The assesment of the implementation of the kanban and two-bin method in the logistic process of Medisch Spectrum Twente

Master Thesis

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Management summary

Context

Medisch Spectrum Twente is a hospital located in Enschede. In 2016, the hospital moved into a new building. Together with this move, the logistic department introduced a new order method to organize the distribution of products from the central warehouse of the hospital to the local warehouses on the hospital departments. In the old situation, the logistic employees checked the stock at every hospital department warehouse and ordered new products using a scan method. Now the products are ordered by order boards, these are located in the department warehouses. The new order method is a combination of the Kanban and the two-bin method. In the local warehouse of a department, every product is stored in two equally stock places (bins) and to every bin an order card is linked. These order cards are attached to the bins. The users on the hospital departments takes products from the first bin. When a bin is empty, the linked order card needs to be placed on the order board by the users of the hospital department and the products need to be moved from the second bin to the first bin. There are four different routes, called blue, red, white, and orange, from the central warehouse along several department warehouse for delivery of ordered products. The system reads out the order boards of each route at a fixed time every weekday. On that moment the products are ordered in the central warehouse. The delivery of the four routes is performed one after the other.

CRQ

One year after the introduction of this new method, there is a need to know how it performs. The main focus of this research is to objectify the new order method performance. Additionally, we focus on the performance improvement and control. We qualitatively analyse the suggested improvements. However, a full quantitative analysis is outside the scope of this research. Therefore, we use the following research question.

How can the new order method be monitored and improved? What data and Key Performance Indicators (KPIs) are relevant to measure how the new order method performs?

Method

In this research we analyse the new process using the DMAIC cycle. First, we carry out a literature study to the effectiveness of the use of Lean management and the corresponding DMAIC cycle. Based on the literature search we define the current situation using our own observations, including interviews with the users of this new method. As a result of these interviews, we set up the following objectives for the new order method performance: *good response time*, *short waiting time*, *correct stock level in the department warehouses*, *low workload*, *well working technology*, *well organized communication*, and *well furnished hospital department warehouses*. We find 49 KPIs to asses the performance of the project objectives. In this report we focus on the KPIs *delivery time, out-of-stock moments,* and *order card and order board errors*. These KPIs are considered the most important for the users to ensure patient care. We measure and analyse these KPIs by creating multiple data warehouses with data from the two systems involved in the hospital's logistics processes, Oracle and Alltrack. In this research we use data from the months November and December 2016, and January 2017. After the analysis we investigate how to improve the performance of the new order method. We discuss multiple solutions for improving the processes. Finally, we describe how to verify the improvements.

Results

The results of the ***delivery time*** are split up in warehouse and sales products. The warehouse products are stored in the central warehouse and the sales products are ordered at an external supplier and are delivered at the central warehouse, after which they are delivered at the hospital departments immediately. 89% of the warehouse products are delivered within 8 hours after the order moment and 61% of the sales products are delivered within 5 days after the order moment. The main causes of too late delivery are (i) the read out moments of the order boards, (ii) the throughput times of the order process, (iii) the number of employees working on a process, (iv) the route plan, and

(v) the delivery time of an external supplier. We conclude the performance for the warehouse products is good, but still can be improved by the logistic department. In our opinion, the performance for the sales products is too low. We conclude that the logistic department cannot guarantee that the department warehouse always has enough stock.

The ***out-of-stock moments*** are calculated by the number of order cards that are placed on the order board. When both cards of one product are placed on the order board, we assume that the department has an out-of-stock moment. We conclude that in 20% of the moments an order card is placed on the order board, it is the second card. In our view this result is not good. The probability to get an out-of-stock moment seems too high. We make a distinction between different reasons of an out-of-stock moment, namely (i) a wrong bin value, (ii) a suboptimal process, and (iii) a wrong order card procedure. With a wrong order card procedure we mean that the user on the department is not following the correct order procedure, mostly this involves forgetting to place the order card on the order board. With a wrong bin value we mean that the determined stored value of a product in a bin is too low to have enough stock until the next delivery moment. A suboptimal delivery process means that the read out time or delivery moment does not correspond to the consumption on the departments. We find that 38% of these out-of-stock moments is caused by a wrong procedure and 62% is caused by a suboptimal process or a wrong bin value. We conclude that not only the logistics process, but also the ordering process should be improved. The logistic process needs to be improved by the logistic department. The wrong procedure needs to be improved by the department staff. Furthermore, we conclude that most out-of-stock moments caused by a wrong bin value or suboptimal process take place in the weekend or on Monday. We suspect that these out-of-stock moments are caused by the fact that the logistic department is not operational in the weekend.

The number of ***order card and order board errors*** are calculated by the number of times the order cards and order boards show errors, caused by a too high or too low signal strength in either the cards or the boards. We find 492 order cards that show an error in our three months reference period. We conclude these decrease the system reliability. We notice 2 order boards that may have a low system reliability.

In order to improve the delivery time performance of the new order method, we have the following recommendations. We advise the hospital to determine the read out moments based on the start time of the picking process to ensure less delay in delivery time. Furthermore, we advise to determine the time intervals between the read out moment such that they agree with the throughput time of order picking. Since it appears that the delivery timeliness of route orange is much lower in comparison with the other routes, we propose to reschedule route orange. In our view the best solution is to remove the departments with an order board from route orange and include these in route blue, red and white.

To decrease the out-of-stock moments we advise the hospital to read out order boards of the nursing and emergency departments and deliver products in the weekend. Furthermore, we advise the hospital to plan a second read out moment on the nursing and emergency department in the afternoon and increase the stock level value of some products. These departments show a high demand of products and the most out-of-stock moments. We also advise to focus on the user procedure. Let the user be aware how the method works, to avoid out-of-stock moments caused by a wrong order procedure.

The last improvement we suggest is to improve the signal strength of the order boards that show errors and replace the order cards that decrease the system reliability. This needs to be done by the logistic deparment, which is responsible for the order boards and order cards.

Conclusion

First, we presume the selected time interval contains enough data to draw a correct conclusion and the results of the KPIs show a clear picture of the performance of the new order method. Overall we conclude, after one year the performance of the new order method is not very good, but not very bad either. We conclude that the processes are carried out correctly because most of the products are delivered within 8 hours and the number of order cards and order boards that show an error is limited and can easily be further reduced. We conclude that the probability of an out-of-stock moment is high. However, we also conclude that the processes can be further optimized with our improvements. We find planning, behaviour and system improvements. We expect that the planning improvements will have the most impact on the performance of the new order method. Furthermore, because the demand of care can vary at different time periods we advise the hospital to analyse the KPIs performance frequently which can be done by the logistic department. The logistic department is responsible for the new order method and has the correct data to analyse the performance. By regularly reassessing the performance the logistic department can respond quickly and adequately to performance changes.

Samenvatting

Context

Medisch Spectrum Twente (MST) is een ziekenhuis in Enschede. In 2016, is dit ziekenhuis verhuisd naar een nieuw gebouw. Samen met deze verhuizing, heeft de logistieke afdeling van het ziekenhuis een nieuwe bestel methode geïntroduceerd om de distributie van het centraal magazijn van het ziekenhuis naar de lokale magazijnen van de ziekenhuisafdelingen te organiseren. In de oude situatie controleerde de werknemers van de logistieke afdeling de voorraden in de magazijnen van de ziekenhuisafdelingen en bestelde producten via een scan methode. In de nieuwe situatie worden de producten besteld met behulp van bestelborden. Deze borden hangen in het lokale magazijn van de afdeling. De nieuwe bestel methode is een combinatie van de Kanban en de two-bin methode. In elke magazijn van een afdeling is elk product opgeslagen in twee even grote voorraadlocaties, deze worden ook wel bins genoemd. Aan elk van deze bins is een bestelkaart gekoppeld. Deze bestelkaarten zitten vast aan de bins. De gebruikers vanuit de ziekenhuisafdelingen pakken de producten uit de voorste bin. Wanneer er een bin leeg is, wordt het kaartje dat aan deze bin vast zit door de afdelingsmedewerkers op het bestelbord geplaatst. Daarnaast worden de producten uit de achterste bin naar de voorste bin verplaatst door de afdelingsmedewerkers. Er zijn in het ziekenhuis vier verschillende routes, genaamd blauw, rood, wit, en oranje, die van het centraal magazijn langs meerdere afdelingsmagazijnen loopt. Het systeem leest de bestelborden van elke route elke werkdag op een vast tijdstip uit. Op dat moment worden de producten besteld in het centraal magazijn. De routes worden na elkaar gepakt en geleverd.

CRQ

Een jaar na de introductie van de nieuwe bestel methode wil het MST weten hoe de nieuwe methode presteert. In dit onderzoek focussen we ons vooral op het objectiveren van de prestaties van de nieuwe bestel methode. Ten tweede focussen we ons op het verbeteren en controleren van deze prestaties. We analyseren deze verbeteringen kwalitatief. Een volledige kwantitatieve analyse valt in dit onderzoek buiten de reikwijdte. Hiervoor hebben we de volgende onderzoeksvraag opgesteld:

Hoe kan de nieuwe bestel methode worden gecontroleerd en verbeterd? Welke gegevens en Key Performance Indicators (KPIs) zijn relevant om te meten hoe de bestel methode presteert?

Methode

In dit onderzoek analyseren we het nieuwe proces met behulp van de DMAIC cirkel. De eerste stap is de uitvoering van een literatuur onderzoek. In dit onderzoek onderzoeken we de effectiviteit van het gebruik van Lean management en de bijbehorende DMAIC cirkel. Gebaseerd op het literatuur onderzoek definiëren we de huidige situatie door gebruik te maken van eigen waarnemingen. Daarnaast nemen we interviews af bij de gebruikers van de nieuwe methode. Uit deze interviews zijn zeven resultaat doelstelling voor de nieuwe methode naar voren gekomen: *goede reactietijd*, *korte wachttijd*, *correct voorraadniveau in de afdelingsmagazijnen*, *lage werkdruk*, *goed werkende technologie*, *goed georganiseerde communicatie*, en *een goede inrichting van de afdelingsmagazijnen*. Om de project doelstellingen te beoordelen hebben we 49 KPIs opgesteld. In dit onderzoek zullen we ons focussen op de KPIs *levertijden, misgrijp momenten* en *technische bestelkaart en bestelbord fouten*. Deze KPIs beschouwen we als het belangrijkst voor de gebruikers om de zorg voor de patiënt te kunnen waarborgen. We hebben met behulp van de twee systemen die gebruikt worden bij de logistieke processen, Oracle en Alltrack, meerdere data warehouses gemaakt. Hiermee meten en analyseren we de KPIs. In dit onderzoek gebruiken we gegevens uit de maanden november en december 2016 en januari 2017. Na de analyse bespreken we hoe de prestaties van de nieuwe bestel methode verbeterd kunnen worden. Hierbij bespreken we meerdere oplossingen om de processen te verbeteren. Tot slot beschrijven we hoe de verbeteringen geverifieerd kunnen worden.

Resultaten

We hebben de resultaten van de ***levertijden*** bekeken voor magazijn en koop artikelen. Magazijn artikelen zijn opgeslagen in het centraal magazijn van het ziekenhuis. Koop artikelen worden direct besteld bij de externe leverancier en worden geleverd in het centraal magazijn, waarna ze direct naar de ziekenhuisafdelingen worden getransporteerd. 89% van de magazijn artikelen wordt binnen 8 uur na het bestel moment geleverd bij de afdeling. 61% van de koop artikelen wordt binnen 5 dagen na het bestelmoment geleverd bij de afdeling. De belangrijkste oorzaken van de late leveringen zijn: (i) de uitleestijden van de bestelborden, (ii) de doorlooptijden van het bestel proces, (iii) het aantal werknemers dat aan een proces werkt, (iv) het routeplan, en (v) de levertijd van de externe leverancier. Voor de magazijn artikelen concluderen we dat de prestaties goed zijn. Echter, we zien ruimte voor verbetering vanuit de logistieke afdeling. Voor de koop artikelen concluderen we dat de prestaties laag zijn. De logistieke afdeling kan er nu niet garant voor staan dat een afdelingsmagazijn altijd voldoende voorraad heeft.

De ***misgrijpmomenten*** zijn berekend aan de hand van het aantal bestelkaarten wat op de borden zijn geplaatst. Wanneer beide bestelkaarten van een product op het bord staan, nemen we aan dat de afdeling op dat moment misgrijpt op dat product. We constateren dat in 20% van de gevallen er een bestelkaart op het bord geplaatst wordt, dit het tweede bestelkaart is. Onze mening is dat deze waarde te hoog is en daarom is het resultaat niet goed. We maken onderscheid tussen de verschillende redenen van een misgrijp moment, namelijk (i) een foute bin waarde, (ii) een niet optimaal proces, en (iii) een verkeerde werkwijze. Met een verkeerde werkwijze bedoelen we dat de gebruiker op de afdeling niet de goede werkinstructies opvolgt, vaak gaat het erom dat de gebruiker vergeet het kaartje te plaatsen wanneer de bin leeg is. Met een verkeerde bin waarde bedoelen we dat het aantal producten dat in een bin is opgeslagen niet goed is vastgesteld. Er is onvoldoende voorraad om tot het volgende levermoment te overbruggen. Een niet optimaal proces betekent dat het bestelproces niet goed aansluit aan de vraag vanuit de afdelingen. We constateren dat 38% van de misgrijp momenten wordt veroorzaakt door een verkeerde werkwijze en 62% wordt veroorzaakt door een verkeerde bin waarde of een niet optimaal proces. Hiermee concluderen we dat niet alleen het logistieke proces verbetering nodig heeft, maar ook het bestel proces. Het logistieke proces moet worden verbeterd door de logistieke afdeling, en de verkeerde werkwijze moet door de afdelingsmedewerkers moet worden aangepast. Daarnaast constateren we dat de meeste misgrijp momenten die veroorzaakt worden door een niet optimaal proces of een verkeerde bin waarde in het weekend en op maandag voorkomen. We suggereren dat dit wordt veroorzaakt door het feit dat in het weekend er op de logistieke afdeling niet wordt gewerkt, waardoor de bestelborden niet worden uitgelezen en de afdelingen dus in het weekend niet beleverd worden.

Het aantal ***technische bestelkaart en bestelbord fouten*** zijn berekend aan de hand van het aantal keren dat de kaarten of borden fouten laten zien in het systeem. Deze fouten worden veroorzaakt door een te hoog of laag signaal sterkte van ofwel de kaarten of de borden. We zien dat 492 bestelkaarten technische fouten laten zien gedurende de drie maanden, we concluderen dat deze bestelkaarten de betrouwbaarheid van het systeem verlagen. Daarnaast merken we op dat twee bestelborden een lage systeembetrouwbaarheid hebben.

Om de levertijdprestaties van de nieuwe bestel methode te verbeteren, hebben we de volgende aanbevelingen opgesteld. We adviseren het ziekenhuis om de uitleesmomenten van de bestelborden te bepalen aan de hand van de begintijd van product-pak-proces om extra vertraging te voorkomen. Daarnaast adviseren we om de tijdsintervallen tussen de uitleesmomenten te bepalen aan de hand van de doorlooptijd van het product-pak-proces. Ook hebben we geconstateerd dat de levertijdprestaties lager zijn voor route oranje in vergelijking met de andere routes. Daarom stellen we voor om het order proces van route oranje te herschikken. We stellen voor om de afdelingen op route oranje die werken met de bestelborden uit deze route te halen en te koppelen aan de andere drie routes.

Om het aantal misgrijpmomenten te verlagen adviseren we het ziekenhuis om de bestelborden van verpleeg- en spoedafdelingen ook in het weekend uit te lezen en te beleveren. Daarnaast adviseren we het ziekenhuis ook om een tweede uitlees moment in de middag in te plannen voor de verpleeg- en spoedafdelingen. Ook kan het ziekenhuis de bin waardes van sommige producten verhogen. De verpleeg- en spoedafdelingen hebben een hoog verbruik van producten en grijpen het meeste mis. We adviseren het ziekenhuis ook om te focussen om de werkprocedure op de afdelingen. De gebruiker moet bewust worden van hoe de methode werkt en hoe misgrijpmomenten door een verkeerde werkwijze voorkomen kunnen worden.

De laatste verbetering die we suggereren is om het signaal sterkte van de bestelborden die een fout laten zien te verbeteren en de bestelkaarten die fouten laten zien te vervangen. Hiermee verwachten we dat de betrouwbaarheid van het systeem verhoogd wordt. Dit moet worden uitgevoerd door de logistieke afdeling, zij zijn ook verantwoordelijk voor de bestelborden en bestelkaarten.

Conclusie

Ten eerste veronderstellen we dat de geselecteerde tijdsinterval voldoende gegevens bevat om een goede conclusie te kunnen trekken. De resultaten van de KPIs geven een duidelijk beeld van de prestaties van de nieuwe bestel methode. Over het geheel genomen concluderen we een jaar na de invoering van de nieuwe methode dat de prestaties van de nieuwe bestel methode niet goed, maar ook niet slecht is. We constateren dat alle bestel processen goed uitgevoerd worden omdat de meeste magazijnartikelen binnen 8 uur geleverd worden en het aantal bestelkaarten en bestelborden die fouten laten zien niet hoog is. Dit laatste is daarnaast makkelijk te verbeteren. Echter, de kans op een misgrijpmoment is hoog. We constateren dat er nog genoeg ruimte is om de processen te verbeteren. Hiervoor vinden we plannings-, gedrags-, en systeemsverbeteringen. We denken dat de planningsverbeteringen het meeste effect zal hebben op de prestaties van de nieuwe bestel methode. Omdat de vraag naar zorg kan verschillen per tijdsperiode adviseren we het ziekenhuis om de KPIs prestaties regelmatig te analyseren. Hier zal de logistieke afdeling verantwoordelijk voor zijn omdat zij verantwoordelijk is voor de nieuwe bestel methode en beschikt over de juiste gegevens om de prestaties te kunnen analyseren. Met deze maatregel kan de logistieke afdeling snel en adequaat reageren op prestatieveranderingen.

Preface

In front of you lies my master thesis. It is a study with a topic “Logistics in Healthcare”. With this thesis I will finish my master study Industrial Engineering and Management (IEM) and my life as a student. In 2011 I came from a small village on the other side of the Netherlands “Honselersdijk” to Enschede to study Health Science. After three years of bachelor and missing mathematics I started the master IEM. During the master I specialized in Healthcare issues and created an interest in warehouse problems. With the help of Peter Schuur I found an interesting and challenging assignment in Medisch Spectrum Twente. Medisch Spectrum Twente opened a new hospital in 2016 and that gave multiple opportunities for my master thesis. I am happy that I could find a thesis subject appropriate to my interest. The time at Medisch Spectrum Twente went very fast, I learned much about the subject and as a result of that I hope Medisch Spectrum Twente can use the results and information I found.

I especially want to thank Peter Schuur, the first supervisor of the University of Twente. During every meeting you took your time for me. Not only the assignment was the subject of the conversation, you also took time to ask how my life was going. I appreciated this enormously. Also my thanks to Nardo Borgman, the second supervisor of the University of Twente. The overall feedback was helpful for the study. Thanks to Rogier van Vliet, the first supervisor from Medisch Spectrum Twente. Your enthusiasm about this subject was very conducive. But also your critical feedback has helped me, leading to what the thesis looks like now. At the end of April you left Medisch Spectrum Twente for a new challenge. I appreciate it that you still gave me feedback by email after your departure and that you are present at my final presentation. Thanks to Ronald Oolderink and Ton Feringa, the two colleagues to whom I always could ask questions about the subject. Furthermore, both of you gave me good feedback to finish my thesis after the departure of Rogier. Thanks to the logistic team of Medisch Spectrum Twente. All of you gave me the feeling that I was part of the group. Thanks for the good discussions, your interest, and of course the best jokes. Finally, I want to thank Stan and my family. You were my silent support on the background, you gave me the confidence that I would achieve a good result. Thanks for checking my master thesis.

After nearly six years I will close my “student book” now. I look back with a good feeling.

Glossary

Alltrack	A system that coordinates the order moments of the order boards and registers the status of the order cards.
Backorder	An order of a product that is not on stock in the central warehouse is a backorder. The backorders are registered on a backorder list. When the product is on stock again, the product will be delivered and the backorder will disappear from the backorder list.
Bin value	Number of products stored in one bin. This is determined per product and department.
BQ model	An order method that is used in the central warehouse. The order moment is variable and the order amount is fixed. When a minimum value of a product is exceeded, new products are ordered.
Central warehouse	In the central warehouse all externally ordered products are received and stored before transportation to the department warehouses.
Department warehouse	The warehouse of a hospital department.
DMAIC method	Method that is used to improve processes. The method consists of the following phases: define, measure, analyse, improve, and control.
First-in-First-out (FIFO)	A method in which products that were stored first are also used first.
iProcurement	An order in oracle placed manually.
Kanban	A method from Lean thinking. It ensures just-in-time production. The Kanban method signals when a product is needed.
KPIs (KPI)	Variables to analyse the performance of a company or process.
Lean Six Sigma	A method that is used to organize quality and efficiency improvements.
Lean thinking	A method that is used to organize operational improvements. The aim of this method is to realise a maximum value for the customer with the least waste possible.
Logistic department	The department of the hospital that is responsible for storing products in the central warehouse, transporting warehouse and sales products to the department warehouses, and replenishing the department warehouses.
Manco	A product that is noted on the order, but is not included in the delivery.
Medisch Spectrum Twente (MST)	The hospital located in Enschede and Oldenzaal.

Oracle	An Enterprise Resource Planning (ERP) system that supports the logistic activities of MST since January 2010.
Order card	Card that is linked to a specific product and location in a department warehouse. When the products of that location are out-of-stock, the order card is placed on the order board by the department staff.
Order board	Electronic board in the department warehouse on which order cards can be placed. The order boards register the statuses of the order cards.
Read out moment/order moment	Moments that the order boards are read out electronical. The order cards on the order board are ordered by Alltrack in Oracle.
Response time	The time interval between the moment a request of the customer is made and the moment the request is executed.
Sales products	Products that are not stored in the central warehouse. The products are directly transported from the central warehouse to the department. Sales products can be ordered by the order boards or iProcurements.
Stock level in the department warehouse	Amount of products that are on stock in the department warehouses.
Transferium	Department in the hospital that ensures an extra safety check for the products of the surgery rooms. Besides, the transferium ensures the transport of the products from the Transferium to the departments on the third floor of the hospital.
Two-bin system	A system where stock of a product is located in two bins. The products are taken from the first bin. When the first bin is empty the products of the second bin are moved to the first bin and the amount of products for one bin is ordered.
Value Focus Thinking (VFT)	Method to determine the users' values and objectives.
Warehouse products	Products that are stored in the central warehouse and the department warehouses.
Waiting time	The time interval between the moment the products are ordered and the moment the products are delivered.
Workload	The throughput time per process.

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1. Introduction

In order to complete my master Industrial Engineering and Management at the University of Twente I conducted a research at Medisch Spectrum Twente into the Logistics department. In this chapter I give an introduction of Medisch Spectrum Twente and I clarify the problem statement, research objective, and the research questions.

1.1 Medisch Spectrum Twente

Medisch Spectrum Twente (MST) is created from a merger of hospitals in Enschede and Oldenzaal. Also the outpatient clinics in Losser and Haaksbergen are involved in this merger. Nowadays, the headquarters of MST is located in Enschede. The other locations in Oldenzaal, Losser, and Haaksbergen are being used for outpatients. The outpatient clinic in Oldenzaal is the second largest location, after Enschede. Many different specialties are located in Oldenzaal and this hospital also has several operating rooms for post clinical treatments.

Until recently, the hospital in Enschede consisted of two locations that were connected by a bridge. The old buildings are referred to as Haaksbergerstraat and Ariënsplein. In the beginning of 2016 MST opened a new hospital that is located next to one of the old buildings. This new building is referred to as Koningsplein. The hospital only has single-patient rooms to increase customer satisfaction, to decrease the patient recovery time, and to decrease the risks of infectious diseases. The bed capacity is reduced in the new hospital. The old capacity was approximately 1100 beds, and the new capacity is 670 beds. One of the main goals of this reduction is to reduce the laying time and therefore reducing the costs.

Figure 1.1 The new hospital of MST opened in January 2016

This project is performed at the logistics department located at the Ariënsplein. The warehouse of the hospital is also located in this building. In this warehouse all materials for the hospital, with the exception of medicines, are received, stored, picked, and transported to the hospital departments. In the future, the warehouse will be moved to a location in Hengelo.

1.2 Problem statement

Since the opening of the new hospital almost every hospital department works with a new order method. This order method is intended for all materials, with the exception of medicines and fluids, that are used on the departments. For example syringes, pumps, and needles, but also towels, waste bins, and coffee milk. This order method was introduced because the inventory storage space of every hospital department became smaller in comparison with the old hospital building. The other reason for introducing the new order method is because there was “waste” in the old order process. Waste is a term which comes from Lean thinking, a methodology that provides a new way of thinking about organizing human activities. This methodology is centred on customer value. “Waste” in Lean thinking means steps that have no value for the customer. In Lean thinking all the steps of a process are evaluated and the process steps that have no value to the customer, the “waste”, will be eliminated. To understand what this “waste” is, we first explain the old method.

The old order method was as follows: two or three times a week logistics staff went through all hospital departments’ storages and reordered new products for them. The logistics staff checked all the storage cupboards and drawers. When there was no stock of a product or the stock of the product was very low, the logistics staff scanned the bar code of this product and reordered the required amount. After scanning, the orders were picked in the central warehouse and the departments’ storages were replenished. The “waste” in this method is the reordering process, when all the storage places in the hospital are checked and the bar codes are scanned. This process gives no added value to the customer, the patient.

To eliminate the waste, the hospital introduced a new methodology that is a combination of the two-bin principle and the Kanban method, both methods of Lean thinking. The department storages are designed with the two-bin principle. For the storage of every product there are two bins, containing the same quantity of that product. Bin one is used to pick products. When bin one is empty all products from bin two will be moved to bin one. With this activity the First-In-First-Out (FIFO) method will be maintained. When bin one is empty the bin quantity will be ordered at the central warehouse, when bin two is also empty the quantity of bin two will be ordered too.

The Kanban method is used to reorder the products. Every bin is linked to a Kanban card, when the bin is empty the linked Kanban card is placed on an order board that is connected to the department's warehouse. The order boards are read out through an internet connection every day at the same time. The orders are picked afterwards and are delivered in a couple of hours after the moment of ordering. The reading moments are in the morning, so in most cases the orders are delivered at the same day. The new order boards are in use since January 2016. There is a need to know how the hospital can measure the performance of the methodology and what the performance is.

1.3 Research objective

MST wants to know how to measure the results of the new order and storage method and what the current performance of this method is. With this information we want to identify issues that occur due to the implementation of the new methodology and what changes can be made to address these issues to further improve the methodology.

Initially the study concerns a research problem, the organization wants to obtain new knowledge. In a later stage this information will be used to find points of improvement, and changes that can be made to address occurring issues.

Therefore, the objective of this research is to develop a program that, by using different KPIs, gives a clear picture of the performance of the new supply strategy and all logistic processes involved. Furthermore, objective is to improve the performance of the new supply strategy.

1.4 Research questions

The objective leads to the following research question:

How can the new order method be monitored and improved? What data and KPIs are relevant to measure how the new order method performs?

1.5 Research structure

In this research a process control approach is used. We describe the approach as a subjective feeling about the processes that needs to be objectified and be improved. We make a cycle of the gut-feeling, objectification, and improvement. Figure 1.2 shows the cycle we developed.

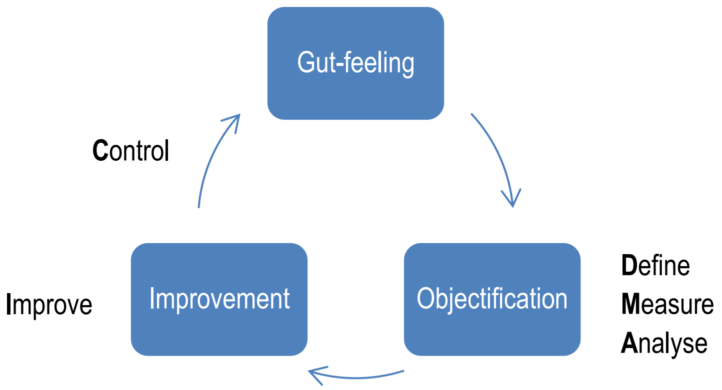

Figure 1.2 The stages of the DMAIC method classified in the approach

Hicks and Matthews made manufacturing improvements paradigms and their corresponding tools and methods (Hicks & Matthews, 2010). In their work they combine all those paradigms and their corresponding tools and methods in one figure (Figure 1.3). We use this figure to determine which methods we can use in this research. This figure shows that the best method for a process control improvement is to use Six Sigma. Six Sigma consists of the tools control chart, DMAIV, DMAIC, and SPC (Hicks & Matthews, 2010). In this research we use the tool DMAIC because this is an improvement cycle that is used to analyse and improve processes. In our opinion this tool includes all steps that are needed to answer the research question. DMAIC is the abbreviation for the phases:

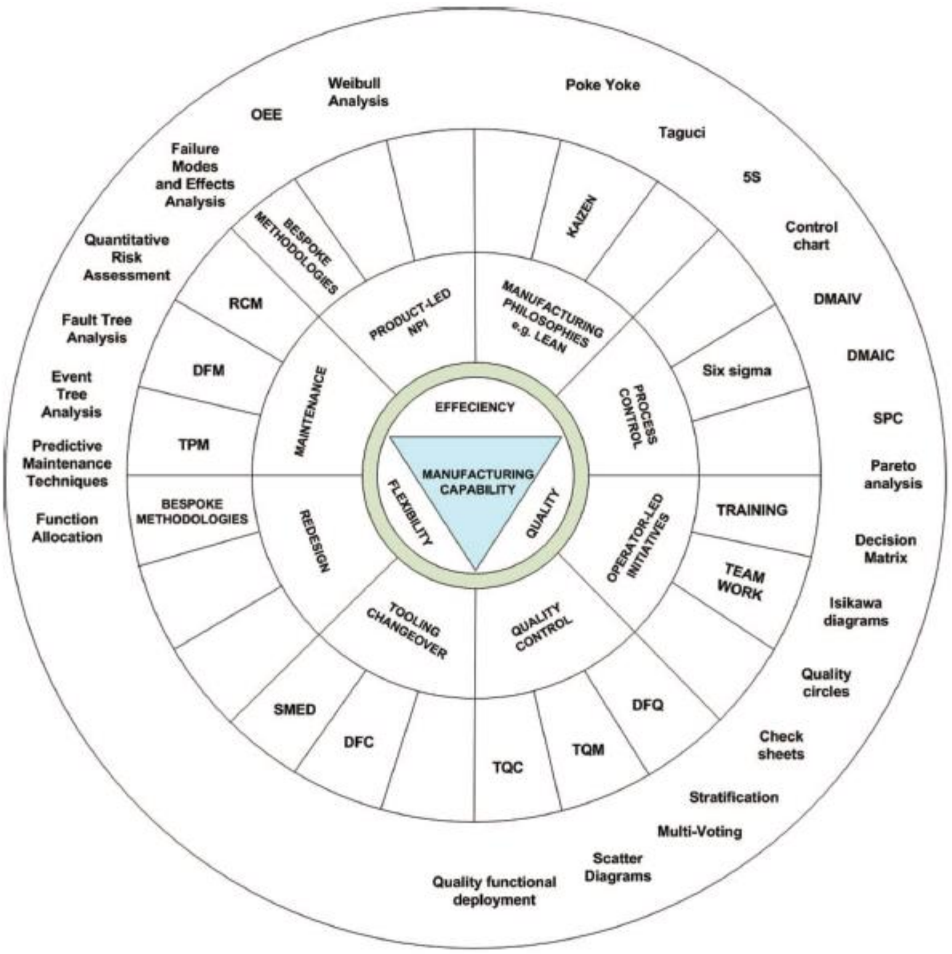

Figure 1.3 The manufacturing improvements paradigms of Hick and Matthews (Hicks & Matthews, 2010)

define, measure, analyse, improve and control (Brook, 2014; Hicks & Matthews, 2010). In Figure 1.2 the phases are combined with the cycle we made. This figure gives a good indication in which situation the phases are located.

1.6 Sub-questions

We compose multiple sub-questions, which are divided into the different stages of the DMAIC method. The aim of this research is to assess the performance of the new order method. Therefore, the main focus is to define, measure, and analyse the performance. In this research we discuss the improvement and control phase. We qualitatively analyse the suggested improvements, however performing a quantitative analysis is outside the scope of this research.

Define
D1 How is the current situation concerning the new order method organized?
D2 How is the new order method implemented in the hospital, what decisions have been made?
D3 How are the logistic processes organized?

We make a SIPOC model, which is a tool that helps to define the process, the inputs, the outputs, the suppliers and the customers. Furthermore we define the current situation with interviews. The conclusions of this model are placed in a Critical to Quality model, which shows the stratical focal points, the project objectives and the KPIs of this research.

Measure
M1 Which KPIs are currently in place and which are relevant to measure the performance of the new order method. How can these KPIs be measured?
M2 What are the results for each key performance indicator?

We use a Critical to Quality model to find the KPIs. We measure the results of the KPIs by making a data warehouse and we visualize the results.

Analyse
A1 What is (are) the main problem(s) of the current situation and what is (are) the root cause(s) of the problem(s)?

To obtain the answers to these sub-questions we perform cause and effect analyses.

Improve
I1 What is the desired situation?
I2 What solutions are possible and what are the pros and cons for each solution?
I3 What is (are) the best solution(s) to solve the problem(s) and what is the best way to implement these solution(s) in the hospital?

To obtain the answers to these sub-questions we conduct a brainstorm session. In this session we come up with solutions to improve the performance.

Control
C1 How can the hospital verify whether the solutions are embedded?

We perform a literature study on methods to validate the improvements. Based on this information we give the hospital our recommendations concerning the verification process.

2. Literature

In the introduction we decide to use the DMAIC cycle to answer the research question. In this chapter we perform a systematic literature study of the effectiveness of the DMAIC cycle. The DMAIC cycle is a tool of the approach Lean thinking and the cycle exists of five phases. In this chapter we explain each phase and discuss which tools can be used in each phase. First we discuss the subject “Lean thinking” and “Lean thinking in healthcare” in Section 2.1. In Section 2.2 we explain the DMAIC method and the phases of the DMAIC method. One of the steps of the DMAIC cycle is to define the processes. In the literature we find an extra method to define the processes, namely administrative organisation. In Section 2.3 we explain this method. In Section 2.4 we give a conclusion about Lean thinking, Lean thinking in healthcare and why the DMAIC cycle is useful in this research.

