistiek
OK KNO	84891 - C31 - OK - BHP - KNO - KP
OK-ANES	KOOPARTIKELEN
OK-Hold	72231- HOLDING - VERKOEVER - KP
OK-R	72112 - C31 OK RENTEX - KP
OK-Verk	KOOPARTIKELEN
OZ 2-O	Spreekuurpoli Dermatologie P143
OZ 2-S	Spreekuurpoli Dermatologie P143
P-Chir OZ	Poli 159 Chirurgie/Mammacare Oldenzaal
P-Chir-OZ	Poli 159 Chirurgie Oldenzaal
PCI	PCI/KAG
P-Cyt P OZ	Poli 290 Pantry Cytostatica/Dagbeh. Oldenzaal
P-Cyto OZ	Poli 290 Cytostatica/Dagbehandeling Oldenzaal
Perf Hepic	THORAX OK - AFD PERFUSIE
P-GIPSK-OZ	Scanartikelen Gipskamer Oldenzaal
P-Intge	Interne Geneeskunde 53
P-Intge 1	84011 - E16 Interne Gen / 1 - KP
P-Intge 2	84011 - E16 Interne Gen / 2 - KP
PM	Hartstimulatie CIC PM & ICD
P-MDL OZ	Poli 210 Maag Darm Leverartsen Oldenzaal
P-Oogh OZ	Poli 085 Oogheelkunde Oldenzaal
P-Ortho OZ	Poli 192 Orthopedie Oldenzaal
P-POK-OZ	Poli 180 Pok Oldenzaal
P-Radio	85972 - F03 RADIOTHERAPIE - HS
P-Radio OZ	Poli 185 Radiologie/mammacare oldenzaal
PRINT	AOK 72100
P-Uro OZ	Poli 228 Urologie Oldenzaal
P-000 P OZ	81003 - P000 PANTRY BG - OZ
SB 72142	AOK koopartikelen steriele berging
Schoonm-KP	Schoonmaak MST Cleancare KP
Schoonm-OZ	Schoonmaak MST-Cleancare Oldenzaal
TAVI	HCK TAVI/ MITRACLIP-PROCEDURE
TOK ANE OS	Anesthesie Thorax OK; onsteriel en koop

Appendix 2: Total cards placed and double cards placed per department

Location	Total cards placed	Double Cards
AIC B	8838	546
TIC	8058	624
AIC A	7959	509
AOK ANES	7952	1002
V-C4 S	7675	296
PACU/VERK	7557	795
V-Verl S	7055	266
V-E4 S	6896	241
V-E61 S	6451	318
AOK OB	6137	454
V-Neo	6111	350
V-Long S	6065	404
P-SEH O	5810	362
V-Neuro S	5285	247
P-Behan	5259	435
P-HEMO S	5227	126
V-E61 O	4993	240
V-Kraam O	4841	491
P-Rontg	4670	175
V-C4 O	4645	233
V-NeuCh	4590	353
AOA BG S	4561	277
V-A5 S	4407	280
V-Long O	4337	253
V-E4 O	4328	194
AOK SB	4087	259
V-Kind O	4082	298
V-A5 O	4004	242
AOA A6 S	3992	167
V-Neuro O	3659	200
V-MDL S	3382	340
P-SEH S	3378	116
P-Gyn	3344	221
P-Uro	3101	154
V-NeuCh O	3089	163
TOK ANES	2977	214
V-E6 HIC	2826	130
V-Kind S	2808	170
V-CCU O	2766	326
P-Dagb RS	2688	201
AOA A6 O	2674	206
TOK S	2659	144
V-Ortho S	2632	267
P-Dagb O	2203	130
V-Ortho O	2094	254
P-MDL S	2089	26
V-Kraam S	2087	281
P-MDL O	2083	267
P-GIPSK	2065	103
AOA BG O	1938	103

P-Longf	1909	143
V-MDL O	1797	160
P-MOKA	1715	139
V-CCU S	1616	41
C3 OBC	1599	95
P-Derm	1337	48
P-Dagb LS	1252	63
Perf	1208	37
V-B4 AO	1199	108
P-KNO	1177	36
V-EHH S	1142	22
TOK O	1123	90
P-Nucl	842	59
Apotheek	818	8
P-Cardio	755	54
V-B4 AS	686	89
6 KEUKEN	597	7
5 KEUKEN	531	5
P-Reuma	487	105
P-KNF	416	9
0 KEUKEN	298	0
DCT	261	19
P-Neuro	220	5
P-HEMO O	183	13
P-Intg	109	9
P-OOG	66	1
V-Verl O	62	8

Appendix 3: Times that both product cards are posted in the electronic order boards in total and per route in a certain time interval

Orange	Times ordered
00:00:00-00:59:59	33
01:00:00-01:59:59	15
02:00:00-02:59:59	8
03:00:00-03:59:59	3
04:00:00-04:59:59	17
05:00:00-05:59:59	11
06:00:00-06:59:59	14
07:00:00-07:29:59	33
07:30:00-08:29:59	230
08:30:00-08:59:59	267
09:00:00-09:59:59	414
10:00:00-10:59:59	298
11:00:00-11:59:59	532
12:00:00-12:59:59	345
13:00:00-13:59:59	659
14:00:00-14:59:59	1515
15:00:00-15:59:59	426
16:00:00-16:59:59	52
17:00:00-17:59:59	48
18:00:00-18:59:59	49
19:00:00-19:59:59	68
20:00:00-20:59:59	27
21:00:00-21:59:59	38
22:00:00-22:59:59	15
23:00:00-23:59:59	41
Total	5158
Avg Yellow	2,55%

Blue	Times ordered
00:00:00-00:59:59	239
01:00:00-01:59:59	150
02:00:00-02:59:59	86
03:00:00-03:59:59	45
04:00:00-04:59:59	16
05:00:00-05:59:59	23
06:00:00-06:59:59	35
07:00:00-07:44:59	21
07:45:00-07:59:59	33
08:00:00-08:59:59	316
09:00:00-09:59:59	278
10:00:00-10:59:59	229
11:00:00-11:59:59	317
12:00:00-12:59:59	184
13:00:00-13:59:59	163
14:00:00-14:59:59	252
15:00:00-15:59:59	228
16:00:00-16:59:59	185
17:00:00-17:59:59	155
18:00:00-18:59:59	67
19:00:00-19:59:59	62
20:00:00-20:59:59	68
21:00:00-21:59:59	57
22:00:00-22:59:59	45
23:00:00-23:59:59	89
Total	3343
Avg Yellow	5,22%

Red	Times ordered
00:00:00-00:59:59	159
01:00:00-01:59:59	113
02:00:00-02:59:59	54
03:00:00-03:59:59	30
04:00:00-04:59:59	33
05:00:00-05:59:59	16
06:00:00-06:59:59	29
07:00:00-07:59:59	108
08:00:00-08:29:59	168
08:30:00-08:59:59	151
09:00:00-09:59:59	274
10:00:00-10:59:59	120
11:00:00-11:59:59	205
12:00:00-12:59:59	121
13:00:00-13:59:59	202
14:00:00-14:59:59	214
15:00:00-15:59:59	197
16:00:00-16:59:59	189
17:00:00-17:59:59	100
18:00:00-18:59:59	44
19:00:00-19:59:59	38
20:00:00-20:59:59	59
21:00:00-21:59:59	48
22:00:00-22:59:59	24
23:00:00-23:59:59	58
Total	2754
Avg Yellow	7,72%

White	Times ordered
00:00:00-00:59:59	113
01:00:00-01:59:59	118
02:00:00-02:59:59	52
03:00:00-03:59:59	27
04:00:00-04:59:59	28
05:00:00-05:59:59	26
06:00:00-06:59:59	13
07:00:00-07:59:59	64
08:00:00-08:59:59	206
09:00:00-09:29:59	152
09:30:00-09:59:59	101
10:00:00-10:59:59	127
11:00:00-11:59:59	184
12:00:00-12:59:59	148
13:00:00-13:59:59	121
14:00:00-14:59:59	212
15:00:00-15:59:59	161
16:00:00-16:59:59	132
17:00:00-17:59:59	68
18:00:00-18:59:59	34
19:00:00-19:59:59	21
20:00:00-20:59:59	52
21:00:00-21:59:59	43
22:00:00-22:59:59	11
23:00:00-23:59:59	32
Total	2246
Avg Yellow	5,08%

Time	Green	Yellow
00:00:00-00:59:59	115	
01:00:00-01:59:59	69	
02:00:00-02:59:59	31	
03:00:00-03:59:59	14	
04:00:00-04:59:59	16	
05:00:00-05:59:59	11	
06:00:00-06:59:59	16	
07:00:00-07:59:59	76	7
08:00:00-08:59:59	235	11
09:00:00-09:59:59	316	6
10:00:00-10:29:59	68	4
10:30:00-11:29:59	125	5
11:30:00-11:59:59	96	2
12:00:00-12:59:59	117	6
13:00:00-13:59:59	126	7
14:00:00-14:59:59	150	8
15:00:00-15:59:59	186	13
16:00:00-16:59:59	136	12
17:00:00-17:59:59	77	2
18:00:00-18:59:59	37	
19:00:00-19:59:59	57	
20:00:00-20:59:59	56	1
21:00:00-21:59:59	46	2
22:00:00-22:59:59	31	
23:00:00-23:59:59	32	
Total	2239	86
Avg Yellow	4,31%	5,23%

Time interval	Times ordered total
00:00:00-00:59:59	659
01:00:00-01:59:59	465
02:00:00-02:59:59	231
03:00:00-03:59:59	119
04:00:00-04:59:59	110
05:00:00-05:59:59	87
06:00:00-06:59:59	107
07:00:00-07:59:59	398
08:00:00-08:59:59	1528
09:00:00-09:59:59	1541
10:00:00-10:59:59	881
11:00:00-11:59:59	1431
12:00:00-12:59:59	921
13:00:00-13:59:59	1278
14:00:00-14:59:59	2351
15:00:00-15:59:59	1211
16:00:00-16:59:59	706
17:00:00-17:59:59	450
18:00:00-18:59:59	231
19:00:00-19:59:59	246
20:00:00-20:59:59	263
21:00:00-21:59:59	234
22:00:00-22:59:59	126
23:00:00-23:59:59	252
Total	15826

Appendix 4: Products ordered per route per time interval

Products ordered per route per time interval for the weekdays. The cells that are marked in yellow are the times shortly after the readout moment.

Orange	Times ordered
00:00:00-00:59:59	621
01:00:00-01:59:59	245
02:00:00-02:59:59	142
03:00:00-03:59:59	70
04:00:00-04:59:59	109
05:00:00-05:59:59	77
06:00:00-06:59:59	139
07:00:00-07:29:59	308
07:30:00-08:29:59	2402
08:30:00-08:59:59	2363
09:00:00-09:59:59	4111
10:00:00-10:59:59	4570
11:00:00-11:59:59	7031
12:00:00-12:59:59	3769
13:00:00-13:59:59	7471
14:00:00-14:59:59	15003
15:00:00-15:59:59	5161
16:00:00-16:59:59	977
17:00:00-17:59:59	576
18:00:00-18:59:59	383
19:00:00-19:59:59	609
20:00:00-20:59:59	391
21:00:00-21:59:59	454
22:00:00-22:59:59	208
23:00:00-23:59:59	718
Percentage Yellow	4.68%

Blue	Times ordered
00:00:00-00:59:59	2464
01:00:00-01:59:59	1788
02:00:00-02:59:59	969
03:00:00-03:59:59	489
04:00:00-04:59:59	277
05:00:00-05:59:59	294
06:00:00-06:59:59	324
07:00:00-07:44:59	334
07:45:00-07:59:59	327
08:00:00-08:59:59	3351
09:00:00-09:59:59	3121
10:00:00-10:59:59	3913
11:00:00-11:59:59	3845
12:00:00-12:59:59	2005
13:00:00-13:59:59	2077
14:00:00-14:59:59	2686
15:00:00-15:59:59	1986
16:00:00-16:59:59	2155
17:00:00-17:59:59	1702
18:00:00-18:59:59	874
19:00:00-19:59:59	857
20:00:00-20:59:59	969
21:00:00-21:59:59	605
22:00:00-22:59:59	489
23:00:00-23:59:59	814
Percentage Yellow	9.50%

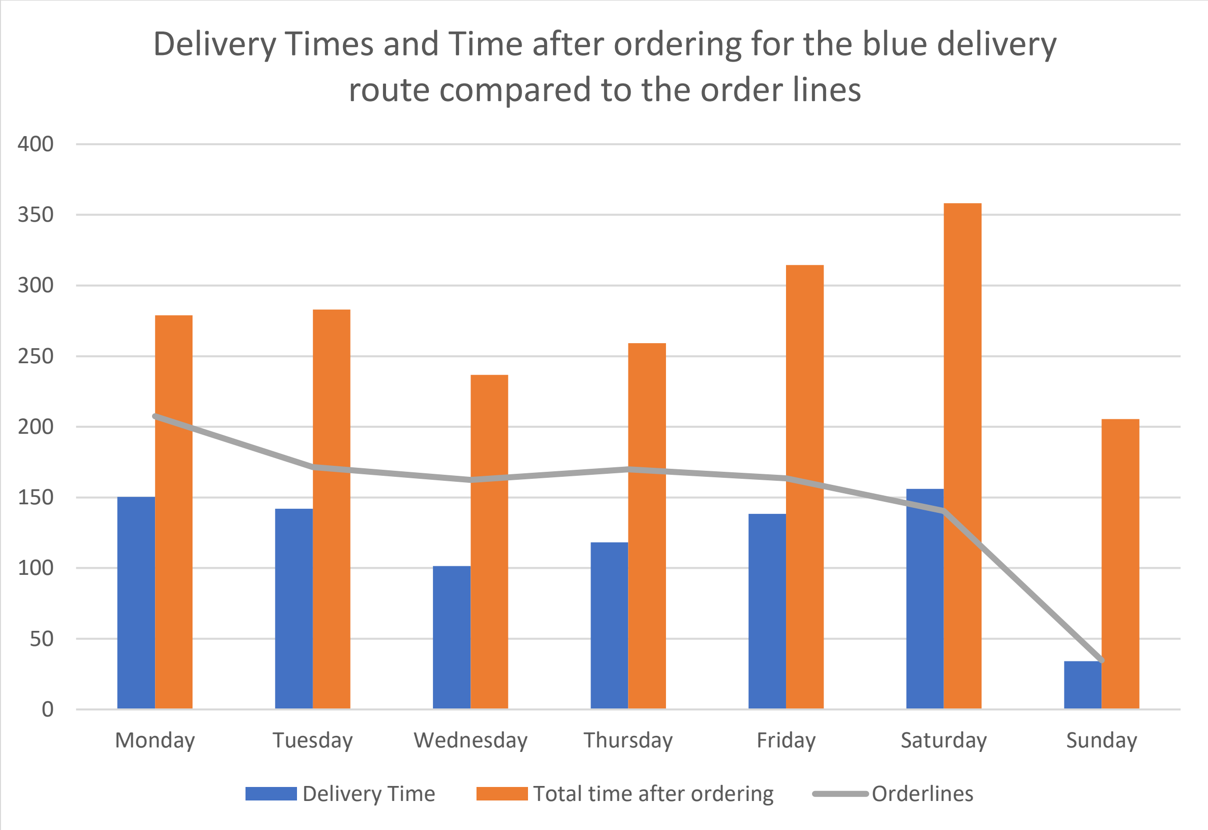
Red	Times ordered
00:00:00-00:59:59	2825
01:00:00-01:59:59	1962
02:00:00-02:59:59	1403
03:00:00-03:59:59	769
04:00:00-04:59:59	319
05:00:00-05:59:59	235
06:00:00-06:59:59	371
07:00:00-07:59:59	1808
08:00:00-08:29:59	2435
08:30:00-08:59:59	2519
09:00:00-09:59:59	4045
10:00:00-10:59:59	2101
11:00:00-11:59:59	4517
12:00:00-12:59:59	2644
13:00:00-13:59:59	3796
14:00:00-14:59:59	3152
15:00:00-15:59:59	2675
16:00:00-16:59:59	2663
17:00:00-17:59:59	1432
18:00:00-18:59:59	661
19:00:00-19:59:59	544
20:00:00-20:59:59	679
21:00:00-21:59:59	448
22:00:00-22:59:59	297
23:00:00-23:59:59	558
Percentage Yellow	14.63%