2.1 Lean

2.1.1 Lean thinking

Lean thinking is an approach to the management of operations. The aim of the Lean approach is to meet the demand instantly, with perfect quality, and without waste. The strategy in Lean thinking is to eliminate waste in the process steps in order to get a faster and more dependable process, lower processes costs, and a higher quality level (Slack, 2015). According to Hayes, the initial Lean thinking started in 1913, when Hendry Ford introduced his first “flow” assembly line to produce the Model T Ford at a larger scale (Hayes, 2014). Later on, F.W. Taylor and the family Toyota tried to improve the Lean thinking of Henry Ford and developed multiple Lean tools (Hayes, 2014; Joosten, Bongers, & Janssen, 2009). Toyota developed the approach for the vehicle industry and later on the approach was also used in the automotive, manufacturing, and service industry, and in healthcare (Joosten et al., 2009).

“Value” is an important concept in Lean thinking (Joosten et al., 2009; Womack & Jones, 2003). The concept is defined as the capability to deliver the right product or service a customer wants with a good quality, good price, and without a high customer waiting time (Joosten et al., 2009; Womack & Jones, 2003). In Lean thinking every process step is assessed on the value for the customer. Some process steps are valuable for the customer and some steps do not have any value. In their book, Womack and Jones describe the five principles of Lean thinking (Womack & Jones, 2003). The principles show that customer value and eliminating waste are the centre of Lean thinking (Joosten et al., 2009).

The five principles of Lean thinking are (Joosten et al., 2009; Womack & Jones, 2003):

- Provide the value customers actually desire
- Identify the value stream and eliminate waste
- Line up the remaining steps to create continuous flow
- Match production with customers consumption
- Start over in a pursuit of perfection as Womack & Jones mention in their work: “The happy situation of perfect value provided with zero waste”

To determine value many different tools have been developed, such as value stream mapping and 5s (Joosten et al., 2009). These tools are explained in this chapter. To eliminate waste, the first step is to find the waste in the process steps. Toyota described eight types of waste (Symbol, 2011):

1. *Over-production*	Produce more than asked by the market
2. *Waiting*	Waiting, idling, or defect equipment
3. *Transport*	Transport of materials or products
4. *Over-processing*	Taking unneeded steps to process parts

5. *Inventory* Unnecessary supplies or stock
6. *Movement* Unnecessary moments or searching
7. *Defects* Human faults or bad quality
8. *Unused expertise* Not using existing expertise or knowledge

2.1.2 Lean Thinking in healthcare

Lean thinking was introduced in healthcare in the late twenties (Symbol, 2011). There are a lot of similarities between Lean thinking and the health care approach. Also in hospitals the aim is to obtain an optimized process. Understanding the notion of value is difficult in healthcare. In healthcare the customer is the patient. The product is the treatment. (Burgess & Radnor, 2013). Every patient establishes his/her own value differently, for that reason consultation with the patient is always needed (Burgess & Radnor, 2013). In the article of Young and McClean the sorts of value found in healthcare are described (Young & McCLean, 2008):

- *Clinical* aim is to get the best outcome for the patient
- *Operational* aim is to get a cost effectiveness of a service
- *Experiential* aim is to get the best experience quality of health care for the patient

Healthcare organisations are very complex and that makes it difficult to implement Lean thinking. In healthcare, organisations are traditionally developed from a functional perspective. The organisations are organized around functions, every function is responsible for a subject (Burgess & Radnor, 2013). All those functions make the healthcare organisations complex. Glouberman defines these functions in four different worlds. These four worlds are community (trustees), control (managers), cure (doctors) and care (nurses) (Glouberman & Mintzberg, 2001). All these worlds require a different way of managing:

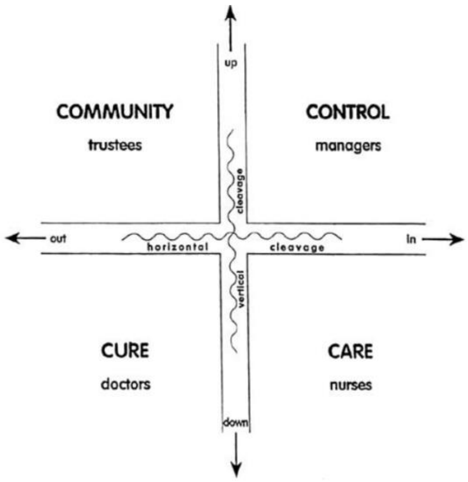

Figure 2.1 Four worlds of Glouberman and the managerial techniques (Glouberman & Mintzberg, 2001).

Down directly into the clinical operations
Up towards those who control and/or fund the institution
In to units and people under clear control of the institution
Out to those who are involved with the institution, but technically independent of its formal authority

Figure 2.1 shows the worlds and managerial techniques.

In many hospitals Lean thinking is introduced (Burgess & Radnor, 2013). Many studies to Lean implementation in health care have been performed. Barriers, but also success factors, are still found in these studies. Lean thinking involves all managers from each level in the hospital (D’Andreamatteo, Ianni, Lega, & Sargiacomo, 2015). It brings together all the four worlds of Glouberman and fosters a long-term view of continuous improvement (D’Andreamatteo et al., 2015).

2.2 Lean Six Sigma: DMAIC

Six Sigma is another approach to improve processes in an organization. The aim of Six Sigma is to increase business profits by eliminating the variability, defects, and waste that undermine customer loyalty (Symbol, 2011). Six Sigma methodology involves the expectations of the stakeholders, manages the facts, and does statistical analysis (Symbol, 2011). Lean thinking and Six Sigma are methodologies which can be used together. The combination of the two approaches is called Lean Six Sigma (LSS), a process improvement method. LSS uses the DMAIC roadmap, a structured improvement cycle. The following quote is from the article of Schroeder *et al.* (Schroeder, Linderman, Liedtke, & Choo, 2008): "In Six Sigma the structured method, DMAIC, provides a metaroutine that organizational members follow to solve problems and improve processes." Figure 2.2 shows the DMAIC method.

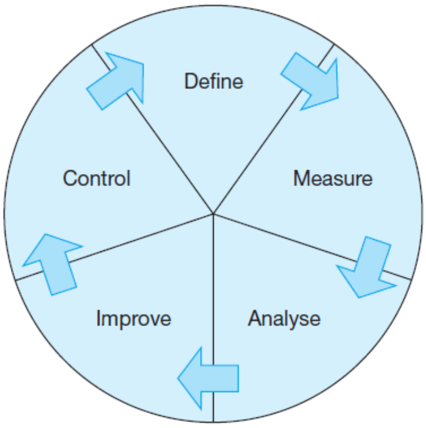

Figure 2.2 DMAIC cycle (Slack, 2015)

Define in this phase the problem will be defined. The problem and the research objective are described. Furthermore, this phase describes how the problem is linked to the customer, how the logistic processes are organized, and how the problem will be managed in this research (Brook, 2014).

Measure in this phase the measurement description will be described. The KPIs will be prepared and the data collection occurs. The quality of the data will be checked. The current situation and performance will be analyzed with respect to the customer (Brook, 2014).

Analyse in this phase the processes and data will be analyzed. The current situation will be compared with the desired situation. Different theories will be developed to find the root cause(s) for the problem(s). The trick is to understand the cause and the effect on the processes (Brook, 2014).

Improve in this phase different solutions will be generated. The best solutions are selected. The advantages, disadvantages, and risks of the solutions will be assessed and the implementation strategies will be analyzed (Brook, 2014).

Control in this phase the aim is to ensure that the solutions that have been implemented become embedded into the process. The conclusions will be prepared and the recommendations are given (Brook, 2014).

In the following sections we explain every phase of the DMAIC method in more detail. To carry out the phases, many tools are developed. For every phase we discuss multiple tools that can be used to carry out the phase. In Section 2.2.1 we discuss the phase define. Section 2.2.2 explains the phase measure. In Section 2.2.3 we discuss the phase analyse. Finally Sections 2.2.4 and 2.2.5 explain the phases improve and control.

2.2.1 Define

In this section we discuss the phase define. There are many methods and tools to define a problem. In this section we describe the methods stakeholder analysis, voice of customer, Critical to Quality, CTQ flowdown and SIPOC analyses.

Stakeholder analysis

A stakeholder analysis is something people do every day. It is the process of considering what people are involved in the problem and processes (Brook, 2014). So which people need to be involved in the project. There are two criteria for a stakeholder analysis: power and position (Brook, 2014). For each stakeholder it is necessary to know in which position they are and what power they have. A stakeholder with a high position needs to be more informed than a lower position stakeholder, and a stakeholder with more power needs to be more satisfied than a stakeholder with less power (Brook, 2014).

Voice of customer

Lean management is customer focused (Brook, 2014). For that reason it is important to do research into the customer's needs (Brook, 2014; Griffin & Hauser, 1993). It is also important to structure the needs and provide priorities for the customer needs. To find the needs there are three stages: the identification stage, the structuring stage, and the priorities stage (Griffin & Hauser, 1993). There are different methods of studying the voice of customer (Brook, 2014; Griffin & Hauser, 1993):

Customer complaints	
Direct contact methods:	Phone calls, focus groups, and interviews
Less direct methods:	Surveys, feedback cards, market research, and competitor analysis
Be your own customer	Call your own call centre or order products from you own online store.

Critical to Quality/Critical to Quality flowdown

To get insight into the voice of customer, it can be useful to define the voice of customer as critical to quality (CTQ). CTQs are measurable indicators (De Koning & De Mast, 2007). Generally CTQs will concern money, time, quality, and customer satisfaction. A CTQ flowdown helps to provide clarity and structure to the voice of customer. The CTQ flowdown visualizes the hierarchical levels of the CTQs and shows how CTQs relate to higher level concepts such as project objectives and strategic focal points. It also shows how to measure the CTQs (De Koning & De Mast, 2007). Figure 2.3 shows how the CTQ flowdown looks like.

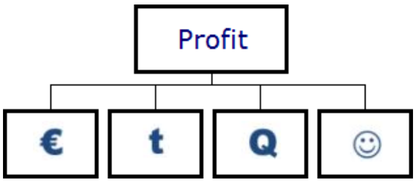

Figure 2.3 CTQ flowdown ("EenBlogjeOm", 2016)

SIPOC-analysis

SIPOC is an abbreviation for suppliers, inputs, processes, outputs and customers. The SIPOC diagram helps to clarify the core process a project is focused on. It helps to build a link between the different variables like people, product, place, price, promotion, and customers' needs and satisfaction (Yeung, 2009). A SIPOC starts with a simple definition of the process. The next step is the decomposition of the process in small steps, but without too much detail. The inputs and outputs are identified and are linked to suppliers and customers(Brook, 2014; Yeung, 2009).

2.2.2 Measure

In this section we discuss the measure phase. There are many tools available to measure the problem. In this section we describe different data types, data visualisation, and questionnaires.

Data types

There are two main types of data, namely categorical and numerical. Categorical data is qualitative data, it means the property of something. This can be used when data can only be classified in categories, for example sex and blood type. The categorical data can be divided into ordered and unordered data. The other main data type is numerical data, which is quantitative data. Quantitative data is expressed in numbers. The data can be quantified and verified, it is possible to do statistical manipulations with it (DWIKAT, 2005). The numerical data can be divided in continuous and discrete data. Discrete data is when the observations can only have certain numerical values, for example the number of phone calls or the number of episodes of a TV series. Continuous data have no limitation in the values. The variables can have any value, for example age or weight (DWIKAT, 2005).

In Six Sigma three types of data are used: continuous, discrete/count, and attribute (Cordy & Coryea, 2006; Symbol, 2011). Continuous data is used when the project needs to measure something. Count data is used when the project is counting something. And attribute data is used when the project is classifying something. The continuous data is used to calculate, for example, variation and averages. The counting data is used for counting whole numbers. The attribute data is used to categorising things into different categories that do not have a numerical value or order (Symbol, 2011). Something to notice about attribute data is that there are always only two categories, for example good or bad, pass or fail, and on time or not on time (Cordy & Coryea, 2006; Symbol, 2011). Continuous data includes a normal distribution, count data includes a Poisson distribution, and attribute data includes a binomial distribution(Symbol, 2011).

Data analysis

There are three information systems topics that are closely related to Six Sigma activities, namely: data warehousing, online analytic processing (OLAP), and data mining (Pyzdek & Keller, 2014).

Data warehousing includes online transaction processing (OLTP) data. This data is mostly stored on several systems, and can be very detailed or is sometimes incomplete. OLTP data focus on single transactions. The data warehouse includes the summarizing, integrating and purification of all of these data in a new store place: This new data warehouse can be used for analysis and also for making decisions (Jensen, Pedersen, & Thomsen, 2010; Pyzdek & Keller, 2014).

Online analytic processing (OLAP) and data mining are both methods to analyse the data out of the database. OLAP involves analysing the data interactively, the data is usually represented and manipulated in the form of multi-dimensional arrays, or spreadsheets. This is expressed in a data cube. Data mining means to explore the data to find more interesting and new knowledge. There is no clear transition moment between OLAP and data mining. The OLAP analyst will usually be given precise instructions, for example what data to focus on, and by data mining the system will often determine by itself where to focus on (Jensen et al., 2010; Pyzdek & Keller, 2014).

Questionnaires

A questionnaire is used for a fundamental scientific research. But above all, it is used to find the needs of practitioners. For example, questionnaires are used to evaluate a course in university or a market research. The questionnaires can be conducted in two different ways; by surveys or by interviews. The surveys are written and interviews are oral (Brinkman, 2000).

There are many different types of questions in a questionnaire. The first division is open and closed questions. The open questions give the respondent the full freedom to give the answers in his/her own way. At the closed questions, the respondent must choose from a limited number of answers. The advantage of this is that the respondent knows directly what sort of answer the researcher expects. The use of closed questions raises the reliability and validity. The disadvantage of closed questions is that the answers do not always reflect the specific situation of the respondent (Brinkman, 2000).

There are many ways to state the open and closed questions. The types are described her below:

Full interrogative sentences: normal, complete question, like in normal life (Brinkman, 2000).
Example: How many grams of meat do you eat on average with a hot meal?

Fill in a contention: at the end of a contention there are dots, the respondent will fill in on the dots what implicated (Brinkman, 2000).
Example: When I wake up in the morning, the first thing I do is ....

Indicate the degree to which an assertion absorbed: the researcher give a statement, the respondent will indicate whether he/she agree with the statement (Brinkman, 2000).
Example: 'I have the feeling everybody likes me. '
Do not agree with1 2 3 4 5 6 Totally agree with

Choose a position between two opposite assertions: the researcher ask a question and the respondent will range the position between two opposite assertions (Brinkman, 2000).
Example: I find my job:
Very annoying 1 2 3 4 5 6 Very nice

Line scales: this type of question is comparable to the above mentioned questions. The only difference is that there are no intervals, but there is a line upon the respondent can give his/her opinion (Brinkman, 2000).
Example: How do you assess the risks during you work?
Absolutely no risks ______________________________ Many risks

Ranking: the researcher ask the respondent to rank priorities or preferences (Brinkman, 2000).

Image questions: this type of question is similar to the position choose question. The difference is that there are no assertions, but with this type there are two opposite images (Brinkman, 2000).

Vignettes: the researcher defines a situation and ask the respondent his/her opinion about the situation. For example a situation where someone has stolen something and what happened before. The researcher asks what punishment the person deserves (Brinkman, 2000).

Checklists: this type of question is the same as a multiple choice question. But at this type of question multiple answers can be filled in (Brinkman, 2000).
Example: What products do you have in the bathroom?

a. Hairdryer
b. Toothbrush
c. Towels
d. Perfume

2.2.3 Analyse

In this section we discuss the analyse phase. We describe the different tools to analyse the data gained by the measure step. We describe the value stream mapping and the cause and effect analysis.

Value stream mapping

Value stream mapping (VSM) is a method of Lean Six Sigma. VSM is a methodology to identify wasted time and actions in processes. Wasted time or actions are time intervals and actions in a process that have no value for the customer. The VSM helps to understand the flow of services through the process, and identifies key process data (Brook, 2014). The VSM method shows the actions within a process that do or do not have an added value. In every process step and between each process step the actions without added value are identified. The next step is to reduce the wastefulness. As a result of that the value added time will increase in the whole process and the process throughput speed will increase (Solutions, 2016). The VSM method can be carried out in multiple phases of the DMAIC cycle, namely the analyse and improvement phase. In the analyse phase, the VSM method is used to analyse the current situation. In the improvement phase, the VSM method is used to analyse the future situation (Brook, 2014). The VSM method helps to improve the effectiveness and efficiency of a process(Solutions, 2016).

Root cause analysis

Another method to analyse the results is the root cause analysis. Every performance has a cause for that performance. The performance can be good, but can also be bad. The bad performance needs to be improved. This can only be done by identifying the cause of the bad performance. The next step is to eliminate the cause (Doggett, 2005). A tool to find the root causes is the cause-and-effect diagram (CED). The CED is developed by Professor Kaoru Ishikawa in 1943. The first step in the analysis is to decide the problem to improve or control. The next step is to find the main factors that may be causing the problem. These factors are classified in the following categories: parts (raw materials), procedures, plant (equipment), and people. The last step is to find if there are more detailed causes that have influence on the main cause (Doggett, 2005).

2.2.4 Improve

In this part we discuss the improving phase. The improve phase aims to develop, select, and implement the best solutions. The first step in this phase is to generate potential solutions, followed by selecting the best solutions. The risks of each solutions needs to be analysed and finally an implementation plan needs to be prepared (Brook, 2014). Many methods are developed to carry out these steps. In this part we first discuss how to find solutions. After that we discuss multiple tools for improving processes, namely: Kanban, 5S and visual management.

Methods to find solutions

The first step is to find good solutions to solve the problems. Brainstorming is a method that can be used to find solutions. This method can be carried out in a group or alone. In this method, people think out loud what solutions are possible to solve the problem. Brainstorming is a method that can be used in many environments and for many purposes. This method ensures the solutions can be found in a broad range (Brook, 2014).

Another method is the assumption busting. This method ensures people try to recognise the underlying assumptions that limit people’s thinking. In this method the purpose is to find the assumptions why people are stopping or limiting to solve the problem and challenge the assumptions. It ensures people will think out of the box (Brook, 2014).

Another method to find solutions is the value stream mapping. We discuss this method in Section 2.2.3. In this section we mentioned that this method can be used in both the analyse and improve phase.

To find the best solutions the solution screening method can be used. This method checks if the potential solutions, that are found in the improving phase still meet the main goal of the project. This method consists of multiple screening criteria that reflect the basic requirements of the goal of the project (Brook, 2014). Another method that can be used to select the best solution is a pilot study. This method is mostly carried out in a further stage. It is a controlled trial of a solution in order to test the effectiveness before full implementation. In order to be effective, a pilot needs to be planned properly in advance (Brook, 2014).

Kanban

Kanban is one of the Lean methods that can improve the processes. The main goal of this method is to minimize the inventory at any time. Kanban is a just-in-time method, the method requires production only when the demand of products is available. Traditional production systems generally work on a "pushed" through the production system. Mostly, this is not directly linked to the demand of the customer. The Kanban method helps to replace this system to a "pull" system. The products are only made when the demand is available. In this method Kanban cards are used to visualize if the demand of the customer is available (Brook, 2014; Rahman, Sharif, & Esa, 2013). There are two types of Kanban methods: production and withdrawal Kanban method. The production Kanban method is used to control the production. When a Kanban card is available the production can take place. The withdrawal Kanban method is used to control the movements of production parts from one cell to the next. When a Kanban card is available the part can be moved from one cell to the next (Brook, 2014). There are rules for a successful Kanban system, namely (Brook, 2014):

- Kanban methods work best where customer demand is relatively stable
- The number of Kanban cards should be minimized whilst supporting expected demand rates
- The quantity of parts in each container should be minimised
- Nothing should be produced or moved without a Kanban card
- Bad parts should never be passed on

5S

Another method to improve the processes is the 5S method. This method provides a structure for improving workplace environments. It is a simple method to organize, standardize, and maintain the workplace. The method involves 5 steps that all starts with S, namely (Brook, 2014):

Sort	the aim of this step is to place only items that are needed frequently in the workplace. All the items that are not needed needs to be removed.
Straighten	the aim of this step is to place the items on a specific place in the workplace. The items that are used often will be located most at hand.
Shine	the aim of this step is to clean up the workplace frequently. It is important to keep the workplace clean and tidy.
Standardise	the aim of this step is to develop a system to ensure the workplace is always tidy.
Sustain	the aim of this step is to continue to perform. To give the right example to the others.

Visual management

The last improvement method we discuss is visual management. This method refers to the use of graphical methods to display and communicate how a workplace or process is managed, controlled, and performing. This is done in real-time. (Brook, 2014). Visual techniques are very effective in improving performance and safety. The technique can help to organise the workplace, monitor processes, and communicate process performance. Examples of visual management are visual standards, process indicators, and information boards(Brook, 2014).

2.2.5 Control

The last phase of the DMAIC cycle is the control phase. The aim of this phase is to ensure the solutions that have been implemented become embedded into the process. In this phase will be discussed how the process can be measured after the project and if the improvements became a standardisation. Besides, in this phase will be analysed if the project goal is achieved and if the project can be closed (Brook, 2014). Multiple methods can be used to answers these questions. Some of these methods we already explained in the other phases. The CTQ flowdown, 5S, and visual management can be used in this phase. In this part we introduce one other method, namely the control plan.

The control plan is a process management document that summarises the measurement details for each process step. For each process step the characteristics that are measured, their specifications, historical capability, measurement method used, and a response plan if out of specification are described(Brook, 2014).

2.3 Administrative organisation

In this section we discuss the administrative organisation. It is a discipline that is used in the information science and business learning. This methods focuses on the functioning of an organization. Administrative organisation is not directly related to Lean thinking.

In the book by Prof. E.O.J. Jans an organisation is defined as: "a group of people, who are working together with the help of resources, and develop and carry out activities to reach the organisation goal in an efficient way"(Jans, 1994). The leadership must take care to maintain the continuity of the organization in society. The current position should be maintained and if possible be improved. The company needs to be flexible and be able to react to internal or external factors. The Characteristics of every organisation are: purposefulness, targeting, and expediency. Many different aspects are important for a good organisation, for example the organisation structure, the decision making, activity control, and communication (Jans, 1994).

There are many methods to organise an organisation. One of these methods was developed by Starreveld. This method is called administrative organisation. This term can be described as: "the complex organizational measures relating to data processing processes in an organisation, focused on information services for the purpose of managing and functioning of an organization and for the accountability" (Jans, 1994).

The creation of information and maintenance of this information is very important in the specialty Administrative Organization. Starreveld set up multiple organisational aspects that need to be involved in this process (Jans, 1994).

Integration with the internal organization	The information system is an integral part of the internal organization
Information needs	The information needs of managers and performers
Information quality	Information needs to be reliable, flexible, and continuous
Internal integration	The interdependence between distinct processes in an organization
External integration	Connect own systems with other similar systems from other companies.

There are multiple methods to find the information. For example encryptions, forms, process analysis, and schedules (Jans, 1994).

2.3.1 Process analysis

A process analysis is a method to get more information on all processes in the logistic department. The main objective of the process analysis is to give the organisation an insight in the opportunities and bottlenecks in the processes (Jans, 1994). In the case of Administrative Organization, process analysis has the object to (Jans, 1994):

- Give the cohesion of all processes in the organization
- Provide insight in the nature and structure of a particular process
- Provide insight in the nature of the leadership function in the process and where in the process information is needed

The process analysis consists of four stages. These are (Jans, 1994):

1. Identifying processes
2. Visualizing the relations between the processes and organisation
3. Visualizing the activities in a certain process
4. Collecting data of every activity

2.4 Conclusion

In this chapter we discussed Lean management. The strategy of Lean thinking is to eliminate waste in the process steps to improve the process. An improved process is a process that is faster, more dependable, has lower costs, or a higher quality level. We conclude that waste is a process step that give no value to the customer. We conclude that in every organisation waste can be found, so also in hospitals. We observed that a hospital organization is complex. Not only the managers are involved in important decisions, we observed that the doctors and nurses are also involved in that kind of decisions. These functions can have other concerns about a subject. Nevertheless, we conclude that Lean thinking can be used in a healthcare organisation because Lean thinking focuses on reducing waste and this occurs also in healthcare organisations. Moreover, we conclude that the reduction can take more time because more people in the hospital are involved.

In this chapter we discussed the DMAIC method. The DMAIC method is a method of Lean management involving an improvement cycle to analyse and improve processes. The method consists of the phases define, measure, analyse, improve, and control. We found multiple tools to assess these phases. We conclude that the DMAIC method can be used for qualitative and quantitative research. We also conclude that the DMAIC methods is well-structured method with a clear beginning and end. We conclude that the DMAIC method is a cycle that is used for continuous improvements and not only for creating new processes. This research involves the evaluation of an implemented process and therefore requires a continuous improvement method. Furthermore, the DMAIC method includes all phases to ensure the full performance of the new order method can be assessed, giving both qualitative as well as quantitative results. Based on these qualities, we conclude that the DMAIC method is a suitable method for answering the research questions.

3. Define

The first phase of the DMAIC method we discuss is the define phase. In this chapter we carry out this phase and we define the current situation and the problem. First we describe the basis processes and give more detail of the inputs, outputs, suppliers and customers with a SIPOC diagram in Section 3.1. In Section 3.2 we describe the processes in more detail. Section 3.3 includes information concerning the different logistic routes. In Section 3.4 we describe the different stakeholders that are involved in this research. In Section 3.5 we study the interests of the users in the different processes. With this information we compose multiple KPIs. The user interests are combined in a Critical to Quality flowdown in Section 3.6. In Section 3.7 we give a conclusion of this chapter.

3.1 SIPOC diagram

In this section we discuss the SIPOC diagram. A SIPOC helps to find more information on the ***s**uppliers, **i**nputs, **p**rocess, **o**utputs, and **c**ustomers*. Figure 3.1 shows the SIPOC diagram used in this research. The first step is to determine the main process in the logistic department. We find five process steps: receiving products, storing products in central warehouse, order picking, transportation, and supply of the products. We will further elaborate on these process steps in Section 3.2.1. until 3.2.5. Also the involved suppliers, customers, inputs, and outputs are

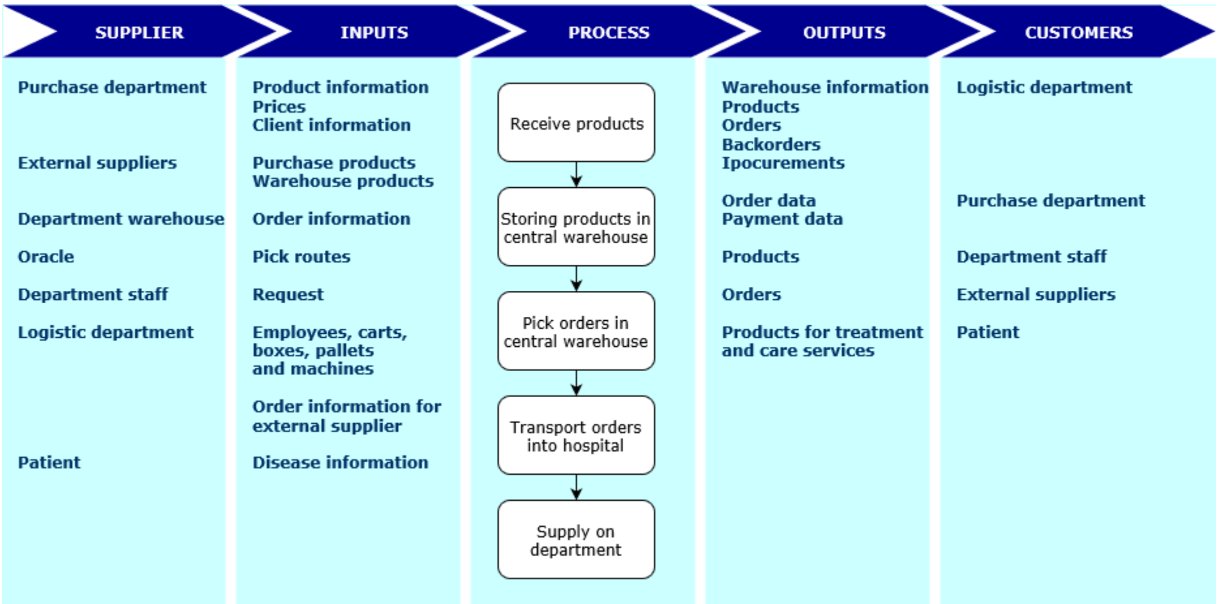

Figure 3.1 SIPOC diagram of the main process in the central warehouse of Medisch Spectrum Twente

investigated per process step. Since one department of the logistic department is nog discussed in one of the steps of the main process, we discuss the backoffice in Section 3.1.6. More detailed information about the customers is included in the stakeholder analysis in Section 3.4

3.2 Process analysis

In the SIPOC diagram we define the main process in the logistic department. In this section we define the main process in more detail. To do this, we use the method *process analysis of the discipline administrative organisation* because this method provides a clear overview of the processes. In the process analysis, we explain every process step of the main process given in the SIPOC diagram separately. For every step we make a scheme. The scheme visualizes the main activities in the process step. Furthermore, we combine the process steps in different flowcharts. In these flowcharts show the responsible department or person. All the processes are managed with Oracle, an enterprise resource planning system. In the new order method Oracle gets more information from the system Alltrack. Alltrack is the system used by the order board and the order cards. Every order card is connected to a specific product at a specific location. This information is linked to Oracle. When an order card is placed, Alltrack will send that information to Oracle so that the products are ordered in Oracle. In Section 3.2.1 until 3.2.5 we discuss the five process steps. Finally, one department of the logistic department is not discussed in one of the steps of the main process, namely the backoffice of the central warehouse. Nevertheless, the backoffice has an important role within the logistic department. In Section 3.2.6 we discuss the role of the logistic backoffice and their responsibilities.

3.2.1 Receive products

The first step in the main process of the Logistics department is the receiving of products from the suppliers. We describe this main process step in more detail using the substeps given in Figure 3.2.

Figure 3.2 The process steps within the receiving of the hospital material process

The orders, which are delivered by external suppliers, are received by the central warehouse. The products, which commonly arrive on pallets, can be delivered between 8.00 am and 4.30 pm during week days, and are booked in Oracle by the logistic employees. Multiple products arrive at the central warehouse, involving both sales products and warehouse products. Warehouse products are products that are stored in the central warehouse of the hospital because the demand of the product in the hospital is high or many hospital departments use this product. Sales products are directly ordered at the extern supplier. These products are not stored in the hospital because the demand of the product in the hospital is low, a few hospital departments use the products, or the product is used for a short time period. After booking a product, the first step is to check if the received product is a warehouse product or a sales product. Furthermore, the warehouse products are separated in sterile products, which are transported to the sterile warehouse, and unsterile products, which are transported to the unsterile warehouse.

Sales products are products that are ordered separately by the hospital departments. These can be ordered using two methods; a hospital department can order a product manually in Oracle or the department can use the order board. The sales products that are ordered by the order boards need to be delivered with the other products that are ordered by the order board. Sales products that are ordered manually, are transported to the carts that are used for these kind of orders. No distinction is made for sterile and unsterile sales products since they arrive in appropriate packaging and are transferred to the hospital departments immediately rather than being stored in the central warehouse. Appendix I shows the receiving and storing step in more detail.. Furthermore, the appendix shows the responsible department or person.

3.2.2 Storing products in central warehouse

The next main process step, the filling of the central warehouse, is subdivided in the steps given in Figure 3.3.

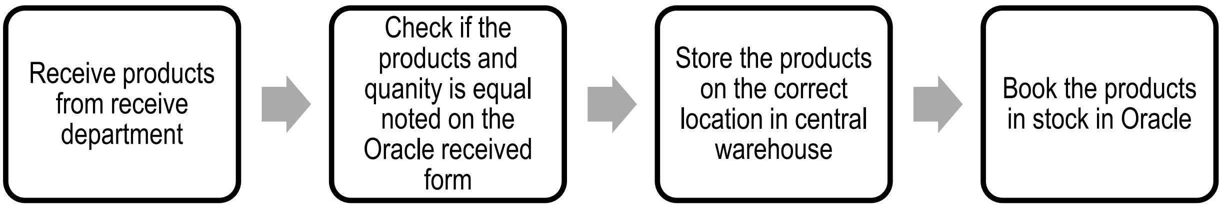

Figure 3.3 The process steps within the fill in central warehouse process

The products are transported from the received department to the central warehouse on pallets. The first step after receiving the products in the central warehouse is to check if the type of products and quantities match the received form obtained from Oracle. If that is correct, the products can be stored in the central warehouse. There are small and large products. The large products are stored on the pallet in the central warehouse. The small products are taken from the pallet and are stored in trays or on shelves. The products are stored at a bulk location when there is not enough space in the central warehouse. The received products need to be booked in Oracle when the products are stored in the central warehouse. The stock levels in Oracle will increase with the number of received products. Appendix I shows the store step in more detail. In these appendix the receiving and store steps are combined. Furthermore, the appendix shows the responsible department or person.

3.2.3 Pick orders in central warehouse

The main process step following the storing in the central warehouse is the picking of orders in the central warehouse. This step is subdivided in steps as presented in Figure 3.4.

Figure 3.4 The process steps within the order picking process

In the department warehouses they work with the two bin system and Kanban cards. The method is to grab the products from bin one first and when bin one is empty the order card of bin one is placed on the order board and the products in bin two will be placed in bin one. The Kanban method is used to reorder the products. Every bin is linked to a Kanban card. When the bin is empty the linked Kanban card is placed on an order board that is connected to the storage place of the department. The order boards are read out with an internet connection every day at the same time. On that moment the linked products are ordered in Oracle. The reading moments are in the morning at 7.00, 7.45, 8.45, and 9.45 AM during the weekdays. The read out time per order board depends on the delivery route. We discuss these routes in Section 3.3. The hospital department can also order warehouse product manually in Oracle. These orders are called iProcurements. The iprocurements are always read out at 2.00 PM every weekday. Ordered products that are not on stock when it is ordered are registered in Oracle as backorders. When the products are received in the central warehouse the backorders are received at the same time as the orders boards are read out.