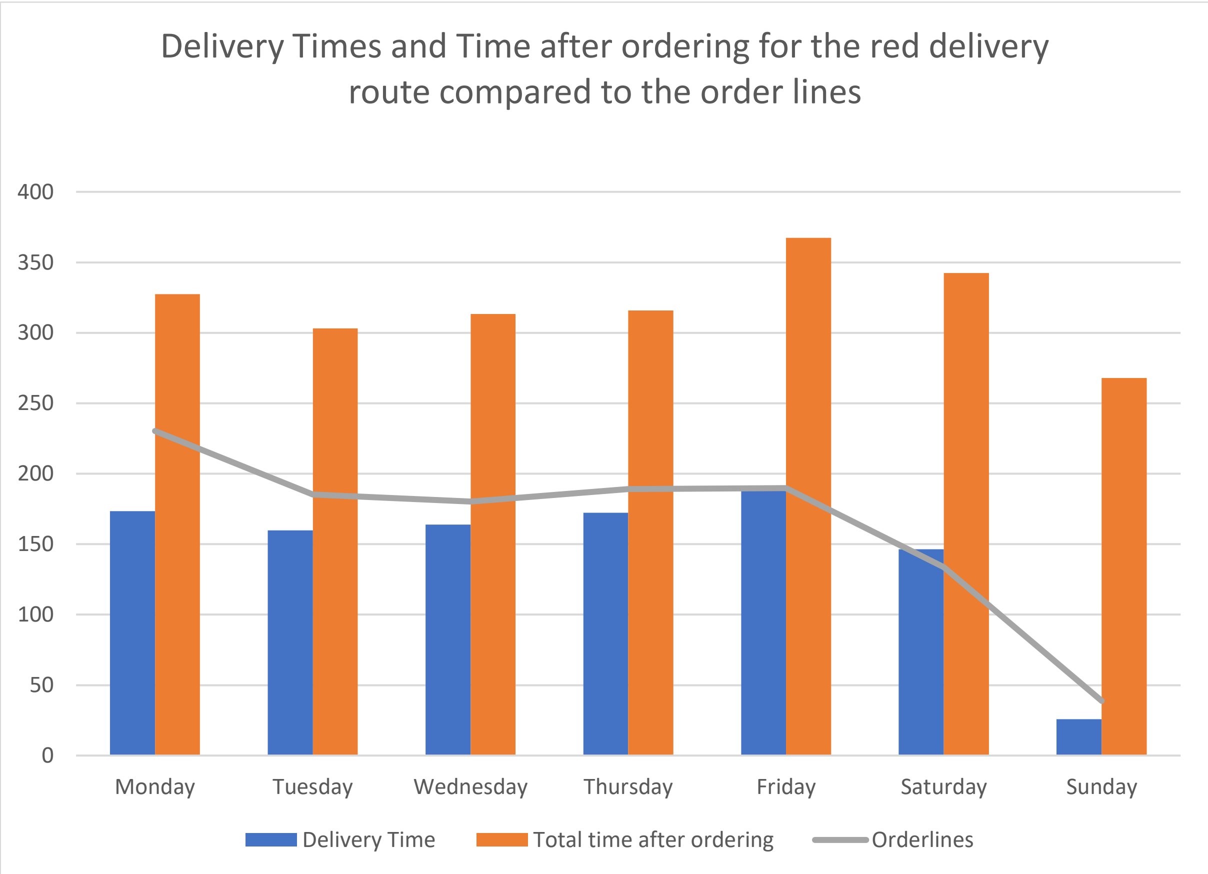
White	Times ordered
00:00:00-00:59:59	1891
01:00:00-01:59:59	2069
02:00:00-02:59:59	733
03:00:00-03:59:59	278
04:00:00-04:59:59	422
05:00:00-05:59:59	316
06:00:00-06:59:59	245
07:00:00-07:59:59	999
08:00:00-08:59:59	2965
09:00:00-09:29:59	1729
09:30:00-09:59:59	1503
10:00:00-10:59:59	1890
11:00:00-11:59:59	3255
12:00:00-12:59:59	1853
13:00:00-13:59:59	3081
14:00:00-14:59:59	3446
15:00:00-15:59:59	2738
16:00:00-16:59:59	1705
17:00:00-17:59:59	832
18:00:00-18:59:59	428
19:00:00-19:59:59	300
20:00:00-20:59:59	601
21:00:00-21:59:59	340
22:00:00-22:59:59	211
23:00:00-23:59:59	298
Percentage Yellow	9.94%

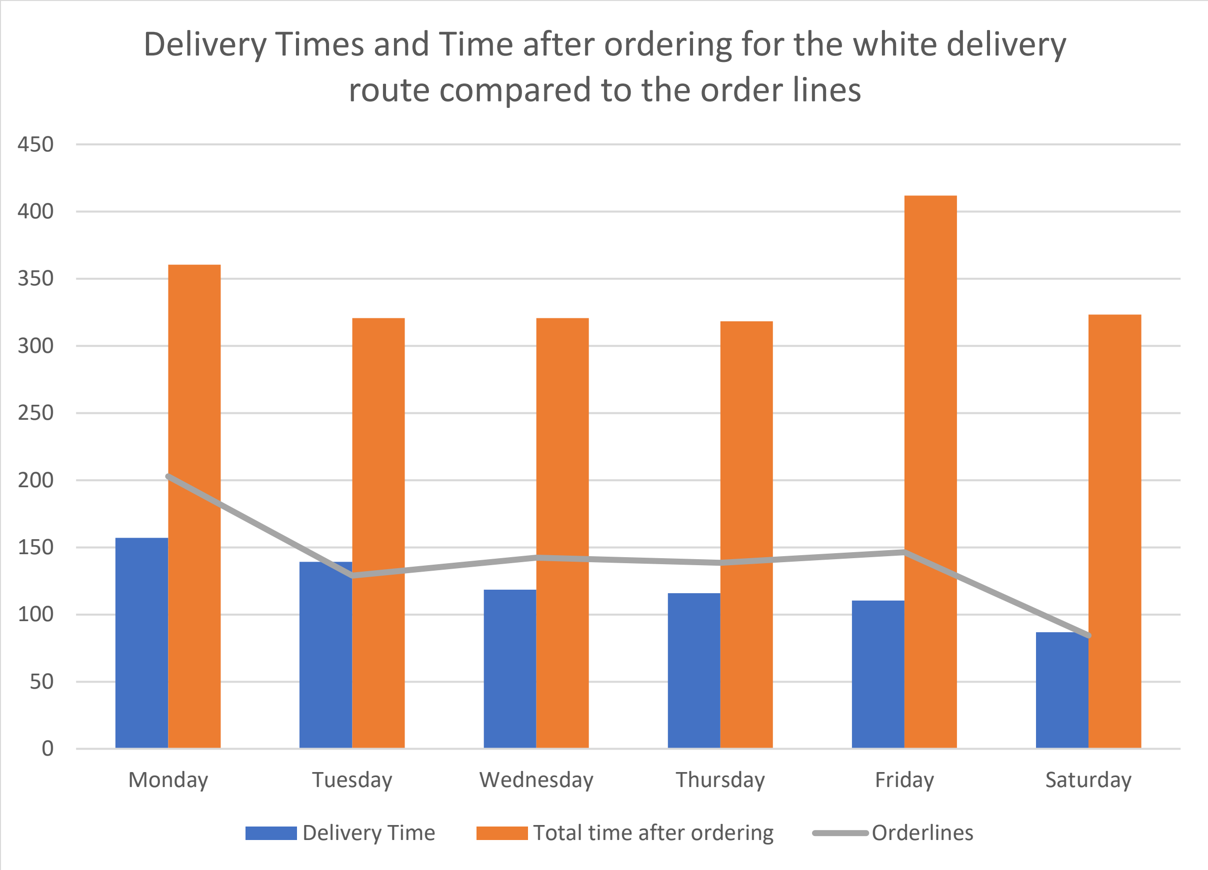
Green	Times ordered
00:00:00-00:59:59	1087
01:00:00-01:59:59	802
02:00:00-02:59:59	318
03:00:00-03:59:59	164
04:00:00-04:59:59	137
05:00:00-05:59:59	158
06:00:00-06:59:59	139
07:00:00-07:59:59	1176
08:00:00-08:59:59	3440
09:00:00-09:59:59	3220
10:00:00-10:29:59	775
10:30:00-11:29:59	1384
11:30:00-11:59:59	1046
12:00:00-12:59:59	1549
13:00:00-13:59:59	2822
14:00:00-14:59:59	2985
15:00:00-15:59:59	3287
16:00:00-16:59:59	1561
17:00:00-17:59:59	459
18:00:00-18:59:59	275
19:00:00-19:59:59	293
20:00:00-20:59:59	385
21:00:00-21:59:59	313
22:00:00-22:59:59	269
23:00:00-23:59:59	283
Percentage Yellow	7.62%

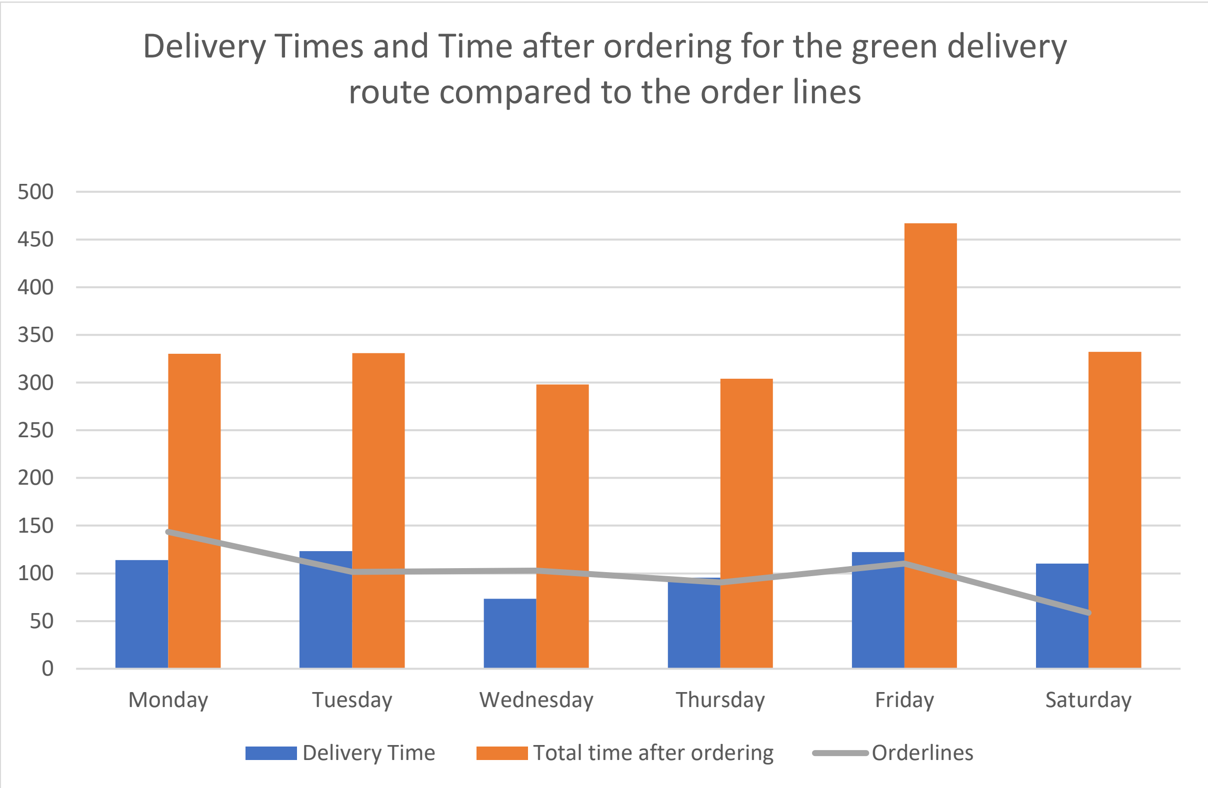
Yellow	Times ordered
00:00:00-00:59:59	2
01:00:00-01:59:59	
02:00:00-02:59:59	
03:00:00-03:59:59	
04:00:00-04:59:59	
05:00:00-05:59:59	
06:00:00-06:59:59	1
07:00:00-07:59:59	81
08:00:00-08:59:59	271
09:00:00-09:59:59	158
10:00:00-10:29:59	83
10:30:00-11:29:59	138
11:30:00-11:59:59	70
12:00:00-12:59:59	155
13:00:00-13:59:59	182
14:00:00-14:59:59	189
15:00:00-15:59:59	280
16:00:00-16:59:59	185
17:00:00-17:59:59	28
18:00:00-18:59:59	
19:00:00-19:59:59	
20:00:00-20:59:59	3
21:00:00-21:59:59	10
22:00:00-22:59:59	
23:00:00-23:59:59	
Percentage Yellow	12.04%

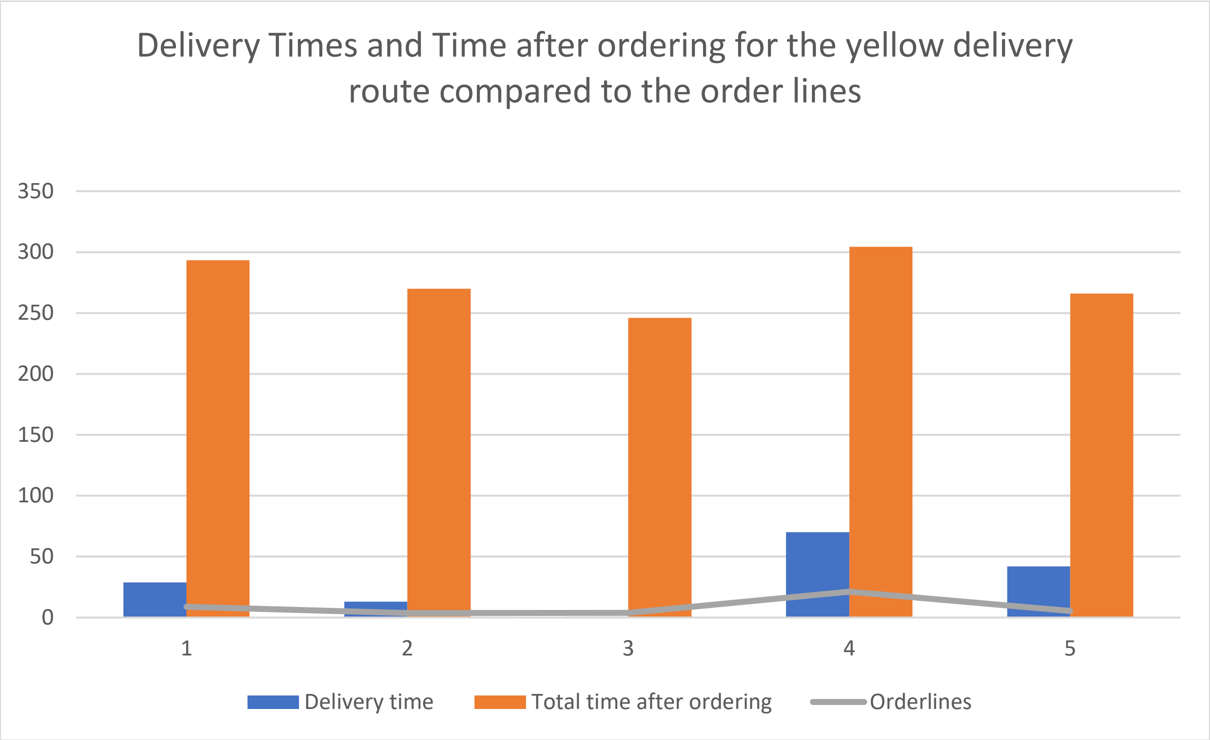
Appendix 5: Delivery times and time after ordering for the delivery routes compared to their average order lines per day