The order picking process step starts at the ordering of products by the hospital departments. This occurs using the order board or by manual orders in Oracle. Next, the orders are received by the central warehouse. The orders are received per department. When the orders are received, the saved stock level of the products in Oracle will decrease with the number of ordered products. Oracle calculates the picking route in the central warehouse. The orders are separated manually into the sterile and the unsterile warehouse because Oracle does not separate it. After that, the orders are picked in the warehouses by the warehouse employees. The products are stored in boxes and are transported on the correct carts.

The central warehouse is working with the BQ model. That means that the order moment of products in the central warehouse is variable, when the stock level of a products is lower than the minimum value of that product new products will be ordered at the external supplier. The minimum value is different per product and is based on the consumption of the product. The number of ordered products is a fixed value. Appendix II shows the order picking process in more detail with the responsible department or person.

3.2.4 Transport orders into the hospital

After order picking the orders are transported to the hospital. This main process step is again subdivided in substeps shown in Figure 3.5.

Figure 3.5 The process steps within the transporting process

The sales and warehouse products are transported from the central warehouse into the hospital. The sales products are transported on carts or, for large orders, on pallets. They can transport 6 carts or one pallet at a time. All carts are transported to the basement of the hospital. On that location the transporters sort the carts with warehouse products and sales products. The sales products are delivered by the transport employees to the backoffices of the hospital departments. After that, the empty carts are transported from the hospital to the central warehouse. The transport process is shown in Appendix I and Appendix II.

3.2.5 Supply on department

After the transport step the products are supplied to the hospital departments. This step is subdivided in substeps shown in Figure 3.6.

Figure 3.6 The process steps within the replenishing process.

The last step of the main process is the supply step. In this step the ordered products are delivered to the department warehouses. The deliver employees take a cart in the basement of the hospital and bring this cart to the designated department. The next step is to remove the order cards that are noted on the order form from the order board. When an order card is on the board, but the products are on backorder they are placed in the top right corner of the board. This allows the department employees to see that the product is ordered but not on stock in the central warehouse at the moment. The next step is to check if no mistakes have occurred in the order process. Mistakes include picking mistakes, no order card on the order board, or a full bin. If mistakes have occurred, the deliver employees need to solve these problems. After that the bins can be filled with the new products and the cart can be moved to the next department. When the cart is empty the cart will be moved to the basement of the hospital. Appendix III shows this process step in more detail with the responsible department or person.

3.2.6 Central warehouse back office

The backoffice of the central warehouse is located in the central warehouse. In this department the administration of the logistic department is tracked. In the backoffice all orders are received. The backoffice employees have multiple responsibilities. They sort the orders manually for the warehouse employees. They book the newly stored products in Oracle. Furthermore, they backoffice is the contact point for the hospital departments for various requests. Most request concern products that are not delivered, an urgent order, lost order card, new products on the departments, or a change in their warehouse. All these request are solved by the backoffice employees. Appendix IV shows the different request and how the backoffice employees react to these request.

3.3 Routes

In this section we describe the different replenishing routes. These routes were established when MST moved into the new location. The logistic department developed five different routes which are distinguished by colour. The different routes are route blue, red, white, orange, and green. The first four routes are located in the new building (Koningsplein). Route green is located in an older location (Haaksbergerstraat). First, we discuss route blue, red, and white. After that we discuss route orange, and finally we discuss route green.

The logistic department decided to transport the products vertically rather than across floors, with the aim of having fewer logistic employees walking through the hospital departments. The blue, red, and white routes are related to three transport elevators. The three routes involve all six floors of the new building, with the exception of the third floor. Figure 3.7 shows the route plan we make of the ground floor. The circles around the elevators show the route colour. The order boards are read out per route at a fixed time on the day. Most hospital department that works with the order boards has one or two order boards, one for the sterile department warehouse and one for the unsterile department warehouse. Most hospital department has two warehouse locations, a sterile and unsterile location. At the read out moment the cards on the board are read out and the products that are connected to the card are ordered in Oracle. The order boards of the blue route are read out at 7.45 AM, the red route at 8.45 AM, and the white route at 9.45 AM. The routes are walked after each other. During the first year, the order boards were read out on Monday to Friday. In March 2017 the logistic department started a pilot involving reading out on

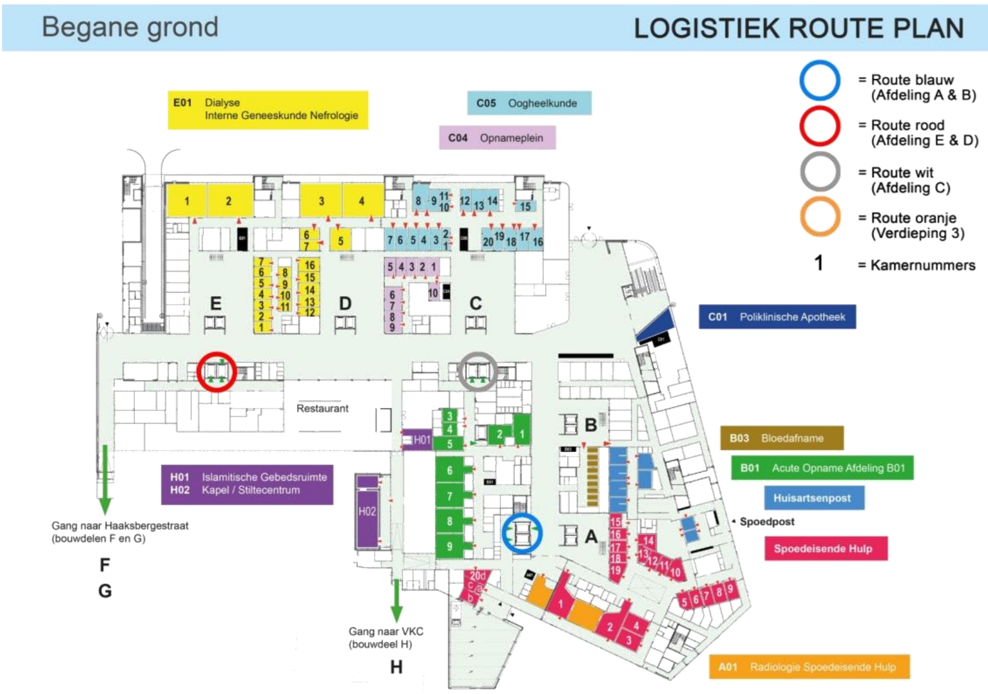

Figure 3.7 The route plan of the ground floor. The three transport elevators are connected to the colours red, white and blue. Appendix VI shows the route plan of the other floors in the hospital.

Saturday. The order boards of the nursing departments, emergency department, and the haemodialysis department are also read out on Saturday and the orders are picked and delivered on Saturday as well.

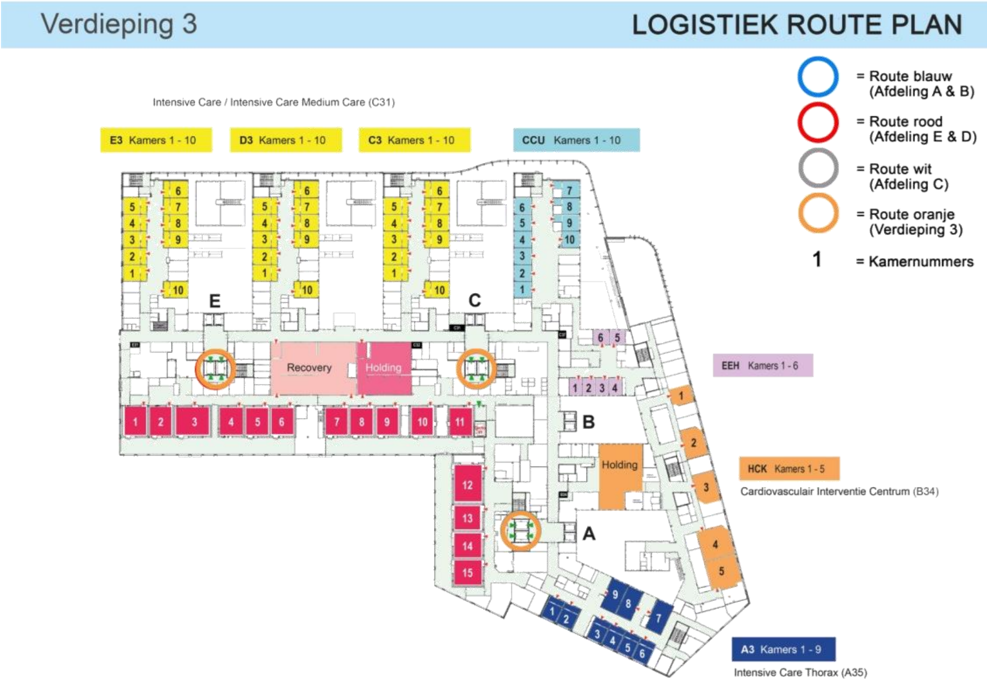

Figure 3.8 The route plan of the third floor

In the new building (Koningsplein) there is another route, the orange route. This route deviates from the other routes. This route is only located on the third floor. Figure 3.8 shows the route plan we make of the third floor. On this floor the operating rooms (ORs), intensive care (IC), and the coronary care departments are located. The products for the ORs need to be packed on specific sterile carts. This process takes place in a sterile room, called the transferium. The supplying of the third floor is done by another department that also organizes other logistic processes on the third floor. For example, they supply the surgical devices at the ORs. On the third floor, only the IC and the coronary care department work with the order boards. The order boards are read out at 7.00 AM every weekday and the products are ordered by Oracle. The logistic staff picks the products and transports the products to the transferium. The Transferium employees deliver the products to the department warehouses. The products of the IC and coronary care departments do not need to be packed on specific carts, which means the carts that are used to transport the products to the Transferium are also used to deliver the products to the department warehouses.

Appendix V shows which department is connected to which elevator/route. Appendix VI shows the floor map we make with every floor of the hospital and the elevators/routes. The logistic staff does not work with a specific sequence of floors and the carts are packed by route without any system support. The sales, sterile, and unsterile products are delivered separately.

The logistic department works with a fifth route, the green route. This route is located in an old building (Haaksbergerstraat). This part of the hospital provides specialized care for mothers and children. The departments in this building do not work with the new order method at the moment. At these departments the logistics employees order the products manually with a scanner. In the future, these departments are going to work with the order boards too. We do not always include route green in the measurements because the route is not working with the order boards yet. In this research we therefore only take route green into account in the workload measurement.

3.4 Stakeholder analysis

In Section 3.1 we describe the customers of the main process of the logistic department. For this analysis we consider these customers as stakeholders. In this section we further analyse the stakeholders. The SIPOC diagram in Section 3.1 shows five stakeholders. These are: *(1) department staff, (2) logistic department, (3) purchase department, (4) external suppliers, and (5) the patient*. The department staff are the employees of the hospital departments. They need products to provide care. The logistic department regulates all receiving products and the orders for the hospital departments. The purchase department coordinates the purchases of the hospital. The external suppliers are all suppliers from which the hospital receives its products. They deliver during the weekdays.

We make a Venn diagram of the stakeholders to get a more visual image of how the stakeholders are classified. Mitchell et al describe how a Venn diagram can be used to classify the position of the stakeholders. Figure 3.10 shows the Venn diagram. Mitchell et al classify the stakeholders in three circles: power, urgency, and legitimacy (Mitchell et al., 1997). Mitchell defines power as "the extent to which a party has or can gain access to coercive, utilitarian, or normative means, to impose its will in the relationship" (Mitchell et al., 1997). He defines legitimacy as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Mitchell et al., 1997). And the last circle, urgency, he defines as "the degree to which stakeholder claims call for immediate attention" (Mitchell et al., 1997). The position of a stakeholder can be in only one circle, but it can also overlap in multiple circles. Figure 3.9 shows what sort of stakeholders Mitchell et all defined.

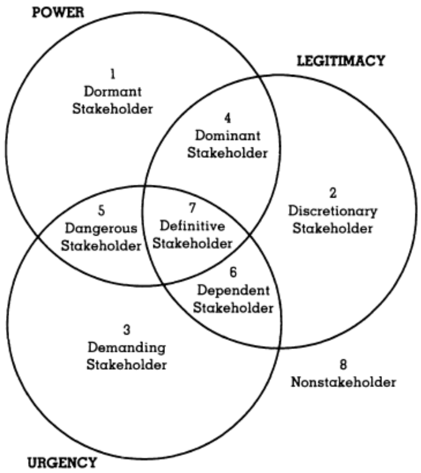

Figure 3.10 Venn diagram of Mitchell et al (Mitchell, Agle, & Wood, 1997)

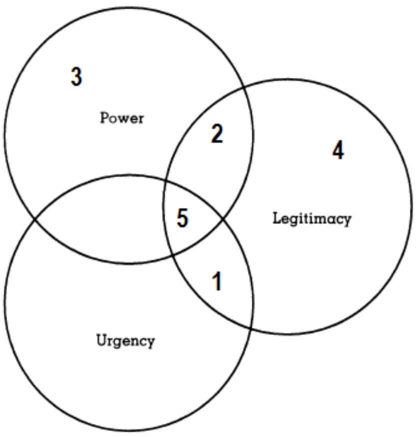

Figure 3.9 Positions of the stakeholders in the logistic process in MST

We classify the stakeholders of this project and give them a position in the Venn diagram of Mitchell et al. Figure 3.10 shows the Venn diagram and the positions of the stakeholders 1 to 5 mentioned above. We position the first stakeholder, the department staff (1), in the urgency and legitimacy circle. We conclude that this department requires immediate attention and wants to act according to the hospital's rules and protocols. It is likely that this stakeholder has a lot of power, however because the department staff is now responsible for their own order process the power of the department decreases. The department staff is dependent on the logistic department. The second stakeholder, the logistic department (2), has more power and works according to the rules. Therefore this stakeholder is positioned in the circles of power and legitimacy. The third stakeholder, the purchase department (3), is positioned in the circle of power. This department decides if products are purchased or not. The fourth stakeholder, the external suppliers (4), are positioned in the circle of legitimacy. They do not have any influence on internal processes. The last stakeholder, the patient (5), is positioned in all circles. The patient is the reason all processes are going on. On one hand, the patient is dependent on the logistic process. But on the other hand the patient has power and urgency when the situation is urgent. At that moment the logistic processes needs to change so that the patient can be treated with the proper products.

3.5 Voice of the Customer

In a Lean six sigma project it is important to ensure it is customer focused. The voice of the customer involves the customer's expectations, preferences, and aversions. To find these aspects we use the value focused thinking method. We describe this method in Section 3.5.1. In Section 3.5.2 we describe who we interview for this research. In Section 3.5.3 we discuss the results of the interviews. With these results we make a critical to quality flowdown to find the KPIs we can measure.

3.5.1 Value Focused Thinking method

There are multiple methods to identify the needs of the customers. In this research, we use the Value Focused Thinking (VFT) method. This method is explained in Appendix VII. We use the VFT method because this method ensures to find more than one objective. The method gives a structured way to identify the objectives and find the relations between those objectives. Besides, the VFT method ensures knowing why the objective is important for a customer. The VFT method will helps to find the KPIs for this research. With this method we develop an interview. Appendix VIII shows the interview. The interview is written in Dutch, because the hospital and staff are Dutch.

3.5.2 Interviews

We collect the interviews from the stakeholders of the logistic department and the hospital departments. All those stakeholders are users of the new logistic methodology. These people are interviewed because they are most involved and carry a lot of responsibility in the processes. The interviews were conducted during one and a half month, in December 2016 and January 2017. At that moment the new logistic method was introduced approximately one year ago. Table 3.1 shows the total number of conducted interviews, 30 interviews in total. The table shows that we involve multiple specialism in the interviews. From almost every hospital department at least one employee is involved in the interviews. From the 28 departments that are working with the new logistic method only three departments did not have time for an interview or did not reply to the invitation for the interview.

Specialism	# interviews
Warehouse employees	2
Supply employees	3
Outpatient department	9
Nursing department	13
Emergency department	1
Room service staff	2
Total	**30**

Table 3.1 Specialism interviews

3.5.3 Results of interviews

The overall voice of the customer is very positive. Most users conclude that the new methodology can work well, when it is used properly. From the interviews we conclude seven different project objectives are important for the users. These are: *good response time, short waiting time, correct stock level in the department warehouses, low workload, well working technology, well organized communication, and well furnished hospital department warehouse*. Overall, we observe that the first four project objectives are the most important for the users because these objectives are most commonly discussed by the users during the interviews. We will now further elaborate on the customer's expectations, preferences, and aversions of these subjects.

Response time

A good response time is an expectation mentioned in the interviews. With the response time we mean the time interval between the moment a request of the customer is made and the moment the request is executed. Some departments were very happy with the response time. They were very satisfied with the communication of the response time. A good response time ensures a good quality, overview, and customer satisfaction. Other departments said sometimes the response time is very short and sometimes it takes very long. They spoke about weeks or months. They could not tell the reason for the long response time. They also said it is not always a problem that it takes a while, but currently they are missing information about the expected delivery time, which means they have difficulty planning their procedures.

Waiting time

With the waiting time we mean the time interval between the moment the products are ordered and the moment the products are delivered. Besides, the waiting time can also be determined as the time interval between the time of a request of the customer and the time that the request is executed. The aim of the new method is to deliver on the same day. The users are very happy with this because they have assurance that they can order products every day and they do not have to wait too long. From the interviews we conclude that this purpose mostly is achieved. However, the users in the hospital do not have any overview when the supply employees will deliver the products. Sometimes they have the feeling that delivery is very late in the day which can be problematic when they are tight on products. The users of the outpatient department also mentioned that sometimes, and only on Mondays, no delivery takes place. A notable remark made by two users during their interviews was that the delivery only takes place two or three times a week. One user had the feeling she thought this because she does not see the deliveries every day and in the old situation they were supplied two times a week. She did not have the feeling they often require materials while they are out of stock. The other user had no explanation why she had the feeling the delivery only takes place two or three times a week.

In some hospital departments it is possible to order the sales products using the new order method while in other departments this is not possible. The departments that can order the sales products with the boards are generally positive about it. One of the reasons they are positive is because it saves a lot of order time. All departments gave the same expectations concerning the sales products. Mainly the users want a fast delivery time, so a short waiting time.

Stock level in the department warehouse

The most important user expectation of an order method is that the products are on stock when the product is needed. When the department warehouse does not have enough stock, there are moments users require materials that have run out. In that case users need to use other materials that are in stock in the department warehouse or they need to borrow the material from another department. That takes time and the quality level of care will decrease. The worst result of not having stock is that the user cannot help the patient and needs to cancel a treatment. The users could not tell how many times this happens in a week or month. But it was easy to make a distinction about the gut feeling of the different specialisms. The nursing departments and the emergency department have the feeling that materials are most often depleted in the weekend and on Monday. They think the reason for this is that there is no supply moment in the weekend, but they have the same demand of care. The outpatient departments said their stocks are often sufficiently supplied.

A good stock level on the hospital departments depends on different aspects. Those aspects were mentioned during the interviews. One of these aspects is the *delivery reliability*. The delivery reliability means the timeliness and completeness of the orders. The users mention that the orders are mostly delivered on the same day. The users on the outpatient departments have the feeling that sometimes the orders are not delivered on Monday. Furthermore, all users have the feeling the delivery time on Monday is higher in comparison with the other days. The users did not say anything about the completeness of the orders. The users said that they do not have any overview if and when the products are delivered. The forms of the delivered orders are not left behind on the department.

Another aspect for a good stock level is *the use of the order cards*. The users now have the feeling they have some control on the order facilities and they have the overview when they order. But the users also came up with disadvantages. The users raised concerns about the high number of people who have responsibilities in the new method. Many people are involved in all processes and that makes the risk on human fault higher. Examples are forgetting to place the order card on the order board or losing cards.

The *reliability of the system* is also an aspect that can promote a good stock level. In the interviews the users mentioned that the system sometimes does not work. In the first few months of the implementation the order boards sometimes ceased to operate or lost their internet connection. The users have the feeling that those errors do not occur very often anymore. Still, the users have the feeling that some cards do not work or the signal of the boards is not sensitive enough. They do not have the overview to see directly that a product is not ordered, they need to observe the card for a couple of days before they notice that there is problem. In the meantime the stocks have already run out. The warehouse employees said they do not have any overview because they deliver the purchase, sterile, and unsterile products separately. They said they have no idea when they are delivering the last products of the day.

Workload

The workload is an important subject for both warehouse employees and hospital department employees. With workload we mean the throughput time per process, both for the logistic staff and departments staff. The *hospital department employees* said they want to spend the least possible time on logistic processes. Their main activity is caring for the patients. The department employees are enthusiastic about the fact that they can order the sales products very easily. It saves a lot of order time because the products are not ordered manually in Oracle anymore. A disadvantage is that the users get no communication of the delivery time of a product. They can only see on the board that the product is ordered, but they do not know when it is going to be delivered. When it takes too long, they will call the purchase department. The disadvantage is that it takes time to call them.

The workload for the *warehouse employees* is determined by the number of orderlines per day. They have the feeling it is not evenly distributed over the weekdays. They feel that the workload on Monday and Friday is much higher. As a consequence all processes are delayed. The deliverers even have the feeling that not all processes are optimally planned. They must wait until all orders of the orange route and the blue route are picked. From that moment they can start with the delivery, most of the time at 11.00 AM. Sometimes they have to start later, because of the higher workload at the picking process.

Technology

Another appointed aspect is the technology. The expectation of the technology is a good human-machine interaction, that means a well working touchscreen, clear windows, and good readability. The users are happy that the order board shows directly on the screen when an order card is placed. On the other hand they said that the touchscreen is not working very well. That makes it difficult to search information of the order afterwards. Also the information provision needs to be accurate. The users are happy the order board shows which order cards are placed. At a glance they can see what is ordered. But in some interviews the users said they do not look at the screen at all.

Communication

The aspect communication means a clear and also available work procedure and evaluation moments. The users want to have a work procedure that is the same for every employee. A work procedure expectation is that the sales products that are ordered without the order board are always delivered at the same point at the department, for example the backoffice, while the sales products that are ordered using the order board will be delivered directly in the department warehouse and not at the department backoffice. In practice, however, often all sales products are delivered to the department's back office. The backoffice employees then have to deliver the products to the warehouse, but they do not always follow the right procedure. One user mentioned that then the fault occurs that one of the backoffice employees of the department will fill the bin with the products, but he or she forgets to remove the card of the order board. And at another department nothing happen with the products because they say they are not allowed to fill the bins by themselves and they also do not know what the procedure is when the bins are filled.

Department warehouse size

The last aspect is the department warehouse size. At some departments there are no problems caused by the warehouse size. The departments that experience problems are departments with the same demand of care in the weekend as during week days. To decrease the risk of running out of stock they have the bin value for three days, because of the weekend. But that is too much for the located warehouses, which results in overflowing closets and boxes. One department even showed a warped closet.

3.6 Critical To Quality (CTQ) flowdown

To get a good insight into the Voice of the Customer, we make a CTQ flowdown. This flowdown includes all project objectives that are mentioned during the interviews.. Figure 3.11 shows the CTQ flowdown we make based on the results of the interviews.

The project objectives are ranked in the second level. The higher up level shows the strategic focal points. The strategic focal points are the overall aim of the project. We come up with two strategic focal points, namely the ***customer satisfaction*** and the ***operational organisation***. We conclude that because the seven project objectives have a good customer satisfaction and a well working operational organisation as main focus.

We translated the strategic focal points into the project objectives. We show these in level 2 of the CTQ flowdown. The project objectives we come up with are: (1) ***response time,*** (2) ***waiting time,*** (3) ***stock level in the department warehouses,*** (4) ***workload,*** (5) ***technology,*** (6) ***communication, and*** (7) ***size of department warehouse***. The aim of all these project objectives is to improve them. Some of the project objectives are split up in more sub-project objectives. We do that because the project objective can be specified by different objectives.

With these project objectives we come up with multiple CTQs. We measure these CTQs to draw a conclusion about the project objectives. We consider the CTQs as KPIs. We come up with 49 KPIs to assess the project objectives. From the interviews, we conclude that the first four project objectives are the most important for the users because these objectives are mentioned in every interview. Furthermore, we consider that the other three project objectives are consequences of the first four project objectives. The project objectives can be determined for multiple KPIs. However, during the interviews the users mostly ask and tell about the ***delivery time of the products, the out-of-stock moments,*** **and** ***the order card and order board errors***. The users conclude that these KPIs have the most influence on the performance of the new order method. The users conclude when the performance of these KPIs are good, the new order method is working well and ensures the department employees can provide good patient care. Because of that, we focus on these three KPIs in this research. Appendix IX shows the measure plan of the remaining KPIs.

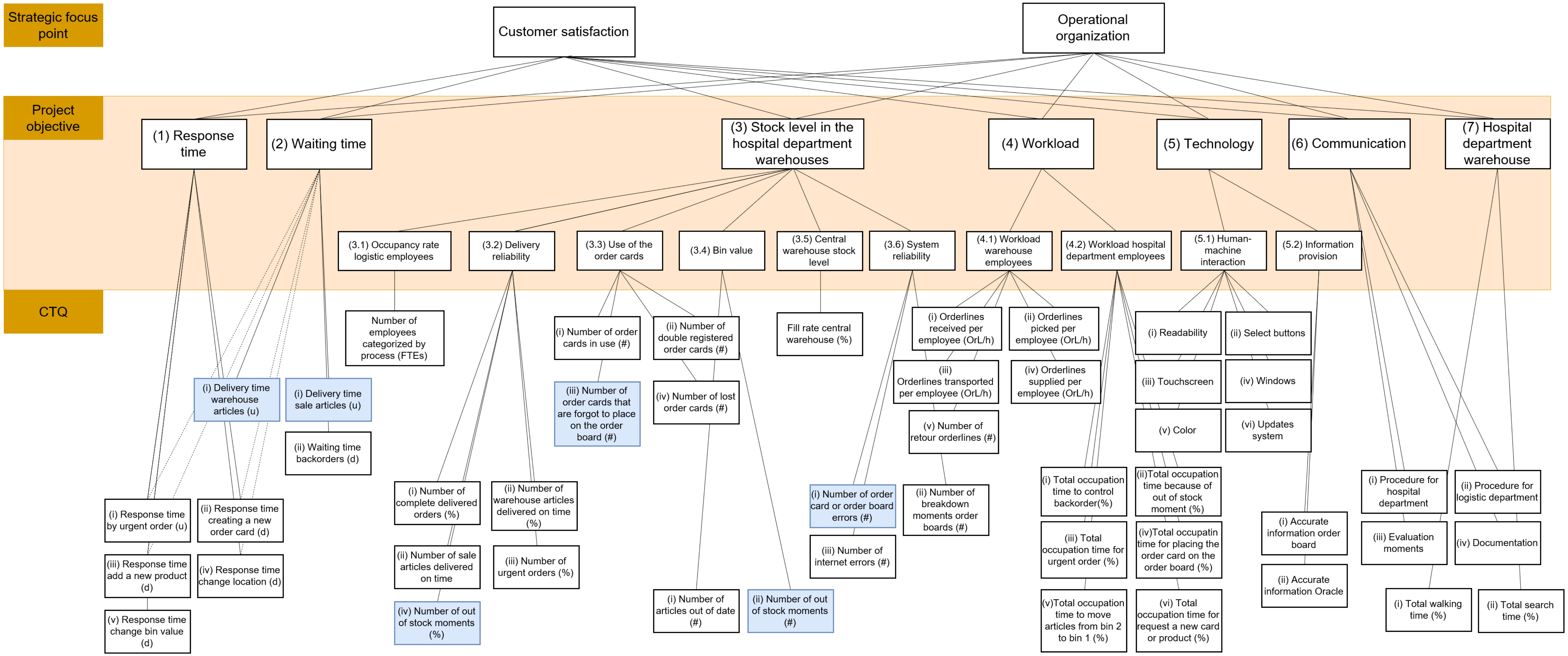

Figure 3.11 The critical to quality flowdown as a result of the interviews. In this paper we discuss the KPIs in the highlighted blocks.

3.7 Conclusion

In this chapter we discussed the current situation of the logistic department at MST and the new order method they introduced in 2016. We define the processes, routes and stakeholders to answer our first research questions:

How is the current situation concerning the new order method organized?
How is the new order method implemented in the hospital, what decisions have been made?
How are the logistic processes organized?

We obtained several results in the define phase. First we explained how the current situation concerning the new order method is organized. The new order method consists of a two bin principle and the Kanban method. The two bin method ensures the First-In-First-Out (FIFO) method. When the first bin is empty, new products are ordered by a Kanban card and the products are moved from the second bin into the first bin. The Kanban cards are placed on the order board. The order boards are read out once every weekday, on that moment the products are ordered. The order boards are read out automatically and electronically.

Concerning to the decisions made during the implementation of the new order method, we found the following:

- The order moments take place at a fixed time on a day
- Every order board is read out once a day, from Monday until Friday
- The departments are assigned to one of four routes, route blue, red, white, green and orange
- Route orange is not delivered by the logistic department
- Route blue, red and white are linked to an elevator
- The users on the department are responsible for ordering products
- The logistic staff is responsible for the picking and delivering process

In the current situation the order boards are read out in the morning.

We derived five different processes in the central warehouse:

- Receiving of the hospital materials
- Storage in the central warehouse
- Picking of orders in the central warehouse
- Transport orders to the hospital
- Supply to departments

The stakeholders are the department staff, the logistic department, the purchase department, external suppliers, and the patient. We mentioned the users of the new order method as the department staff and the logistic staff. In the current situation all these users have their expectations of the new order method. We combined the project expectations in a CTQ flowdown to find the KPIs we can measure in the next phase. The expectations we found are:

- Good response time
- Short waiting time
- Correct stock level in the department warehouses
- Low workload
- Well working technology
- Well organized communication
- Well furnished hospital department warehouse

We determined the project expectations with 49 KPIs. We conclude that the KPIs *delivery time, out-of-stock moments,* and *order card and order board errors* as the most important KPIs. We conclude that because the users tell and ask in the most interviews about these subjects. Because of that, we will focus on these KPIs in this research. Let us know measure the results of these three KPIs.

4. Measure

In chapter 3 we identified the current situation, processes, and developed a critical to quality flowdown. Using this information we derived 49 KPIs. In this chapter, we measure and discuss the results of the KPIs delivery time, out-of-stock moments, and order board or order cards errors. In the interviews these KPIs are mostly mentioned by the users. In our opinion, these KPIs are the most important for the customers. In this research we also measure the results of the remained KPIs of the project objectives (1) response time, (2) waiting time, (3) stock level in the department warehouse, and (4) workload. We show these results in Appendix X. There was not enough time to measure the results of the project objectives (5) technology, (6) communication and (7) size of the department warehouse. Appendix XI contains information on how the results of the technology, communication and size of the department can be measured.

In Section 4.1 we describe how we measure the KPIs. Section 4.2 shows the results of the *delivery time*. In Section 4.3 we discuss the results of the *out-of-stock moments*. Section 4.4 shows the results of the *number of order board or order card errors*. In Section 4.5 we give a conclusion of this chapter.

4.1 Measure method

We use the data from Oracle and Alltrack to measure the KPIs. Oracle contains a lot of order information. The program shows the order numbers, order data, and the products ordered per order. Alltrack contains information about the order cards. Alltrack shows the times when the order cards are placed on the order board, when the products of the order cards are ordered, and when the order cards are removed from the order board.

We make a data warehouse with MySQL to combine and select the data we need to measure a KPI. We use the program MySQL to build the 'skeleton' of the data warehouse, which means an empty data warehouse. To fill this empty data warehouse with data we use the program Spoon. In this program we select the useful data and perform measurements. At the end of the spoon model, we fill the data warehouse tables with the right data. The last step is visualizing the results. With the program Tableau we show the results and carry out more measurements.

Beforehand of this research we know these programs are not installed on the computers of MST. First, the hospital needs to buy these programs to work with it. However, we choose to use these programs because these can quickly measure a lot of data. Furthermore, the hospital does not have a similar program available on their computers.

We exclude the data of early 2016 because the new order method is introduced in January 2016 and we expect that the results are significantly influenced by the fact that the method is new. We select the data of the months November and December of 2016 and January 2017. We select these three months because such a period gives a lot of data, from which we expect accurate results can be obtained.

4.2 Delivery time warehouse and sales products

The delivery time of the warehouse and sales products are relevant to the project objective waiting time. Delivery time is the time interval between the order moment and the delivery moment. We calculate the delivery time for warehouse and sales products separately because the order processes of both types of articles are different.

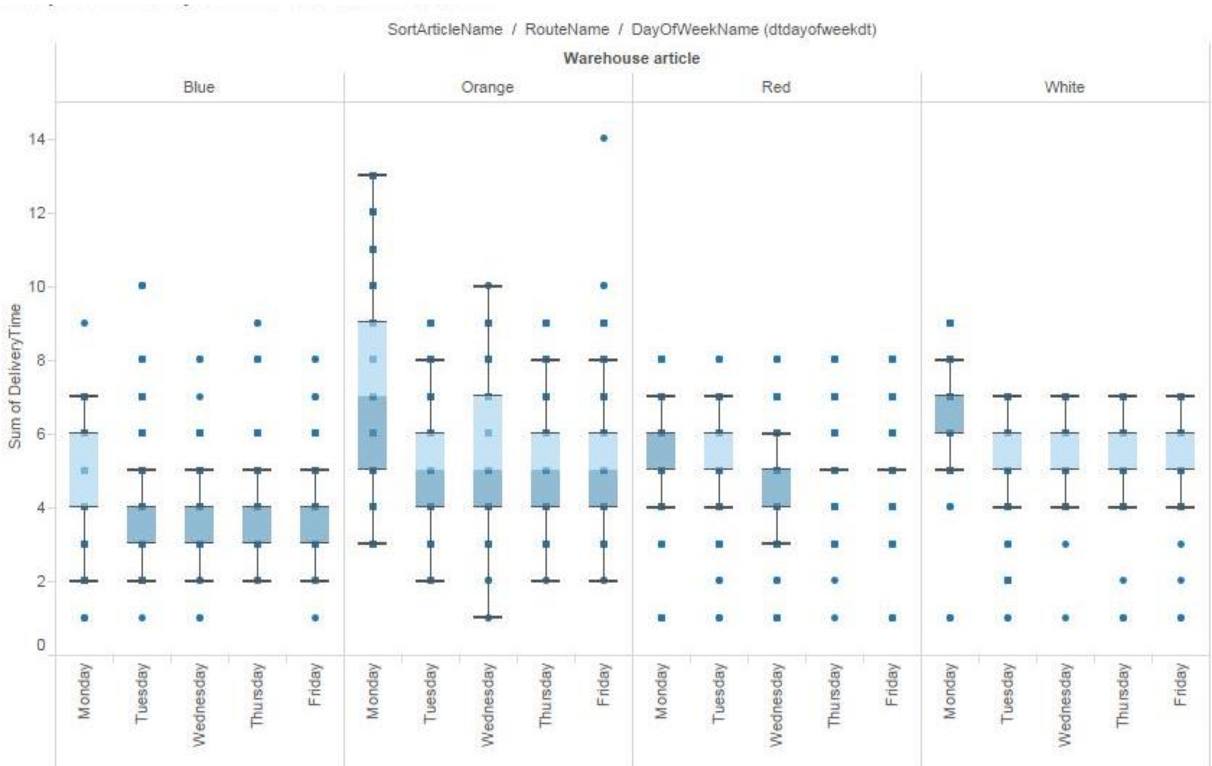

Figure 4.1 Box plots delivery times of warehouse products given for every route and day of week. The delivery times are measured based on the data from Alltrack. The delivery times are given in hours.