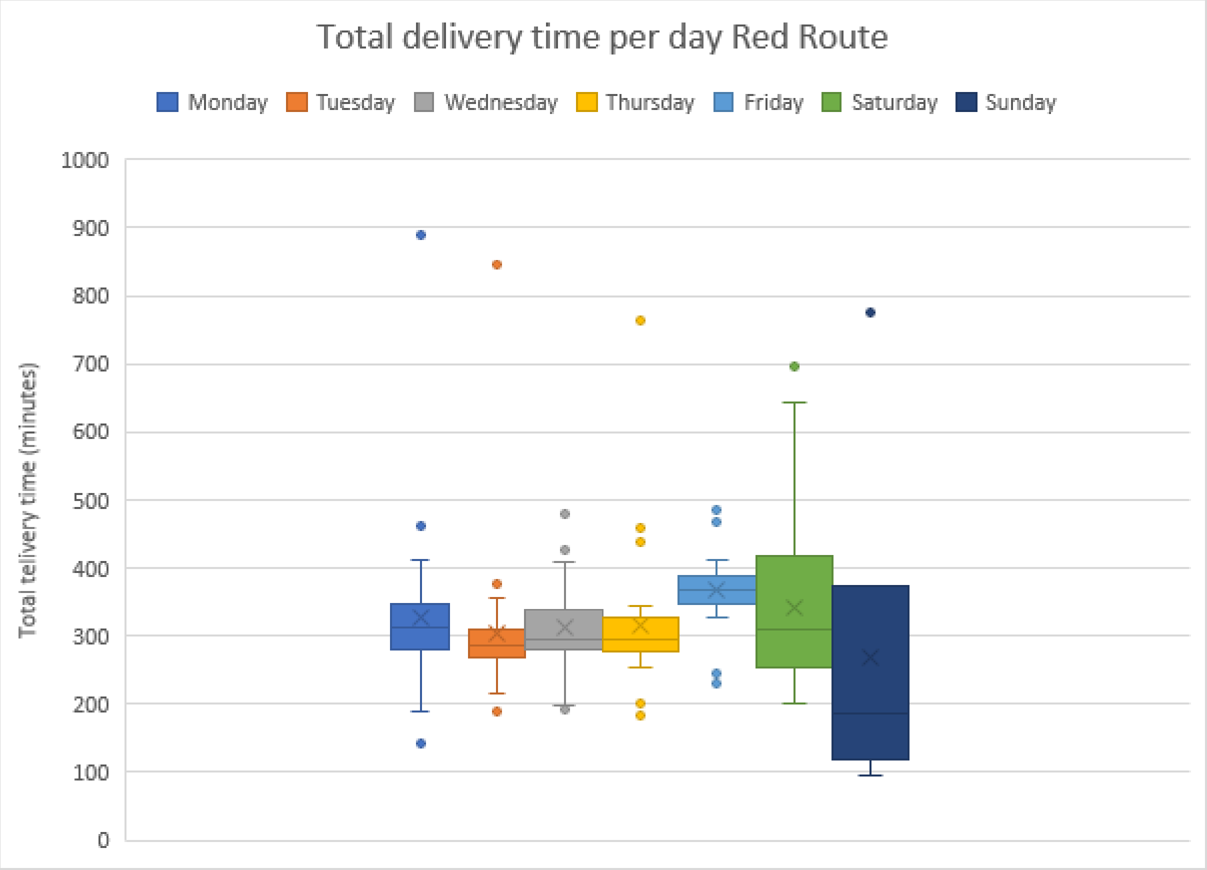


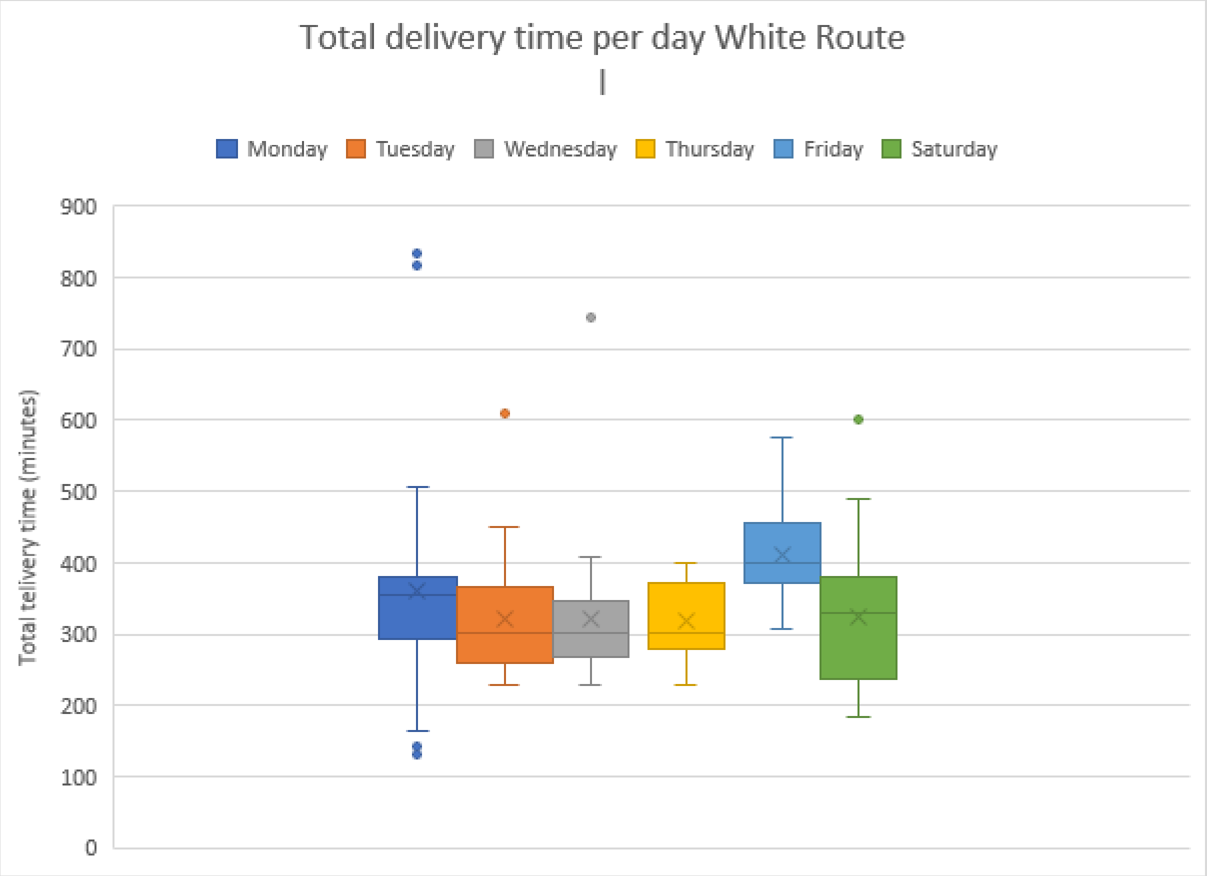

Delivery Times and Time after ordering for the white delivery route compared to the order lines
450
400
350
300
250
200
150
100
50
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Delivery Time
Total time after ordering
Orderlines

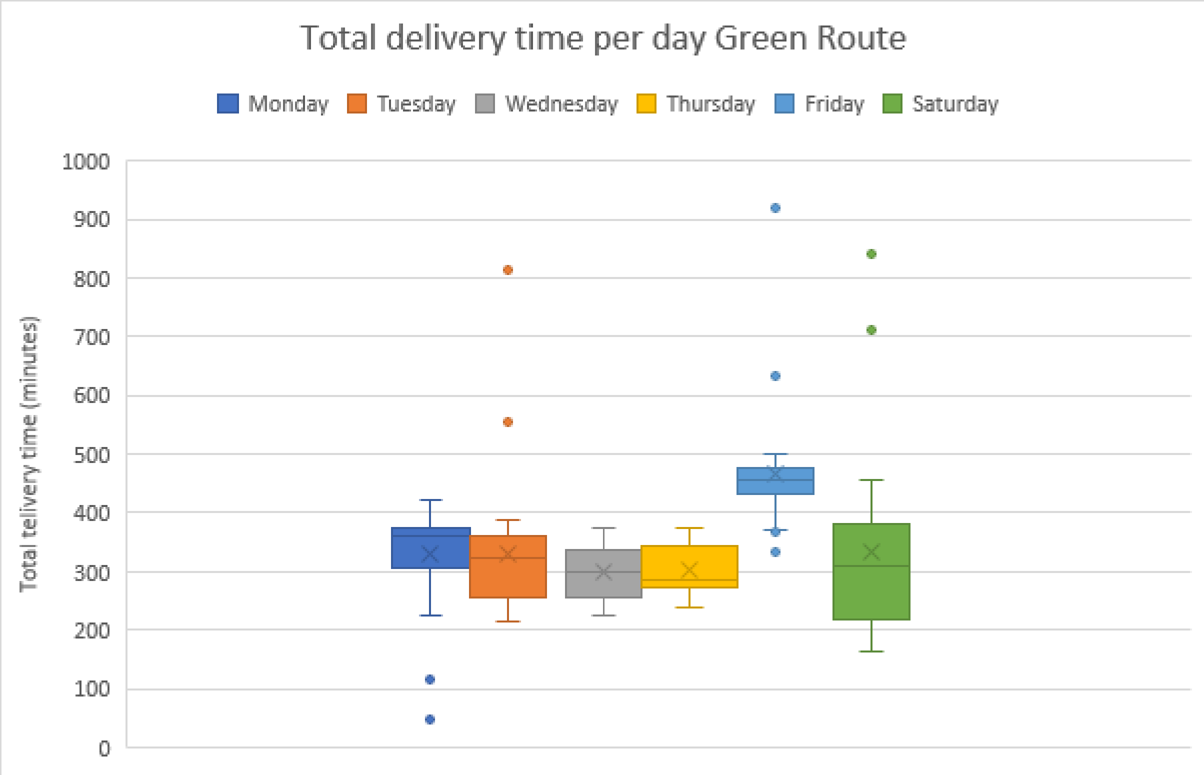

Delivery Times and Time after ordering for the green delivery route compared to the order lines
500
450
400
350
300
250
200
150
100
50
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Delivery Time
Total time after ordering
Orderlines


Delivery Times and Time after ordering for the yellow delivery route compared to the order lines
350
300
250
200
150
100
50
0
1
2
3
4
5
Delivery time
Total time after ordering
Orderlines

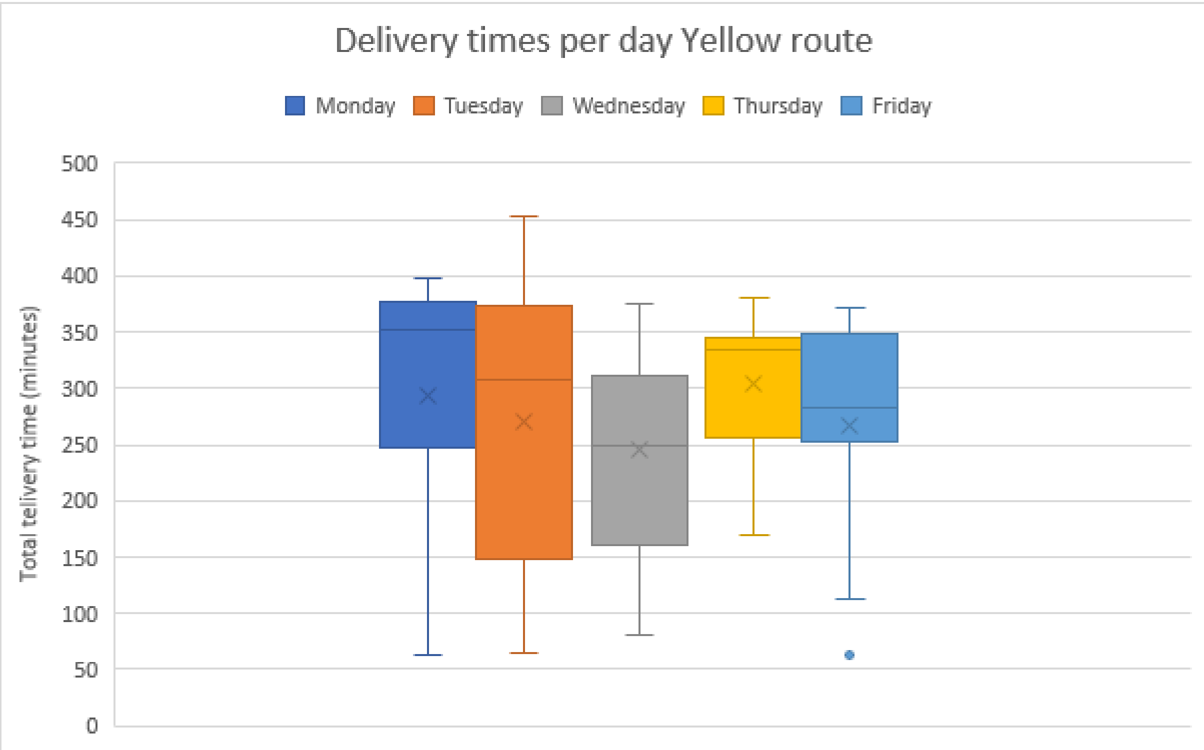
Appendix 6: Box plots of the total delivery times per route per day





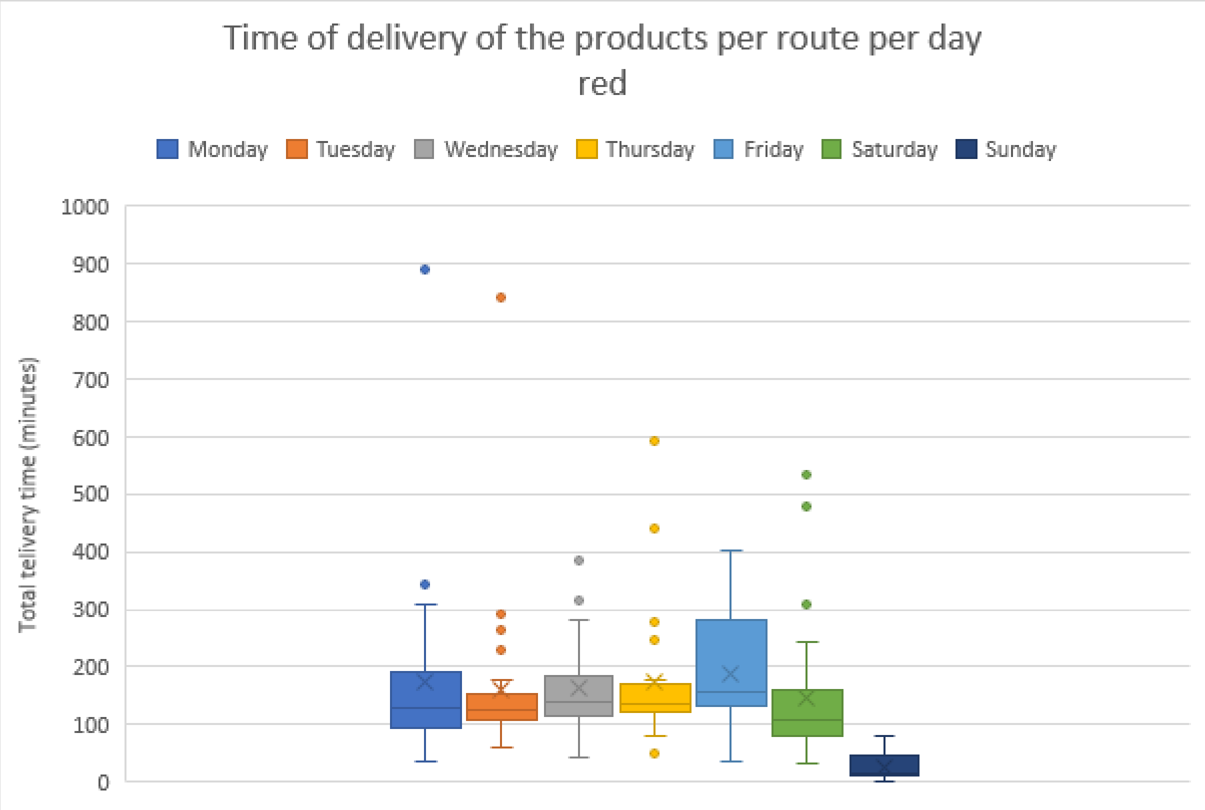


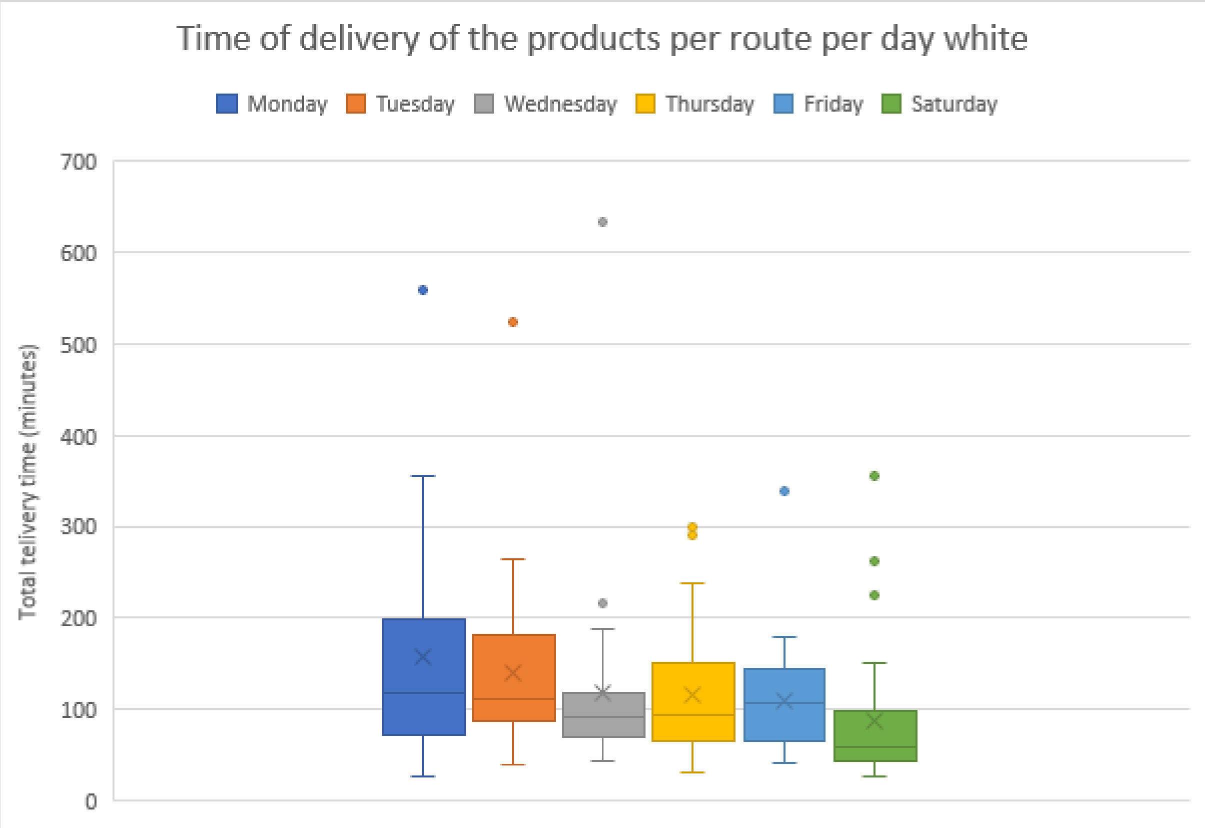
Total delivery time per day Green Route
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Total telivery time (minutes)
0
100
200
300
400
500
600
700
800
900
1000