First we calculate the delivery time of warehouse products using the data from Alltrack. We measure the time interval between the order moment and the delivery moment of each order card. In the reference period, we find 48,474 data points of warehouse products in Alltrack. Because we find outliers in the data, we conclude it is not valid to use the average value of the delivery time. The outliers may be caused by a system error, incorrect procedure, or an out-of-stock moment in the central warehouse. Therefore, we show the results in box plots. We use the median to draw a conclusion and we use the box plots to give a conclusion of the variance. We observe that the delivery times of the warehouse products are related to the delivery route and delivery day, therefore we decided to calculate the delivery time per route and per weekday. Figure 4.1 shows the results of the warehouse products.

Table 4.1 shows the medians for every route and weekday. We see multiple remarkable results. We conclude that the delivery process of route red, blue, and white are well organized because these routes do not have much variance. We conclude that one or more of the process steps ensures a delay in the delivery times of route red, blue, and white because we observe that the delivery time increases in the same order the routes are being processed. Furthermore, the order process of each route is the same. We conclude that the delivery process of route orange is not well organized because the average delivery times of route orange and the variance is much higher in comparison with the other routes. We conclude that because the products of route orange are picked first and because of that the delivery time cannot be delayed by the other routes. Finally, we observe higher delivery time median on Monday in comparison of the other weekdays. We conclude these values are too high. We conclude that that is not directly caused by the organization of the order process because on Monday the order process is the same as on the other weekdays. We conclude that another factor have an influence on the high delivery time on Monday.

	Monday	Tuesday	Wednesday	Thursday	Friday
Warehouse products					
Route orange (h)	7	5	5	5	5
Route blue (h)	4	4	4	4	4
Route red (h)	6	5	5	5	5
Route white (h)	7	5	5	5	5
Sales products					
Median sales products (h)	54	54	54	124	103

Table 4.1 Calculated medians of the delivery time of warehouse products per route and deliver day. Calculated medians of the delivery time of sales products per order day.

We calculate the delivery time of the sales products with the same method as we use for the calculation of the delivery time of the warehouse products. In the three months, we find 586 data points of sales articles in Alltrack. Again, we observe some outliers in the database. For a sales product, the outlier can also be caused by a higher delivery time of an external supplier. Table 4.1 shows the medians per order day. In our opinion the sales products are delivered quickly. We conclude that the high delivery times at the end of the week are caused by the weekend. Furthermore, we conclude that only a few sales products are ordered by the order boards because of the low number of data points we find.

The delivery time can be expressed in hours, but we can also express it in a timeliness ratio. That means if the products are delivered within the required time. This ratio say something about the required delivery time of the users. In the hospital, requirements about the delivery are composed. The requirement they composed for the warehouse products is that those products needs to be delivered within 12 hours after the order moment. The delivery time of the sales products depends on the delivery time of the external supplier and it is not always possible to have a fixed delivery time from an external supplier. For that reason the composed requirement for the sales products is that when the product is delivered by the external supplier, the central warehouse employees need to deliver the product within 12 hours at the departments.

	Warehouse product	Sales product
Meet the required time	89%	61%
Do not meet the required time	11%	39%

Table 4.2 The total number of products that meet or do not meet the required time in percentage for the warehouse products and sales products. The required times are 8 and 120 hours.

When the new order method was implemented the logistic department composed other requirements for the delivery times for the warehouse products. Nowadays, the required delivery time of warehouse products is on the same day. The order boards are read out in the morning and the articles are delivered in the afternoon before half past four, the end of the workday of warehouse employees. Therefore, we set the required time on 8 hours to calculate the number of warehouse products that are delivered on time. There is an unwritten rule that the sales products need to be delivered in 48 hours, but still the delivery time depends on the external supplier. For that reason we compose the requirement time on five days. In these five days, we take the weekend into account because in the weekend the hospital department can need the products. We assume that when the delivery time of sales products is equal to or higher than 120 hours the delivery does not meet the required time. Table 4.2 shows the results of the average delivery rate.

We observe that 89% of the warehouse products are delivered on time meaning that 11% is not delivered on time because of a suboptimal process or an out-of-stock moment in the central warehouse. We include the outliers in this calculation and because of that we can say that the 11% can also be caused by an out-of-stock moment in the central warehouse. We conclude that the number of warehouse products that are delivered within the required time is high. We conclude that a low number of sales products is delivered within 120 hours, only 61%.

For the warehouse products, we expect that there is a correlation between the delivery time of products and the route. We also expect that there is a correlation between the delivery time and number of ordered products each weekday. To calculate the first correlation we calculate the delivery rates per route. Table 4.3 shows the results of this calculation.

	Blue	Orange	Red	White
Meet the required time	96 %	70 %	93 %	91 %
Do not meet the required time	4 %	30 %	7 %	9 %

Table 4.3 The total number of warehouse products that meet or do not meet the required deliver time per route.

We observe two remarkable results. First of all, we see that many products delivered on route orange are not delivered within 8 hours. From this we conclude the delivery process on route orange is not optimal. Secondly, we observe that a high number of products delivered on route blue, red and white are delivered within 8 hours, however the delivery rates decrease in the same order the delivery routes are being processed. We conclude that the results of route blue, red, and white are good, but we think these results can be improved.

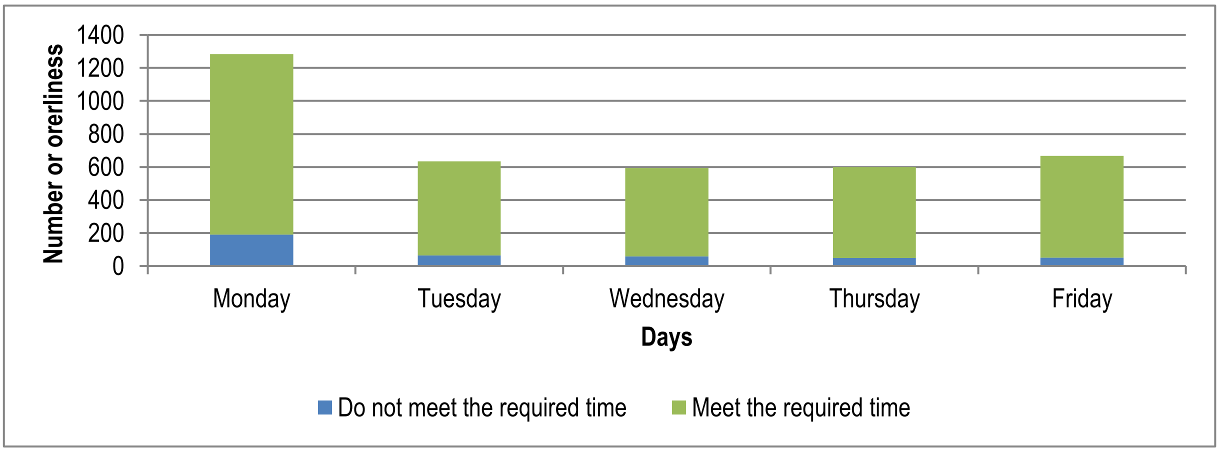

Figure 4.2 The total number of warehouse orderlines per weekday, split up in orderlines that are delivered in the required time (green) and orderlines that are not delivered in the required time (blue).

Figure 4.2 shows the results of the second correlation calculation. We calculate the total number of orderlines per weekday and split them up in orderliness that are delivered on time and orderliness that are not delivered on time. We conclude there is a correlation between the number of ordered products and the number of products that do not meet the required time. When the number of ordered products is high, the number of products that is not delivered on time is also high. We conclude that the order process on Monday is not well organized to prevent the high number of products not delivered within 8 hours. We think this result can be improved.

4.3 Number of out-of-stock moments

It may happen that a product is out-of-stock, meaning a product is not present in the department warehouse. Several aspects may cause an out-of-stock moment, namely a wrong order card procedure, a wrong bin value, a suboptimal delivery process, or an incident. With a wrong order card procedure we mean that the user is not following the correct order procedure, mostly this involves forgetting to place the order card on the order board. With a wrong bin value we mean that the determined stored value of a product in a bin is too low to have enough stock until the next delivery moment. A suboptimal delivery process means that the read out time or delivery moment does not correspond to the consumption on the departments. An incident is an unpredictable situation. An example of an incident is an outbreak of a disease on the department.

In Section 3.2 we explain the order procedure for the hospital department users. During the interviews we concluded that not all the users are placing the order card of bin 1 first and bin 2 second. Because of that it is not valid to calculate how many times the order card of bin 2 is placed in order to determine the number of out-of-stock moments. For this reason, we make the assumption that when both order cards are placed on the other board, the department does not have any stock of that product in their warehouse. The out-of-stock moments were determined based on the data from Alltrack by counting the placing of both cards for one product on the board. Table 4.4 shows the results of this calculation. We observe that when an order card is placed on the order board the probability that it is the first card is 80% and the probability that it is the second card is 20%. We conclude the probability value of the second card is high because every out-of-stock moment is one too many.

The number of card placed on the board	Probability
One card	80 %
Both cards	20 %

Table 4.4 The probability that one or two cards are placed on the order board because of a sub optimal process or wrong bin value

We make some assumptions to measure the out-of-stock moments distributed by the different reasons. The first assumption we make in this measurement is that when both cards are placed within one minute the department users have forgotten to place the card on the order board when the first bin was empty. We assume improper execution of the procedure in this case because the probability that both bins are emptied at the same moment is very low. The second assumption we make in this measurement is that no incidents take place during the reference period. We expect that the probability of an incident is low. We assume all order cards that are placed with a time difference of more than one minute are caused by a wrong bin value or suboptimal process. In the analyse phase we make a distinction between those two causes.

Reason out-of-stock	Percentage
Wrong bin value or suboptimal process	62 %
Wrong procedure	38 %

Table 4.5 Causes of out-of-stock moments in percentage

Table 4.5 shows the result of the reason measurement. We observe that 62% of the out-of-stock moments is caused by a suboptimal process or a wrong bin value and 38% of the out-of-stock moments is caused by a wrong procedure. We conclude that the value of out-of-stock moments that is caused by a wrong procedure is too high. We conclude that not only the logistic process needs to be optimize, but also the ordering process needs to be improved.

We calculate the out-of-stock moments per weekday and per reason.

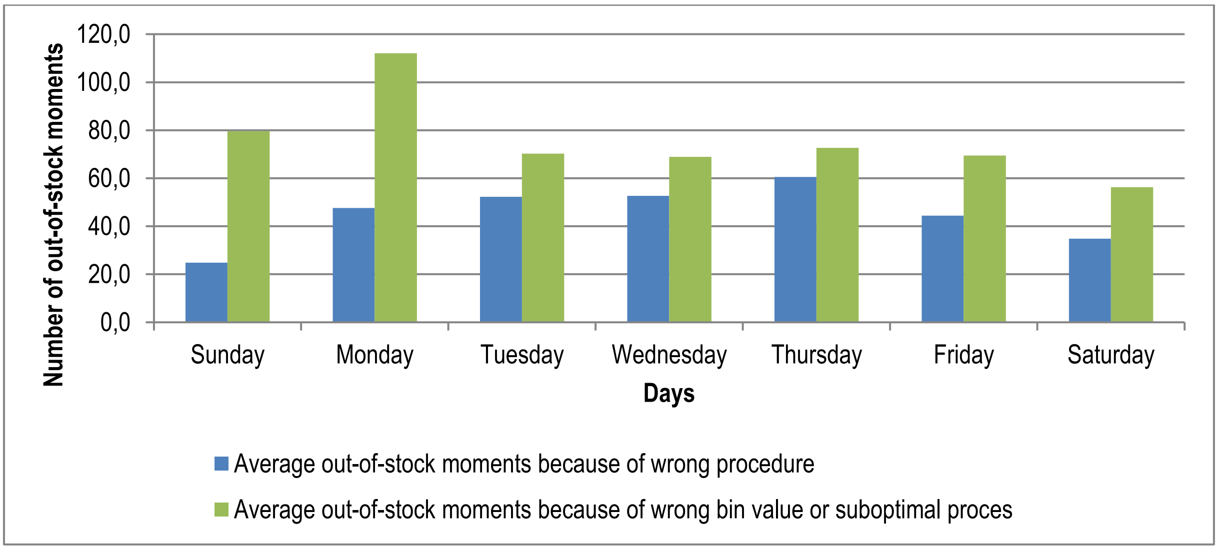

Figure 4.3 Average out-of-stock moments per day caused by a wrong procedure (blue) or caused by a wrong bin value or suboptimal process (green).

Figure 4.3 shows the average number of out-of-stock moments caused by a wrong bin value or suboptimal procedure moments per weekday (green). We observe that every day more than 50 out-of-stock moments occur because of a suboptimal process or a wrong bin value. We conclude this is a high value. Also, most out-of-stock moments occur in the weekend and on Monday. In our view this is caused by the fact the department warehouses are not replenished during the weekend.

Figure 4.3 shows the out-of-stock moments caused by a wrong procedure (blue). We observe more out-of-stock moments caused by a wrong procedure during the weekdays in comparison with the weekend. Also, we observe a peak on Thursday. We conclude that during the working time the most card mistakes happens. During the interviews the users explains that they check the department warehouses on forgotten cards on Thursday. We conclude that department staff check the department warehouse for forgotten cards on Thursday to ensure they have enough products in the weekend and reduce the risk for an out-of-stock moment during the weekend. Because of that, we conclude the peak on Thursday is caused by the weekend. We conclude that the awareness of the work procedure needs to be improved to decrease the out-of-stock moments.

4.4 Number of order cards and order board errors

One of the mistakes that decrease the system reliability is an error in the order card or an error in the order board. We can distinguish errors in the order cards using the data in Alltrack since these cause card status changes that do not normally belong to the cycles. We consider these as real errors. Furthermore, we observe status changes that are uncommon, but can be explained without necessarily involving a broken order card or order board. It may indicate that a card is just not seen by the board because the signal strength of either the order board or the order card is not high enough. But it can also be a single incident. In this measurement we consider this error as a possible error. To be sure it is a real error we will do more research in the analyse part further in the study.

	Percentage
No error	93.7 %
Maybe an error	6.0 %
Error	0.3 %

Table 4.6 The percentage that no error, error or maybe errors occur in the status changes

We use the data from the reference period from Alltrack to determine the errors occurring in the status changes. Table 4.6 shows the results given in percentage. We conclude that in 93.7% of all status changes no errors are detected, in 6.0% an error may be detected and in 0.3% a real error is detected. Based on this data we conclude that the number of errors in the status changes is relatively low.

	Number of order cards
Error	418
Maybe an error	3762

Table 4.7 Total erroneous order cards

We also calculate how many order cards show an error during the time interval. We use the data of the reference period from Alltrack. Table 4.7 shows the results given in percentage. We observe 7,745 order cards are used in the reference period. We conclude 418 (5%) of the order cards show a real error and 3,762 (49%) of the order cards show a possible error. We conclude that this number of erroneous order cards have a significant influence on the system reliability. Especially the number of order cars that show a possible error is high.

The errors can also be caused by the order board. For example the signal of the order board is not properly adjusted. Therefore, we measure the no errors, errors, and possible errors per order board. Appendix XI shows the results of errors per order board. In this results we observe no big errors with the order boards and therefore our conclusion is that the order boards are working well.

4.5 Conclusion

In this chapter we measured the performance of the KPIs to answer the following research questions:

Which KPIs are currently in place and which are relevant to measure the performance of the new order method?
How can these KPIs be measured?
What are the results for each key performance indicator?

In this chapter we discussed the results of the KPIs that give a good picture of the performance of the new order method, namely the *delivery time, out-of-stock moments,* and *order board or order card errors*.

For the delivery time, we conclude that for each route the delivery time can be improved. Especially the results in delivery time of route orange needs an improvement. We conclude that the delivery process of route blue, red, and white is well organized because the variance of the delivery time is not high and most of the warehouse products are delivered on time. We conclude that there is some delay caused by one or more of the process steps of the order process in route blue, red and white because every order process of each route is the same. We conclude that the delivery process of route orange is not well organized because we observe a high median and variance in the delivery time and 30% of the warehouse products are not delivered on time. We conclude that this value is too high. Furthermore, we conclude that the medians of the delivery time are high on Monday because of the higher number of orderliness. We conclude that the order process on Monday needs to be improved.

For the out-of-stock moments we conclude that too many out-of-stock moments occur during the time interval. We found that in 20% of the moments an order card is placed on the order board it is the second card. From this we conclude that many products get out-of-stock in the department warehouses. Furthermore, we observe that 62% of the out-of-stock moments is caused by a wrong bin value or suboptimal process. The other 38% is caused by a wrong procedure. From this we conclude that not only the logistics process but also the ordering process should be improved. We observed that the out-of-stock moments caused by a wrong bin value or suboptimal process occur every day, but are more common in the weekend and on Monday. We suspect this is caused by the fact the logistic employees do not read out the order boards and deliver in the weekend.

The last conclusion we make are conclusion about the number of order card and order board errors. Based on the status changes we conclude that 5% of the order cards show an error and 49% show a possible error. We conclude the system reliability is low because of that. Basis on the status changes we conclude no order board show a low reliability.

In this chapter we measured the results of the KPIs. In the next chapter we carry out a more detailed research. In this chapter we discuss the causes of the results.

5. Analyse

In this chapter we analyse the results of chapter 4. In chapter 4 we measure the results of the KPIs *delivery time, out-of-stock moments,* and *order board or order cards errors.* In this chapter we try to explain some of the results with a cause and effect analysis. In Appendix XIII III we show the results of the analysis of the remaining KPIs. In Section 5.1 we analyse the causes of the delivery time. In Section 5.2 we analyse the causes of the out-of-stock moments, and in Section 5.3 we analyse the causes of the number of order card and order board errors. Finally, we give a conclusion of chapter 5 in Section 5.6.

5.1 Delivery time

In chapter 4 we discuss the delivery time of warehouse and sales products. We analyse the delivery time of the warehouse and sales products separately.

5.1.1 Delivery time warehouse products

In Section 4.2 we conclude that the delivery process of route blue, red, and white is well organized because the variance of the delivery time is not high and most of the warehouse products are delivered on time. We conclude that there is some delay caused by one or more of the process steps of the order process in route blue, red, and white, because the medians of delivery time increases in order of these routes. We also conclude that the delivery process of route orange is not well organized because we observe a high median and variance and 30% of the warehouse products are not delivered on time. Furthermore, we observe that the medians of the delivery time are high on Monday and we conclude that this is because of the higher number of orderlines on Monday compared to the rest of the weekdays.

Delay in delivery time route blue, red and white

The first effects we analyse are the variance and the medians of the delivery times of route blue, red and white. We observe a delay in order the delivery routes are processed. We conclude this is caused by one or more steps in the order process because the order processes for every route are the same. The delay is not caused by for example an extra process step. The first cause we identify is that the first read out moment of the order board is not matching with the starting time of the logistic employees. The first read out moment is at 7.00 AM and the starting time of the logistics employees is 8.00 AM. The orders of the first read out moments already start with a delay. The second read out moment is at 7.45 AM. Because the orders of the first read out moment are picked first, the orders of the second read out moment also start with a delay.

	Monday	Tuesday	Wednesday	Thursday	Friday
Orange sterile (HH:mm)	2:29	1:21	1:26	1:18	1:34
Blue sterile (HH:mm)	1:50	0:53	0:49	0:49	0:49
Red sterile (HH:mm)	1:52	0:58	0:59	0:58	1:04
White sterile (HH:mm)	0:44	0:24	0:19	0:25	0:25
Orange unsterile (HH:mm)	4:33	2:36	2:40	2:29	2:55
Blue unsterile (HH:mm)	6:21	3:14	2:48	3:13	2:56
Red unsterile (HH:mm)	4:48	2:20	2:22	2:26	2:43
White unsterile (HH:mm)	2:38	1:38	1:17	1:26	1:24

Table 5.1 Average picking time per route per weekday given in hours and minutes

Another cause that can ensures a delay is one of other process steps. First, we measure the processing time of the picking process per route with the data from Oracle. Table 5.1 shows the results of this measurement. The time is measured with the assumption one person is picking all orderlines. Commonly three warehouse employees are picking the unsterile orderlines and two warehouse employees are picking the sterile orderlines. We use this information to make a conclusion.

We observe that on Monday the picking process of route orange, blue, and red takes more time than the time interval between the read out moments. We conclude that this ensures a delay in the delivery time. On the other weekdays we observe that the picking process scarcely takes more time than the time interval between the read out moments. From this we conclude that on these weekdays the delay in the delivery time is not caused by the picking process.

The next step is to transport the orders. In is difficult to measure the throughput time of a transporter during the day. We assume that the transportation time from the central warehouse into the hospital takes 17 minutes, which is the average of the transportation times measured by several employees. The transporters can only transport six carts at a time. The number of carts depends on what products are ordered, for example large or small products. Because of that it is difficult to measure how many carts are needed for one route. We assume a maximum of 12 carts for one route, and based on that we conclude that the maximum transportation time of one route takes 34 minutes. This is lower that the time intervals between read out moments, we can conclude that the transportation process does not lead to a delay in delivery time. In this conclusion we assume that the transport employees give priority to the products ordered by the order boards instead of the sales products.

The last process is the delivery process. We measure the average delivery time of route blue, red, and white with the data from Oracle. During the reference period commonly three logistic employees were delivering the orders, however the data given in Table 5.2 is calculated for the delivery by only one employee to account for a varying number of delivery employees. To obtain the average delivery time per route the calculated times are divided by the number of employees delivering that route. We observe that on Monday the average delivery times of route blue and red are twice as long as the interval time between the read out moments when delivery is done by three employees. We observe route white exceeds the interval time between the read out moments on Monday but not on the other weekdays. We conclude this is caused by the high number of orderlines because of the weekend. In the weekend no products are ordered and delivered. On the other weekdays, the average delivery time of route blue and red is higher than the time interval between the read out moments. We conclude this is caused by the higher number of orderlines requiring more walking time between the departments and the basement. According to our measurements 40% of the delivery time is walking time. We conclude the walking time is not preventable, but we think the walking time can be decreased. We observed that the walking time is caused by the fact the employees need to walk from the basement to the departments, from department to department and from the last department to the basement. We think that the walking time between the departments can be decreased because now the sales, sterile and unsterile products are delivered separately.

	Monday	Tuesday	Wednesday	Thursday	Friday
Average orderlines blue (#)	485	242	215	236	222
Average deliver time blue (h)	8:10	4:04	3:37	3:59	3:44
Average orderlines red (#)	413	206	209	210	236
Average deliver time red (h)	6:58	3:27	3:31	3:32	3:58
Average orderlines white (#)	198	118	92	110	109
Average deliver time white (h)	3:20	1:59	1:33	1:51	1:49

Table 5.2 Average orderlines and deliver time per route and per weekday calculated for one person

Variance route blue, red, and white

Secondly, we discuss the variance in delivery time. In Section 4.2 we show the variance in delivery time per route and per day. We observe some variance in the three routes, but the variance is not remarkably high. On Monday the variance is higher in comparison with the other weekdays, the variances on the other weekdays are comparable to each other. We conclude that a stable variance is caused by two aspects: the number of employees working per process and the number of ordered orderlines. In Section 4.2, we observe a correlation between the average total number of orderlines and the number of orders that are delivered on time. We conclude that when the number of orderlines is higher, the variance of the delivery time is also higher. Furthermore, we conclude that the variance is higher when the number of employees working on the delivery process is lower than 3 and the number of orderliness of the route stays the same.

Median and variance delivery time route orange

Above, we observe the results of route blue, red, and white. We analyse route orange separately because this route is only picked and transported by the logistic department. Delivery to the department warehouses is done by a different department, the Transferium. We show the results of the delivery time of route orange in Section 4.2. The delivery time medians and variance per day are much higher in comparison with the other routes. We conclude above that the first read out moment does not match with the starting time of the warehouse employees. The first read out moment is for the orders of route orange. Because of that we conclude that the delivery time of route orange is delayed because of the read out moment. The delay is not influenced by the other order route because the orders of route orange are picked first. Furthermore, we observe three other causes for the results: the number of orderlines, the route plan, and the number of delivery employees.

	Orange	Blue	Red	White
Monday	460	485	413	198
Tuesday	257	242	206	118
Wednesday	268	215	209	92
Thursday	247	236	210	110
Friday	292	222	236	109

Table 5.3 The average number of orderliness per route per day

First we analyse the average number of orderlines per day of route orange and compare these with the other routes using the data from Oracle. Table 5.3 shows that the average number of orderlines for route orange are only slightly higher than for the other routes. The difference is too small to account for the increased delivery times. From this we conclude that the number of orderlines is not the cause of the difference in performance of route orange compared to the other routes.

Besides the number of orderlines, we assess the number of employees working on the delivery process and the delivery plan for route orange. We find that often only one delivery employee per day is delivering the products to

Figure 5.1 Box plots of delivery time per department of the routes orange and blue given in hours

the department warehouses on route orange. Besides that, delivery of route orange is done horizontally. We can image both aspects can have influence on the walking times between the department warehouses and thus have influence on the delivery time. We analyse these aspects by comparing the delivery time box plots per department of route orange and blue. Figure 5.1 shows the results of this measurement. The first 5 departments are linked to route orange and the other 9 departments are linked to route blue. We observe a significant difference in variance between the departments of route orange and route blue. The delivery times of the departments of route blue all have the same median and variance and while a remarkable difference in medians and variances between the departments of route orange is observed. Route blue is delivered by three employees and route orange by one employee. Furthermore the route plan is different, but all other factors are the same. We conclude that the number of employees have influence on the median and variance of the delivery times because of the difference in the results. We also expect that the route plan has an influence in the results because horizontal delivery causes more walking time. We conclude that the difference is high and we think this can be improved.

5.1.2 Delivery time of sales products

In Section 4.2 we conclude that that the average delivery time of the sales products on Monday, Tuesday, and Wednesday is 54 hours. At the end of the week the delivery time increases because of the weekend. We conclude that 61% of the sales products are delivered within 5 days. We conclude that many external suppliers have a high delivery time and that ensures a low rate of sales products that are delivered on time.

We observe that the delivery time strongly depends on the delivery time of the external supplier. Every external supplier has their own stock system, for example the external supplier may have a high stock level of a product or has no stock of the product, but manufactures the product when it is ordered. Therefore we consider it is important to analyse the delivery time per product. We measure this with the data from Alltrack. We observe 586 orderlines and 249 sales products that are ordered in the analysed time interval. We show the results in Appendix XIV. Firstly, we conclude that the sales products are not ordered often during the time interval, the highest number is 11 orders for a product in the three months. We observe 105 sales products are ordered once during the time interval. We observe 142 of the 249 products have an average delivery time below 120 hours, so five days. The other 107 products have an average delivery time over 120 hours. The delivery times varies between 120 and 652 hours, meaning waiting times up to one month are observed. We conclude that delivery times of external suppliers are high and we conclude the central warehouse cannot guarantee that the sales products are delivered on time.

5.2 Out-of-stock moments

In chapter 4 we discuss the out-of-stock moments. In this section we make a distinction between two types of out-of-stock moments, namely a wrong procedure and a wrong bin value or suboptimal process. In this section we will discuss the causes in more detail to conclude what the main causes are.

5.2.1 Wrong bin value or suboptimal process

In this section we carry out multiple analyses. First we analyse the number of out-of-stock moments per department and per weekday caused by a wrong bin value or suboptimal process. Appendix XVV shows the results of this measurement. For the measurement we use the data from Alltrack. We observe a low average number of out-of-stock moments at the outpatient departments. We observe on the nursing departments and the emergency department more out-of-stock moments and we observe a peak on Monday and in the weekend. We suspect that the departments that are open 24 hours every day have many out-of-stock moments because in the weekend no products are delivered and on the weekdays the products are delivered only once while the need for materials is constant during the week for these departments. Furthermore the departments that are open 24 hours show a high number of out-of-stock moments during the weekdays. In our opinion, this value is too high.

We observed out-of-stock moments can be caused by two reasons. When the out-of-stock moments happens only with a couple of products, we assume the bin value of these products needs to be increased at that department. When the out-of-stock moments happens with many different products, we assume that the order and deliver process is not optimal and it needs to be changed. With the following calculation we want to determine if the bin value is not correct or the process needs to optimized. We measure the total number of products that run out-of-stock per department during the reference period. The measurement is performed only for the weekdays because there is no read out or delivery of orders in the weekend. We already conclude that the out-of-stock moments in the weekend are caused by a suboptimal process. Appendix XVII shows the results of the measurement. We observe many different products run out-of-stock per department. We observe the largest number of different products run out-of-stock on the nursing and emergency departments. However, at these departments also a higher number of different products are ordered. We conclude that the number of different products that get out-of-stock for the most departments is too high to solve with a bin value change.

We analyse the out-of-stock moments for the different products to determine their causes. As mentioned, we expect that when a product gets out-of-stock often in comparison with the other products of the department, the bin value is still not correct. When the product gets out-of-stock a few times the out-of-stock moment may be caused by a suboptimal process. And when the product gets out-of-stock only once it is caused by an incident. We measure the number of times the different products get out-of-stock with the data from Alltrack, again only including the weekday data because in the weekend the order process is not activated. We observe 1610 different products get out-of-stock on all departments together during the reference period. We observe 5% get out-of-stock at least 10 times. We conclude the bin value of these products needs to increase. We observe 39% of the products get out-of-stock once. We could say this is caused by incidents, but on the other hand these are too many incidents to ignore. We conclude, based on the results, the demand of products strongly difference per time period and is difficult to predict.

The last aspect we analyse is the time of the out-of-stock moments. We measure this aspect to observe if there is a correlation between the time and the out-of-stock moments. Therefore we divided the day in time intervals of one hour. For example hour 0 is the time interval between 00.00 AM and 00:59 AM.

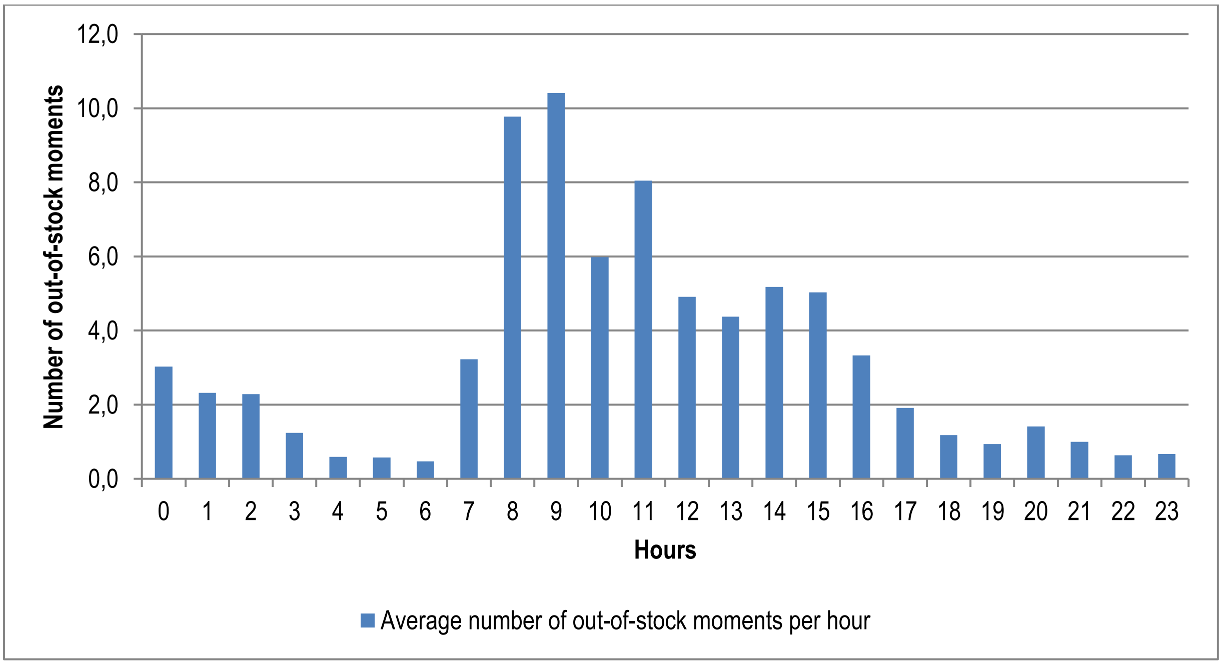

Figure 5.2 The average number of out-of-stock moments caused by wrong procedure or wrong bin value per hour

Figure 5.2 shows the overall results of this analysis. In this figure we show the average number of out-of-stock moments for all departments. We observe a peak in the time intervals of hours 8 and 9. In these time intervals the order boards are read out. We suggest this peak is caused by the fact the working day starts, new patients come arrive and the nurses are picking many products to start the treatments. We conclude that it is a good decision to read out the order boards in the morning. Furthermore, we observe out-of-stock moments during all time intervals and most often the out-of-stock moments are taking place between 8.00 AM and 17.00 PM. We conclude that the most out-of-stock moments take place during the work day.

5.2.2 Wrong procedure

The other cause of an out-of-stock moment is a wrong procedure. In Section 4.3 we discuss what we mean with a wrong procedure and how we measure the number of out-of-stock moments caused by a wrong procedure. We conclude that 38% of the out-of-stock moments is caused by a wrong procedure.

We expect that the users carry out the wrong procedure because they are taking care of a patient and they forget to place the order card on the order board. We analyse if there is a correlation between the total number of placed order cards and the number of out-of-stock moments caused by a wrong procedure per department. Appendix XVIIII shows the results of this measurement. We give the comparison with a ratio calculation. We observe the highest number of cards are placed on the nursing departments and the emergency departments. We conclude on these departments the patients need a lot of care and therefore many products are needed. However, we observe no correlation between the total number of placed cards and the number of out-of-stock moments caused by a wrong procedure. We conclude the number of out-of-stock moments caused by a wrong procedure is not related on how many products are ordered by a department.

5.3 Number of order cards and order board errors

The next subject we discuss is the number of order cards and order boards errors.

In Section 4.4 we make a distinction between status changes that show no errors, possible errors, and errors. First we discuss the status changes we indicate as errors. These cards show status changes that are not programmed in advance. We conclude these cards decrease the system reliability. In Section 4.4 we find 418 order cards, 5% of all order cards, which show a real error at least once. This decrease the system reliability. We relate such errors to malfunctioning of the card and we advise the hospital to destroy the card and create a new order card for the product.

Next, we discuss the possible errors. For these errors, we consider two causes, namely an error in the order card or an error in the order board. Every order card sends a signal to the order board. These signals are very strong or weak depending on the card quality. We observe sometimes the order board receives the signal of an order card with a too strong signal when the order card is still on the product location. The signal strength fluctuates and because of that the order board can also lose the signal with an order card that is still on the product location again. When the signal is very weak, at some moment the board receive the signal, but on another moment it can happen that the order board does not receive the signal. Both situations results in a reverse status order. However, these status changes can occur without an error. We measure per order card the number of times these status changes occur in Alltrack during the selected time interval. When the status changes do not occur often, we assume that these changes are incidents. Appendix XVIII shows the order cards that show an possible error frequently. We conclude that 74 order cards are not working properly. We conclude that these order cards decrease the system reliability.

On the other hand also the order board can cause errors. The order board also sends a signal to determine if there are order cards placed on the order board. This signal can be too strong or too weak. It is possible to adjust the signal manually. A too strong or too weak signal causes the same problems that can occur with an order card with a too strong or too weak signal. In Section 4.4 we conclude the order board do not show any errors. We conclude this based on the many times the order boards show an error. Now, we compare the number of errors with the number of no errors. We do not include the order cards we are sure are broken in this measurement because for these cases we know the order cards are the cause of the error. We measure the total number of status changes we registered as possible errors per order board. We observe two types of status changes that may be an error of the board. One is likely to be caused by a too low signal while the other is likely to be caused by a too strong signal. We compare these status changes with the normal status changes to draw a conclusion on the order boards. Appendix XVIIIIX shows the results of this measurement. As you can see the order boards P-Intg and V-E5 MDLS have a high ratio value in one of the two errors, 89% and 81% respectively. We observe no other remarkable high ratio values in the results. We conclude that the system reliability of these order board may be low. However, since these errors can also be caused by card errors further assessment of the boards is required after replacing order cards with high error rates to obtain more reliable information on the order board errors.

5.6 Conclusion

In this chapter we analyse the causes of the results to answer the research question:

What is (are) the main problem(s) of the current situation and what is (are) the root cause(s) of the problem(s)?

Here, we analyse the effects and causes of the KPIs *delivery time, out-of-stock moments,* and n*umber of order cards and order board errors*. We observe multiple small and large causes. Overall, we conclude the causes are system, behaviour, and planning causes.

For the first KPI, delivery time of warehouse products, we found multiple causes of the effects. We conclude that the first read out moment of the order board is not equal to the starting time of the logistic employees. Furthermore, we conclude that on Monday the time interval between the read out moments is not equal to throughput time of the picking process. Because of that the orders need to wait before they can be picked by the logistic employees. We conclude this waiting time is non-added value and can be decreased. For route red and blue, we conclude that the delivery throughput time is higher than the time interval between the read out moments. This is mainly due by the walking time, the delivery throughput time consist for 40% of walking time. We conclude this walking time can be decreased by decreasing the walking time between the departments. We conclude that the variance of route blue, red, and white is low because three employees deliver the products. We conclude that the variance and median of route orange are high because one employee delivers the products and the route plan involves horizontal transportation. We conclude that these aspects ensures more walking time in comparison with a vertical route plan.

The cause of the results of the delivery time of sales products is the delivery time of external suppliers. We conclude that for some products the delivery time is high and because of that the hospital cannot guarantee the sales product is delivered on time.

The next KPI involves the out-of-stock moments. We mention two types of out-of-stock moments: out-of-stock moments because of a wrong bin value or a suboptimal process. The out-of-stock moments caused by a wrong bin value or suboptimal process are mostly caused by a suboptimal process because many different products get out-of-stock. To solve this problem the hospital cannot increase all bin values. We observed that 39% of the products that got out-of-stock, got out of stock only once during the time interval. From this we conclude the demand of care is unpredictable. Furthermore we conclude that 5% of the products that got out-of-stock is caused by a wrong bin value. We conclude the bin values of the products can be increased to decrease the out-of-stock problem. We conclude that the most out-of-stock moments take place in the weekend and on nursing and emergency departments. We conclude that this is caused by a suboptimal process. The order processes of the logistic department are not correctly linked to the openings hours of these departments.

For the out-of-stock moments caused by a wrong procedure we did not find a correlation between the total number of placed cards and the number of out-of-stock moments caused by a wrong procedure. This suggests that there is a variation in how well the order procedure is followed. We conclude that possibly not all users are aware of the correct order procedure. The behaviour of the users need to change to lower the number of the out-of-stock moments.

The last KPI we analysed is the number of order cards and order board errors. We conclude that 418 order cards show a real error and this decreases the system reliability. Furthermore, we conclude that 74 order cards show a possible error, which also decreases the system reliability. From the order boards, we conclude that the order boards P-Intg and V-E5 MDLS show many errors. We conclude that the signal of the order board may be too low or too high, which would decrease the system reliability. This, however, needs further assessments after replacing the malfunctioning order cards to obtain more definite results.

In this chapter we found the main causes of the effects. Let us now find the solutions to improve the effects. In chapter 6 we discuss the improvements.

6. Improve

This chapter describes the fourth phase of the DMAIC cycle, the improve phase. This phase follows the define, measure, and analyse phases. In this phase we propose the solutions and improvements for the problems. In this research we focus on the assessment of the new order method. Therefore, the aim focus is to define, measure, and analyse the performance. We qualitatively analyse the suggested improvements, however full a quantitative analysis is outside the scope of this research. In this chapter we discuss the solutions for the KPIs *delivery time, out-of-stock moments* and *order card and order board errors.* In Section 6.1 we discuss the ideal situation per KPI. Section 6.2 shows the possible and best solutions. In Section 6.3 we give more detail about some solutions and in Section 6.4 we come up with an implementation plan. We end this chapter with a conclusion in Section 6.5. In Appendix XX we discuss six other solutions to solve the problems of the remaining KPIs.

6.1 Ideal situation

Per KPI we explain the ideal situation. With the information of the other chapters and the ideal situation we come up with solutions to solve the problems and optimize the process.

Delivery time warehouse and sales products

In the ideal situation the delivery time is equal to the execution time. With execution time we mean the time the orders are read out, picked, transported, and delivered. In case of the sales products, the delivery time of the external supplier is also execution time. The execution time is the throughput time of all processes that are needed for the delivery. Waiting time between the processes caused by a delay of other processes has no added value to the process. Therefore, we want to prevent waiting time to occur.

Out-of-stock moments

In the ideal situation there are no out-of-stock moments in the department warehouses. That means there is always enough stock for the department staff and they do not need to take at other departments. The ideal situation is that the bin value is sufficient and the order process is well organized so that the department has enough stock between the two delivery moments. However, the bin value and process needs to be determined correctly to prevent that products expire or the process adds no value.

Number of order card and order board errors

In the ideal situation no order card or order board errors occur. When one of these technologies show an error, the performance is not correct. To get the ideal situation all errors need to be tackled directly when these appear.

6.2 Solutions

Above we discuss the ideal situation per KPI. The next step is to brainstorm on the possible solutions. After that, it is important to analyse what the best solution is. In this chapter we discuss possible solutions for every KPI and decide on the best solutions.

6.2.1 Delivery time

The delivery time is the time interval between the order moment and the delivery moment. In this section we discuss the solutions to decrease the delivery times.

I. *<u>Determine the order moments on the workload</u>*

In Section 5.1 we observe the delivery is delayed because of the read out times of the order boards. Currently, the first order boards are read out at 7.00 AM every day and the second read out moment is at 7.45 AM. However, the order picking process starts at 8.00 AM. Furthermore, the time interval between the read out times is not always equal to the throughput time of the picking process. To decrease the waiting time of orders we conclude that the read out times need to be determined based on the starting time of the logistic employees and the throughput times of the picking process.

Therefore we develop a new order schedule. The schedule is based on the starting time of the logistic employees and the throughput times of the picking process. This process is the first step in the order and delivery process.

	Monday	Tuesday	Wednesday	Thursday	Friday
Orange	07:30	07:30	07:30	07:30	07:30
Blue	8:45	8:15	8:15	8:15	8:15
Red	9:45	8:45	8:45	8:45	8:45
White	10:45	9:30	9:30	9:30	9:30

Table 6.1 New read out moments based on the workload

Table 6.1 shows the schedule of the read out moments. The first read out moment is at 7.30 because it takes 15 minutes before the orders are printed in the backoffice. One employee of the backoffice starts before 8.00 AM and can sort the orders. That means at 8.00 AM the orders are ready to pick. In the white route we take the morning break of 15 minutes into account. We advise the hospital to check these read out time frequently. These checks should also include verification whether the time interval between the read out moments is equal to the average throughput times of the picking process.

II. *Combine sterile, unsterile, and sales products on one cart*

In Section 5.1 we conclude that the delay in delivery time is caused by the walking time of the delivery employees. The walking time is the time it takes to move a cart between the basement and the department, and from one department to the next department.

We conclude that walking time from the basement to the department and back is unavoidable. We conclude that the walking time between the departments can be decreased. We observe that the sterile, unsterile, and sales products are delivered separately. That means that a logistic employee delivers at least three times per day at one department. Our solution is to combine the three kinds of products on one cart. This reduces the number of delivery moments per department and may also decrease the walking time between departments since fewer products of different departments will be packed onto a single. We suggest this will reduce the total walking time.

Another benefit of this solution is that all products of one department are delivered at the same time. The delivery employees know they are the only one who are delivering at that department that day. After the delivery they can check if products are not delivered or if other mistakes occur. This solution gives the delivery employees a better overview.

III. *Remove the departments with an order board from route orange and include these in route blue, red, and white*

In Section 5.1 we conclude that the delivery time of the products of route orange is higher in comparison with the other routes. We conclude that this is caused because the products are delivered horizontally and by only one person. We found three solutions to decrease the delivery time of route orange.

The first solution is to read out the different order boards of route orange at different times and combine them with the other routes. That means that, for example, two orders boards of route orange are read out and ordered with route blue, two order boards of route orange are read out and ordered with route red, and one order board of route orange is read out and ordered with route white. We expect the delivery time of these products will decrease because the order times are later in time. The disadvantages of this solution is that the logistic department needs to transport the products to the transferium three times instead of one time. We conclude that this increases the waste in the order process.

The second solution is that the staff of the transferium replenishes the department warehouses with more employees. In this solution the order boards of this route are read out at the same time. When they delivery with more employees at the same time, the delivery time will decrease.

The third solution is to remove the departments with an order board from route orange and involve these in route blue, red, and white. We observe that the carts of route orange do not need any additional treatment. The carts are transported to transferium and from there the carts are directly transported into the hospital. In our opinion, this ensures extra workload and more waiting time. In our solution, the orders of the orange departments with an order board will be combined with the other routes and are delivered on the same time. Each department will be linked to the closest elevator of route blue, red, or white. We expect the median and variance of the delivery time of the orange department will decrease. This solution may increase the delivery time of the other routes, however this is compensated by the reduced delivery via route orange.

For the first and third solutions we observe another advantage. In both solutions the time interval between the order moments of the orange departments will increase. Because of that, more order cards can be read out. Because we expect the delivery time of these departments will improve, the number of out-of-stock moments will decrease.

Department third floor	Route	Average number of placed cards in 24 hours
ICC A (TIC)	Blue	28.2
EHH	White	18.2
CCU	White	
ICC C	White	20.7
ICC D	Blue	21.9
ICC E	Red	22.4

Table 6.2 Average number of placed cards in 24 hours on the departments of route orange during the reference period

In our opinion, the best solution is to remove the departments with an order board from route orange and include these in route blue, red, and white. That means route orange will only continue for the orders of the operating rooms. We add the departments of the third floor to the closest elevator/route. Table 6.2 shows the schedule we make. The departments EEH and CCU are located on the same location, are delivered on the same time and are payed by the same department. Because of that we combine these departments. Furthermore, the table shows the average number of placed cards per day and per department. This result shows what extra workload the logistic department can expect. We expect that the delivery times decrease and at the end the extra workload for the logistic department is lower than the original workload that the orange department now has.

IV. *<u>Determine the order moments based on the openings hours of the hospital departments</u>*

To decrease the delivery times, another solution is to determine the order moments based on the openings hours of the hospital departments. The nursing and emergency departments are open 24 hours per day, also during the weekend. The outpatient departments are open from 8.00 AM until 5.00 PM on weekdays, and are closed during the weekend. For the outpatient departments, we conclude that the order cards are only placed between 8.00 AM and 5.00 PM. We think the order boards of these departments can also be read out at the end of the working day. The orders will be picked directly and can be delivered the next day directly in the morning. This way the outpatient department have a lower delivery time, without missing any products because they do not place order cards on the order board after 5.00 PM. Furthermore, delivery employees can start delivering products immediately without having to wait for the order picking process in the morning.

The other departments also benefits from this solution. Because the outpatient departments do not have to be taken into account the throughput times of the processes will decrease. However, this solution does involve a change the starting and end time of the logistic employees. We find 12 departments that only place order cards during the daytime. These departments are:

Behandelpoli	*Poli Dermatologie*	*Poli MDL/Endoscopie*
Dagbehandeling	*Poli Interne Geneeskunde*	*Poli Mondkaak*
Gipskamer	*Poli KNO*	*Poli Neurologie*
Poli Cardio/Cardiochirurgie	*Poli Longgeneeskunde*	*Poli Reumatologie*

Route	Average number of placed cards on the out-patient departments within 24 hours
Orange	-
Blue	23.3
Red	38.0
White	31.0

Table 6.3 Average number of placed cards in 24 hours on the out-patient departments per route during the reference period

Table 6.3 shows the average number of placed cards on the 12 departments per route. With this information, we expect that when two logistic employees are picking these products the picking time will be one hour. We advise the hospital to read out the boards of the out-patient departments at 4.00 PM, because of that the last logistic employee can finish their work at 5.30 PM.

6.2.2 Out-of-stock moments

The out-of-stock moments are the moments that there are no products on stock in the department warehouse. In Section 5.2 we conclude that a part of the out-of-stock moments is caused by the fact the users forgot to place the cards. They are following the wrong procedure. We conclude that a large number of the out-of-stock moments is caused by a suboptimal procedure. And we conclude that some out-of-stock moments are caused by a wrong bin value. In this section we discuss multiple solutions to decrease the out-of-stock moments.

V. *Read out the order boards and deliver the products in the weekend*

We conclude that the most out-of-stock moments occur in the weekend. We conclude that the nursing and emergency departments are open 24 hours and seven days per week. Over the year, the department staff try to determine the bin value for three days to have enough stock over the weekend. However, we still observe out-of-stock moments. Because the department warehouses are not very big there is a limit to increasing the bin value. Because of that we conclude the logistic department needs to read out the order boards and deliver products at the nursing and emergency departments in the weekend.

I. *Determine the order moments on the workload*

This solution is mention above, but we conclude this solution can also solve the out-of-stock problem. The aim of the order moments is to include as many order cards as possible. In Section 5.1 we conclude multiple aspects that cause a delay in the processes. One of these aspects is the read out moments, the moments the order boards are ordering the products that are linked to the placed cards. Currently, the first order boards are read out at 7.00 AM every day and the second read out moment is at 7.45 AM. Although, the order picking process starts at 8.00 AM. We expect when the read out moments are determined considering the picking throughput time, more order cards can be read out and ordered. We expect that this improves the efficiency of the order process and causes a reduction in out-of-stock moments. The details are discuss above.

VI. ***Determine the read out moments based on the demand***

In Section 2.2.4 we explain the Kanban method. We observe that the new order method is a type of the Kanban method with the difference that the ordering process is not triggered immediately as the card is placed. The used system has fixed read out times to trigger to order process. Since the departments also use the two-bin method, placing of the order card does not immediately mean that the department has no stock because there are two order cards available per product. Nevertheless, we conclude the fixed read out times increase the risk of out-of-stock moments.

Another rule of the Kanban method is that the demand of the customer needs to be stable. In Section 5.2 we conclude that the demand of products on the departments is highly variable. We observe three solutions to solve this problem. The first solution is that the products are ordered directly when the order card is placed on the order board, like the Kanban method originally dictates. The second solution is to read out the order board when a certain amount of order cards are placed on that order board. The last solution we observe is to maintain the fixed read out moments, but determine based on the demand of hospital department how often the order boards are read out per day.

The first two solutions are working with variable order moments. The third solution works with fixed order moments. We conclude that the first solution is not efficient. In this case we will start the process per product. That takes a lot of time because many products are ordered per day. We think it is more efficient to combine the different products per department and pick and deliver these products together as is currently the case. In our opinion, the second solution will also not solve the out-of-stock problem. We conclude that the demand of products differs strongly per day. Besides, we observe that there is demand for products every moment per day. Both aspects ensures that it is difficult to forecast the moments that the specific amount of order cards are placed on the order boards. That makes it difficult to plan the processes on the logistic departments. Besides, the logistic staff does not work 24 hours per day, meaning the process cannot be active all day. We conclude the last solution is the best solution. This solution works with fixed read out moments. Within this method the read out moments per order board are based on the demand of the hospital departments. When the demand of the hospital department is high, the order board needs to be read out more than once a day. This solution reduces out-of-stock moments while still allowing for in advance schedule for the logistics department.

We analysed the average out-of-stock moments per day and per department. We analyse which departments need to be read out more than once a day. Therefore we found the following departments:

ICC C	*Spoed eisende hulp*	*VPU Interne geneeskunde en HIC*
ICC D	*VPU Thoraxchirurgie*	*VPU MDL*
ICC E	*VPU Strokeunit/Neurologie*	*VPU Longgeneeskunde*
Thorax IC	*Haemodialyse*	*VPU Neurochirurgie/shortstay*
Acute opname afdeling	*VPU Chirurgie/Oncologie*	*VPU Vaat/Trauma/Ortho*

We analyse the average number of placed cards per hour for each department. We make a new order schedule with the order information and the information of the total throughput time of the order process. First we measure the average total number of placed cards during the day for every department, the average number of placed cards between 8.00 or 9.00 AM and 1.00 PM or 2.00 PM, and the average number of placed cards between 1.00 PM or 2.00 PM and 8.00 or 9.00 AM. The start and end time depends on the read out moment of the order board.

	Orange				Blue			
	ICC C	ICC D	ICC E	Thorax IC	Acute Opname Afdeling	Spoed Eisende Hulp	VPU A5 Thoraxchirurgie	VPU Strokeunit/Neurologie
Total average placed cards in 24 hours	20,7	21,9	22,4	28,6	49,8	36,8	29,8	27,3
Average placed cards between 8 until 13	11,4	12,0	11,4	14,8	14,8	14,5	11,0	10,1
Average placed cards between 13 until 8	9,4	9,9	11,0	13,8	35,0	22,3	18,8	17,1
	Red				**White**			
	Haemodialyse	VPU Chirurgie/Oncologie	VPU Interne geneeskunde and High and Intensive Care	VPU MDL	VPU Longgeneeskunde	VPU Neurochirurgie/shortstay	VPU Vaat/Trauma/ Ortho	
Total average placed cards in 24 hours	20,5	39,5	39,9	27,0	32,8	25,9	36,7	
Average placed cards between 9 until 14	7,6	10,0	12,4	10,2	9,3	8,3	7,2	
Average placed cards between 14 until 9	12,9	29,5	27,5	16,8	23,5	17,6	29,5	

Table 6.4 The average number of placed cards in 24 hours, between 8 or 9 AM and 13 or 14 PM, and between 13 or 14 PM and 8 or 9 AM given per department with a high value of out-of-stock moments. Calculated in the reference period.

We assume that the order boards of route orange and blue are read out in hour 8 and the order boards of route red and white are read out in hour 9. For every department we determine two different read out times, namely 1.00 PM and 2.00PM. We have decided on these times because we expect the number of orderlines involved will not take much picking time. We expect that two routes can be picked at the same time. We suggest route orange and route blue will be read out close to 1.00 PM and route red and white will be read out close to 2.00 PM. Because we expect the number of orderlines is not very high the aim is to transport the orders at the same time into the hospital. Besides, the delivery employees need to have enough time to deliver the orders. We expect, when the order boards are read out between 1.00 PM and 2.00 PM there is enough time for all processes.

Route	Average number of placed cards at 1.00 PM or 2.00 PM
Orange	49.6
Blue	50.4
Red	40.2
White	24.8

Table 6.5 The average number of placed cards at 1.00 PM or 2.00 PM per route during the reference period.

Table 6.4 shows the results of the first measurement. This table shows the results per department. In Table 6.5 we show the average total order cards that are placed between the start time and the extra read out time per route.

We observe per department that the average number of placed order cards within the time interval is bigger than the number of out-of-stock moments we analyse in Appendix XV. We expect that the out-of-stock moments will decrease significantly. Because of that, we expect for every department only one extra order moment is needed.

Based on this information we advise the hospital to implement an extra order moment for the 15 departments mentioned above. The order moments can be established at 1.00 PM and 1.30 PM. We expect that the products of route orange and blue can be picked in 30 minutes. We advise the hospital to transport the products of all routes at the same time into the hospital. Besides reducing the number of out-of-stock moments for the departments, we expect that the workload for the logistic department in the morning will decrease.

VII. *Increase bin value*

We observed 80 products that show many out-of-stock moments in comparison with other products. We conclude that the bin value of these products are not correctly established. A solution to decrease the out-of-stock moments caused by a wrong bin value is to increase the bin value.

VIII. *Support work procedure*

Another cause of out-of-stock moments we observe is a wrong procedure. The users forgot to place the order cards and because of that get an out-of-stock moment. We suggest two solutions to solve this problem. The first solution is that one person per department will place the order cards. The second solution is to develop a clear working procedure and communication plan. The logistic department needs to inform the hospital departments on the right procedure and make the departments aware of the out-of-stock moments caused by a wrong procedure problem.

We consider the second solution to be most effective because it ensures a constant placing of cards. The first solution involves a single person having to check the stocks regularly. This delays the placing of cards and involves extra work for the person responsible for checking the stocks. Besides when all users know how to work with the method, they will be more considerate of the system. We expect when the hospital departments are well informed, they get more aware of the method and execute the procedures properly.

6.2.3 Number of order card and order board errors

In Section 5.3 we discuss the number of order card and order board errors. We observe that during the reference period most errors are caused by broken order cards. In this section we discuss multiple solutions to increase the system reliability.

IX. *Replace unreliable order cards*

First of all we suggest to replace the unreliable order cards. In Section 5.3 we find order cards that show errors. That makes the order cards unreliable. The user cannot totally trust that the order card is working well. Therefore the solution is to work with reliable order cards. We advise the hospital to replace the unreliable order cards with new, reliable order cards.

X. *Check order system frequently for errors*

It is important to check the system frequently for errors, because new order cards are still added to the system. Besideds, we expect the performance of the order board will decrease over time.

6.3 Combine schedule solutions

In Section 6.2 we give 10 solutions. These solutions are planning, behaviour, and system improvements. In this section we combine the planning improvements to make one optimized schedule. In this schedule we assume that the order moments are based on the demand and workload of logistic employees. We determine the read out moments based on the openings hours of the departments and we combine the departments with an order board of route orange with the other routes. Table 6.6 shows the overall schedule we make.

Route	Departmentname	Order time 1	Order time 2	Average placed order cards per day
Blue	Acute Opname Afdeling	7:30	13:00	49.8
	Spoed Eisende Hulp	7:30	13:00	36.8
	VPU A5 Thoraxchirurgie	7:30	13:00	29.8
	VPU Psychiatrie/Paaz	7:30	-	8.0
	VPU Strokeunit/Neurologie	7:30	13:00	27.3
	Thorax IC	7:30	13:00	28.6
	ICC D	7:30	13:00	21.9
Red	ICC E	± 8:45	13:00	22.4
	Haemodialyse	± 8:45	13:00	20.5
	Poli Radiologie	± 8:45	-	12.6
	VPU Chirurgie/Oncologie	± 8:45	13:00	39.5
	VPU Interne geneeskunde and High and Intensive Care	± 8:45	13:00	39.9
	VPU MDL	± 8:45	13:00	27.0
White	VPU Longgeneeskunde	± 9:30	13:30	32.8
	VPU Neurochirurgie/shortstay	± 9:30	13:30	25.9
	VPU Vaat/Trauma/Ortho	± 9:30	13:30	36.7
	Eerste Harthulp	± 9:30	-	18.2
	ICC C	± 9:30	13:30	20.7
Poli Route	Poli Reumatologie	± 16.00	-	2.9
	Poli Cardio/Cardiochirurgie	± 16.00	-	2.8
	Poli KNO	± 16.00	-	3.5
	Poli Longgeneeskunde	± 16.00	-	8.7
	Poli Mondkaak	± 16.00	-	8.3
	Poli Interne Geneeskunde	± 16.00	-	0.8
	Poli MDL/Endoscopie	± 16.00	-	16.7
	Poli Dermatologie	± 16.00	-	5.7
	Poli Neurologie	± 16.00	-	0.3
	Dagbehandeling	± 16.00	-	17.6
	Gipskamer	± 16.00	-	6.8
	Behandelpoli	± 16.00	-	18.3

Table 6.6 New order schedule as a result of multiple improvements

In this table we show the routes we determine, the linked departments and the read out moments. Furthermore, in the last column we show the average placed order cards per day per department. With these values we show which departments ensures a high workload.

We make multiple decisions in this improvement. First of all, we combine the departments with an order board of route orange in the other order routes. We do that because we observe no added value when transporting products to transferium and from there to the hospital departments. We observe more delay in comparison with the other routes.

The second decision we make to increase the number of order moments for the nursing and emergency departments. We know this improvement is not optimal. In the analyse phase we observe that the out-of-stock moments happen for many different products. The improvement to increase the bin value can help, but not in all situations and this solution is limited by the department warehouse's storage space. Therefore, we think that the departments with a lot of out-of-stock moments needs a second order moment. We advise the hospital to check every month if the second order moment is still needed.

The third decision we make is to read out the order boards on the outpatient departments in the afternoon. These departments are open from 8.00 AM until 5.00 PM. We think reading out the other boards at the end of the day or in the morning will make no difference since no cards are placed on the order board of these departments in the evening.

The fourth decision we make is to keep the read out moments in the morning. Only the order boards of the outpatient departments are read out in the afternoon because of the opening hours. At all other departments cards are being placed in the evening and at night. The picking process starts in the morning so to increase the number of cards incorporate in the picking process the read out moment should also be in the morning.

The last decision we make is to determine the read out moments based on the workload of the picking process. The read out moments need to better match with the throughput times of the picking process. With the help of historical data we make a new order schedule. We make this schedule per weekday. Table 6.7 shows the estimates we make for the read out moments. The read out times on Monday differ from the other days. That is caused by the average number of orderlines on Monday. The given times are estimates. We advise the hospital to try out the new read out times and adjust the times when these are not yet optimal.

	Monday	Tuesday	Wednesday	Thursday	Friday
Blue	7:30	7:30	7:30	7:30	7:30
Red	9:00	8:30	8:30	8:30	8:30
White	10:00	9:15	9:15	9:15	9:15

Table 6.7 New order schedule per weekday

6.4 Implementation

In Section 6.2 we discuss multiple solutions. The solutions can be seen as improvements. The next step is to implement these improvements in the current situation. In this section we discuss how we make an implementation plan. In Section 6.4.1 we discuss the effects of the improvements. In Section 6.4.2 we discuss which improvements need to be implement first.

6.4.1 Implementation effects

In this section we discuss what effects the improvements have on the current situation. Therefore we set up multiple attributes. For every improvement we give a score to each attribute. These scores are used to make a ranking of the solutions. We set up the following attributes:

Increase the customer value	does the improvement increase the customer value (*none, low, medium, high)*
Increase the non-added value	does the improvement increase the non-added value activities in the process (*none, low, medium, high*)
Costs	the amount of money the implementation of the improvement costs (*none, low, medium, high*)
Implementation time	the amount of time the implementation of the improvement costs (*Very short, short, long, very long*)
Linked to KPIs	the number of KPIs the improvement is linked to (*1 to 3*)

We express every attribute with another scoring scale. We show scoring scales behind the explanation of each attribute. Table 6.8 shows the scores we give to each attribute for each improvement.

Improvement	Increase the customer value	Increase the non-added value	Costs	Implementatio n time	Linked to KPIs
I	High	None	None	Very short	2
II	Medium	None	None	Short	1
III	High	None	None	Very short	2
IV	Medium	Low	Low	Short	2
V	High	None	Low	Short	2
VI	Medium	Medium	None	Very short	2
VII	Medium	None	Low	Short	1
VIII	High	Medium	Medium	Very long	1
IX	High	Medium	Medium	Long	1
X	Medium	Medium	Low	Short	1

Table 6.8 Scoring table of every improvement

6.4.2 Implementation raking

The next step is to rank the improvements. This ranking shows which improvement has the most effect with low costs and little effort. For all attributes we use different scoring scales. These scoring scales are developed based on what we expect that has the most impact on the customer satisfaction. Table 6.9 shows the scoring scales for each attribute.

Customer value		Non-added value		Costs		Time		Project issues	
High	100	None	100	None	100	Very short	100	3	100
Medium	80	Low	65	Low	75	Short	70	2	75
Low	60	Medium	30	Medium	50	Long	40	1	50
None	0	High	0	High	0	Very long	0	0	0
Attr. Rank	100	Attr. Rank	80	Attr. Rank	80	Attr. Rank	70	Attr. Rank	40

Table 6.9 Score scale per attribute

Besides, we also determine the overall ranking of the attributes. In our opinion, the effect to the customer value is more important than the linked project issues. Therefore we give every attribute an overall rate that is taken into account in the calculation. With that rate we measure the weight of each attribute. We calculate the total score by multiplying the attribute score with the weight factor and sum all results of the improvement. Table 6.10 shows the results of this calculation.

Improvement	Increase the customer value	Increase the non-added value	Costs	Implementation time	Linked to project issues	Total
I	100	100	100	100	75	97,3
II	80	100	100	70	50	83,5
III	100	100	100	100	75	97,3
IV	80	65	75	70	75	73,2
V	100	100	75	70	75	86,2
VI	80	30	100	100	75	76,8
VII	80	100	75	70	50	78,1
VIII	100	30	50	100	50	68,6
IX	100	30	50	40	50	57,3
X	80	30	75	70	50	63,0
Rate	100%	80%	80%	70%	40%	370
Weight	0.27	0.22	0.22	0.19	0.11	1

Table 6.10 Scores per improvement

With this calculation we can make a ranking of the improvements. Table 6.11 shows the ranking. This ranking shows which improvements ensures a high effect on the customer value without high costs and effort.

Ranking place	Improvement	Ranking place	Improvement
1.	I	6.	VI
2.	III	7.	IV
3.	V	8.	VIII
4.	II	9.	X
5.	VII	10.	IX

Table 6.11 Ranking of improvements

6.5 Conclusion

In this chapter we developed a method to improve the performance of the logistic process. For this we formulated the ideal situation per project objective. We came up with solutions and summarize the best solutions. Finally we ranked the improvements to conclude which solutions ensure the most effect without a lot of effort. We used these methods to answer the research questions. The questions are as follows:

What is the desired situation?
What solutions are possible and what are the pros and cons for each solution?
What is (are) the best solution(s) to solve the problem(s) and what is the best way to implement these solution(s) in the hospital?

We observed system, behaviour, and planning problems. We conclude that we can find solutions to solve these problems. In this chapter we explained the planning improvements in more detail. We came up with a new schedule, which was made separately for each improvement, but we also combine the improvements. Furthermore, we rank the improvements. We found the following top five:

1. Determine the order moments on the workload
2. Remove the departments with an order board from route orange and include these in route blue, red, and white
3. Read out the order boards and deliver the products in the weekend
4. Combine sterile, unsterile, and sales products on one cart
5. Increase bin value

We conclude that the most profit can be achieved from the planning improvements because the planning improvement have impact on two KPIs, namely the delivery time and out-of-stock moments. We conclude that it is very difficult to improve a behaviour problem. It takes a long time and much effort. Nevertheless, we conclude it is not impossible. Furthermore, we need these improvements because there are no other improvements to solve the problems. In case conversations do not have the desired effect on behaviour, we advise the hospital to set up consequences for the department. The system improvements takes some time, but we conclude that it is clear what improvements need to be carried out to solve the problems.

Let us now carry out the last phase of the DMAIC cycle, namely the control phase. In this phase we discuss how the improvements can be controlled by the hospital.

7. Control

The last phase of the DMAIC method is the control phase. In this phase the aim is to check whether the solutions are embedded. In this research we do not implement the solutions, because of that we discuss in this section how the hospital can verify if the improvements are correctly implemented and what the results are. In this section we answering the research question:

How can the hospital verify whether the solutions are embedded?

In Section 6.4.2 we measure a ranking of improvements. We think the hospital cannot implement all improvements at the same time. We advise the hospital to plan the implementations in steps. For example implement two or three improvements at one time.

As mentioned before, it is important to analyse the performance of the new order method frequently. Especially when the hospital implements improvements. The processes are dynamic, for example the demand of products or the reliability of an order card can change. Therefore it is important to check if performance changes occur, so that new improvements in the processes can be made. To check the performance we advise the hospital to use the visual management.