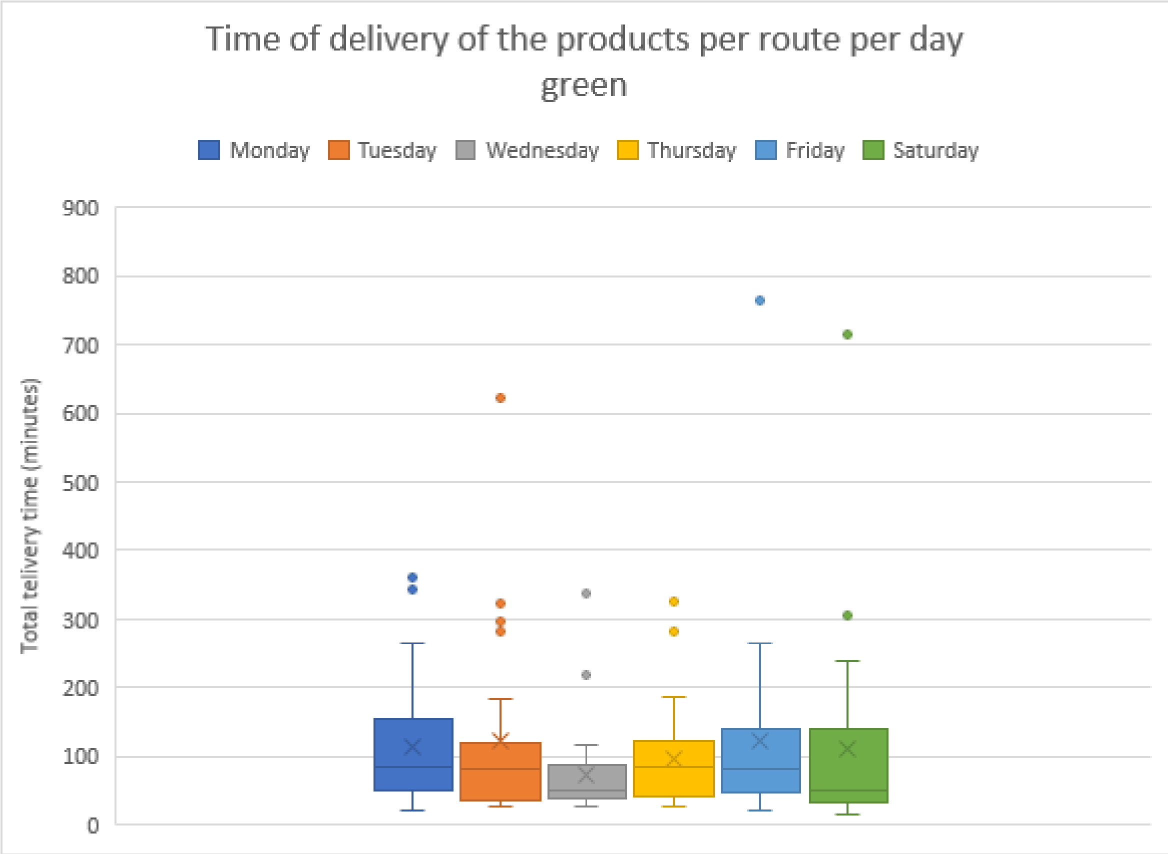


Delivery times per day Yellow route
Monday
Tuesday
Wednesday
Thursday
Friday
Total telivery time (minutes)
0
50
100
150
200
250
300
350
400
450
500

Appendix 7: Box plots of time between first restock of the day and last restock of the day per day per route






Time of delivery of the products per route per day green
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
900
800
700
600
500
400
300
200
100
0
Total telivery time (minutes)

Appendix 8: Instruction manual and dashboard EBQ-tool

Tool Min/Max Berekeningen

Input			Wordt berekend				
Bestelkosten per order	€ 13,00		Geschatte levertijd (uren)	9	Min/Max berekenen	Input velden leegmaken	Extra informatie tonen
% Voorraadkosten van de prijs per eenheid	20%		Geschatte periode (dagen)	300			
Aantal levermomenten per week*	5		1				Extra informatie verbergen
Berekening over vraag van aantal maanden*	10		1				

Input vereist — * = verplicht zelf in te vullen, zonder * hoef je niet in te vullen — Data ophalen — **Output**

Artikelnummer*	Product naam	Stuks Besteld*	Min/Max*	Aantal keer besteld	Uitgifte eenheid	Prijs per eenheid	Nieuwe Min/Max
101127	HDPE plastic zak zwart T15 63x70cmÂ 50st	218	2	109	1	€ 1,26	5
132069	Scott* 600 toilet tissue rollen 2-lgs 600v 6rl	124	1	124	1	€ 3,59	2
110247	Medisavona handzeep 500ml	110	2	55	1	€ 2,08	3
109015	Ecolab Brialspray 750ml	87	1	87	1	€ 5,02	2
115955	Rietje buigzaam 5x210mm 250st	42	1	42	1	€ 1,00	2
100503	Afwasmiddel extra citroenÂ fles 1000ml	20	1	20	1	€ 0,73	2
138594	Mask white barrier FFP2 20st	33	1	33	1	€ 37,19	1
125139	Koffie Fresh Brew royal 1kg	84	1	84	1	€ 9,61	1
101181	HDPE plastic zak wit 58x100cm T23 20st	182	2	91	1	€ 1,24	5
100702	HDPE plastic zak grijs 85x100 30mu 20st	94	2	47	1	€ 2,50	2
133066	Dustpanzakjes zwart 450x500mm T10 50st	76	2	38	1	€ 0,41	5
132065	Scott handdoeken Multifold Airflex 1lgs wit	540	5	108	1	€ 1,39	7
125167	Suikersticks 5gr 600st	15	1	15	1	€ 8,98	1
101120	HDPE plastic zak zwart 700mmx1.10m 20st	136	2	68	1	€ 2,14	3
101119	HDPE plastic zak zwart 450x500mm 0.01 50st	120	2	60	1	€ 0,46	6
140397	Urinepotje met afnamesysteem 100st	4	1	4	1	€ 0,01	1
100692	Abri-Light Normal inlegverband 12st	40	1	40	1	€ 1,00	2
133062	Roll-O-Wipe tendertex kleefdoek 40gr 50vel 60x2(	13	1	13	1	€ 4,71	1
140431	Vileda Micron vezeldoek 25x32cm 180st.	71	1	71	1	€ 22,35	1
140231	Absorin Comfort Onderlegger paars 60x60 30st	78	2	39	1	€ 4,07	2
125170	Roerstaafjes plastic wit 2500st	13	1	13	1	€ 7,31	1
100694	Abri-San Premium 7 inlegverband 30st	23	1	23	1	€ 7,66	1
22730	Geen naam gevonden	16	1	16	1	€ 0,50	2
101139	Lady-lux maandverband maxiÂ Â Â Â 20st	16	1	16	1	€ 0,73	2
123212	Swash Gold Gloves washand parfumvrijÂ Â 40vpl	55	1	55	1	€ 32,91	1
100855	tuitbekerdeksel onderverpakt jonibeker 25st	78	2	39	1	€ 1,97	2
100854	Joni 4502 tuitbeker 200ml toppac 25st	96	2	48	1	€ 2,96	2
100570	Sharpsafe naaldencontainer afvoerdoos	16	1	16	1	€ 3,89	1

MinMax Berekenen | Uitgifte eenheid | Prijs | Voorbeeld MDL | Drop voor MinMax | ABC-Analysis

The instruction manual is available on the next page.

The instruction manual is written in Dutch since the native language of the users of the EBQ-tool is Dutch.

Handleiding EBQ-tool

De EBQ-tool is bedoeld om de min/max te berekenen, gebaseerd op de vraag per SKU, de huidige min/max, de bestelkosten, de voorraadkosten, aantal levermomenten per week en de geschatte tijd tot levering.

Het gebruik van de tool:

1. Zorg dat de data uit het tabblad 'MinMax Berekenen' weg is door op de knop 'Input velden leegmaken' te klikken.
2. Zorg dat de data uit het tabblad 'Drop voor MinMax' weg is door op de knop 'Data verwijderen' te klikken.
3. Plak de data van de afdeling die u wilt onderzoeken in het tabblad 'Drop voor MinMax'. Zorg er hierbij voor dat de juiste data in de juiste kolom staat, zoals in de eerste rij staat aangegeven.
4. Ga vervolgens weer terug naar het tabblad 'MinMax Berekenen' en klik op de knop 'Data ophalen' om ervoor te zorgen dat de input velden voor de min/max berekeningen worden ingevuld.
5. Vul de volgende vaste inputparameters in bovenaan de sheet 'MinMax Berekenen':
    - Bestelkosten per order
    - % Voorraadkosten van de prijs per eenheid
    - Aantal levermomenten per week
    - Berekening over vraag van aantal maanden
6. Nu heeft u alle benodigde informatie ingevuld. De min/max kan berekend worden door op de knop 'Min/Max berekenen' te klikken. De nieuwe min/max, oftewel de EBQ, wordt weergegeven in de kolom 'Nieuwe Min/Max'

Analyse van de data:

Nu de nieuwe min/max is berekend kan er worden gekeken naar andere data en veranderingen binnen de voorraadstanden. Deze data kan u tonen of verbergen door op een van de knoppen 'Extra informatie tonen' of 'Extra informatie verbergen' te klikken. De volgende data zijn beschikbaar per SKU en kan gebruikt worden om deze SKU verder te analyseren:

- Bin verbruik per dag
- Aantal eenheden verbruikt per dag
- Aantal eenheden verbruikt per uur
- Aantal dagen voor één bin leeg is, met de huidige min/max
- Aantal dagen voor één bin leeg is, gebaseerd op de nieuwe EBQ
- Kosten huidige Min/Max
- Kosten EBQ
- Verandering van min/max (Hoger, Gelijk, Lager)

Deze data staan per SKU aangegeven. Daarnaast is de reductie in voorraadwaarde aangegeven, net als het gemiddelde aantal dagen voor één bin leeg is voor de huidige min/max en de EBQ. Daarnaast is ook de variantie aangegeven van het aantal dagen voor één bin leeg is voor de huidige min/max en de EBQ.

Appendix 9: Instruction manual periodic review tool

The instruction manual is written in Dutch since the native language of the users of the EBQ-tool is Dutch.

Periodic review tool

Deze tool is bedoeld om de tijd tussen twee bestelmomenten te optimaliseren. Dit optimale bestelinterval is gebaseerd op het gemiddelde verbruik van SKUs per afdeling, aantal SKUs per afdeling, kosten voor tekorten op afdelingen, bestelkosten, aantal geschatte levermomenten en levertijden na bestellen.

Gebruik van de tool:

1. Zorg dat in het tabblad 'Data' de kolommen A, B en C (en eventueel G) zijn ingevuld met de naam van de afdeling (A), het aantal producten dat op die afdeling ligt (B), het aantal dagen dat het gemiddelde duurt voordat één bin leeg is (C). Kolom G is er om te vergelijken of, nadat de EBQ-tool gebruikt is om nieuwe min/max te bepalen, het nieuwe verwachte aantal dagen voordat één bin leeg is nog wat verandert aan de bestelfrequentie. Deze hoeft niet altijd ingevuld te worden.
2. Controleer of de volgende parameters op het tabblad 'Periodic Review Dept' goed zijn ingevuld:
   - ρ (Kosten voor tekorten op afdelingen)
   - $\hat{\rho}$ (Kosten voor de tijd dat er een tekort is op een afdeling)

   Voor deze waarden is op dit moment het gemiddelde van de gezondheidszorgsector ingevoerd.

   - K (Bestel kosten)
3. Klik vervolgens op de knop 'Start periodic review' om de periodic review te starten. De tool rekent nu voor alle afdelingen waarvan informatie is ingevuld in het tabblad 'Data' uit wat de optimale tijd is tussen twee bestelmomenten. Lees uit kolom F (en/of J) af wat de tijd zou moeten zijn tussen twee bestelmomenten van die afdeling.

Appendix 10: Current and (proposed) new storage locations of SKUs in the unsterile warehouse

Article number	Description	Old warehouse location	New warehouse location
101766	Handschoen, Nitra-Tex, Maat S, 100st	1.27.A.C	1.1.A.A
101768	Handschoen, Nitra-Tex, Maat L, 100st	1.14.A.A	1.2.A.A
123212	Swash Gold Gloves washand parfumvrijÂ Â 40vp8st	1.5.A.A	1.4.A.A
138618	Isolatiejas Q-Plus met manchet blauw maat XL	1.13.A.A	1.5.A.A
101008	Nierbekbakjes pulpÂ Â Â Â Â 80st	1.12.A.A	1.6.A.A
140565	Medi-Vac Flex Advantage liner 1500 ml	1.27.A.A	1.7.A.A
100700	Abri-Form Premium L2 slip 22st	1.26.A.A	1.8.A.A
101838	Handschoen, Nitra-Tex, Maat XL, 100st	1.27.A.B	1.9.A.A
132069	Scott* 600 toilet tissue rollen 2-lgs 600v 6rl	1.7.A.A	1.10.A.A
140431	Vileda Micron vezeldoek 25x32cm 180st.	1.16.A.B	1.11.A.A
132065	Scott handdoeken Multifold Airflex 1lgs wit	1.6.A.A	1.12.A.A
125171	Hot Cups SMR8 karton 240cc 50st	1.15.A.B	1.13.A.A
101767	Handschoen, Nitra-Tex, Maat M, 100st	1.11.A.A	1.14.A.A
101031	Afvalcontainer 50l met deksel blauw	1.4.A.A	1.15.A.B
101032	Afvalcontainer 30l met deksel blauw	1.2.A.A	1.16.A.A
100570	Sharpsafe naaldencontainer afvoerdoos	1.21.A.B	1.16.A.B
100694	Abri-San Premium 7 inlegverband 30st	1.25.A.A	1.17.A.A
100699	Abri-Form Premium M2 slip 24st	1.25.A.B	1.17.A.B
101001	Zuurstofverbindingsslang 3mmx30m	1.23.A.B	1.18.A.A
101880	A4 papier Black Label Zero 75g wit 2500vel	1.31.A.A	1.18.A.B
101146	Satino onderzoekstafelpapier 150x0.46m 1rl	1.24.A.B	1.19.A.A
101148	Satino onderzoekstafelpapier 150x0.59m 1rl	1.17.A.B	1.19.A.B
102408	Envelop met venster algemeen A5 250st	1.28.A.A	1.19.A.C
141378	Isolatie Overall met voet, non-woven donkerblauw XXL 50st	1.20.A.C	1.20.A.B
128451	Sharpsafe Naaldencontainer 1L	6.4.C.A	1.20.A.C
124915	Accu-chek Safe T-Pro 200st	7.5.B.A	1.21.A.B
129272	Markant beschuit naturel 13st	1.33.B.A	1.22.A.A
100821	Broxo onthardingszout 25kg	1.1.A.A	1.23.A.A
127060	Sharpsafe naaldencontainer 7L	1.18.A.B	1.23.A.B
125730	Bestekpochette 50 grams Airlaid 40cm wit 225st	1.17.A.A	1.24.A.A
140567	Medi-Vac Flex Advantage liner 3000 ml	1.22.A.A	1.24.A.B
140260	Protectielaken 210X80cm 100st	1.10.A.A	1.25.A.A
127048	Sharpsafe naaldencontainer 4L	1.18.A.A	1.25.A.B
101089	Verbindingsslang 5mmx30m pvc	1.23.A.A	1.26.A.A
101186	Paper2paper toiletpapier 2-laags 400vel 4rl	1.9.A.A	1.27.A.A
127046	Sharpsafe naaldencontainer 3L	1.19.A.A	1.27.A.B
140230	Absorin Comfort Onderlegger paars 40x60 30st	1.24.A.A	1.27.A.C
101152	plastic beker 180ml wit 100st	1.16.A.A	1.28.A.A
140231	Absorin Comfort Onderlegger paars 60x60 30st	1.8.A.A	1.31.A.A
101689	E-swab Regular roze dop / voorheen Culturette	8.3.B.A	1.32.A.A
124921	Test strips accucheck inform II 50st	7.3.B.C	1.32.C.A