In this research we focus on the KPIs *delivery time, out-of-stock moments* and *order card and order board errors*. To control the improvements we conclude it is important for the hospital to calculate the performance of these KPIs frequently. In this research we use programs that are not installed on the computers of the hospital. Furthermore, the hospital does not have any similar program that can carry out the calculations. We calculate the performance of these KPIs with the data from Alltrack. We assume that Alltrack can also carry out the performance calculations we make. In our opinion, the best way to analyse the performance of the KPIs is to build the performance calculations in Alltrack. We conclude Alltrack need to add a tool to make reports of the performance of the KPIs for a certain time period. The reports can be used to analyse the results of the KPIs for a certain time period. The advantage of this is that the logistic employees can easily do this by themselves. They do not need to carry out any calculations by themselves. The disadvantage is that the hospital needs to investigate in this plan.

Another method to analyse the performance of the KPIs is that the hospital buy the programs MySQL, Spoon and Tablaue. With these programs, the hospital can carry out the calculations by themselves. However, it takes more time and the logistic employees need to carry out the calculations by themselves. Furthermore, the programs costs a lot of money.

We consider that a screen in the backoffice with real moment statistical information can help to analyse the performance frequently. This screen will show information about the delivery times, system errors, and out-of-stock moments. This information is measured by Alltrack because Alltrack can measure real time data. The screen makes it possible to react directly to a problem. Furthermore, Alltrack needs to have a tool that the program will give a signal when it determines common problems. With that information the logistic department can directly tackle this problem.

The last method to control the improvements is to document the performance and document what improvements are implemented to improve the performance. With that information the decisions can be made faster in the future. The documents make it possible to compare different performances.

8. Research conclusion

In this chapter we give an overall conclusion of this research. In Section 8.1 we give an answer to the problem statement and the research questions. In Section 8.2 we discuss the recommendations, and in Section 8.3 we explain some discussion points of this research.

8.1 Conclusion

In 2016 Medisch Spectrum Twente introduced a new order method. This system ensures the products in the department warehouses are ordered by order cards and order boards. A big change for many employees in the hospital. The warehouse employees are not responsible for the stock level and ordering of products in the department warehouse anymore. In the new situation, the department staff is responsible for these processes.

The problem statement of this research is:

How can the new order method be monitored and improved? What data and KPIs are relevant to measure how the new order method performs?

The aim of this research is to assess the performance of the new order method. Therefore, we mainly focused on defining, measuring, and analysing the performance. In this research we discussed the improvement and control phases, but we did not analyse these phases quantitatively.

In the define phase we interviewed the users of the new order method while making use of the method Value Focused Thinking. As a result of these interviews multiple project objectives are determined. The project objectives are assessed by different KPIs. We distinguish the following project objectives:

1. Good response time
2. Short waiting time
3. Correct stock level in the department warehouses
4. Low workload
5. Well working technology
6. Well organized communication
7. Well furnished hospital department warehouse

We found 49 KPIs to assess these project objectives. Of these 49 KPIs 29 were actually analysed in this research, however in this report we focussed on the KPIs *delivery time, out-of-stock moments,* and *order card and order board errors.* We focussed on these KPIs because we conclude from the interviews that these are the most important for the customers to ensure good patient care. Data on the other KPIs can be found in the appendices of this report. We obtained data from Oracle and Alltrack to measure the performance. We used the data from the months November and December 2016, and January 2017.

We conclude that the delivery times of route blue, red, and white are good. More than 90% of the products are delivered within 8 hours after the ordering moment. The 10% that is delivered too late is caused by a delays in the order process or backorders. We conclude the variance in delivery time of the three routes is low because the products are delivered by three deliver employees. However, we conclude that there is some delay caused by one or more of the process steps of the order process in route blue, red, and white, since all process steps are the same for these routes. In our view the delay in delivery time can be improved by the logistic department. We observe that the delay in delivery time in these three routes is caused by the read out moments of the order boards, the picking process, and delivery process.

We conclude that the delivery process of route orange is not well organized because we observe a high median and variance in the delivery time. Also, 30% of the warehouse products is not delivered within 8 hours. Besides causes mentioned for the other routes, we conclude that these results are also caused by the fact that the orange route products are delivered by one person and the route plan involves crossing the whole floor.

We found that in 20% of the moments an order card is placed on the order board it is the second card, from which we conclude that many products get out-of-stock in the department warehouses. In our view, this value is high. We make a distinction between different reasons of an out-of-stock moment, namely (i) a wrong bin value, (ii) a suboptimal process, and (iii) a wrong order card procedure. With a wrong order card procedure we mean that the user is not following the correct order procedure, mostly this involves forgetting to place the order card on the order board. With a wrong bin value we mean that the determined stored value of a product in a bin is too low to have enough stock until the next delivery moment. A suboptimal delivery process means that the read out time or delivery moment does not correspond to the consumption on the departments. We conclude that many out-of-stock moments are caused by a wrong procedure, namely 38%. This value shows that not only the logistics process, but also the ordering process should be improved. The other 62% is caused by a wrong bin value or suboptimal process. We found many out-of-stock moments caused by a wrong bin value or suboptimal process occur in the weekend and on Monday. We observed that the nursing and emergency departments have the most out-of-stock moments. We suspect this is caused by the fact that these departments are operational 7 days per week while the logistic department does not deliver in the weekend. We conclude that many different products get out-of-stock during the three month reference period. Also, we conclude that the demand of care is unpredictable and the out-of-stock problem cannot easily be solved by increasing the bin value. The out-of-stock problems needs to be solved by the logistic department, but also the department staff needs to get aware of the correct work procedure.

The last conclusion we make is a conclusion about the number of order card and order board errors. We conclude that 492 order cards show an error. We conclude that these cards decrease the system reliability. We also conclude that the order boards P-Intg and V-E5 MDLS show errors and that decreases the system reliability. However, since these errors can also be caused by card errors further assessment of the boards is required after replacing order cards with high error rates to obtain more reliable information on the order board errors.

We suggest the 10 best solutions to improve the performance of the KPIs *delivery time, out-of-stock moments,* and *order card and order board errors*. We conclude that the improvements are planning, system, and behaviour improvements. We think that the planning improvements will have the most impact on the performance. For the system improvements it is clear how they are to be carried out. We expect that the behaviour improvements will take a long time and more effort. Nevertheless, we conclude these improvements are also needed to improve the overall performance. We rank the improvements to advise the hospital on which improvement they need to implement first. The top 5 of this ranking is:

1. Determine the order moments based on the workload
2. Remove the departments with an order board from route orange and include these in route blue, red, and white
3. Increase bin value
4. Combine sterile, unsterile, and sale products on one cart
5. Determine the read out moments based on the demand

To monitor the performance we advise the hospital to reanalyse the results frequently, using the methods developed in this study. Furthermore, we advise the hospital to document the results and use visual management to analyse the results. We advise the hospital to visualize the results of the delivery time, out-of-stock moments, and system errors on a screen in the backoffice of the logistic department. We conclude that the best system to measure the results of these KPIs is Alltrack because that is the source of the data. Furthermore, we expect this system can carry out the calculations too. From there the logistic employees can monitor if all performance are correct and the logistic department can make respond directly when performance changes occur. We conclude that this system needs to save the data and determine remarkable results, like which department has the most out-of-stock moments.

8.2 Recommendations

In this research we come up with multiple improvements. We advise the hospital to implement the improvements step by step. We deem it unwise for the hospital to implement all improvements at the same time. The ranking will help them find an order for the implementation of the improvements. For the planning improvement we developed an overall schedule. We advise the hospital to combine multiple schedule improvements and implement them together. This will prevent confusion because the processes change multiple times. We advise to ensure that the processes are changed only once or twice.

During the research we did not have enough time to measure and analyse all KPIs. In Appendix XI we explain how to measure the remaining KPIs. To get an overall conclusion, we advise the hospital to measure and analyse the KPIs in a follow up research. One of the remaining project objectives is communication. In this research we conclude that multiple problems need to be solved with a behaviour improvement. Because of that, we think it is important to analyse the communication objective. With that information the hospital can create a better plan of action to improve the behavioural aspects.

In the improvement phase we take into account that the central warehouse is going to move to Hengelo. That means that the transportation time will increase. We think that the logistic department will try to transport as many products as possible from the central warehouse to the hospital to minimize the times the truck needs to drive from Hengelo to Enschede. Because of that we exclude some improvements. We think all improvements we discuss in this research can be implemented in the future situation. We advise the logistic department to analyse the performance and adjust the schedule on the new situation to avoid waiting time for the logistic employees and for the orders.

Finally, we advise the hospital to analyse the performance frequently with a visual method and document these results. We suggest with a screen that shows the performance of the new order method. The screen needs to be located on the backoffice, from where the employees can monitor it. The system will save the data and come up with remarkable results. The documents make it possible to compare different performances and make a decision with information from different situations.

8.3 Discussion

We observe some restriction that can have an influence on the research results. The first restriction we observe is that only warehouse products get out-of-stock during the three months reference period. We observe warehouse and sales products can be ordered by the order boards. We observe that most products that are ordered by the order boards are warehouse products. In the data we noticed only the warehouse products get out-of-stock during the reference period. Because few sales products are ordered during the reference period it is not valid to conclude the sales products have a probability of 0% to get out-of-stock. In the future the hospital wants to add more sales products to the new order method. We advise the hospital to measure the out-of-stock moments again when more sales products are ordered by the order boards to get a valid conclusion.

We assume that when both order cards of a single product are placed within one minute, the out-of-stock moment is caused by a wrong procedure. We established this value because we conclude that it is not possible to empty both bins in one minute. Besides, from the interviews we know that the out-of-stock moments are also caused by a wrong procedure. We expect the out-of-stock moments caused by a wrong procedure is even higher in reality, since both order cards placed within two minutes is also likely to indicated a wrong procedure. However increasing this time threshold in our analysis also increases the probability that the out-of-stock moment is not caused by a wrong procedure. For this reason we based our analysis on the assumption of one minute as a time window for wrong procedures.

We calculate the throughput times of every process step of the logistic staff. However, we have no written data from the transferium staff. Therefore, we use the Alltrack data and the throughput times of the logistic staff. The experience is that it is was difficult to get more information from the transferium department. This department was not closely involved in this research. To get a more reliable conclusion we advise to measure their written results.

We rounding off the delivery time in hours. Now, we expect that when the delivery time was calculated in hours and minutes it will give more detailed information. We expect that the results are then more accurate

In this research we use three programs to measure the performance of the KPIs. These programs are not in use by the hospital. We choose for these programs because these make it easy to measure a lot of data in a short time. Furthermore, the hospital is not using a similar program. The program that we could use is Excel. However, this program takes a lot more time to measure the performance. To avoid the hospital is required to buy one of the programs or investigate in Alltrack, we try to make the calculations of the KPIs we discuss in this research in Excel. This will help the hospital to analyse the follow up results until they decide to investigate in one of the control plans.

Further restrictions we found for the other KPIs are restrictions in the backorders and urgent orders. We observe that at some orderlines 0 products are ordered. We could not find what the reason was. We observe that some orderlines with an amount of 0 ordered products are linked to a backorder. We expect this is caused by a failure in Oracle or a wrong manual depreciation in Oracle. Because we filter out the orderlines with 0 products, we did not involve the linked backorders in the research.

We expect that these restrictions do not result in significantly different performance of the KPIs. We belief that the performance of the delivery time, out-of-stock moments, and order card and order board errors will increase when MST implement the improvements we suggest in this study. Overall we believe the new order method helps MST to provide good patient care.

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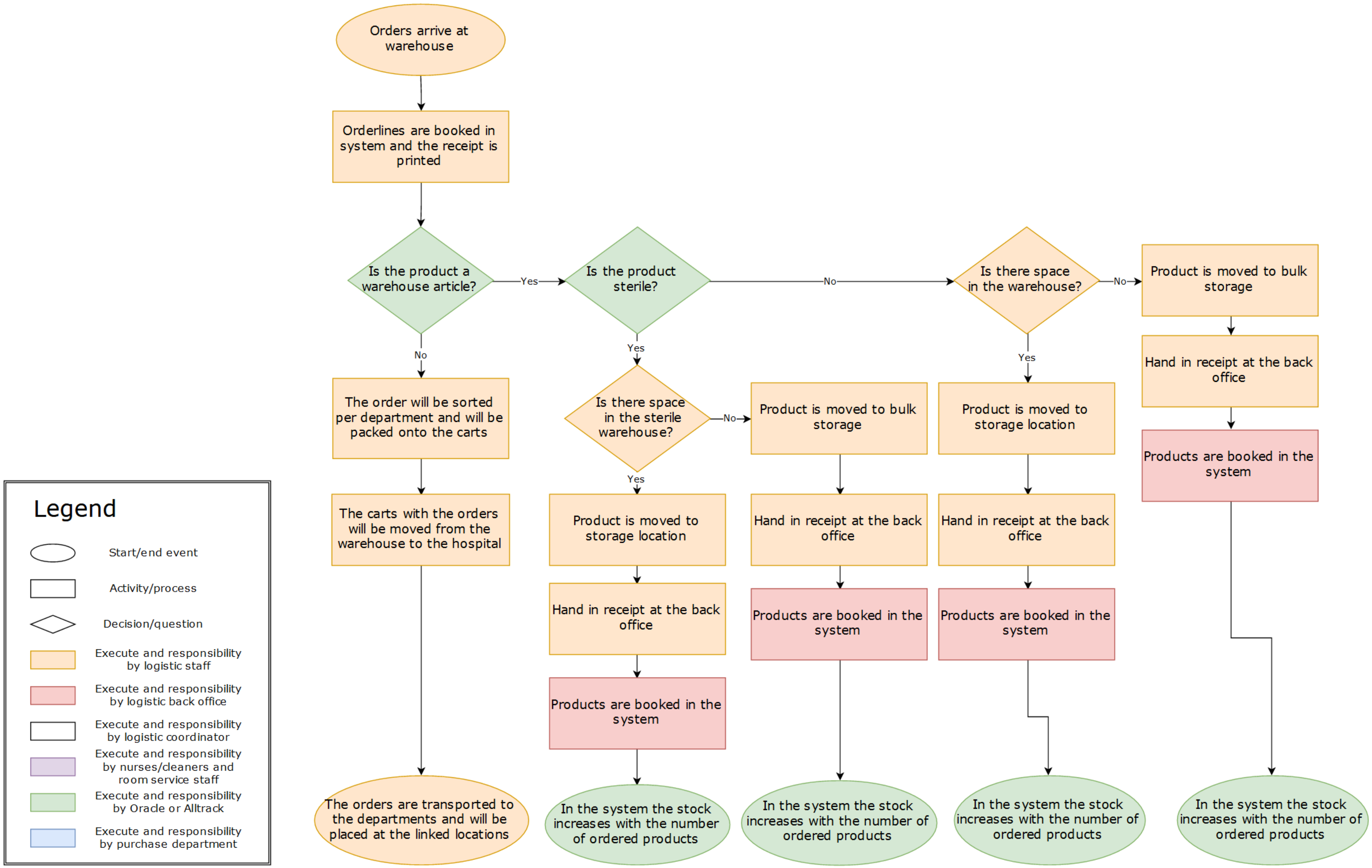
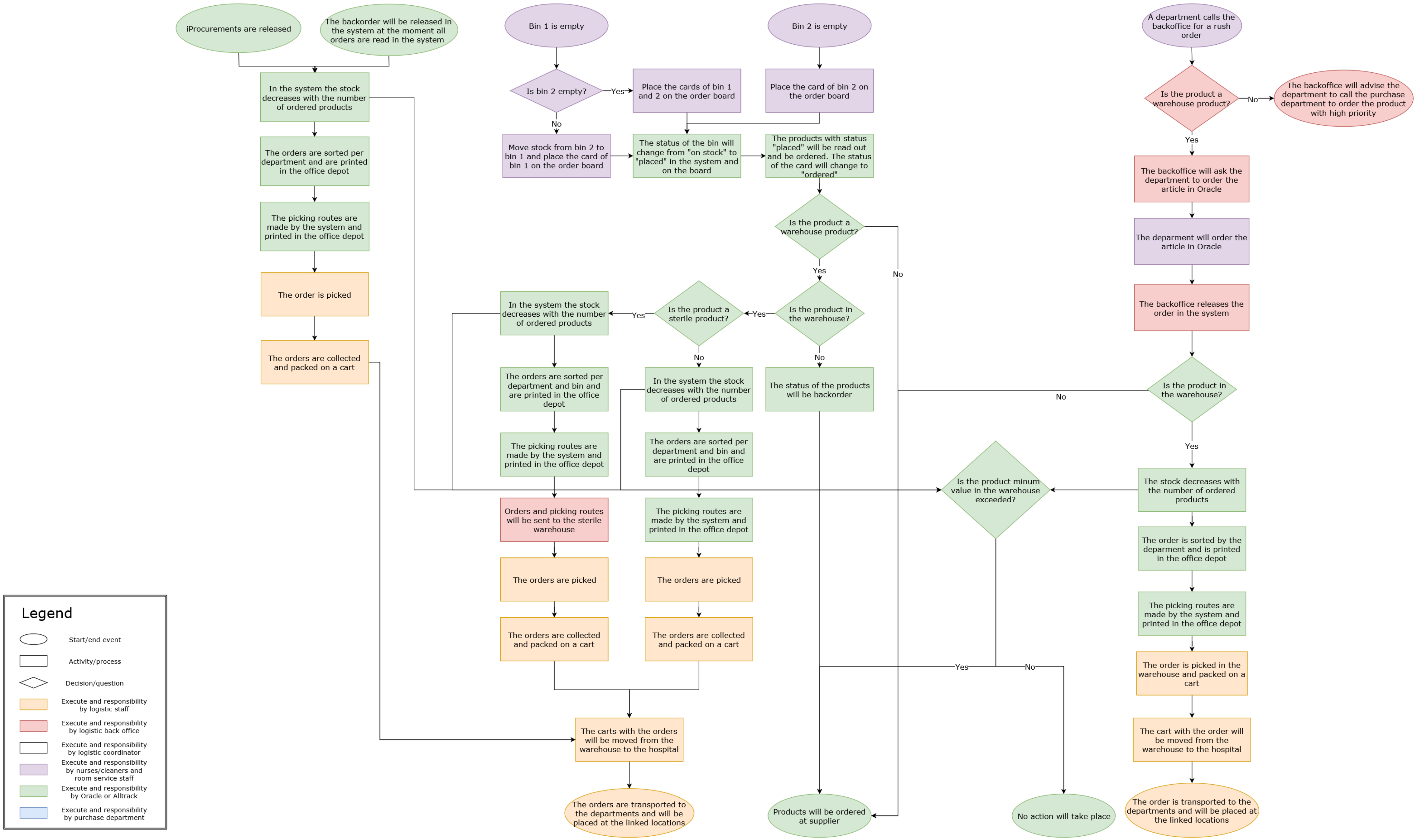
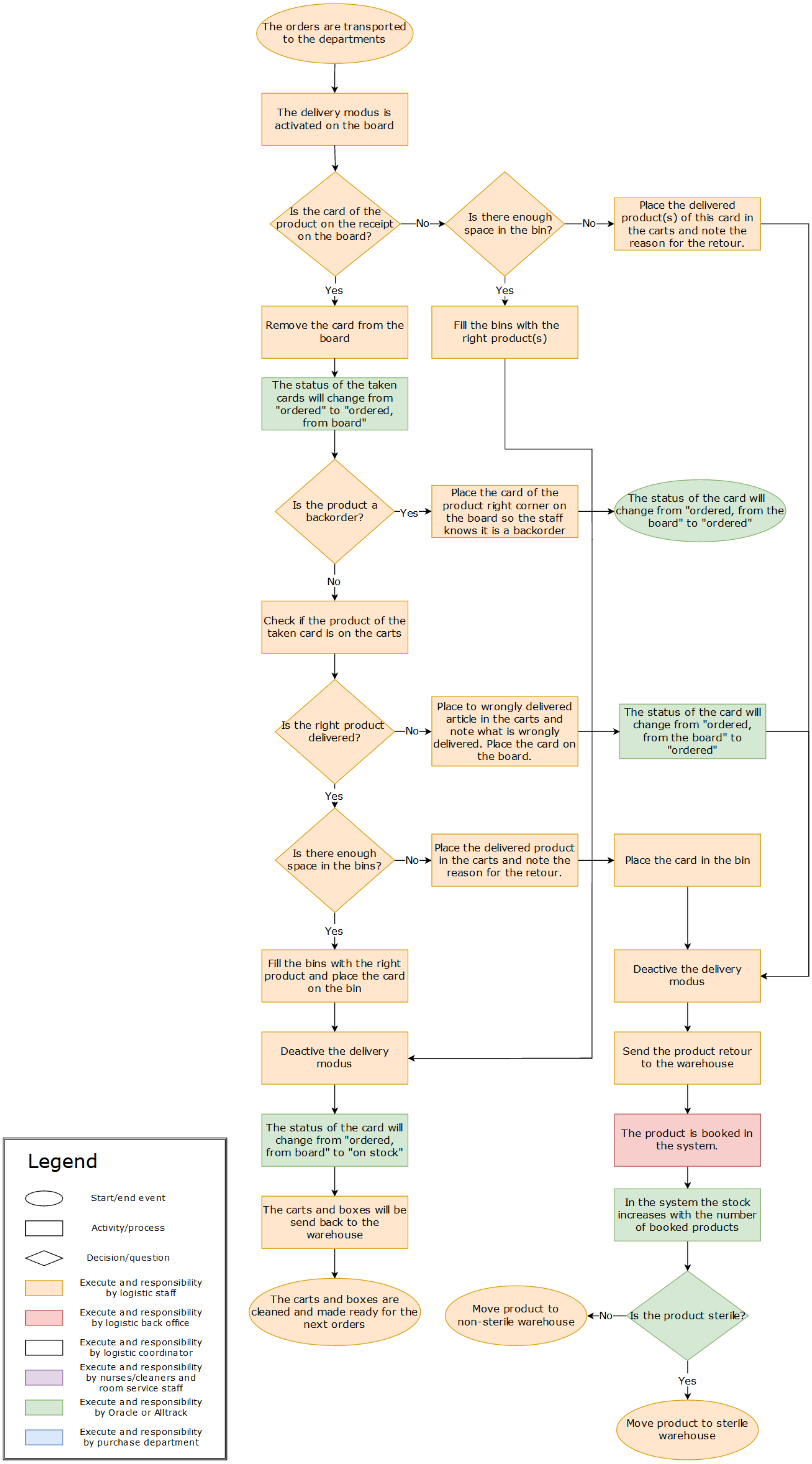
Appendix I Receive products and fill in the central warehouse



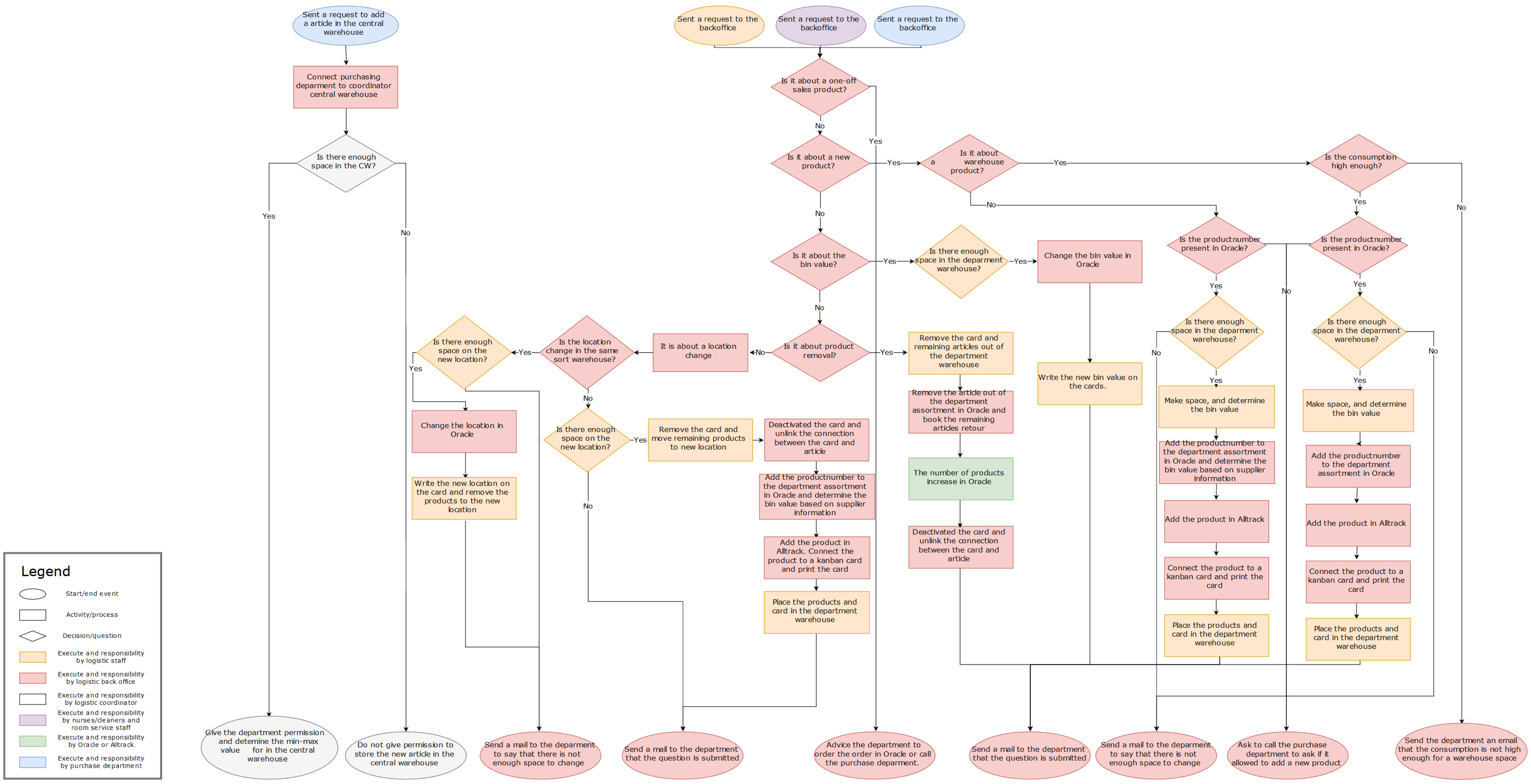
Appendix II Order receiving, picking and transport of products



Appendix III Replenish of products



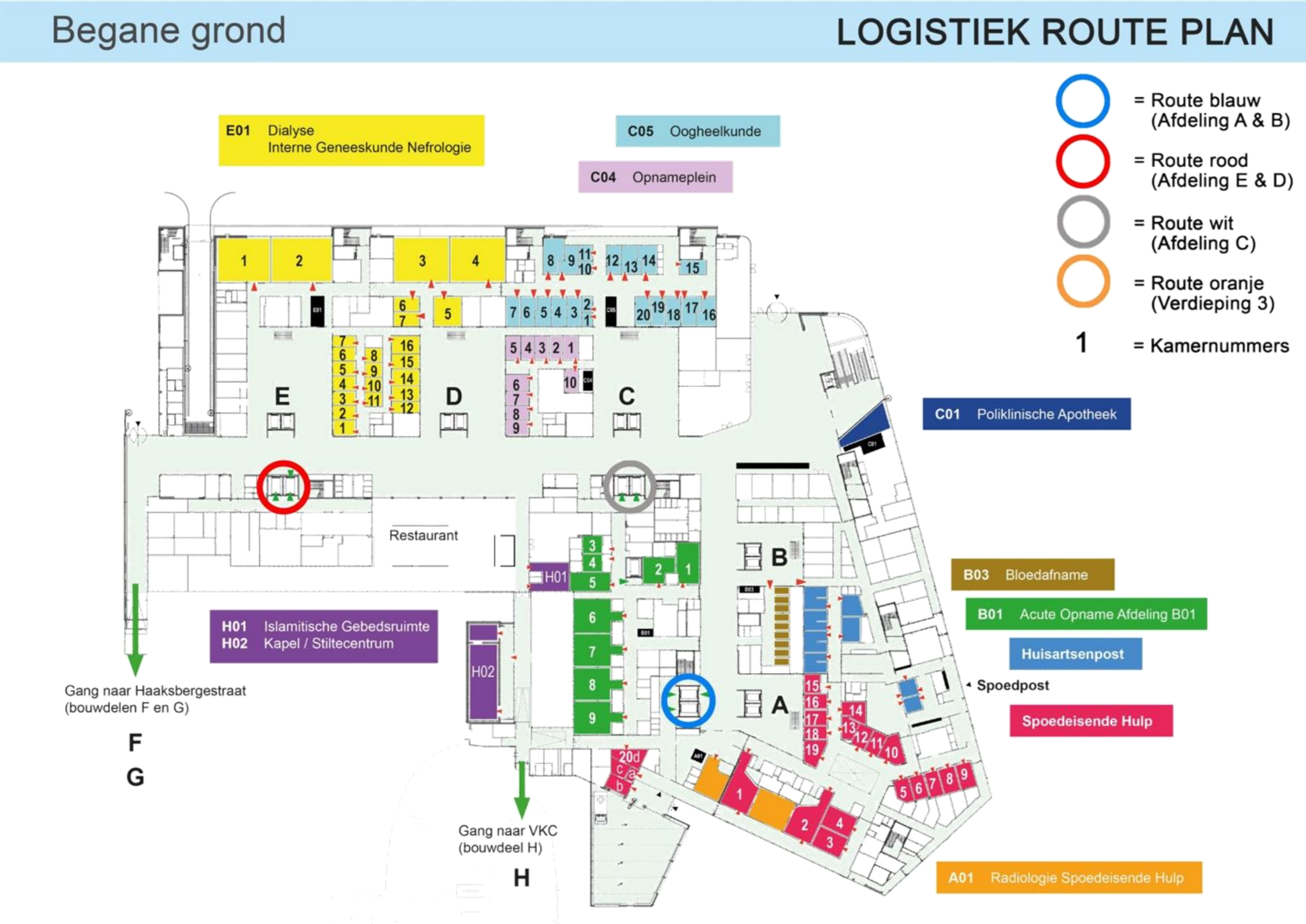
Appendix IV Central warehouse back office



Appendix V Order times automatic order boards per August 3 2016

Order time	Release time	Elevator	Floor	Department	Name in system
7:00	7:15	Orange	3	C34 ICC Unit A (TIC)	TIC
7:00	7:15	Orange	3	C37 EHH	V-EHH
7:00	7:15	Orange	3	C37 CCU	V-CCU
7:00	7:15	Orange	3	C34 ICC Unit C	AIC C
7:00	7:15	Orange	3	C34 ICC Unit D	AIC D
7:00	7:15	Orange	3	C34 ICC Unit E	AIC A
7:45	8:00	Blue	6	A61 VPU Strokeunit/Neurologie	V-A61
7:45	8:00	Blue	5	A51 VPU A5 Thoraxchirurgie	V-A5
7:45	8:00	Blue	4	B43 VPU Psychiatrie/Paaz	V-B4 A V-B4 B
7:45	8:00	Blue	1	A17 Poli MondKaak	P-MOKA
7:45	8:00	Blue	1	A14 Poli KNO	P-KNO
7:45	8:00	Blue	2	B23 Poli Longgeneeskunde	P-Longf
7:45	8:00	Blue	2	A25 Poli Cardio/Cardiochirurgie	P-Cardio
7:45	8:00	Blue	6	A61 AOA	AOA A6
7:45	8:00	Blue	0	B01 AOA	AOA BG
7:45	8:00	Blue	0	A01 SEH	P-SEH
8:45	9:00	Red	5	E51 VPU MDL	V-E5 MDL
8:45	9:00	Red	4	E41 VPU Chirurgie/Oncologie	V-E4
8:45	9:00	Red	6	E61 VPU Interne Geneeskunde	V-E61
8:45	9:00	Red	1	D15 Poli Radiologie	P-Rontg
8:45	9:00	Red	1	D17 Poli Reumatologie	P-Reuma
8:45	9:00	Red	2	E21 Dagbehandeling	P-Dagb
8:45	9:00	Red	0	E01 Heamodialyse	P-HEMO
8:45	9:00	Red	2	D25 Poli MDL/Endoscopie	P-MDL
	9:00	Red	6	E61 HIC handscan	V-E6 HIC
9:45	10:00	White	6	C61 VPU Neurochirurgie/shortstay	V-C61
9:45	10:00	White	5	E51 VPU Longgeneeskunde	V-E51 LON
9:45	10:00	White	4	C44 VPU Vaat/Trauma/Ortho	V-C4
9:45	10:00	White	1	C13 Poli Dermatologie	P-Derm
9:45	10:00	White	1	C16 Gipskamer	P-GIPSK
9:45	10:00	White	1	C16 Behandelpoli, Poli Ortho/Ravalidatie/Plastische/Chirurgie	P-Behan