101688	bloedkweek volwassenen	8.1.B.A	1.32.D.B
100877	Mollelast fixatie windsel 6cmx4mtr 20st	3.3.C.A	1.32.D.C
101759	Humid-vent filter compact a 25st	12.2.B.A	1.32.E.A
100692	Abri-Light Normal inlegverband 12st	9.8.C.A	1.33.B.A
129275	Prominent limonadesiroop Framboos 750ml	1.36.C.A	1.33.B.B
133066	Dustpanzakjes zwart 450x500mm T10 50st	6.3.B.A	1.33.C.A
129274	Sunleaf Thee English blend 100 zakjes a 2gr	1.34.B.A	1.33.C.C
138144	Klinion kompres 4-lgs 10x10cm 175034 100st	2.5.C.A	1.33.C.D
100702	HDPE plastic zak grijs 85x100 30mu 20st	6.1.C.A	1.33.C.E
138593	Surgical Mask blue met oorlussen type II 50st	4.8.C.A	1.33.D.A
100572	Braun proscan hoesjes oorthermometer 200st	9.6.C.A	1.33.D.B
126715	Formelta koffiemelk plantaardig 500 gr.	1.35.C.A	1.33.E.A
115955	Rietje buigzaam 5x210mm 250st	11.6.C.A	1.33.E.C
100995	Medicijnglaasjes polypropyleen 25/30ml 50st.	9.7.B.A	1.34.A.A
113530	Disp washand Molton wit 80grÂ 50st	10.2.C.A	1.34.B.A
101139	Lady-lux maandverband maxiÂ Â Â Â 20st	9.4.C.A	1.34.C.A
101150	Luier Premium Protection 1 newborn 2-5kg PampersÂ 36st	11.3.B.A	1.34.C.B
100880	Micropore Chirurgische pleister 2,5x9.1m 12st	2.1.B.A	1.34.D.A
128703	Telic Transonic gel clear 250ml	4.3.C.B	1.34.D.B
137774	Deksel PP 101 mm wit 50st	6.2.C.A	1.34.D.C
101158	Paloma premium zakdoekjesÂ Â Â Â 10st	10.6.C.B	1.34.E.A
126232	Anesthesie Masker Medium Adult-5	5.7.D.A	1.34.E.B
101696	Urine container	8.7.C.A	1.34.E.C
101181	HDPE plastic zak wit 58x100cm T23 20st	6.1.B.A	1.35.A.A
137773	Beker PP 101mm wit 500ml 50st	6.8.B.A	1.35.C.A
101120	HDPE plastic zak zwart 700mmx1.10m 20st	6.2.B.A	1.35.D.A
101127	HDPE plastic zak zwart T15 63x70cmÂ 50st	6.5.B.A	1.35.D.B
100855	tuitbekerdeksel onderverpakt jonibeker 25st	6.8.C.A	1.35.E.B
110247	Medisavona handzeep 500ml	9.8.B.A	1.36.A.A
101119	HDPE plastic zak zwart 450x500mm 0.01 50st	6.4.B.A	1.36.B.A
109015	Ecolab Brialspray 750ml	9.3.C.A	1.36.B.B
100516	Koffiemelkcups Markant 7.5g 10st	1.36.E.A	1.36.C.A
100854	Joni 4502 tuitbeker 200ml toppac 25st	6.6.C.A	1.36.E.A
100739	ideaalwindsel 120mmx5m nobalastik	3.2.C.A	2.1.B.A
101853	Bair Hugger Upper Body warmtedeken 62200	5.4.C.A	2.1.C.A
100658	Beer pluche beige met t-shirt Baby boa	14.6.A.A	2.1.C.B
132067	Satino hygienezakjes PE wit 25st	10.2.B.A	2.1.C.C
100682	Red Dot monitoring Electrode 2560 5st	4.5.C.A	2.1.D.A
101762	Kosack Surgical Cap, violet 120st	4.4.C.A	2.1.D.B
101695	sputumcontainer	8.7.B.A	2.3.B.A
136183	Dental kit	10.3.D.A	2.3.B.B
136766	Etiketten tbv Zebra LP 2824	9.2.B.A	2.3.B.C
136768	Posey anti-slip sokken maat Standaard oranje	10.6.A.A	2.3.C.A
140734	Canister Spherasorb 1.0kg/1.2L	12.4.B.A	2.3.C.B
101691	fecescontainer	8.5.B.A	2.3.D.A

141319	Zuurstofbril Adult Nasal cannula + tubing	5.2.B.A	2.3.D.B
101170	Pampers babydoekjes sensitive navulpak 56st	11.5.B.A	2.5.C.A
134634	Curion urineopvangzak zonder kraan 1,5ltr L90cm onsteriel	7.7.B.A	2.7.A.A
132058	Tiger reserve closetborstel wit	9.5.B.C	2.7.A.B
101141	Absorbtiedoeken 45x37cm extra sterk 50st	9.2.C.A	2.7.B.A
102390	Abri-Light Extra 3 inlegverband 10st	11.2.C.A	2.7.B.C
100519	Karvan Cevitam limonadesiroop citroen 750ml	1.36.B.A	2.7.C.A
136177	Hair & Body Wash, flesje	10.2.B.C	2.7.C.B
138545	Cirrus2 vernevelaar met T-stuk mondstuk 1.8m slang	5.1.B.A	2.7.D.A
102749	Sunleaf thee rooibos 20 zakjes a 2gr	1.34.D.C	3.1.A.A
100812	Plastic zak wit tbv cytostatica 58x100cm 25st	6.2.D.A	3.1.B.A
100736	crepewindsel 80mmx4m nobacrepe	3.5.B.B	3.1.C.A
100734	ideaalwindsel 100mmx5m nobalastik	3.2.B.A	3.2.A.A
140846	Brother DK-11204 Label 400st	13.4.B.A	3.2.B.A
139822	Baby zuigfles 150ml, disposable 40st	11.4.B.A	3.2.B.B
123199	Patientline hoofdtelefoon zwart met kabel, 2.5m	10.7.B.A	3.2.B.C
116115	Conveen Optima condoomkatheter 30mm	7.2.D.B	3.2.C.A
100878	Mollemast fixatie windsel 8cmx4mtr 20st	3.1.C.A	3.2.C.B
140378	VAC 4ml K2EDTA Paars 50st	7.1.B.A	3.3.A.A
125170	Roerstaafjes plastic wit 2500st	1.35.A.A	3.3.B.A
100513	Natrena gourmet zoetjes tafeldispencer 400st	1.33.E.C	3.3.B.B
137067	Prontosan oplossing fles 350ml	4.3.C.A	3.3.B.C
101223	Comprilan zwachtel 10cmx5m per 2st	3.1.B.A	3.3.C.A
140825	Infinty ID Expiration Valve Adult V500	12.3.C.A	3.4.A.A
132025	Handschoen, Nitrile, Maat XL, 100st	6.7.B.A	3.4.A.B
123992	Soffban synth. watten 10cmx2.7m 12st	3.1.A.A	3.4.B.A
101128	LDPE draagtas 370x440mm witÂ Â Â 100st	6.4.A.A	3.4.B.B
100731	tricotwindsel 200mmx4m	3.7.C.A	3.4.B.C
133548	Rinse ontkalkings/naspoelmiddel voor pospoeler 5L	9.8.A.A	3.4.C.A
133054	Sontara micropure AP wipes 300st	10.8.C.A	3.4.C.B
100860	Batterij Duracel AA 1.5V LR6	10.4.B.A	3.4.C.C
129866	Sunleaf thee greentea lemon 20 zakjes a 2gr	1.34.E.A	3.4.D.A
100737	crepewindsel 100mmx4m nobacrepe	3.5.B.C	3.5.A.A
134635	Urinezakhouder blauw nylon	10.1.C.A	3.5.B.A
138592	Surgical Mask blue type II 50st	4.6.C.A	3.5.B.B
102017	Elastomull haft 12cmx20m	2.3.C.A	3.5.B.C
123987	Celstofdepper 4x5 2x500st	3.8.B.A	3.5.C.A
129276	Prominent limonadesiroop Sinas 750ml	1.36.B.B	3.5.C.B
132023	Handschoen, Nitrile, Maat M, 100st	6.5.C.A	3.5.C.C
101149	Luier premium protection 0 micro 1,5-2,5kg Pampers 24st	11.1.B.A	3.6.B.A
140571	Nessy neutraalplaat 5st	7.7.C.B	3.6.B.B
130675	Innospire Masker volwassen ref.1100E	5.3.C.A	3.6.B.C
102015	Elastomull haft 8cmx20m	2.3.B.C	3.6.B.D
100680	Handzeep Soft Care Fresh 800ml	9.1.B.A	3.6.C.A
101192	Schilmesje 6cm	10.1.B.C	3.6.C.B

132024	Handschoen, Nitrile, Maat L, 100st	6.7.B.B	3.6.C.C
140377	VAC 3,5ml Li/Hep/Gel Groen/Geel 50st	7.5.B.C	3.6.D.A
124887	Naaldhouders Macro	7.3.B.B	3.7.B.A
100879	Durapore hechtpleister 25mm 12st	2.1.C.A	3.7.C.A
101151	Europroducts facial tissues 100st	10.5.C.A	3.7.D.A
101129	schuurspons met greep blauw	9.4.B.C	3.8.B.A
101182	MST kledingtas met hengsel 600x500mm	6.3.C.A	3.8.C.A
136771	Nutrilon Standaard 1, Nutriset 70ml 24st	1.32.C.A	3.8.C.B
138594	Mask white barrier FFP2 20st	4.7.B.A	3.8.C.C
100635	HDPE plastic zak grijs 70x110cm T30 25st	6.6.B.B	3.8.C.D
100811	kam middel	9.6.B.C	3.8.D.A
100684	Vliesdoekje groen 38x40cm	10.3.B.A	3.8.D.B
100905	pupillampje penlight disposable	10.4.B.C	3.8.D.C
122197	Symphony Afkolfset disp. met membraan maat M	11.2.B.A	4.1.C.A
101846	Beademingscircuit RT200 L150cm	5.8.A.A	4.2.A.A
101694	punctaat	8.5.C.B	4.2.B.A
133549	Detergent reinigingsmiddel voor pospoeler 5L	9.3.A.A	4.2.B.B
102752	Sunleaf thee green tea 20 zakjes a 2gr	1.34.C.A	4.2.B.C
101220	Dauerbinde elastische zwachtel 10cmx7mtr	3.6.C.A	4.2.C.A
100815	veiligheidsspeld nr.3 12st	10.1.B.A	4.3.B.A
125497	Zebra polsband wit 25.4x279.4 mm cartridge	11.8.C.A	4.3.C.A
113856	Red Dot monitoring Electrode 2269T 30st	4.2.B.B	4.3.C.B
140237	Emmer PP wit +/- 2.5ltr met hengsel	13.3.A.B	4.3.D.A
133062	Roll-O-Wipe tendertex kleefdoek 40gr 50vel 60x20cm rol	10.2.D.A	4.4.B.A
140238	Klemdeksel PP wit voor +/- 2.5ltr emmer	13.3.A.A	4.4.C.A
100740	driekante doek 960mmx960mmx1.36m	4.2.A.A	4.4.D.A
101153	plastic bord wit 1-vaks 220mm 100st	15.7.B.C	4.5.B.A
123991	Soffban synth. watten 7.5cmx2.7m 12st	3.2.A.A	4.5.C.A
100923	Tubifast elast.buisverband 10m blauw	2.7.B.A	4.5.D.A
101098	Guedel keelpijp rood mt4 ref1114100	5.6.B.C	4.5.D.B
124470	bloedkweek Pediatrie	8.1.C.B	4.6.A.A
126561	Anesthesie Masker Large Adult-6	5.5.B.A	4.6.A.B
140380	VAC 2ml Na-Citr 3,2% Blauw/Wit 50st	7.1.B.B	4.6.C.A
100529	nobanetz nr.4 elast netverband	3.8.C.D	4.7.B.A
138602	Bouffant Nurses cap Large, blueÂ Â 150st	4.1.C.A	4.7.C.A
103321	Sunleaf thee tropical fruit 20 zakjes a 2gr	1.34.D.B	4.8.A.A
122198	Symphony Afkolfset disp. met membraan ready-to-use maat L	11.2.B.B	4.8.B.A
138153	Wattenstok kleine prop hout 15cm 100st	3.4.A.B	4.8.C.A
137129	Bic Easy Flex scheermesjes 5st	9.2.A.B	5.1.B.A
115414	Sunleaf thee green tea mint 20 zakjes a 2gr	1.34.E.C	5.1.C.A
109158	Sunleaf thee apple cinnamon 20 zakjes a 2gr	1.34.D.A	5.1.C.B
100727	tricotwindsel 80mmx4m	3.5.C.B	5.1.C.C
101412	BIS 4 elektrode Sensor 1860106 25st	4.3.D.A	5.1.D.A
125167	Suikersticks 5gr 600st	1.35.E.B	5.2.B.A
100819	Koortsthermometer digitaal Digitemp	10.4.B.D	5.2.B.B

100503	Afwasmiddel extra citroenÂ fles 1000ml	9.7.C.B	5.2.C.A
100730	tricotwindsel 150mmx4m	3.7.B.A	5.3.B.A
100733	ideaalwindsel 80mmx5m nobalastik	3.2.B.B	5.3.C.A
140388	Uri-plus 24-uurs Urinecontainer 3ltr	7.5.D.A	5.3.C.B
101757	Humid-vent filter compact-sÂ Â Â 25st	12.6.B.A	5.4.B.A
101118	HPDE plastic zak T11grijs 31,5x65cm 0.01 50st	6.3.B.C	5.4.B.B
101014	Red Dot monitoring Electrode 2268 3st	4.2.B.C	5.4.C.A
100713	Bair Hugger Full Body warmtedeken 61000	5.4.D.A	5.4.D.A
101097	Guedel keelpijp oranje mt3 ref1113090	5.4.B.A	5.5.B.A
129363	Sunleaf thee forrest fruit 20 zakjes a 2gr	1.34.E.B	5.5.C.A
100735	crepewindsel 60mmx4m nobacrepe	3.5.B.A	5.6.B.A
138591	Surgical Mask green, antifog type II 60st	4.2.C.A	5.6.B.B
138700	Mask white barrier FFP1 20st	4.5.B.A	5.6.B.C
114484	Conveen Optima condoomkatheter 25mm	7.2.D.A	5.6.C.A
101144	Wypall handpapier 2 lg blauw 300x510mm 100st	10.4.C.A	5.6.D.A
103356	Total non rebreathing mask	5.2.B.B	5.7.A.A
140845	Anchor Fast tube fixatiesysteem	12.4.C.B	5.7.B.A
132022	Handschoen, Nitrile, Maat S, 100st	6.7.C.B	5.7.B.B
100698	Abri-Fix Fixatiebroekjes 100st	11.4.C.A	5.7.D.A
100865	Batterij Duracel AAA 1.5V LR03	10.6.B.B	5.8.A.A
140376	VAC 3,5ml Serum/Gel Rood/Geel 50st	7.1.B.C	5.8.C.A
100975	Buis Liquor, U, PS, 12ml, 16x100mm, grip/groen	7.5.C.A	6.1.A.A
102014	Peha-Haft fixatiezwachtel 6cmx20m	2.3.B.B	6.1.B.A
138619	Isolatiejas korte mouw zonder manchet blauw maat M	11.8.B.A	6.1.C.A
140859	Stuwband blauwe band voor patient specifiek 15st	12.5.B.A	6.1.C.B
100892	oordopjes e.a.r. classic bescherm foam 2st	10.7.C.A	6.1.D.A
118389	Veiligheidsbril Virtua AP Blank 3M	10.5.A.B	6.1.D.B
100882	Transpore fixatiepleister 2,5cmx9,1m 12st	2.1.C.B	6.2.B.A
125129	Ontkalkingsmiddel t.b.v. Animo koffie-apparaat 50gr.	10.7.C.B	6.2.C.A
100626	TuBo-Flex (fixatie)	10.7.C.C	6.2.D.A
140556	Luxe OK-Jas lange mouw maat M 10st	6.7.A.A	6.3.A.A
100932	Fixomull stretch zelfklevend 5cmx10m	3.4.B.A	6.3.A.B
109148	Ecolab Into spray 750ml	9.1.C.A	6.3.B.A
100725	Noba tricotzwachtel 4cmx4m	3.5.C.A	6.3.B.B
101123	LDPE Plastic zak transparant 58x100 0.05 25st	6.6.B.A	6.3.B.C
101096	Guedel keelpijp groen mt2 ref1112080	5.4.B.B	6.3.C.A
100888	Delta Pre-Tape 10cmx30m	3.4.C.B	6.4.A.A
101028	Zuurstofmasker multi-vent volwassenen	5.3.C.B	6.4.B.A
100864	Batterij Duracel 9V 6LF22 blok	10.8.B.A	6.4.C.A
101692	Liquorbuis	8.3.C.A	6.4.D.A
101122	Suma Tab D4 chloortabletten 300st	9.1.C.B	6.5.B.A
113590	Prominent sinaasappelsap 1lt	1.33.D.A	6.5.C.A
140389	VAC 10ml Urine Geel/Geel 50st	7.1.C.B	6.6.B.A
101760	Smooth-Flo flex catheter mountÂ 35st	12.6.D.B	6.6.B.B
112887	Prominent appelsap 1lt	1.33.D.B	6.6.C.A

141294	Disp. hoezen AVE 2 \midden beendeel\" 5st"	11.7.C.A	6.7.A.A
101408	Waterset volw. Met 2 ltr ballon ref. 2108000	5.2.C.A	6.7.B.A
138601	Bouffant Nurses cap Medium, blue 150st	4.4.B.A	6.7.B.B
140742	UniFlow beademingssyst D30mm L2.0m +spirometrieset 10st	12.3.B.A	6.7.C.B
101199	Gilette scheergel basic 200ml	9.4.B.D	6.8.B.A
100999	Red Dot monitoring Electrode 2255 50st	4.7.C.A	6.8.C.A
140828	Infinity ID Flowsensor voor beademing V500 5st	12.7.B.A	7.1.A.A
100936	Nexcare pleisters 10cmx6cm 10st	2.3.D.B	7.1.B.A
100934	Fixomull stretch zelfklevend 15cmx10m	3.4.B.C	7.1.B.B
100813	urinaal plastic	9.7.D.A	7.1.B.C
138543	EcoLite aerosol gezichtsmasker voor kinderen	7.1.C.A	7.1.C.A
101145	Scott handdoekrol 115 kc6681 1-laags	10.8.D.A	7.1.C.B
100931	Fixomull stretch zelfklevend 10cmx10m	3.4.B.B	7.1.D.A
113527	Beschermdoek 45x33cm Wit PE 50st	9.6.D.A	7.2.A.A
101698	E-swab XS oranje dop / voorheen draadwat	8.3.A.A	7.2.A.B
102013	Elastomull haft 4cmx20m	2.3.B.A	7.2.B.B
140239	Emmer PP wit +/- 5ltr met hengsel	13.1.A.A	7.2.B.C
102016	Elastomull haft 10cmx20m	2.3.C.B	7.2.C.A
130645	Defibrillatorpads (PC) 10st	7.7.A.A	7.2.C.B
140397	Urinepotje met afnamesysteem 100st	7.3.D.A	7.2.C.C
140240	Klemdeksel PP wit voor +/- 5ltr emmer	13.1.A.B	7.2.C.D
140573	Reusable aansluitsnoer voor patientplaten L5mtr	7.5.C.C	7.2.D.A
132399	Scheermesje voor Clipper 9681Â Â 50st	9.2.D.A	7.2.D.B
101218	Tubigrip elast. buisverband maat D wit 10m	3.2.C.B	7.2.D.C
130651	Verzendcontainer voor 5 objektglazen	7.3.B.A	7.2.E.A
141045	Luier Pampers New Baby 2 mini 3-6kg 41st	11.3.C.B	7.2.E.B
138181	Flaminal Hydro Enzym Alginogel 25gr	7.2.C.D	7.3.B.A
140814	Leukoplast fixatiepleister 2.5cm L5m 12st	12.3.D.A	7.3.B.B
137916	Proshield Plus Skin Protectant 115gr	3.8.D.C	7.3.B.C
100876	Mollelast fixatie windsel 4cmx4mtr 20st	2.7.B.C	7.3.C.A
130652	Specimen beker met schroefdop	7.1.A.A	7.3.C.B
115418	Sunleaf thee earl grey 20 zakjes a 2gr	1.34.C.B	7.3.C.D
141296	Disp. hoezen AVE 2 \midden beendeel\" 5st"	11.5.C.A	7.3.C.E
100814	centimeter op rol 1.50m	10.6.B.D	7.3.D.A
132839	A5 papier 120gr 12x250vel	1.32.A.A	7.4.E.A
102078	Platrix gipsverband 20cmx25m	13.5.B.A	7.4.E.B
100557	Luier baby dry large 13-18 kg PampersÂ 33st	11.1.C.A	7.4.E.C
136770	Nutrilon Nenatal Start, Nutriset 70ml 24st	1.32.E.A	7.5.B.A
123666	Polsbandje neonatal foam wit 24st	11.8.D.A	7.5.B.B
129283	Mineraalwater blauw koolzuurvrij 50cl	1.35.D.B	7.5.B.C
101403	Beademingssysteem uniflow 1.6m ref. 2900000	5.8.C.A	7.5.C.A
140818	Flexi-Seal Signal Fecaal management systeem	12.5.B.B	7.5.C.C
140843	PROSource Nocarb Neutraal sachets 30ml 42st	12.4.C.A	7.5.D.A
100884	nobatricot 60mmx20m	2.7.C.B	7.7.A.A
102455	Septodry absorbtiekorrels 10 zakjes	10.8.B.B	7.7.A.B

101095	Guedel keelpijp wit mt1 ref1111065	5.6.B.B	7.7.B.A
101215	Actimove Sling 5.5cmx12m 2 rol	3.7.D.A	7.7.C.A
138152	Wattenstok grote prop hout 15cm 50st	3.4.A.A	7.7.C.B
100883	Durapore fixatiepleister 1,25cmx9.1m 24st	2.1.D.A	8.1.B.A
132066	Vulling Kimberly Clark Zen luchtverfrisser	9.5.B.A	8.1.C.A
140851	Tracoe fixatiebandjes breed 2.5x43cm	13.8.C.B	8.1.C.B
100933	Fixomull stretch zelfklevend 20cmx10m	3.6.B.A	8.1.D.A
100817	Prameta stuwband groen	3.8.C.B	8.1.D.B
140848	Filta-Guard ademhalings filter	13.4.A.A	8.3.A.A
120048	Delta-Cast Conf. blauw 3,6m x 10cm 10st	13.3.B.A	8.3.B.A
101187	Broxomatic Onthardingszout 1kg	9.5.C.A	8.3.C.A
141389	CaluClean afvalzak 70x110cm kleur geel HDPE	6.1.A.A	8.3.C.B
100809	Bair Hugger Full Access warmtedeken 63500	5.3.B.A	8.5.B.A
116116	Conveen Optima condoomkatheter 35mm	7.2.D.C	8.5.C.A
100646	Cavilon spray No Sting Barrier Film 28ml	3.6.C.B	8.5.C.B
138660	Mediplast Braakzak 1500ml 50st	11.7.A.B	8.7.B.A
100729	Noba tricotzwachtel 12cmx4m	3.5.C.C	8.7.C.A
100831	Pillow-paw pantoffel maat 38-42 groen 1pr	10.5.B.A	9.1.A.A
137199	Novalife1 GX+9630-10 ileozak midi 30st	7.2.B.B	9.1.B.A
140830	Beademingsslang Oxylog 3000 disp.	12.7.B.B	9.1.B.B
131741	Novalife2 ileozak high output 70mm 1207-70 10st	7.4.E.B	9.1.C.A
102253	MENZ-1 verwijsformulier paramedische zorg 25st	14.1.B.A	9.1.C.B
140773	Zebra Z-Select 2000D, 102 x 38 mm, 1790 labels	11.6.B.A	9.1.D.A
120047	Delta-Cast Conf. blauw 3,6m x 7,5cm 10st	13.3.B.B	9.1.D.B
100580	Pampers baby dry luiers midi 4-9kg 60st	11.7.B.A	9.2.A.A
129278	Markant vruchtenmix 500ml	1.33.C.C	9.2.A.B
100536	gaaskompres 100x100mm x-ray 100st	3.4.C.A	9.2.A.C
134815	Elset S stompzwachtel lang 10cmx12m	3.8.D.A	9.2.B.A
114587	Welland huidbeschermings creme 50gr WSC50	7.2.C.B	9.2.B.B
140387	VAC 2ml K2 EDTA Paars/Wit 50st	7.3.C.B	9.2.C.A
100807	Welland Adhesive poeder 25gr WPP025	7.2.C.A	9.2.D.A
140568	Medi-Vac Specimen sock	11.1.A.A	9.3.A.A
140855	Steun-drukverband voor de romp mt 5 105-115cm	12.8.B.B	9.3.C.A
140338	Actimove Umerus Comfort LÂ	14.1.C.A	9.4.A.A
101157	schort wit 165x81x0.25 100st	11.8.A.A	9.4.B.A
100732	ideaalwindsel 60mmx5m nobalastik	3.2.B.C	9.4.B.B
140847	Sternasafe Universeel 10st	12.8.C.A	9.4.B.C
101226	handschoen katoen large maat 13 1paar	9.6.B.A	9.4.B.D
101155	plastic vork wit 175mm 100st	15.7.B.B	9.4.C.A
130659	Clinitubes 100UL 75st	7.5.B.B	9.4.D.A
120045	Delta-Cast Conf. wit 3,6m x 12,5cm 10st	13.3.D.B	9.5.A.A
112933	Slimpie limonade siroop framboos suikervrij 58cl	1.33.C.D	9.5.B.A
138182	Klinion Koud Kompres 15X21cm 12st	12.2.C.B	9.5.B.B
100687	Food-wipes anti-bacterie voelerdoekÂ Â Â 200st	9.2.B.B	9.5.B.C
123990	Soffban synth. watten 5cmx2.7m 12st	2.7.D.A	9.5.C.A

100893	Klinion gipstricot geribt 5cmx20m	13.7.C.A	9.5.C.B
140864	Hudson Medicijnvernevelaar Micromist met klep 50st	13.6.B.A	9.5.C.C
122199	Symphony Afkolfset disp. met membraan maat XL	11.2.A.A	9.5.D.A
140393	VAC. 5ml Droog niet Gesil. Glas 100st	7.3.C.E	9.6.A.A
125138	Koffie Royal snelfilter 1kg	1.34.A.A	9.6.B.A
130692	Coloplast irrigatie conus klein 1110	7.2.A.B	9.6.B.B
101154	plastic mes wit 175mm 100st	15.7.B.A	9.6.B.C
100920	Tensoplast steunverband 2.4cmx4.5m	3.6.B.B	9.6.B.D
129282	Cristaline Water Koolzuurhoudend 500ml	1.35.D.A	9.6.C.A
101217	Tubigrip elast. buisverband maat E wit 10m	3.3.B.A	9.6.D.A
102077	Platrix gipsverband 15cmx25m	13.7.B.A	9.7.B.A
101699	doosje tbv sputumcontainer	8.1.D.A	9.7.C.A
120044	Delta-Cast Conf. wit 3,6m x 10cm 10st	13.3.D.A	9.7.C.B
100845	Afwasborstel nylon slee model uitstaand	9.6.B.B	9.7.D.A
100937	Nexcare Comfort strips 19mm 100st.	2.1.C.C	9.8.A.A
140340	Hudson Ademvolumemeter voldyne 5000	13.2.C.B	9.8.B.A
100693	Abri-San Premium 6 inlegverband 34st	3.5.A.A	9.8.C.A
102084	Pampers baby dry luiers junior 11-25kg voordeelpak 50st	11.1.C.B	10.1.A.A
140817	Flexi-Seal opvangzakjes 10st	12.7.D.B	10.1.A.C
140815	Leukoplast fixatiepleister 1.25cm L5m 24st	12.3.D.B	10.1.A.D
100918	Klinion gipstricot geribt 10cmx20m	13.5.C.B	10.1.B.A
140827	CO2 cuvettes disp. 10st	12.4.D.A	10.1.B.B
137196	Novalife2 GX+1870-10 huidplaat 10-62mm 5st	7.4.E.A	10.1.B.C
101137	Biotex handwas inweek poeder 750gr	9.5.C.B	10.1.C.A
124076	Delta-Cast Conf. zwart 3,6m x 7,5cm 10st	13.3.C.B	10.1.D.A
124077	Delta-Cast Conf. zwart 3,6m x 10cm 10st	13.3.C.A	10.2.A.A
101117	Vloeibaar schuurmiddel Actiff 750ml	9.5.C.C	10.2.B.A
140390	VAC 4ml K3EDTA Roze/Zwart 50st	7.3.C.A	10.2.B.B
102397	MST-38 08 10 af Akte envelop A4 algemeen 250st	14.7.A.A	10.2.B.C
101188	Scotch afplaktape 19mmx50m	11.7.A.A	10.2.C.A
140337	Actimove Umerus Comfort M	14.4.C.B	10.2.D.A
101194	Spoelglansmiddel SunÂ 1l	9.7.C.A	10.3.A.A
140840	Optiflow THF trache interface voor MR850	12.5.C.A	10.3.A.B
100832	Pillow-paw pantoffel maat 42-46 bruin 1pr	10.5.B.B	10.3.A.C
100634	Pocketmasker (voor reanimatiekoffer)	5.1.C.C	10.3.B.A
101772	Neodisher alka 800 12kg	9.1.A.A	10.3.D.A
100581	Pampers baby dry luiers maxi 7-18kg 52st	11.3.C.A	10.4.B.A
101175	HS tandenborstel Acclean+ 24 Child	10.2.B.B	10.4.B.B
140856	Steun-drukverband voor de romp mt 4 95-105cm	12.8.B.A	10.4.B.C
141212	Klemdeksel PE wit voor +/- 10ltr emmer	13.5.A.B	10.4.B.D
141213	Emmer PP wit +/- 10ltr met hengsel	13.5.A.A	10.4.C.A
140822	Halita tongreiniger 12st	12.7.D.A	10.5.A.A
132336	AirSpiral verwarmde beademingsset voor Airvo	12.8.A.A	10.5.A.B
138180	Flaminal Forte Enzym Alginogel 25gr	7.2.C.C	10.5.A.C
140813	Calcium line for Prismaflex-ca250 24st	12.5.C.B	10.5.B.A