Appendix VI Logistic route plan



Verdieping 1

LOGISTIEK ROUTE PLAN

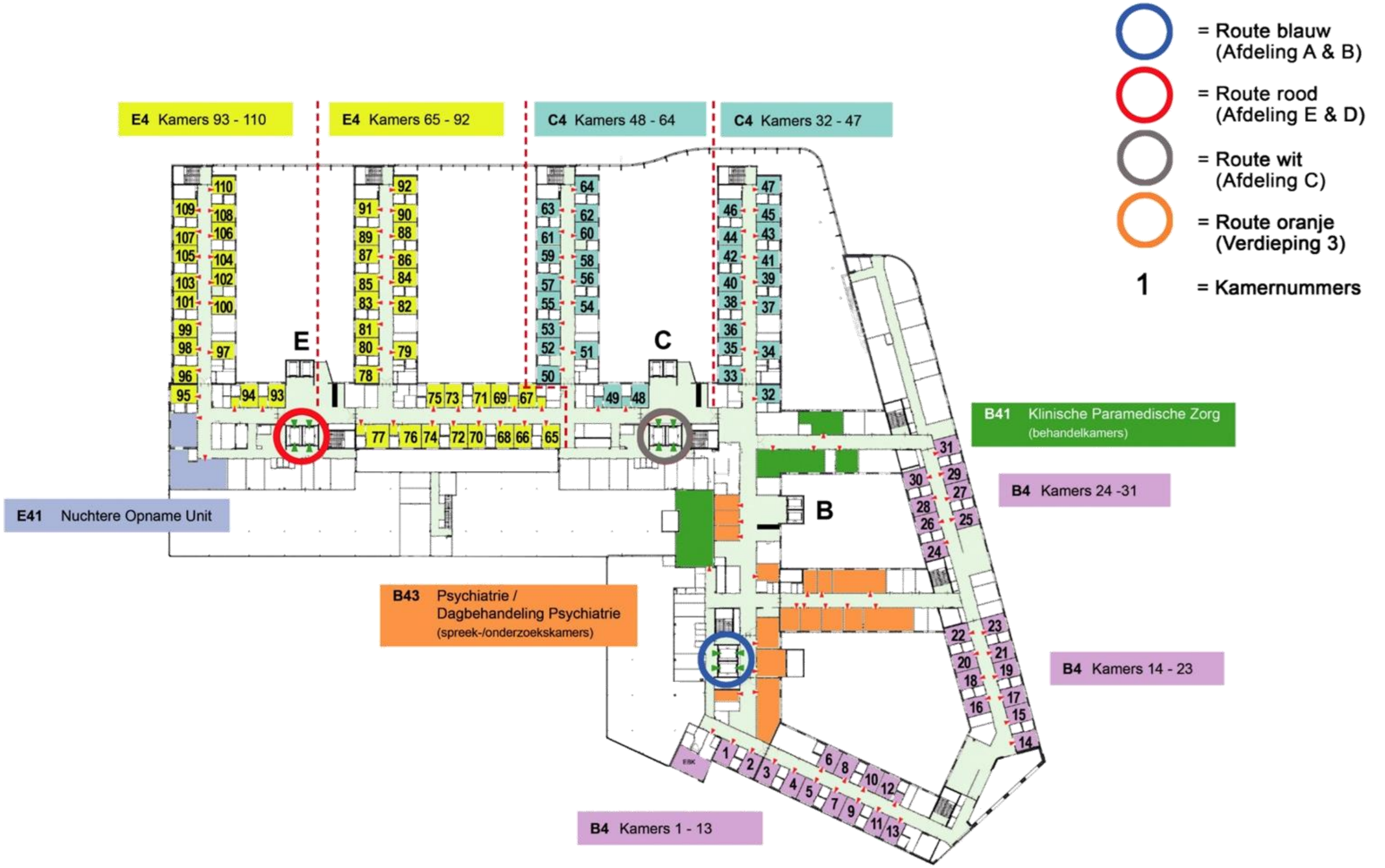
Verdieping 2

LOGISTIEK ROUTE PLAN

Verdieping 3

LOGISTIEK ROUTE PLAN

Verdieping 4 — LOGISTIEK ROUTE PLAN



Verdieping 5

LOGISTIEK ROUTE PLAN

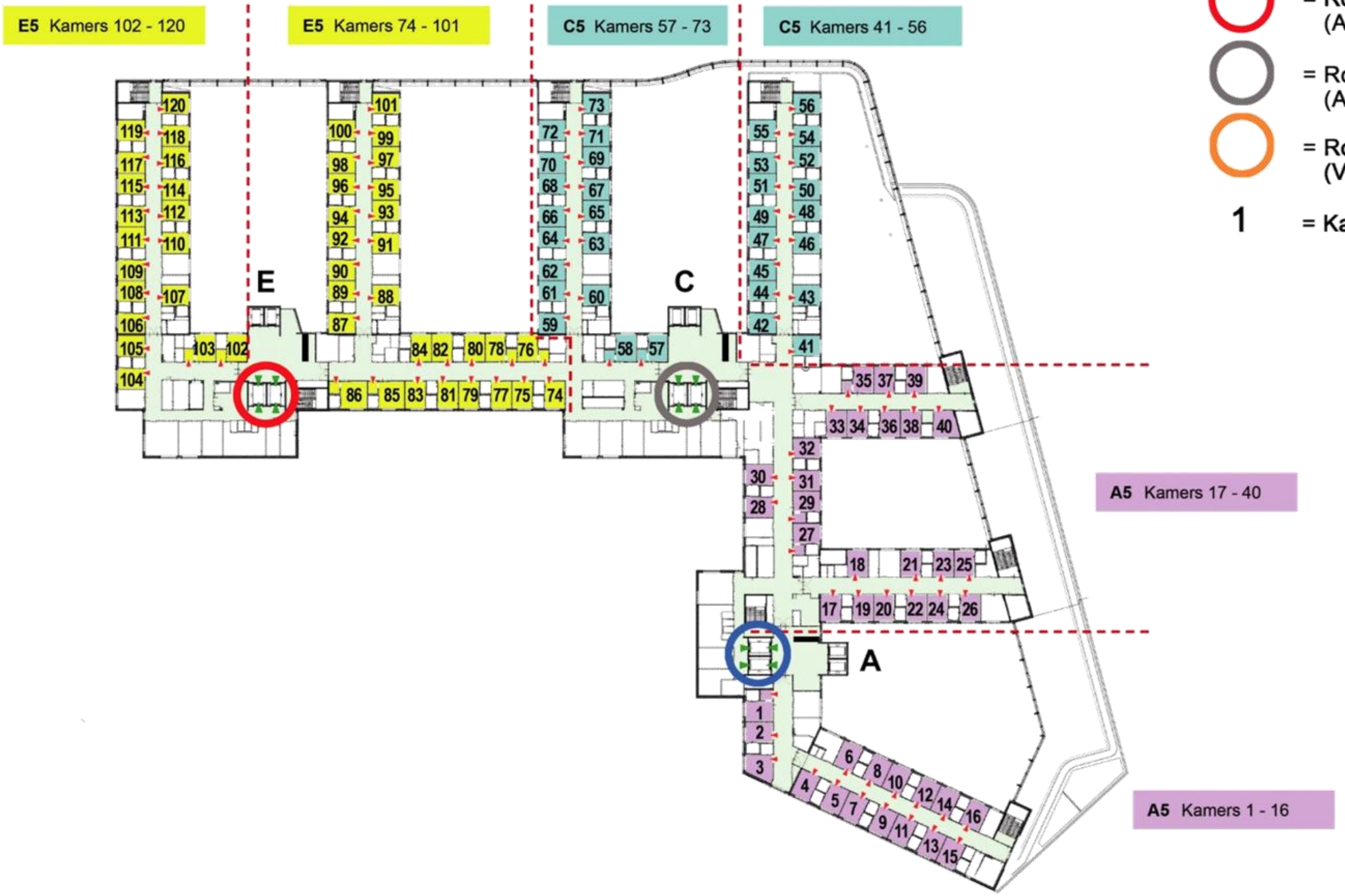
= Route blauw (Afdeling A & B)

= Route rood (Afdeling E & D)

= Route wit (Afdeling C)

= Route oranje (Verdieping 3)

1 = Kamernummers



Verdieping 6

LOGISTIEK ROUTE PLAN

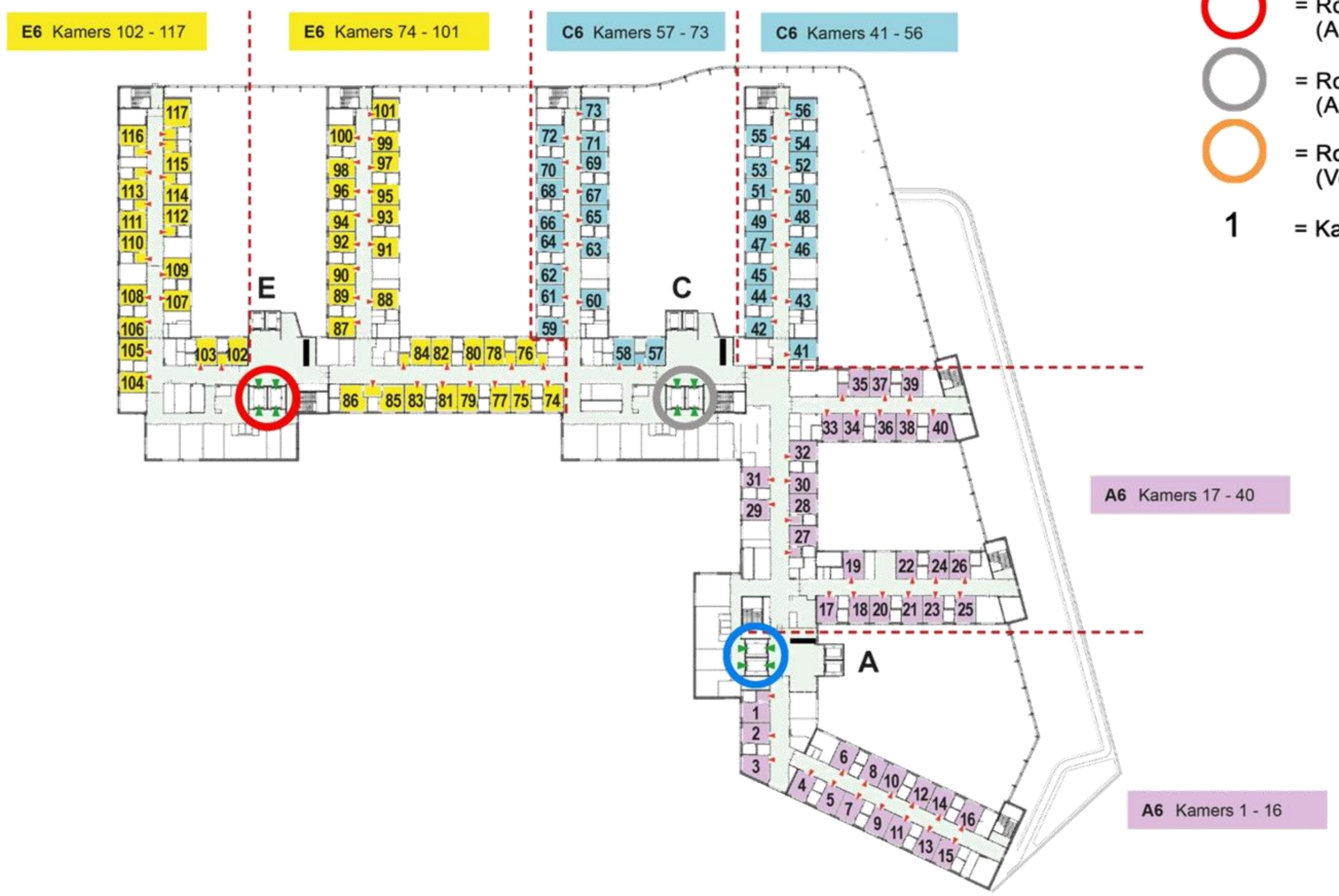
= Route blauw (Afdeling A & B)

= Route rood (Afdeling E & D)

= Route wit (Afdeling C)

= Route oranje (Verdieping 3)

1 = Kamernummers



Appendix VII Value Focused Thinking method

The VFT approach provides a systematic way to identify desirable decisions opportunities and create alternatives. Furthermore, the approach identifies values of every desirable decision and organizes those values. The approach is helpful to find the objectives, and values of those objectives, a customer cares about (Keeney, 1996). Besides, VFT can help to find hidden objectives. An objective is a statement of something which a customer wants to achieve. The first step in VFT is to identify the objectives, for this a questionnaire is used. The purpose of this questionnaire is for the customer to come up with a list of objectives (Keeney, 1996). There are many techniques to find those objectives, for example a wish list, alternatives, problems and consequences. (Keeney, 1996) Some of the questions we use in this research are:

Can you tell us what you expect of the new order method? How would you like to see it?

Can you tell us what aspects of the new order method you like and which you don't?

Can you tell us what opportunities or challenges you see in the new method?

The second step in the VFT is to structure the objectives. Not all objectives in the list are real objectives, in this step it is important to find the fundamental objectives and the means objectives. Fundamental objectives are important in a decision situation, means objectives are relevant to other objectives. To find the two different types of objectives Keeney developed the "Why is that important?" test. In this test the interviewer will ask the customer to be specific about all objectives. It is important to know why the objective is important for a customer (Keeney, 1996). The third step in the VFT is to create a model in which all relations between the fundamental and means objectives are shown. With this model it is easier to understand the complexities of the decision maker's value system, and to select alternatives to achieve the statements the customer wants to achieve (Keeney, 1996).

Appendix VIII Orientative interview

Inleidende vragen:

Kunt u mij vertellen hoe voorheen de voorraad werd bijgevuld?

Kunt u mij vertellen wat het nieuwe bevoorradings systeem precies inhoud?

Kunt u mij vertellen hoe het nieuwe systeem bij u op de afdeling wordt gebruikt? (Is er een bepaalde strategie om de kaartjes te plaatsen, is er een iemand verantwoordelijk of meerdere. Hoe verloopt de communicatie rondom het nieuwe systeem?)

Kunt u mij uitleggen waarom het nieuwe bevoorradings systeem in het MST is geïmplementeerd?

Vragen over het systeem

(*Wish list*) Kunt u mij vertellen wat u verwacht van een bevoorradingssysteem? Hoe zou u dit graag ingericht willen zien?

(*Problems and shortcomings*) Kunt u mij vertellen welke aspecten van het nieuwe systeem u goed bevallen?

(*Consequences*) Kunt u mij een of meerdere situatie(s) beschrijven waarbij het nieuwe systeem naar uw mening een positief resultaat heeft geboekt? Waarom was dit resultaat positief? (*Het is hier belangrijk om hier concrete voorbeelden uit te halen en ook cijfers uit te kunnen halen.*)

(*Problems and shortcomings*) Kunt u mij vertellen welke aspecten van het nieuwe systeem u niet goed bevallen?

(*Consequences*) Kunt u mij een of meerdere situatie(s) beschrijven waarbij het nieuwe systeem naar uw mening een negatief resultaat heeft geboekt? Waarom was dit resultaat negatief? (*Het is hier belangrijk om hier concrete voorbeelden uit te halen en ook cijfers uit te kunnen halen.*)

(*Goals, constraints, and guidlines*) Kunt u mij vertellen welke mogelijkheden u ziet in het nieuwe systeem?

(*Goals, constraints, and guidlines*) Kunt u mij vertellen welke uitdagingen u/jullie zijn tegen gekomen?

(*Different perspectives*) Kunt u mij vertellen of u ook zorgen draagt over het systeem en wat deze zorgen inhouden?

(*Strategic objectives*) Stelt u zich het voor, er zijn nog helemaal geen regels opgesteld voor het nieuwe systeem. Kunt u mij vertellen hoe u het zou inrichten?

Appendix IX Measure plan remaining KPIs

We observe that some KPIs are more important than other some KPIs are considered main causes and others can be seen as consequences of the main causes. In this case, we belief that the demand for a better usability will decrease when the processes are more optimally designed. For example, when the orders are delivered always completely and on time the demand for more information on the order board will decrease. The users then know that the orders will always be on time and without many backorders.

In chapter 3 we find seven project objectives. These are: : (1) ***response time,*** (2) ***waiting time,*** (3) ***stock level in the department warehouses,*** (4) ***workload,*** (5) ***technology,*** (6) ***communication, and*** (7) ***size of department warehouse***. We split up the project objectives into three stages. In the first stage the timeliness and quality is measured. In this stage we measure the project objectives 1, 2, and 3. In the second stage we measure the workload. We expect these results are needed to calculate the optimal solution for the processes. In this stage we measure the project objective 4.1. We expect that the workload of the department employees will decrease when the other project objectives are optimized. We consider project objective 4.2 as an effect on the suboptimal processes. In the last stage we measure the usability of the system and the department warehouses. In this stage we measure the project objectives 4.2, 5, 6, and 7. We consider these project objectives as effects of the other project objectives. We expect that the demand to these project objectives will decrease when the other project objectives are improved.

Appendix X Remaining results of the KPIs

In chapter 4 we measure the performance of the KPIs *delivery time, out-of-stock moments,* and *order card or order board errors*. In this research we also measure the results of the remaining KPIs of the project objectives *(1) response time, (2) waiting time, (3) stock level in the department warehouse*, and *(4) workload*. In this appendix we show the results of the remaining KPIs.

(1) Response time

We determine the response time as the time interval between a request moment and the moment the request is executed. The KPIs of the response time are the response time for: *(i) urgent orders, (ii) creating a new order card, (iii) adding a new product, (iv) location change, and (v) bin value change.* We could not deduce the direct response times from the data of the systems Oracle or Alltrack. Therefore we collect data from an interview.

Response action	Target time	Actual time
(i) Urgent order		Directly or within arranged time
(ii) Create a new order card	2 days	3 days
(iii) Add a new product	3 days	4 days
(iv) Location change	2 days	3 days
(v) Bin value change	2 days	3 days

Table X.1 The results of the response time conduct by interviews with the back office employees

Table X.1 shows the results. We conclude that the response time by urgent orders are correct. The response time of the other request are high. When we consider the process steps to carry out the request, we conclude that the response time can be much lower.

(2) Waiting time

The remaining KPI of waiting time is the *waiting time of backorders*. Backorders are ordered products that are not on stock in the central warehouse. We count the number of days a product stays on backorder and calculate the average waiting time per ordered day. Therefore, we use the data from Oracle. Table X.2 shows the results. We conclude that the average waiting time of backorders is 3.5 days. We conclude this value is good. We conclude that the higher waiting times on the order days Thursday and Friday are caused by the weekend.

Weekday	Waiting time (d)
Monday	3.5
Tuesday	3.5
Wednesday	3.6
Thursday	4.2
Friday	5.7

Table X.2 Average waiting time backorders per order day given in days

(3) Stock level in the department warehouse

3.1 Occupancy rate logistic employees

When the logistic department is under occupied this will have an impact on the stock level. On that moment there are not enough employees available to deliver the products within the required delivery time in the department warehouses. The occupancy rate of the central warehouse is 25 fte. In Dutch healthcare organizations 1 fte is 36 hours. In the back office of the central warehouse is 1.8 fte. For the other processes the ftes are distributed differently every day. We conclude that it can be that the logistic department has too many employees working in the department because we do not observe any overtime caused by the processes and throughput times.

3.2 Delivery reliability

The remaining KPIs of the delivery reliability are the *number of completely delivered orders* and *the number of urgent orders*. In the calculation of the number of completely delivered orders we include the warehouse products. We assume that sales products cannot be delivered on the order day. We use the data from Oracle.

	Monday	Tuesday	Wednesday	Thursday	Friday
Complete orders	81%	91%	87%	90%	88%
Incomplete orders	19%	9%	13%	10%	12%

Table X.3 The number of orders that are delivered completely or not given in percentage.

Table X.3 shows the results of the calculation. In the three months that were analysed we find 9,363 orders were placed during the weekdays. We conclude that the overall completeness rate is low and especially on Monday the rate is low. We calculate the correlation between the total number of orders and the total number of completely delivered orders. Figure X.1 shows the results of this calculation. We conclude there is no correlation between the number of orders and the number of orders that are delivered complete.

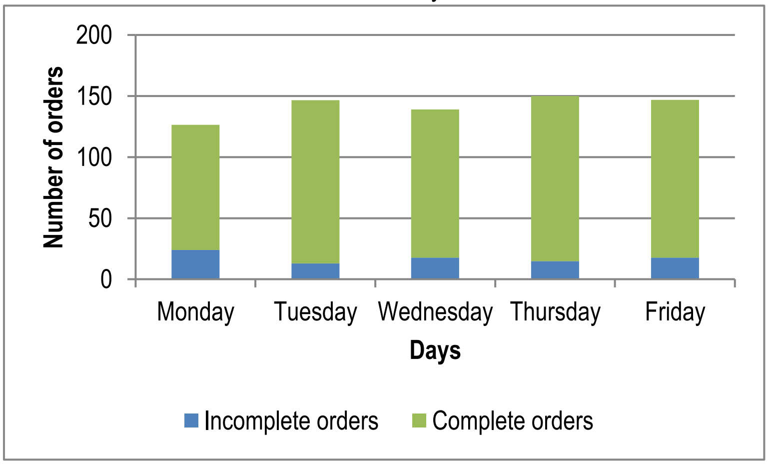


Figure X.1 The average products delivered completely and incompletely per weekday

The urgent orders are orders of products that are needed directly by the department staff, but are not present in the in the department warehouse or other department warehouses. We calculate the number of urgent orders with the data from Oracle. In the calculation we only include the hospital departments that are working with the new order method. Table X.4 shows the results. We observe an average of 3,513 orderlines ordered by the order boards per week, of which 29 orderlines were urgent orderlines. We conclude 0.8% of the orderliness are urgent. We conclude that the number of urgent orders is not high

Sort order	Average number in a week (#)	Percentage
Normal order	3513	99.2 %
Urgent order	29	0.8 %

Table X.4 Average number of orderlines classified as normal order, urgent order or return order. In the third colom given in percentage.

3.3 Use of order cards

The remaining KPIs are *number of registered order cards, number of double registered order cards* and *the number of lost order cards*. The total number of registered order cards are calculate with the data from Alltrack. We measure the KPI immediately after the selected time interval, namely on 9th of February 2017. We find on that date 12,760 registered order cards. We conclude that 6,380 product-location combinations can be ordered with the new order method, because for every product on stock in the department warehouse two order cards are in use. We observe that some order cards are linked to two different product-location combinations. We conclude 30 order cards are double registered. We conclude that that number is less than 1% and because of that do not have many impact on the use of order cards. The performance of the last KPI are not registered in any system. We count the request of a new order card at the backoffice because of a lost order card between the 10th of February 2017 until the 31st of March 2017. We conclude that 119 order cards will get lost in one year, that is 0.9% of all order cards in use. We conclude that is a low value and do not have many influence on the performance of the use of order cards.

3.4 Bin value

The remaining KPI of the project objective bin value is *the number of products expired*. We observe there is no registration place of the number of products that expire. We ask the department staff to give us more information. Most interviewed people replied with the answer that they do not register the expired products because there is almost nothing that exceeds the expiration date. A few departments noted that sometimes the ordered amount is very high, higher than the demand is. There is no other option than ordering these amount for some products and because of that products sometimes expire. The departments themselves have made a solution for this problem. Before the products expires, they bring the products to other hospital department that have a higher movement of this product. We conclude that the bin value in the department warehouses are mostly not too high.

3.5 Central warehouse stock level

This project objective is calculated by the KPI fill rate. The fill rate is the probability that a product is available in the warehouse at the moment the product is ordered.

To find the fill rate we use the following formula:

$$Fill\ Rate_m = (B_m/D_m) * 100$$

To find the fill rate we divide the total back order amount (B) of month m by the total demand amount (D) of month m and multiplied by 100 to calculate the fill rate in percentages. We use this formula separately for every product. We calculate the fill rate for every month of the reference period separately. To find one average fill rate per product we calculate the average fill rate of the three months, provided that in every month an order is placed of the product. To calculate the fill rate we use data from Oracle. To make a good comparison and conclusion, we compare the fill rate with the total orderlines, total demand amount and total backorder amount of the three months in the results.

Appendix XXI shows the products with a fill rate value of 95% or lower, which is, 14% of the ordered products in the three months. We conclude that most of the 143 products have a fill rate value of at least 80%. We conclude this is a good result, but we think this result can be improved. We conclude that some of the low fill rates are caused by the low number of times the products are ordered in the reference period.

3.6 System reliability.

The remaining KPIs of the system reliability are the *number of breakdown moments of the order boards* and *the number of internet errors*. When there is a breakdown moment of an order board, the order board will fall out. We observe the breakdown moments are not registered in any system or document. Because of that we asked the project manager, who managed the new order boards for more information. The project manager did not get any notifications of a breakdown moment over the selected three months and the two months after. With this information we conclude that the order boards are working well and without any breakdown moments during the reference period.

The last system mistake we find is the internet error. The order boards sent the orders to Oracle using internet. The order boards do not work wireless, but are connected by cable. When a problem arises with internet, there is no backup system. We conclude that the system reliability is low caused of the internet connection. There is no backup plan available. We observe no registration point when an internet problem occurs. Since March 2017 it is possible to see in Alltrack when there is an internet problem. The home page shows which order board have little or no connection with the internet at the moment, when the connection is working well again the order board will disappear from the list. However Alltrack does not save the number of errors.

(4) Workload

The remaining sub-project objectives of workload are *workload logistic employees* and *workload department staff*.

4.1 Workload logistic employees

The workload is the time the employees are working on a process. The logistic employees work every weekday from 8.00 AM to 4.30 PM. Since March they also work on Saturday. In Section 4.1 we give the time interval of this research, in this time interval the logistics employees did not work on Saturday. For that reason we do not show any results of the Saturday.

The workload of logistics employees is classified in different roles. In Section 3.2 we discuss five different processes. These processes are all carry out by the logistic staff, but every employee has a different role. The roles we find in the central warehouse are *(i) receiving role, (ii) pick and fill role, (iii) transport role,* and *(iv) deliver role*. We measure the workload for each role with the data from Oracle.

The ***(i) receiving role*** is the role of receiving orders from external suppliers. Table X.5 shows the average total orderlines for products that are received in the received department per day. We observe a low value on Monday in comparison with the other weekdays. We did not measure the time a receiving employee needs to perform all steps because each order differs in size and how it is received at the received department. We observe three people are working in the receiving department every day from 8.00 AM to 4.30 PM

Weekday	Average number of received orderlines
Monday	276
Tuesday	388
Wednesday	366
Thursday	341
Friday	341

Table X.5 Average number of received orderlines per weekday

The ***(ii) pick and fill role*** involves the employees who are working in the warehouse department of the central warehouse. The main activity we observe in the warehouse is the order picking. The other activities are ordering the warehouse by placing received products into the warehouse, weekly counting products in the warehouse, clean up empty cards, and keep the warehouse clean and tidy. The counting activity is taking place once a week. We ask the logistic employees to measure how many orderliness can be picked in one hour. We observe in the sterile warehouse a number of 95,8 orderlines per hour and in the unsterile warehouse an average number of 48,7 orderlines per hour. We calculate the average picking time per weekday and per kind of warehouse when one employee is picking the products. Currently, most often two employees are working in the sterile warehouse and three employees are working in the unsterile warehouse. Table X.6 shows the results.

	Average total orderlines for sterile warehouse	Average picking time for sterile warehouse (HH:mm)	Average total orderlines for unsterile warehouse	Average picking time for unsterile warehouse (HH:mm)
Monday	737	7:42	909	18:39
Tuesday	399	4:10	577	11:51
Wednesday	427	4:27	530	10:52
Thursday	350	3:19	518	10:38
Friday	455	4:45	534	10:58

Table X.6 The average orderlines per weekday and kind of warehouse and the average picking time per weekday and per kind of warehouse.

We conclude that the average picking time on Monday is high because on Monday more orderliness need to be picked. We conclude this is caused by the weekend, because in the weekend no orders are picked. We conclude that the picking process in the unsterile warehouse takes more time because the number of orderlines is higher and the warehouse is bigger and more complex. That results in more walking time.

Another activity of this role is placing received products in the warehouse. We measure the average orderlines that are fill in the central warehouse each day. Table X.7 shows the results. We do not measure how long it takes to place a received orderline into the warehouse because in the first place we focused on the main activity, namely order picking. For that reason we cannot conclude how much time is occupied by placing the received orderlines into the warehouse.

	Average orderliness fill in sterile warehouse	Average orderliness fill in unsterile warehouse
Monday	28	47
Tuesday	45	54
Wednesday	37	60
Thursday	60	55
Friday	33	44

Table X.7 Average orderliness fill in the two kind of warehouses.

The next role we discuss is the ***(iii) transport role***. The transport employees have multiple activities. They transport the ordered products from the central warehouse to the hospital and the empty carts back again. The other activity is to deliver the sales products that are not connected to the order boards to the hospital departments. Commonly two employees are transporting the carts and pallets into the warehouse and one employee is transporting the products from the carts to the hospital departments. Table X.8 shows the average number of orderlines of sales products that are transported to the hospital departments per day. We conclude the value on Monday is low in comparison with the rest of the week because of the weekend. We measure that it takes 17 minutes to transport one pallet or maximum 6 carts from the central warehouse to the hospital.

	Average sales products transported
Monday	201
Tuesday	290
Wednesday	269
Thursday	225
Friday	263

Table X.8 Average products transported into hospital per weekday

The last role we discuss is the ***(iv) deliver role***. The employees of this role are mainly deliver the ordered into the department warehouses. Besides, these employees have other activities. Namely checking if a change request can be implemented and implement the change request, we described the different change requests in Section 3.2.6. Other activities are checking whether the order cards are too long been placed on the board, checking if the order boards are still working properly and check if the department warehouses are still tidy. Mostly three employees have this role each day. We measure the lead time per cart and the average number of orderlines delivered in an hour. We observe that 40% of the lead time is walking time, that is the time that the employee is walking to the next department or to the basement to take another cart. We measure the average total delivery time per weekday by one person.

	Monday	Tuesday	Wednesday	Thursday	Friday
Average orderlines (#)	1096	566	516	556	567
Average delivery time (HH:mm)	18:28	9:30	8:41	9:22	9:31

Table X.9 Average orderlines and delivery time per weekday by one person

Table X.9 shows the results of this measurement. We did not include route orange, because this rout is not delivered by the logistic employees. We conclude that on Monday the average delivery time is high because of the average orderliness. The high number of orderlines is caused by the weekend. We conclude the total delivery time on Monday is too high and the probability that the logistic employee needs to work overtime. We conclude that the other delivery times are stable and good.

The last KPI of the workload of logistic employees is the extra workload. The extra workload is caused by return orderlines. The return orderlines are products that are ordered, but are not yet needed at the hospital department. The products are sent back to the central warehouse. In the return orderline process every role, with the exception of the receiving role, is involved. We measure the number of return orderlines per week with the data from oracle. With the data from Oracle, we conclude that 2% of all orderlines is sent return. We conclude that every return orderline is too much, but this result do not result in many extra workload.

(4.2) Extra workload department employees

The second sub-project objective of workload is the workload of the department employees. We observe the workload of the department employees that is connected to the new order method is not directly related for providing care. We observe this workload is an extra workload for the department employees. Moreover, we have not enough time to measure and analyse the results of this sub-project objective. In Appendix IX we set up a measure plan. We observe some of the KPIs will appear as a result of the other KPIs. We expect that when the other KPIs are improved, the extra workload caused by the system will decrease. Because of that this sub-project objective was less important to measure and analyse directly.

Appendix XI The not measured project objectives

The last three project objectives are *technology, communication, and size of department warehouse*. We do not show the results of those project objectives because we did not have enough time to measure the results. In Section 3.6 we discuss the measure planning of the project objectives. In this planning the project objectives technology, communication, and size of department warehouse are the last project objectives we want to measure. We discuss in this appendix our recommendations on how to measure these project objectives.

We split the *technology* into two sub-project objectives: *human-machine interaction and information accuracy*. With *human-machine interaction* we mean that the machine is doing what the human (user) expects of the machine and on the other hand the machine expects a particular action of the human (user). We compose the following KPIs for this project objective: *readability, touchscreen, colour, selection buttons, windows,* and *update system*. We expect that when the system has for example a good working touchscreen or clear selection buttons the human-machine interaction will be correct. The other project objective of technology is *information accuracy*. With *information accuracy* we mean that the users are provided with the correct and expected information by the machine, so the users are well informed by the machine. We compose the following KPIs to measure the project objective information accuracy: *accurate information on the order board* and *accurate information on Oracle*.

The next project objective is *communication*. With a good communication system users know what they can expect and how they have to work with the new order method. We determine the following KPIs to measure the communication: *procedure for hospital department, evaluation moments, procedure for logistics department,* and *documentation.*

The last project objective is the *size of department warehouse*. We determine the project objective by the KPIs *walk time* from patient rooms to department warehouse and back again and the *search time* in the department warehouse.

The project objectives we describe above can be measured in multiple ways. Almost all of these project objectives can only be assessed very subjectively. We advise the hospital to compose a questionnaire to assess the project objectives. We advise them to make one questionnaire for all project objectives to prevent the users are demotivated to fill out many questionnaires. The type of questions the hospital can use can be determined based on information they want to obtain. On the other hand, the project objective communication can also be assessed based on the document information. For example, are the procedures available and are there evaluation moments planned? Also the project objective size of department warehouse can be assessed by facts. The hospital can measure what the walking times are and how long the search times are. But still, we conclude that the hospital needs questionnaires to assess how the users experience the project objectives. When the hospital works with questionnaires we think that a total picture of the project objectives can be obtained.

Appendix XII The total errors per order board

Order board	No error	Maybe an error	Error
AIC A	88.08%	11.04%	0.88%
AIC B	93.28%	6.08%	0.64%
AIC C	88.70%	10.03%	1.26%
AOA A6 O	94.97%	4.95%	0.08%
AOA A6 S	98.56%	1.44%	
AOA BG O	95.44%	4.47%	0.10%
AOA BG S	96.84%	3.16%	
P-Behan	91.82%	7.70%	0.48%
P-Cardio	98.53%	1.47%	
P-Dagb LS	96.82%	3.02%	0.16%
P-Dagb O	93.04%	6.87%	0.09%
P-Dagb RS	97.56%	2.44%	
P-Derm	94.51%	5.49%	
P-GIPSK	95.72%	4.12%	0.15%
P-HEMO O	98.61%	0.69%	0.69%
P-HEMO S	93.82%	6.09%	0.09%
P-Intg	75.88%	19.30%	4.82%
P-KNO	97.56%	2.13%	0.32%
P-Longf	93.43%	6.32%	0.25%
P-MDL O	96.74%	3.09%	0.17%
P-MDL S	94.88%	5.03%	0.09%
P-MOKA	95.12%	4.88%	
P-Neuro	98.97%	1.03%	
P-Reuma	97.37%	2.63%	
P-Rontg	95.64%	4.28%	0.09%
P-SEH O	94.81%	5.18%	0.01%
P-SEH S	95.74%	4.26%	
TIC	91.77%	7.79%	0.44%
V-A5 O	94.84%	5.12%	0.04%
V-A5 S	94.37%	5.42%	0.22%
V-A61 O	96.65%	3.35%	
V-A61 S	96.32%	3.62%	0.05%
V-B4 AO	97.36%	2.64%	
V-B4 AS	96.00%	3.33%	0.67%
V-B4 BO	97.78%	2.22%	
V-B4 BS	97.88%	1.89%	0.24%
V-C4 O	93.21%	6.74%	0.05%
V-C4 S	96.30%	3.59%	0.11%
V-C61 O	94.06%	5.91%	0.02%
V-C61 S	96.84%	3.10%	0.06%

Order board	No error	Maybe an error	Error
V-CCU O	92.43%	7.15%	0.42%
V-CCU S	93.93%	5.68%	0.39%
V-E4 O	95.26%	4.67%	0.07%
V-E4 S	94.05%	5.61%	0.34%
V-E5 LONO	96.04%	3.92%	0.04%
V-E5 LONS	90.15%	9.77%	0.07%
V-E5 MDLO	97.87%	2.00%	0.13%
V-E5 MDLS	83.56%	15.82%	0.62%
V-E61 O	93.14%	6.71%	0.15%
V-E61 S	96.21%	3.77%	0.02%
V-EHH S	95.42%	4.42%	0.16%

Appendix XIII Remaining analyse results of the KPIs

In chapter 5 we analyse the causes and effects of the KPIs *delivery time, out-of-stock moments,* and *order card or order board errors*. In this research we also analyse the cause and effects of the remaining KPIs of the project objectives *(1) response time, (2) waiting time, (3) stock level in the department warehouse*, and *(4) workload*. In this appendix we show the results of the remaining KPIs.