102407	Envelop zonder venster 250st	14.5.A.A	10.5.B.B
101110	Schoenovertrek blauw 100st	6.3.A.B	10.5.C.A
120046	Delta-Cast Conf. blauw 3,6m x 5cm 10st	13.3.B.C	10.6.A.A
100530	nobanetz nr.6 elast netverband	3.4.C.C	10.6.B.A
101172	Nilodor ruimte-deodorant	9.6.B.D	10.6.B.B
100627	Tracheamasker volwassenen aerosol	5.1.C.B	10.6.B.C
140837	Optiflow Nasale Canule voor MR850 maat M	12.7.C.B	10.6.B.D
140862	Handschoen Affinity micro touch Maat M 100st	13.6.A.A	10.6.C.A
101183	LDPE boterhamzak 10x4x30Â Â 0.02Â Â Â Â 1000st	6.1.D.B	10.6.C.B
101165	Zwitsal Shampoo 500ml	11.7.B.B	10.7.B.A
101125	G-label LDPE boterhamzakje 14x4x35cmÂ Â 1000st	6.1.D.A	10.7.C.A
100930	Micropore Chirurgische pleister 1,25x9.1m 24st	2.1.D.B	10.7.C.B
101219	Tubigrip elast. buisverband maat F wit 10m	3.3.B.C	10.7.C.C
114589	Blueline wegwerpzakjes met gripstrip VA0410M 100st	7.2.E.A	10.8.B.A
130484	Navulcontainer elektrodenspray 5000 ml	4.6.A.A	10.8.B.B
100711	Verkade biscuit volkoren San Francisco 250gr	1.32.D.B	10.8.C.A
120043	Delta-Cast Conf. wit 3,6m x 7,5cm 10st	13.1.D.B	10.8.D.A
123621	Afnameset DFT (parasitologie)	8.1.C.A	11.1.A.A
102171	MAD-6 afsprakenkaart 400st	14.3.A.A	11.1.A.B
113595	Slimpie limonadesiroop sinaasappel 580ml	1.33.C.E	11.1.B.A
120051	Delta-Cast Conf. rood 3,6m x 10cm 10st	13.1.B.A	11.1.C.A
102076	Platrix gipsverband 12cmx25m	13.7.C.B	11.1.C.B
101948	HYG-7 11 10 infectiepreventie kaart	14.1.A.A	11.2.A.A
141303	Oogbeschermende Lenzen tbv Frames 25st	5.6.D.A	11.2.B.A
101216	Tubigrip elast. buisverband maat C wit 10m	3.3.B.B	11.2.B.B
101179	papieren afvalzakje 150x90x260mm 1000st	6.3.A.A	11.2.C.A
100686	Vouwboekje HP-M1911A 150mmx100mm 10st	14.5.C.C	11.3.A.A
140839	Optiflow Nasale Canule voor MR850 maat L	12.7.C.C	11.3.B.A
138603	Charlotte Nurses cap M (elastic), wit 200st	4.8.B.A	11.3.C.A
140853	Etiketten voor Zebra GK420d rol 2000st	13.6.C.B	11.3.C.B
112921	Biscuits Deluxe Koekjes Populair assorti 3 srt. 150st	1.36.A.A	11.4.B.A
124060	Delta-Cast Conf. roze 3,6m x 10cm 10st	13.1.C.A	11.4.C.A
100863	Batterij Duracell 1.5V LR14 staaf	10.4.B.B	11.5.A.A
138590	Surgical Mask blue incl. spatscherm type Iir 50st	4.4.D.A	11.5.B.A
101690	dermapak	8.1.D.B	11.5.C.A
140871	Nobacare Kous K30-38cm/L74-84cm - middel/wit	13.6.D.A	11.6.B.A
140659	Medi-Vac 1200ml Canister incl. deksel	11.3.A.A	11.6.C.A
134848	Nobafast buisverband 5cmx10m, groen	2.7.A.B	11.7.A.A
140339	Actimove Umerus Comfort XLÂ Â	14.4.C.A	11.7.A.B
100867	HDPE plastic zak roze 58x100cmÂ T23 20st	6.3.B.B	11.7.B.A
100869	nobatricot 80mmx20m	2.7.C.A	11.7.B.B
100574	schuurspons met greep geel	9.4.B.B	11.7.C.A
137200	Novalife1 GX+9610-10 ileozak maxi 10st	7.4.E.C	11.7.D.A
100741	tongspatels 100st	3.8.C.C	11.8.A.A
140816	Chemoprotect jas XL onsteriel 30st	12.5.A.A	11.8.B.A

137195	Novalife2 GX+1855-10 huidplaat 10-47mm 5s	7.2.B.C	11.8.C.A
138546	Oxygen Flowmeter nipple D.I.S.S.	10.1.B.B	11.8.D.A
139823	Baby zuigfles 250ml, disposable 40st	11.5.A.A	12.1.B.A
100549	neusverband nobarhinal 10st	3.6.D.A	12.1.C.A
136872	Handschoen Affinity micro touch onsteriel Maat L 100st	13.8.A.B	12.2.B.A
140860	EzPAP met disp. manometer en mondstuk 10st	13.7.A.A	12.2.C.B
132070	KC toiletbrilreiniger 400ml	9.1.B.B	12.2.D.A
140849	Reanimatie systeem volwassen met peepklep	13.4.C.A	12.3.B.A
140852	Zakjes Silent Knight medicijnvermaler 1000st	13.6.C.A	12.3.C.A
140842	FreeMotion Non-vent. full face masker maat S	13.2.C.A	12.3.D.A
100922	Tensoplast steunverband 7.5cmx4.5m	3.6.B.D	12.3.D.B
140870	Nobacare Kous K38-44cm/L46cm - groot/wit	13.6.D.A	12.4.B.A
140868	Swash shampoo cap 56st	13.2.A.A	12.4.C.A
136769	Niko naso-fix fixatiepleister met vleugel 100st	2.3.D.A	12.4.C.B
101409	Reanimatie set volw ballon 1.5l masker ref.7152000	5.5.C.A	12.4.D.A
100921	Tensoplast steunverband 5.0cmx4.5m	3.6.B.C	12.5.A.A
100997	Wilkinson scheermesje disposable 100st	9.1.D.B	12.5.B.A
101225	Varicex Zinklijmzwachtel 10cmx10mtr	2.7.A.A	12.5.B.B
124075	Delta-Cast Conf. zwart 3,6m x 5cm 10st	13.3.C.C	12.5.C.A
130656	Objektglazen Superfrost + matrand 50st	7.3.C.D	12.5.C.B
140836	Optiflow Nasale Canule voor MR850 maat S	12.7.C.A	12.6.B.A
100896	Liner ondersteek pulp 2L 6412439	12.2.D.A	12.6.D.A
101094	Guedel keelpijpje grijs mt0 ref 1110055	5.6.B.A	12.6.D.B
116918	HYG-7A 11 09 Aerogene strikte isolatie	14.5.B.A	12.7.A.A
130075	Afnameset E-swab MRSA	8.5.C.A	12.7.B.A
131747	Hollister Faecesopvangzak 1ltr 9821 10st	7.2.A.A	12.7.B.B
120042	Delta-Cast Conf. wit 3,6m x 5cm 10st	13.1.D.A	12.7.C.A
140861	Handschoen Affinity micro touch Maat S 100st	13.8.B.A	12.7.C.B
101124	LDPE plastic zak blauw 58x100cm 25st	6.4.D.A	12.7.C.C
101196	rekfolie scheurstrip 300mmx50m 1rl	9.1.D.A	12.7.D.A
102254	MENZ-2 alg.aanvraagform farmacie 25st	14.1.C.B	12.7.D.B
102179	MAG-15 stickervel cytostatica 16st	14.8.C.C	12.7.D.C
100695	Abri-San Premium 9 inlegverband 25st	3.3.A.A	12.8.A.A
124059	Delta-Cast Conf. roze 3,6m x 7,5cm 10st	13.1.C.B	12.8.B.A
100891	Notac tractie kit foam kinderen	3.8.C.A	12.8.B.B
100913	Zuurstofbril neonataal gebogen 2.1m 1160001	5.1.C.A	12.8.C.A
120050	Delta-Cast Conf. rood 3,6m x 7,5cm 10st	13.1.B.B	12.8.D.B
123988	Wattenbollen small	14.8.D.A	13.1.A.A
101888	Signaaltape 19mm x 66m zwart	14.8.C.B	13.1.A.B
101952	Signaaltape 19mm x 66m rood	14.8.C.A	13.1.B.A
102398	MST-38A MST envelop A4 met venster	14.8.B.A	13.1.B.B
102328	MST-191 Uw opname in MST	14.8.A.A	13.1.B.C
135010	ISO-kaarten	14.7.D.A	13.1.C.A
102256	MST-0A Envelop combi tape lock	14.7.C.B	13.1.C.B
102177	MAG-12 Stickervel laserprinters	14.7.C.A	13.1.C.C

134946	MST-257 waarschuwingskaart Links en rechts geen rr en lab	14.7.B.B	13.1.D.A
102251	MAZ-6 Intermac etiketrol blanco 1-baans	14.7.B.A	13.1.D.B
102172	MAD-6A Etui afsprakenkaart patient	14.6.D.A	13.2.A.A
101876	RON-40 Verwijzing MRI	14.6.C.B	13.2.B.A
134939	Kofferlabel 'Telemetrie'	14.6.B.C	13.2.C.A
134937	Kofferlabel 'Nuchter' 50st	14.6.B.A	13.2.C.B
100798	Red Dot monitoring Electrode 2248 50st	4.2.B.A	13.3.A.A
102330	Presentatiemap algemeen, nieuwe uitvoering	15.7.D.A	13.3.A.B
125414	Etikethouder creditkaart rood	15.7.C.B	13.3.A.C
125413	U-klem ABS t.b.v. vastzetten separaties kleur rood	15.7.C.A	13.3.A.D
101894	Kunststof etiketstrip 40mm hoog , dubbelzijdig plakband, 500mm	15.5.D.A	13.3.B.A
125410	Separatie ABS 600x200 mm	15.5.C.B	13.3.B.B
125409	Separatie ABS 400x200 mm	15.5.C.A	13.3.B.C
141821	Sticker polsband NTBR	15.5.B.C	13.3.C.A
101953	Signaaltape 19mm x 66m blauw	15.5.B.A	13.3.C.B
125404	Mand ABS separeerbaar 600x400x100 mm	15.3.D.A	13.3.C.C
125406	Separatie ABS 600x100 mm	15.3.C.B	13.3.D.A
125405	Separatie ABS 400x100 mm	15.3.C.A	13.3.D.B
125419	PVC kaart credit-card formaat kleur rood	15.3.B.A	13.4.A.A
125407	Mand ABS separeerbaar 600x400x200 mm	15.1.D.A	13.4.B.A
125418	PVC kaart credit-card formaat kleur groen	15.1.B.C	13.4.B.B
125417	PVC kaart credit-card formaat kleur blauw	15.1.B.B	13.4.C.A
125415	PVC kaart credit-card formaat kleur wit	15.1.B.A	13.4.D.A
128702	Eco supergel 5ltr clear	4.6.A.B	13.5.A.A
101697	Afnameset soa panel (E-swab roze dop)	8.3.C.B	13.5.A.B
140857	Threshold IMT 10st	12.8.D.B	13.5.B.A
100833	Theelepeltje es-85 metaal 115mm	9.2.A.C	13.5.C.B
141302	Oogbescherming Frames diverse kleuren	5.7.B.B	13.6.A.A
140858	Verzegellabel voor Metro life line wagen 100st	12.6.D.A	13.6.B.A
120049	Delta-Cast Conf. rood 3,6m x 5cm 10st	13.1.B.C	13.6.C.A
101130	schuurspons met greepÂ rood/wit	9.4.B.A	13.6.C.B
101749	Flanel windsel 4m x 10 cm	3.8.D.B	13.6.D.A
137917	Opsite wondpleisterspray	3.6.C.C	13.6.D.B
101140	Tork keukenrol wit 2 laags 12.02.69 2rol	9.4.D.A	13.7.A.A
101142	Fasana servet wit 1 laags 330x330mm 100st	10.2.A.A	13.7.B.A
140863	Handschoen Affinity micro touch Maat XL 100st	13.8.B.B	13.7.C.A
124058	Delta-Cast Conf. roze 3,6m x 5cm 10st	13.1.C.C	13.7.C.B
140841	FreeMotion Non-vent. full face masker maat M	13.2.B.A	13.8.A.B
100624	Eakin fistelzak met tuit 4.5x3cm 839260 10st	7.2.E.B	13.8.B.A
140336	Actimove Umerus Comfort S	14.4.C.C	13.8.B.B
140865	Hudson Iso-Neb Medicijnvernevelaar Iso-Neb	13.8.C.A	13.8.C.A
140681	Medi-Vac Flex Advantage Tube flex tandem	11.1.A.B	13.8.C.B
102108	LAB-2 02 16 Aanvraagformulier Lab.	14.5.C.B	14.1.A.A
102107	LAB-16 11 10 Aanvraag bloedprodukten	14.5.C.A	14.1.A.B

128257	HYG-7D Aërogene isolatie bij (verdenking) TBC	14.5.B.C	14.1.B.A
134956	HYG-7C Beschermende isolatie	14.5.B.B	14.1.B.C
134936	Kofferlabel ‘Spreekverbod’	14.4.B.C	14.1.C.A
134935	Kofferlabel ‘Vochtbalans’	14.4.B.B	14.1.C.B
134934	Kofferlabel ‘Links geen rr en lab’	14.4.B.A	14.1.D.A
134945	MST-256 waarschuwingskaart Links geen rr en lab	14.4.A.C	14.2.A.A
134944	MST-255 waarschuwingskaart Rechts geen rr en lab	14.4.A.B	14.2.A.B
134943	MST-254 waarschuwingskaart Vochtbalans	14.4.A.A	14.2.A.C
141197	Actimove Carpal L rechts	14.3.D.A	14.2.B.A
101879	RON-83A Verwijzing Radiologie/Echografie	14.3.C.A	14.2.B.B
101943	GYN-59 11 16 Aanvraag Echoscopie Gyn/Obstetrie	14.3.B.C	14.2.B.C
101941	GEM-3 03 95 Formulier verklaring van overlijden (pbz 115)	14.3.B.B	14.2.C.A
101940	GEM-2 12 00 Envelop B inclusief Doodsoorzaakverklaring CBS	14.3.B.A	14.2.D.A
102405	MST-7 09 17 Volgvel algemeen	14.2.D.A	14.3.A.A
102404	MST-6 Briefpapier algemeen	14.2.C.A	14.3.B.A
134933	Kofferlabel ‘Rechts geen rr en lab’	14.2.B.C	14.3.B.B
134932	Kofferlabel ‘Rechts en links geen rr en lab’	14.2.B.B	14.3.B.C
101966	STA-6B 04 16 Overlijden	14.2.B.A	14.3.C.A
134942	MST-253 waarschuwingskaart Spreekverbod	14.2.A.C	14.3.D.A
134941	MST-252 waarschuwingskaart Nuchter	14.2.A.B	14.4.A.A
134940	MST-251 waarschuwingskaart Cytostatica	14.2.A.A	14.4.A.B
141198	Actimove Carpal L links	14.1.D.A	14.4.A.C
101939	GEM-1 03 95 Envelop A tbv verklaring van overlijden (BRUIN)	14.1.B.C	14.4.B.A
116922	HYG-7B Contact - druppelisolatie	14.1.A.B	14.4.B.B
140869	Aluminiumfolie 300mmx250m	13.4.D.A	14.4.B.C
140850	EMMA Airway adapter adult/pediatric box	13.4.B.B	14.4.C.A
140236	Klemdeksel PE wit voor +/- 1ltr emmer	13.3.A.D	14.4.C.B
140235	Emmer PP wit +/- 1ltr zonder hengsel	13.3.A.C	14.4.C.C
140844	Thermisch papier 50mm geen grid	12.7.D.C	14.5.A.A
140854	Hudson RCE Ademvolumemeter voldyne 2500	12.7.A.A	14.5.B.A
141605	Luxe OK-Jas korte mouw maat M	12.1.C.A	14.5.B.B
140750	UniFlow beademingssyst D30mm L1.6m +spirometrieset	12.1.B.A	14.5.B.C
141602	Patienten overtil laken disp. 101x203cm	11.7.D.A	14.5.C.A
100683	Suma Total d2.4 geconcentreerd 1.5ltr	10.6.C.A	14.5.C.B
100660	Batterij Duracel CR2032 knoopcel	10.6.B.C	14.5.C.C
100861	Batterij Duracell Industrial ID 1300 LR20	10.6.B.A	14.6.A.A
100858	Schaar RVS Westcott handvat zwart 210mm	10.5.A.C	14.6.B.A
100859	Staaflantaarn Energizer impact incl. 2xAA	10.5.A.A	14.6.B.C
100838	Maatbeker-kunststof 3.0ltr.	10.3.A.C	14.6.C.B
101201	Ballonnen gemengd	10.3.A.B	14.6.D.A
100837	Maatbeker-kunststof 1.0ltr.	10.3.A.A	14.7.A.A
141345	Wartel met Tule wit	10.1.D.A	14.7.B.A
101355	Kabelbinder Pan Ty 203x3.6mm naturel	10.1.A.D	14.7.B.B
101354	Kabelbinder Pan Ty 142x3.6mm naturel	10.1.A.C	14.7.C.A
101334	Kabelbinder Pan Ty 99x2.5mm naturel	10.1.A.A	14.7.C.B

102249	MAG-9 A3 papier Black Label Zero	9.6.A.A	14.7.D.A
100823	Urinaal houder geplastificeerd	9.5.D.A	14.8.A.A
101131	Taski Jontec 300 NC navulflacon 1ltr	9.5.B.B	14.8.B.A
100520	Neodisher SBR Extra voor pospoeler 10L	9.5.A.A	14.8.C.A
129994	Dymo Adresetiket 54x101mm rol	9.4.A.A	14.8.C.B
100795	Stethoscoop dual head 641100	9.2.A.A	14.8.C.C
100779	Diathermiesnoer met knopschakelaar L4.6mtr	7.7.C.A	14.8.D.A
112936	Bayman Cream Crackers	1.32.D.C	15.1.B.A
141392	Isolatiejas eenmalig gebruik	1.20.A.B	15.1.B.B
141800	MST-9B Envelop C5 met venster Corona ballon	1.19.A.C	15.1.B.C
132362	ANE-3 Informatie van de Anesthesioloog	1.19.A.B	15.1.D.A
100537	Noba kompres 12-lgs X-Ray 5x5cm 821055	3.4.D.A	15.3.B.A
100643	Peijnenburg ontbijtkoek mono	1.33.E.A	15.3.C.A
100586	Roosvicee dieet 500ml	1.33.C.A	15.3.C.B
113587	Toppits Ijsblokzakjes	1.33.B.B	15.3.D.A
101314	Beademingssysteem smoothbore 1.6m ref. 5008006	5.1.D.A	15.5.B.A
141375	3M Deltaplus stofmasker FFP3 met ventiel	4.8.A.A	15.5.B.C
101681	PRO6000 oorthermometer plaatsingsstation small	4.5.D.B	15.5.C.A
127642	Temperatuurlogger TRID30-7F incl. accessoires	4.5.D.A	15.5.C.B
141601	Chirurgisch masker met striklinten speciaal anti wasem	4.3.B.A	15.5.D.A
140392	VAC 3ml K3EDTA Oranje/Zwart	7.7.A.B	15.7.B.A
136935	Urinebokaal, Fles vierkantig 1l	7.1.D.A	15.7.B.B
125535	LDPE plastic zak transparant 65x25x140cm 70mu 240 liter	6.1.C.B	15.7.B.C
141388	Veiligheidsbril voor brildragers	5.7.B.A	15.7.C.A
141304	Veiligheidsbril type Speedy	5.7.A.A	15.7.C.B
141390	Gelaatsbeschermer volledige gezicht	5.6.C.A	15.7.D.A
124913	I-stat CG8+ cartirdge 25 test	17.1.B.A	17.1.B.A
124914	I-Stat G3+ cartridge 25 tests	17.1.C.A	17.1.C.A
124918	E3+ Istat cartridge	17.1.D.A	17.1.D.A
124910	I-Stat CG4+ cartridge 25 test	17.1.D.B	17.1.D.B
130660	ACT Kaolin	17.1.E.A	17.1.E.A

Appendix 11: Delivery schedule based on ABC-analysis of bin usage per day

Route	Floor	Department name	Code	Delivery frequency	Bin usage per day
Orange	3	TOK Anesthesie/TOK steriele gang	TOK S	Daily	9,8954
Orange	3	TOK Anesthesie/TOK steriele gang	TOK O	Three times a week	4,1997
Orange	3	TOK Anesthesie/TOK steriele gang	TOK ANES	Daily	10,969
Orange	3	C34 ICC-A (TIC)	TIC	Daily	28,232
Orange	3	C37 EHH	V-EHH S	Three times a week	4,2065
Orange	3	C37 CCU	V-CCU S	Three times a week	5,8299
Orange	3	C37 CCU	V-CCU O	Daily	10,682
Orange	3	C3 OBC	C3 OBC	Three times a week	6,109
Orange	3	C34 ICC-D	AIC B	Daily	30,663
Orange	3	C34 ICC-E	AIC A	Daily	28,411
Orange	3	AOK Anesthesie	AOK ANES	Daily	31,21
Orange	3	AOK	AOK SB	Daily	15,356
Orange	3	AOK	AOK OB	Daily	22,744
Orange	3	Perfusie	Perf	Three times a week	4,436
Orange	3	PACU/VERKOEVER	PACU/VERK	Daily	27,688
Blue	6	A61 VPU MDL	V-MDL S	Daily	11,632
Blue	6	A61 VPU MDL	V-MDL O	Three times a week	6,3052
Blue	6	A61 AOA	AOA A6 S	Daily	14,885
Blue	6	A61 AOA	AOA A6 O	Daily	9,9873
Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 S	Daily	16,06
Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 O	Daily	13,479
Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AS	Once a week	2,6644
Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AO	2 times a week	4,2108
Blue	4	B4 VPU Orthopedie	V-Ortho S	Daily	9,2418
Blue	4	B4 VPU Orthopedie	V-Ortho O	Three times a week	7,1983
Blue	2	A25 Poli Cardio/Cardiochirurgie	P-Cardio	2 times a week	2,8315
Blue	2	B23 Poli Longgeneeskunde	P-Longf	Three times a week	6,828
Blue	1	A17 Poli MondKaak	P-MOKA	Three times a week	6,5298
Blue	1	A14 Poli KNO	P-KNO	2 times a week	4,2158
Blue	0	B01 AOA	AOA BG S	Daily	16,957
Blue	0	B01 AOA	AOA BG O	Three times a week	7,3222

Blue	0	A01 SEH	P-SEH S	Daily	12,737
Blue	0	A01 SEH	P-SEH O	Daily	22,565
Red	6	E61 HIC E6	V-E6 HIC	Daily	10,763
Red	6	E61 VPU Interne Geneeskunde	V-E61 S	Daily	24,506
Red	6	E61 VPU Interne Geneeskunde	V-E61 O	Daily	18,088
Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh S	Daily	16,82
Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh O	Daily	11,444
Red	4	E41 VPU Chirurgie/Oncologie	V-E4 S	Daily	25,953
Red	4	E41 VPU Chirurgie/Oncologie	V-E4 O	Daily	15,991
Red	2	D25 Poli MDL/Endoscopie	P-MDL S	2 times a week	7,5242
Red	2	D25 Poli MDL/Endoscopie	P-MDL O	2 times a week	7,8891
Red	2	E21 Dagbehandeling	P-Dagb O	2 times a week	7,6464
Red	2	E21 Dagbehandeling	P-Dagb LS	2 times a week	4,6906
Red	2	E21 Dagbehandeling	P-Dagb RS	Daily	9,5219
Red	1	D17 Poli Reumatologie	P-Reuma	Once a week	1,9085
Red	1	D15 Poli Radiologie	P-Rontg	Daily	16,458
Red	1	E16 Interne Gen/1-KP	P-Intg	Once a week	0,3845
Red	0	E01 Hemodialyse	P-HEMO S	Daily	17,81
Red	0	E01 Hemodialyse	P-HEMO O	Once a week	0,6875
Red	0	Magazijn verdiepingskeuken BG	0 KEUKEN	Once a week	1,2074
White	6	C61 VPU Longeneeskunde	V-Long S	Daily	23,129
White	6	C61 VPU Longeneeskunde	V-Long O	Daily	15,523
White	6	Magazijn verdiepingskeuken 6E	6 KEUKEN	Once a week	2,2511
White	5	C51 VPU Neurologie/stroke unit	V-Neuro S	Daily	16,373
White	5	C51 VPU Neurologie/stroke unit	V-Neuro O	Daily	13,403
White	5	Magazijn verdiepingskeuken 5E	5 KEUKEN	Once a week	2,0455
White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 S	Daily	27,425
White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 O	Daily	16,095
White	4	Magazijn verdiepingskeuken 4E	4 KEUKEN	Once a week	1,2
White	2	C21 KNF (ma/wo/vr)	P-KNF	Once a week	1,5657
White	2	C21 NEUROCHIRURGIE 1 - KP	P-Neuro	Once a week	0,8874
White	1	C16 Behandelpoli	P-Behan	Daily	19,631
White	1	C13 Poli Dermatologie	P-Derm	Three times a week	5,1637
White	1	C16 Gipskamer	P-GIPSK	Three times a week	8,0779
White	0	C05 Oogheelkunde	P-OOG	Once a week	0,09
Green	4	H41 Urologie	P-Uro	Daily	10,881
Green	3	H31 Kinder/tienerafdeling	V-Kind S	Daily	10,378
Green	3	H31 Kinder/tienerafdeling	V-Kind O	Daily	14,092
Green	2	H21 Moeder/kind afdeling	V-Kraam S	Three times a week	7,7599
Green	2	H21 Moeder/kind afdeling	V-Kraam O	Daily	17,128
Green	1	H11 Verloskamers	V-Verl S	Daily	20,383

Green	1	H11 Verloskamers	V-Verl O	Once a week	0,2276
Green	1	H11 Neonatologie	V-Neo	Daily	19,614
Green	0	H03 Gyn-Pok	P-Gyn	Daily	12,39
Yellow	0	F02 Nucliare Geneeskunde	P-Nucl	Once a week	3,0011
Yellow	0	Diagnostich Centrum	DCT	Once a week	0,9482
Yellow	0	Apotheek	Apotheek	Once a week	3,0078

Appendix 12: Proposed delivery schedule with outpatient clinic route.

Route	Floor	Department that works with order boards	Warehouse code at Dept.	Delivery frequency	Days
Orange	3	TOK Anesthesie/TOK steriele gang	TOK S	Daily	mo/tu/we/th/fr/sa
Orange	3	TOK Anesthesie/TOK steriele gang	TOK O	Three times a week	mo/we/fr
Orange	3	TOK Anesthesie/TOK steriele gang	TOK ANES	Daily	mo/tu/we/th/fr/sa
Orange	3	C34 ICC-A (TIC)	TIC	Daily	mo/tu/we/th/fr/sa
Orange	3	C37 EHH	V-EHH S	Three times a week	mo/we/fr
Orange	3	C37 CCU	V-CCU S	Three times a week	mo/we/fr
Orange	3	C37 CCU	V-CCU O	Daily	mo/tu/we/th/fr/sa
Orange	3	C3 OBC	C3 OBC	Three times a week	mo/we/fr
Orange	3	C34 ICC-D	AIC B	Daily	mo/tu/we/th/fr/sa
Orange	3	C34 ICC-E	AIC A	Daily	mo/tu/we/th/fr/sa
Orange	3	AOK Anesthesie	AOK ANES	Daily	mo/tu/we/th/fr/sa
Orange	3	AOK	AOK SB	Daily	mo/tu/we/th/fr/sa
Orange	3	AOK	AOK OB	Daily	mo/tu/we/th/fr/sa
Orange	3	Perfusie	Perf	Three times a week	mo/we/fr
Orange	3	PACU/VERKOEVER	PACU/VERK	Daily	mo/tu/we/th/fr/sa
Blue	6	A61 VPU MDL	V-MDL S	Daily	mo/tu/we/th/fr/sa
Blue	6	A61 VPU MDL	V-MDL O	Three times a week	mo/we/fr
Blue	6	A61 AOA	AOA A6 S	Daily	mo/tu/we/th/fr/sa
Blue	6	A61 AOA	AOA A6 O	Daily	mo/tu/we/th/fr/sa
Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 S	Daily	mo/tu/we/th/fr/sa
Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5 O	Daily	mo/tu/we/th/fr/sa
Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AS	Once a week	mo
Blue	4	B43 VPU Psychiatrie/ Paaz	V-B4 AO	2 times a week	mo/th
Blue	4	B4 VPU Orthopedie	V-Ortho S	Daily	mo/tu/we/th/fr/sa
Blue	4	B4 VPU Orthopedie	V-Ortho O	Three times a week	tu/th/sa
Blue	0	B01 AOA	AOA BG S	Daily	mo/tu/we/th/fr/sa

Blue	0	B01 AOA	AOA BG O	Three times a week	tu/th/sa
Blue	0	A01 SEH	P-SEH S	Daily	mo/tu/we/th/fr/sa
Blue	0	A01 SEH	P-SEH O	Daily	mo/tu/we/th/fr/sa
Red	6	E61 HIC E6	V-E6 HIC	Daily	mo/tu/we/th/fr/sa
Red	6	E61 VPU Interne Geneeskunde	V-E61 S	Daily	mo/tu/we/th/fr/sa
Red	6	E61 VPU Interne Geneeskunde	V-E61 O	Daily	mo/tu/we/th/fr/sa
Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh S	Daily	mo/tu/we/th/fr/sa
Red	5	E51 VPU NeuroChirurgie/Urologie	V-NeuCh O	Daily	mo/tu/we/th/fr/sa
Red	4	E41 VPU Chirurgie/Oncologie	V-E4 S	Daily	mo/tu/we/th/fr/sa
Red	4	E41 VPU Chirurgie/Oncologie	V-E4 O	Daily	mo/tu/we/th/fr/sa
White	6	C61 VPU Longeneeskunde	V-Long S	Daily	mo/tu/we/th/fr/sa
White	6	C61 VPU Longeneeskunde	V-Long O	Daily	mo/tu/we/th/fr/sa
White	6	Magazijn verdiepingskeuken 6E	6 KEUKEN	Once a week	mo
White	5	C51 VPU Neurologie/stroke unit	V-Neuro S	Daily	mo/tu/we/th/fr/sa
White	5	C51 VPU Neurologie/stroke unit	V-Neuro O	Daily	mo/tu/we/th/fr/sa
White	5	Magazijn verdiepingskeuken 5E	5 KEUKEN	Once a week	mo
White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 S	Daily	mo/tu/we/th/fr/sa
White	4	C44 VPU Vaat/Trauma/Ortho	V-C4 O	Daily	mo/tu/we/th/fr/sa
White	4	Magazijn verdiepingskeuken 4E	4 KEUKEN	Once a week	fr
Green	3	H31 Kinder/tienerafdeling	V-Kind S	Daily	mo/tu/we/th/fr/sa
Green	3	H31 Kinder/tienerafdeling	V-Kind O	Daily	mo/tu/we/th/fr/sa
Green	2	H21 Moeder/kind afdeling	V-Kraam S	Three times a week	tu/th/sa
Green	2	H21 Moeder/kind afdeling	V-Kraam O	Daily	mo/tu/we/th/fr/sa
Green	1	H11 Verloskamers	V-Verl S	Daily	mo/tu/we/th/fr/sa
Green	1	H11 Verloskamers	V-Verl O	Once a week	th
Poli	2	A25 Poli Cardio/Cardiochirurgie	P-Cardio	2 times a week	tu/th
Poli	2	B23 Poli Longgeneeskunde	P-Longf	Three times a week	tu/th/sa
Poli	1	A17 Poli MondKaak	P-MOKA	Three times a week	ma/wo/fr
Poli	1	A14 Poli KNO	P-KNO	2 times a week	ma/fr
Poli	2	D25 Poli MDL/Endoscopie	P-MDL S	2 times a week	tu/th
Poli	2	D25 Poli MDL/Endoscopie	P-MDL O	2 times a week	tu/th

Poli	2	E21 Dagbehandeling	P-Dagb O	2 times a week	tu/th
Poli	2	E21 Dagbehandeling	P-Dagb LS	2 times a week	tu/th
Poli	2	E21 Dagbehandeling	P-Dagb RS	Daily	mo/tu/we/th/fr/sa
Poli	1	D17 Poli Reumatologie	P-Reuma	Once a week	fr
Poli	1	D15 Poli Radiologie	P-Rontg	Daily	mo/tu/we/th/fr/sa
Poli	1	E16 Interne Gen/1-KP	P-Intg	Once a week	fr
Poli	0	E01 Hemodialyse	P-HEMO S	Daily	mo/tu/we/th/fr/sa
Poli	0	E01 Hemodialyse	P-HEMO O	Once a week	we
Red	0	Magazijn verdiepingskeuken BG	0 KEUKEN	Once a week	we
Poli	2	C21 KNF (ma/wo/vr)	P-KNF	Once a week	fr
Poli	2	C21 NEUROCHIRURGIE 1 - KP	P-Neuro	Once a week	fr
Poli	1	C16 Behandelpoli	P-Behan	Daily	mo/tu/we/th/fr/sa
Poli	1	C13 Poli Dermatologie	P-Derm	Three times a week	tu/th/sa
Poli	1	C16 Gipskamer	P-GIPSK	Three times a week	tu/th/sa
Poli	0	C05 Oogheelkunde	P-OOG	Once a week	mo
Poli	4	H41 Urologie	P-Uro	Daily	mo/tu/we/th/fr/sa
Poli	0	H03 Gyn-Pok	P-Gyn	Daily	mo/tu/we/th/fr/sa
Poli	0	F02 Nucliare Geneeskunde	P-Nucl	Once a week	we
Poli	0	Diagnostich Centrum	DCT	Once a week	we
Poli	0	Apotheek	Apotheek	Once a week	we