(1) Response time

For the response time no required time is prepared in advance. The response time of urgent orders is directly or within arranged time, we conclude this is a good result. The other response times are for creating new order cards, addition of a new product, location change, and bin value change. We conclude the response time can be improved. We find that the response time of the last four request are dependent on multiple steps. We observe these steps do not take much time, but the time between these steps is too long. The waiting time between these steps is caused by multiple reasons: one employee is educated to create new order cards, the new order cards are mostly only created on Tuesday, and all communication is done by forms.

(2) Waiting time

The remaining KPI is the *waiting time of backorder*. We observe the waiting time of backorders depends on the delivery time per product, the delivery time per external supplier and the order moment of the hospital.

We show the average delivery time per product in Appendix XXII. We calculate these with the data from Oracle. We observe 133 products have an average delivery time of 2 days or less. We conclude this do not cause a high waiting time. In the appendix we show the 101 products with a delivery time of at least 2 days. The values vary between the 2 and 54 days. We conclude some delivery times of the products are too high. Because of that, the probability of an out-of-stock moment in the central warehouse is high.

We show the average delivery time per supplier in Appendix XXIII. We calculate these results with the data from Oracle. We observe 63 different external suppliers, and most of these suppliers have an average delivery time lower than 5 days. We observe 14 suppliers have an average delivery time higher than 5 days. We conclude this is a high value. We observe the average delivery time depends on the number of ordered products. It can happen that the external supplier had a delivery problem for one product and that results in a high average delivery value. Because of that we combine the information of the average delivery time per product with the supplier information. Appendix XIV shows the results of this measurement. We conclude that some of the high values of suppliers are caused by one product, and at some suppliers all average product delivery times are high. We think this can be improved.

The last cause we discuss is the order moments hospital. With that moment we mean when the hospital orders products at the external suppliers. At some suppliers the hospital can order products every day, but at some the hospital orders once a week. We combine the order moment information with the average delivery times of the external suppliers in Appendix XIII. We use a supplier list from 2015 because that is the last available list. We conclude that the hospital cannot order at most suppliers every weekday. We conclude that multiple high values can, at least partially, be explained by the order moment. We conclude the suppliers ICT Spirit and Terumo Europe have a long average delivery time and that cannot be explained by the order moment.

Overall we conclude that the average external delivery time depends mostly on the product type, and specifically on the external supplier. The supplier is responsible for the delivery, but what we observe is that an incident can happen at the external supplier that results in a high delivery value of a product. The hospital needs to check if it happen often with one product to avoid out-of-stock moments with that product.

(3) Stock level in the department warehouse

(3.2) Delivery reliability

The remaining KPI is the rate of completely delivered orders. We consider the possibility that when the order contains many orderlines the probability that one of these orderlines is out-of-stock gets higher. For that reason we analyse if there is a correlation between the number of orderlines on an order and if the order is delivered completely. We use the data from Oracle to calculate this. Appendix XXV shows the results of this analysis. We use the orders with 1 until 37 orderlines because higher than 37 the number of orders get too low to make a conclusion. We conclude that there is a correlation between the number of orderlines on the order and the probability that the order is not delivered completely. We conclude that the probability that an order is delivered completely is high at a high number of orderlines on the order. We think the performance can be improved. Besides, we measure the average orderlines on an order per weekday. Table XIII.1 shows the results. We conclude that the low complete rate on Monday is caused by the average number of orderliness on the orders.

(3.5) Fill rate

Weekday	Average number of orderlines on an order
Monday	12,7
Tuesday	6,6
Wednesday	6,9
Thursday	5,7
Friday	7,5

Table XIII.1 Average number of orderlines on the order per weekday.

The fill rate is the probability that the product is on stock at the moment it is ordered. One cause is very easy to imagine, that is that the stock level in the central warehouse is not correct. The minimum and maximum value is not determined correctly meaning there is not always enough stock in the central warehouse to manage the demand. Another cause we observe is the number of orderlines per product. We can image that when the order is not ordered often the logistic department decided to not store a lot of this product in the central warehouse. This increases the probability that the product expires and the value of the products decreases.

(4) Workload

(4.1) Workload logistic employees

The last effects we discuss is the extra workload of the logistic employees. The extra workload is caused by the orders that are sent return to the central warehouse. In Oracle, we find a rate of 2% of the total orderlines that is sent return. We ask the logistic employees to note the reason for the orderline to be sent return. This data is collected from 24th of October until 21th of December. The most common reason is that the order card placed too soon (68%). That means that the order card is located on the order board, but the bin is not empty. The second reason is that the order cards is not placed on the board and the bin is not empty (12%). This can be caused by a system mistake. The third reason is a pick mistake (3%). That means the wrong product is picked in the central warehouse.

Appendix XIV Delivery time sales products

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A01677	Vicryl Rapide ongekl 3-0 75cm FS-1 VR2252 36st	3.0	1
A01523	Hurricane RX dil ballon dilatatiekatheter? 8-40mm	6.7	3
A02594	Ph-teststrips 2.0-9.0 gradiation 0.5 100st	12.0	4
A01581	Alliance II Inflation System Syringe 60cc??? 5st	16.5	2
A01620	Delta-Cast Soft wit 10cmx3.6m 10st.	18.0	2
A02715	Stuwband blauwe band voor patient specifiek 15st	28.0	1
A01514	Trapezium RX Basket wireguided basket 25mm	28.3	3
A01544	Pushing Catheter 7Fr	29.0	2
A01482	Advanix al-in-one Stent 10Fr 15cm	29.3	3
A01584	Wirelock voor Olympus/ Fuijnon scoop? 10st	29.4	5
A01603	Elastomull haft color Blauw 10cmx20m 24st.	30.0	3
A01981	Limoenspray LaproCare 50ml	30.0	1
A01978		31.0	1
A02268	Plastic zak LPDE zwart 70x110cm 68mu 15st	37.5	11
A01566	Wirelock voor Olympus/ Fuijnon scoop? 10st	38.0	3
A01977		38.5	2
A01586	Jagwire High Performance Guidewire stiff shaft .035/027 L450cm 2st	39.2	10
A01527	CRE wireguided dilatatie ballon 10-11-12mm	45.3	3
A01985	Cellona Polster 5mm dik in foliezak 19cmx38mtr 10st	45.7	3
A01479	Advanix al-in-one Stent 10Fr? 7cm	46.0	3
A01552	Dreamtome RX 44 Sphinct?rotome	49.4	5
A01660	Delta-Cast Soft zwart 5cmx3.6m 10st.	50.0	2
A01510	Maxi bite block 20mm 100st	51.0	4
A01986	Ethilon zwart 6-0 L45cm P-1 PRIME 697H 36st	51.0	1
A02168	Radial Jaw 4 Biopsy Forceps Capacity L160cm 40st	51.3	4
A01498	Fusion katheter Pushing 5.0Fr L170	52.0	1
A01500	Resolution clip device L2.35m??? 10st	52.0	1
A01506	Roth net L2.30m 30x60mm 5st	52.0	1
A01709	HS filterpapier wit 18x28cm 250st	52.0	1
A01755	Biopsieventiel,bronchoscopen,single use,steriel verpakt MAJ-210 20st	52.0	2
A02196	Cavex Colorchange 500 g	52.0	1
A01470	Captivator Polypectomy Snare Small Oval 13 mm 10st	52.2	5
A01463	Injection Gold Probe Electrohemostase katheters 25G L210cm ms6016	53.0	1
A01469	Captivator II Polypectomy Snare 20mm Rounded 10st	53.0	1
A01478	Advanix al-in-one Stent 10Fr? 5cm	53.0	2
A01502	Injection Gold Probe Electrohemostase katheters 25G L210cm ms6015	53.0	1
A01503	Interject Sclerotherapie naald 25G L200cm 5st	53.0	2
A01565	Fusion Guidewire Locking Device 10st.	53.0	1
A01580	CRE wireguided dilatatie ballon 18-19-20mm	53.0	1
A01589	ERCP Guidewire Eder-pustow monofil L3.15m 2st	53.0	1

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A02048	Spot endoscopic marker (syringe 5ml) 10st	53.2	5
A01518	Dreamtome RX 44 Sphinct?rotome	53.3	6
A01585	Jagwire High Performance Guidewire standaard? .035 L450cm?? 2st	53.5	2
A01930	Ethilon zwart 6-0 L45cm P-1 PRIME 697H 36st	53.5	2
A01477	Geenen Soft-Flex Stent Pancreatic 5Fr L30mm	54.0	1
A01481	Advanix al-in-one Stent 10Fr? 12cm	54.0	1
A01520	Hurricane RX dil ballon dilatatiekatheter? 6-40mm	54.0	1
A01533	Advanix al-in-one Stent 10Fr? 5cm	54.0	1
A01573	Naso biliary drainage set 7.0Fr L250cm	54.0	1
A01582	Encore 26 Inflation Device	54.0	4
A01591	Naso biliary drainage set 7.0Fr L250cm	54.0	1
A01593	Combo Cath RX Cytology Brush voor korte voerdraad L200cm	54.0	1
A01892		54.0	1
A01901	Vicryl plus ongekl 4-0 L45cm PS2 VCP496ZH 24st	54.0	1
A01905	PDS plus ongekl 5-0 L45cm P-3 PDP493H 24st	54.0	1
A01495	Stent Biliary Zimmon 7Fr L40mm	54.3	3
A01521	Rigiflex II Achalasie-ballondilator 35mm	55.0	1
A01540	Stent Biliary Zimmon 7Fr L40mm	55.0	3
A01609	Leukotape Classic 3.75cmx10m 5st.	55.0	1
A01648	Delta-Lite spalk wit 5 laags 7.5x20cm 10st.	55.0	1
A01517	Extractor Pro RX Triple-lumen Retrieval Balloon 12-15mm	56.7	7
A01467	Interject Sclerotherapie naald 23G L240cm 5st	60.3	7
A01484	Endogator tubing voor Olympus OFP pump 50st	61.0	3
A01466	Sensation Jumbo Oval Poliepectomiesnaar 5st	61.3	3
A01559	CRE wireguided dilatatie ballon 12-13.5-15mm	64.5	2
A02198	KH CLeanpolish 45gr 360	64.5	2
A01895	Ethilon blauw 4-0 L45cm PS-2 PRIME EH7162H 36st	66.5	2
A02316	Delta-Cast Soft roze 5cmx3.6m 10st.	66.5	2
A01471	Exacto coldsnare diam. 2.4mm, lengte 230cm 10st	69.0	3
A01597	Radial Jaw 4 Biopsy Forceps L240cm 40st	70.0	3
A01950	Ethilon blauw 3-0 L45cm PS PRIME W1625T 24st	70.0	3
A01505	Interject Sclerotherapie naald 23G L240cm 5st	71.2	5
A01461	Speedband Superview Super 7 Bandligatie 2st	71.4	5
A01472	Maxi bite block 20mm 100st	73.2	6
A01456	Polyp trap 25st	75.0	10
A02195	Lact Protheseborstel p.st.	75.0	1
A01512	Fusion Oasis Stent 9fr met 5.5Fr radiopaque guiding catheter	75.5	2
A01925	Limoenspray LaproCare 50ml	75.8	4
A01751	Blunt Fill met filter opzuignaald rood 18G 40mm 100st	76.0	5
A01764	Biopsieventiel,bronchoscopen,single use,steriel verpakt MAJ-210 20st	76.0	1
A01982	Batterij Duracell knoopcel DL2032	77.0	1

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A02228	Radial Jaw 4 Biopsy Forceps Capacity L160cm 40st	77.8	4
A01487	Polyp trap 25st	78.0	4
A01524	Hurricane RX dil ballon dilatatiekatheter? 10-40mm	78.0	2
A01894	Ethilon blauw 3-0 L45cm PS PRIME W1625T 24st	78.0	2
A01951	Ethilon blauw 4-0 L45cm PS-2 PRIME EH7162H 36st	78.0	1
A01611	Delta-Cast Soft zwart 5cmx3.6m 10st.	79.0	1
A01664	Delta-Cast Prints camouflage 7.5cmx3.6m 10st.	79.0	1
A01668	Delta-Cast Soft wit 7.5cmx3.6m 10st.	79.0	2
A01908	Disp. Hechtverwijderset 100st	79.0	1
A01468	Roth net L2.30m 30x60mm 5st	82.8	4
A01551	Extractor Pro RX Triple-lumen Retrieval Balloon 12-15mm	83.0	4
A02206	Irrigatie spuit curvedtip 12ml 50st	83.7	3
A02310	Delta-Cast Soft roze 5cmx3.6m 10st.	84.0	3
A01588	Dreamwire ST Guidewire L260cm??? 2st	84.7	3
A01812	Ethilon blauw 4-0 L45cm PS-2 PRIME EH7162H 36st	85.0	5
A01614	Delta-Cast Prints camouflage 5cmx3.6m 10st.	86.0	2
A01504	Sensation Jumbo Oval Poliepectomiesnaar 5st	87.5	2
A02655	Thopaz / Thopaz+ slangenset enkel met afnamepunt steriel 10st	87.5	2
A01587	Jagwire High Performance Guidewire standaard .035 L260? 2st	88.0	2
A01526	CRE wireguided dilatatie ballon 15-18mm	89.0	2
A01583	Fusion Guidewire Locking Device 10st.	90.0	2
A02190	Halita tongreiniger kunststof 12st	90.0	2
A01572	Voerdraad Nitinol soft tip 35inch 400cm	93.3	3
A01673	Delta-Cast Soft blauw 10cmx3.6m 10st.	94.7	3
A01902	Vicryl ongekl 5-0 45cm P1 PRIME W9501T 24st	95.0	1
A01452	WaterJet connector met terugslagklep Olympus scoop? 50st	96.0	5
A01600	Delta-Lite spalk wit 5 laags 10x38cm 10st.	98.3	3
A01661	Delta-Cast Soft zwart 7.5cmx3.6m 10st.	99.0	4
A01501	Injection Gold Probe Electrohemostase katheters 25G L210cm ms6016	100.0	1
A01630	Vicryl Rapide ongekl 3-0 75cm FS-1 VR2252 36st	100.0	1
A02205	Endosheath tbv flexibele scoop 20st	100.0	1
A02227	HS Speekselzuigers wit losse dop 100st	100.0	1
A01622	Delta-Cast Soft blauw 5cmx3.6m 10st.	100.6	5
A01616	Delta-Cast Soft hondenpoot 5cmx3.6m 10st.	100.7	3
A01464	Injection Gold Probe Electrohemostase katheters 25G L210cm ms6015	101.0	1
A01476	Geenen Stent Pancreatic 5Fr L50mm	101.0	2
A01534	Advanix al-in-one Stent 10Fr? 7cm	101.0	1
A01753	Echo Tip Ultra Endobronchial HD Ultrasound Needle 22G 4.1Fr	101.0	2
A02595	Ph-teststrips 2.0-9.0 gradiation 0.5 100st	101.0	2
A02088	Delta-Cast Soft rood 7.5cmx3.6m 10st.	101.2	5
A01881	Microlance injectienaald groen 21G 0,8x50mm 100st	101.8	4

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A01465	Interject Sclerotherapie naald 25G L200cm 5st	102.0	1
A01592	Howell Biliary Introducer	102.0	1
A01962	Ethilon II blauw 5-0 L45cm FS-3 EH7823H 36st	102.0	1
A02299	Opsite IV3000 canule folie met opening 60x70mm 100st	102.0	1
A01511	Fusion katheter Omni ERCP 7Fr L200cm	103.0	1
A01675	Delta-Cast Prints pastel 7.5cmx3.6m 10st.	105.6	5
A02207	Cold-pack 12x28cm onsteriel 120st	108.0	3
A01906	Ethilon II blauw 5-0 L45cm FS-3 EH7823H 36st	110.0	3
A01651	Delta-Lite spalk wit 5 laags 12.5x90cm 10st.	110.7	3
A02313	Delta-Cast Soft rood 5cmx3.6m 10st.	111.0	2
A01590	Voerdraad Nitinol soft tip 35inch 400cm	111.2	5
A01595	Capsule endoscope minoca MC1200? 5st	114.0	6
A01931	Monocryl plus ongekl 3-0 70cm PS2 MCP4271H 36st	114.5	2
A01619	Delta-Cast Soft wit 7.5cmx3.6m 10st.	116.0	3
A02028	Ethilon II blauw 3-0 L75cm FS-1 EH7795H 36st	117.0	1
A02305	Netverband Nobanetz nr.0.5 tenen	117.0	3
A01462	Resolution clip device L2.35m??? 10st	117.7	3
A01937	Microlance injectienaald groen 21G 0,8x50mm 100st	117.7	3
A01954	Monocryl plus ongekl 4-0 70cm P3 MCP494H 36st	119.0	1
A02035	Ethilon II blauw 3-0 L75cm FS-1 EH7795H 36st	119.0	1
A01516	RX Needle Knife XL Triple-Lumen papillotoom	120.0	1
A01805	Vicryl plus ongekl 4-0 L70cm SH1 VCPV426H 36st	120.0	1
A01483	WaterJet connector met terugslagklep Olympus scoop? 50st	120.4	5
A01525	CRE wireguided dilatatie ballon 12-13.5-15mm	123.0	1
A01569	Jagwire High Performance Guidewire standaard .035 L260? 2st	123.0	1
A01570	Dreamwire ST Guidewire L260cm??? 2st	123.0	1
A01631	Durr Orotol plus 2,5l	123.0	1
A02222	Moyco Beauty Pink wax x-hard 454g	123.0	1
A02311	Delta-Cast Soft roze 7.5cmx3.6m 10st.	123.0	2
A01615	Delta-Cast Prints camouflage 7.5cmx3.6m 10st.	123.5	4
A01577	Capsule endoscope minoca MC1200? 5st	124.0	1
A01633	HS filterpapier wit 18x28cm 250st	124.0	1
A02191	Lact Tandenborstel IQXSoft 144st	124.0	1
A02220	Lact Protheseborstel p.st.	124.0	1
A01485	Radial Jaw 4 Biopsy Forceps L240cm 40st	124.5	2
A01453	Endogator tubing voor Olympus OFP pump 50st	125.0	2
A01968	Sapimed Haemorrhoiden Lem Ligator,disp 25st.	125.0	1
A02270	Plastic zak LPDE zwart 70x110cm 68mu 15st	125.4	5
A01958	Vicryl ongekl 5-0 45cm P1 PRIME W9501T 24st	126.0	1
A02515	Microlance injectienaald groen 21G 0,8x50mm 100st	126.0	1
A02520	Microlance injectienaald groen 21G 0,8x50mm 100st	126.0	1

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A01647	Delta-Lite spalk wit 5 laags 5.0x20cm 10st.	126.5	2
A02197	Polijstpasta 170gr. Dply Zircate	127.0	1
A02312	Delta-Cast Soft roze 10cmx3.6m 10st.	127.0	1
A02315	Delta-Cast Soft rood 10cmx3.6m 10st.	127.0	1
A02369	Prolongation lijn LLF-LLM L75cm 150st	127.0	2
A01602	Delta-Lite spalk wit 5 laags 12.5x90cm 10st.	131.3	3
A01710	Perio Aid Easy Pack 5ltr	147.0	1
A02314	Delta-Cast Soft rood 7.5cmx3.6m 10st.	147.7	3
A01878	Microlance injectienaald blauw 23G 25mm 100st	148.0	3
A01934	Microlance injectienaald blauw 23G 25mm 100st	148.0	2
A02192	HS Polijstborsteltjes latexvrij lila 100st	148.0	2
A02194	GC Reline soft cartridge 48ml	148.0	1
A02221	GC Reline soft cartridge 48ml	148.0	1
A01912	Sapimed Haemorrhoiden Lem Ligator,disp 25st.	149.5	2
A02317	Delta-Cast Soft roze 7.5cmx3.6m 10st.	149.5	2
A01817	Huidstansjes Stiefel voor biopsie 5mm 10st	150.0	1
A02430	Mepore chirurgische pleister 6x7cm steriel 480st	150.0	1
A01815	Huidstansjes Stiefel voor biopsie 3mm 10st	150.5	2
A01629	Vicryl Rapide ongekl 3-0 70cm SH-1 V2190H 36st	152.2	6
A01670	Delta-Cast Soft wit 12.5cmx3.6m 10st.	153.4	5
A01634	Perio Aid Easy Pack 5ltr	156.3	3
A02214	Schudbuisjes disp. voor de Silamat 50st	159.0	2
A02308	Delta-Cast Soft rood 5cmx3.6m 10st.	159.0	2
A01650	Delta-Lite spalk wit 5 laags 7.5x76cm 10st.	159.5	2
A01662	Delta-Cast Soft zwart 10cmx3.6m 10st.	163.0	2
A02297	Fistula-klem das260 2st	166.2	5
A01599	Delta-Lite spalk wit 5 laags 7.5x20cm 10st.	166.7	3
A01623	Delta-Cast Soft blauw 7.5cmx3.6m 10st.	169.3	6
A01624	Delta-Cast Soft blauw 10cmx3.6m 10st.	170.0	2
A01672	Delta-Cast Soft blauw 7.5cmx3.6m 10st.	171.0	4
A01762	Echo Tip Ultra Endobronchial HD Ultrasound Needle 22G 4.1Fr	171.0	1
A02203	VarioSurge koelslangetjes steriel en disp 25st	172.0	1
A02657	Thopaz / Thopaz+ slangenset enkel met afnamepunt steriel 10st	172.0	1
A01752	Echo Tip Endoscopic Ultrasound naald HD 22G 5.2Fr ECHO-3-22	172.3	3
A01885	Huidstansjes Stiefel voor biopsie 3mm 10st	173.0	1
A01924	Oogbescherming Lenzen tbv Frames 250st	173.0	1
A01598	Delta-Lite spalk wit 5 laags 5.0x20cm 10st.	173.2	5
A02636	LMA MADgic Larynx Mucosal atomization device 25st	174.0	1
A01816	Huidstansjes Stiefel voor biopsie 4mm 10st	174.5	2
A02318	Delta-Cast Soft roze 10cmx3.6m 10st.	175.0	1
A02209	Irrigatie spuit curvedtip 12ml 50st	181.3	3

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A02188	HS Speekselzuigers wit losse dop 100st	184.0	4
A01929	Cellona Polster 5mm dik in foliezak 19cmx38mtr 10st	190.7	3
A01669	Delta-Cast Soft wit 10cmx3.6m 10st.	191.0	1
A01612	Delta-Cast Soft zwart 7.5cmx3.6m 10st.	192.8	5
A02212	VarioSurge koelslangetjes steriel en disp 25st	196.0	1
A01884	Huidstansjes Stiefel voor biopsie 2mm 10st	197.0	1
A01926	Batterij Duracell knoopcel DL2032	197.0	1
A02348	Posey anti-slip sokken maat L groen	197.0	1
A02408	Posey anti-slip sokken maat L groen	197.0	1
A01964	Disp. Hechtverwijderset 100st	197.8	4
A01671	Delta-Cast Soft blauw 5cmx3.6m 10st.	198.0	1
A01676	Vicryl Rapide ongekl 3-0 70cm SH-1 V2190H 36st	198.0	5
A01758	Insyte Autoguard IV katheter 20G L30mm 50st	198.0	1
A01888	Huidstansjes Stiefel voor biopsie 6mm 10st	198.0	1
A01889	Huidstansjes Stiefel voor biopsie 8mm 10st	198.0	1
A01928		198.0	1
A02549	Abri-Flex Premium M3 broekluier 84st	198.0	1
A02554	Abri-Flex Premium M3 broekluier 84st	198.0	1
A01458	Adapter voor FiAPC-sonde 2200A D2.3mm L2.2mtr 10st	205.7	3
A02714	Stuwband blauwe band voor patient specifiek 15st	207.0	2
A02555	Abri-Flex Premium M3 broekluier 84st	212.7	3
A01626	Delta-Cast Prints pastel 7.5cmx3.6m 10st.	213.0	4
A01515	Bijtring voor kinderen? 5st	221.0	1
A01820	Huidstansjes Stiefel voor biopsie 8mm 10st	222.0	1
A01594	Flocare Bengmark voedingssonde 145cm Ch10 (569942) 3st	229.3	3
A02309	Delta-Cast Soft rood 10cmx3.6m 10st.	231.0	3
A01900	Vicryl plus ongekl 3-0 L70cm SH1 VCP219H 36st	233.5	2
A01457	Nessy Plate pati?nt neutral-elektrode 50st	238.3	3
A01750	Swann Morton mes nr. 10 met heft (steriel) 10st	244.0	1
A02201	Schudbuisjes disp. voor de Silamat 50st	244.0	1
A01759	Swann Morton mes nr. 10 met heft (steriel) 10st	267.0	1
A01854	Huidstansjes Stiefel voor biopsie 3mm 10st	270.0	1
A02635	LMA MADgic Larynx Mucosal atomization device 25st	313.0	1
A01653	Elastomull haft color Blauw 8cmx20m 24st.	314.0	2
A01499	Pushing Catheter 7Fr	317.3	3
A02208	Cold-pack 12x28cm onsteriel 120st	329.0	2
A01645	Surgistar Myringotomy Spear Blade 6st	366.0	1
A02289	Fistula-klem das260 2st	406.5	4
A02656	Thopaz opvangpot 800ml steriel 6st	436.0	1
A02304	Netverband Nobanetz nr.0.5 tenen	453.0	3
A02521	Steri-Strip basis wondsluiting 3x75mm 4x50st	497.0	2

Product code	Name of product	Avg. Delivery time (h)	Total orderlines (#)
A02654	Thopaz opvangpot 800ml steriel 6st	508.0	1
A01749	Insyte Autoguard IV katheter 20G L30mm 50st	509.0	2
A01556	Rigiflex II Achalasie-ballondilator 40mm	509.5	2
A01763		652.0	1

Appendix XV Average out-of-stock moments per weekday and per department

Name of department	Weekday	Average products get out-of-stock (#)
VPU Interne geneeskunde and High and Intensive Care	Sunday	9.8
	Monday	8.5
	Tuesday	4.6
	Wednesday	5.4
	Thursday	6.1
	Friday	6.9
	Saturday	5.7
Acute Opname Afdeling	Sunday	8.7
	Monday	7.2
	Tuesday	3.4
	Wednesday	6.1
	Thursday	4.1
	Friday	3.5
	Saturday	6.5
Spoed Eisende Hulp	Sunday	7.2
	Monday	7.9
	Tuesday	5.4
	Wednesday	3.5
	Thursday	4.2
	Friday	4.8
	Saturday	4.5
VPU Chirurgie/Oncologie	Sunday	8.3
	Monday	8.5
	Tuesday	2.8
	Wednesday	4.4
	Thursday	3.6
	Friday	4.3
	Saturday	3.6
VPU Longgeneeskunde	Sunday	5.0
	Monday	9.9
	Tuesday	3.8
	Wednesday	4.4
	Thursday	4.1
	Friday	2.8
	Saturday	3.1
VPU Vaat/Trauma/Ortho	Sunday	5.5
	Monday	8.5
	Tuesday	2.6
	Wednesday	2.9
	Thursday	4.5

Name of department	Weekday	Average products get out-of-stock (#)
VPU Vaat/Trauma/Ortho	Friday	4.4
	Saturday	3.9
VPU Strokeunit/Neurologie	Sunday	4.8
	Monday	4.6
	Tuesday	3.4
	Wednesday	2.9
	Thursday	3.4
	Friday	4.0
	Saturday	3.2
Thorax IC	Sunday	5.7
	Monday	3.7
	Tuesday	2.1
	Wednesday	3.8
	Thursday	3.8
	Friday	3.2
	Saturday	3.8
VPU A5 Thoraxchirurgie	Sunday	3.6
	Monday	6.8
	Tuesday	4.9
	Wednesday	1.8
	Thursday	2.4
	Friday	3.2
	Saturday	2.8
VPU Neurochirurgie/shortstay	Sunday	4.1
	Monday	5.4
	Tuesday	3.1
	Wednesday	3.7
	Thursday	2.9
	Friday	2.0
	Saturday	4.2
VPU MDL	Sunday	3.1
	Monday	6.5
	Tuesday	3.1
	Wednesday	2.3
	Thursday	3.2
	Friday	3.2
	Saturday	2.2
ICC E	Sunday	3.0
	Monday	4.0
	Tuesday	2.0
	Wednesday	3.0

Name of department	Weekday	Average products get out-of-stock (#)
ICC E	Thursday	2.5
	Friday	4.0
	Saturday	2.2
ICC C	Sunday	4.5
	Monday	3.0
	Tuesday	2.3
	Wednesday	1.8
	Thursday	2.5
	Friday	1.9
	Saturday	2.5
Haemodialyse	Sunday	0
	Monday	3.9
	Tuesday	3.2
	Wednesday	2.6
	Thursday	2.6
	Friday	2.8
	Saturday	2.3
ICC D	Sunday	3.3
	Monday	2.2
	Tuesday	1.9
	Wednesday	2.6
	Thursday	2.3
	Friday	2.2
	Saturday	2.9
Dagbehandeling	Monday	2.8
	Tuesday	3.4
	Wednesday	3.3
	Thursday	3.2
	Friday	3.9
Poli MDL/Endoscopie	Sunday	0.1
	Monday	3.0
	Tuesday	3.6
	Wednesday	3.5
	Thursday	4.8
	Friday	1.6
	Saturday	0
Behandelpoli	Sunday	0
	Monday	4.1
	Tuesday	3.7
	Wednesday	1.7
	Thursday	2.4

Name of department	Weekday	Average products get out-of-stock (#)
Behandelpoli	Friday	2.0
	Saturday	0
Eerste Harthulp	Sunday	2.5
	Monday	3.5
	Tuesday	2.5
	Wednesday	1.5
	Thursday	1.6
	Friday	1.0
	Saturday	1.2
Poli Radiologie	Sunday	0.1
	Monday	2.5
	Tuesday	1.9
	Wednesday	2.8
	Thursday	1.9
	Friday	2.1
	Saturday	0.8
Poli Mondkaak	Sunday	0
	Monday	1.4
	Tuesday	1.6
	Wednesday	1.5
	Thursday	1.4
	Friday	1.2
	Saturday	0
VPU Psychiatrie/Paaz	Sunday	0.5
	Monday	0.8
	Tuesday	0.9
	Wednesday	0.9
	Thursday	1.4
	Friday	1.1
	Saturday	0.5
Poli Longgeneeskunde	Sunday	0
	Monday	0.8
	Tuesday	0.8
	Wednesday	1.0
	Thursday	1.2
	Friday	1.4
	Saturday	0.2
Gipskamer	Sunday	0
	Monday	1.1
	Tuesday	1.7
	Wednesday	0.5

Name of department	Weekday	Average products get out-of-stock (#)
Gipskamer	Thursday	0.9
	Friday	0.8
	Saturday	0
Poli Dermatologie	Sunday	0
	Monday	0.7
	Tuesday	0.7
	Wednesday	0.7
	Thursday	0.5
	Friday	0.2
	Saturday	0
Poli Cardio/Cardiochirurgie	Sunday	0
	Monday	0.2
	Tuesday	0.4
	Wednesday	0.2
	Thursday	0.6
	Friday	0.5
	Saturday	0.1
Poli Reumatologie	Sunday	0
	Monday	0.5
	Tuesday	0.3
	Wednesday	0
	Thursday	0.2
	Friday	0.4
	Saturday	0
Poli KNO	Sunday	0
	Monday	0.1
	Tuesday	0.3
	Wednesday	0.1
	Thursday	0.3
	Friday	0.2
	Saturday	0
Poli Neurologie	Sunday	0
	Monday	0
	Tuesday	0.1
	Wednesday	0
	Thursday	0
	Friday	0
	Saturday	0

Appendix XVI Total products ordered per department and total different products get out of stock or not get out of stock

Name of department	Total ordered products (#)	Total product get not out of stock (#)	Total product get out of stock (#)
Spoed Eisende Hulp	227	139	88
VPU Chirurgie/Oncologie	222	126	96
VPU Vaat/Trauma/Ortho	209	112	97
VPU Interne geneeskunde and High and Intensive Care	204	92	112
Acute Opname Afdeling	199	98	101
ICC E	195	128	67
Thorax IC	193	118	75
Behandelpoli	188	122	66
ICC D	187	137	50
VPU Neurochirurgie/shortstay	184	103	81
VPU MDL	183	95	88
VPU Longgeneeskunde	182	84	98
ICC C	181	126	55
VPU A5 Thoraxchirurgie	174	91	83
Eerste Harthulp	160	108	52
VPU Strokeunit/Neurologie	149	83	66
Haemodialyse	136	81	55
Poli MDL/Endoscopie	131	88	43
Dagbehandeling	98	49	49
Gipskamer	94	68	26
Poli Longgeneeskunde	90	58	32
VPU Psychiatrie/Paaz	86	65	21
Poli Mondkaak	82	57	25
Poli Radiologie	81	42	39
Poli Dermatologie	66	51	15
Poli KNO	53	46	7
Poli Cardio/Cardiochirurgie	39	28	11
Poli Reumatologie	32	22	10
Poli Interne Geneeskunde	24	24	0
Poli Neurologie	9	8	1

Appendix XVII Total out-of-stock moments caused by wrong procedure per department

Departmentname	Total placed cards (#)	Wrong procedure (#)	Ratio wrong procedure
Acute Opname Afdeling	4585	381	8%
VPU Chirurgie/Oncologie	3634	175	5%
VPU Interne geneeskunde and High and Intensive Care	3671	277	8%
VPU Vaat/Trauma/Ortho	3376	245	7%
Spoed Eisende Hulp	3384	209	6%
VPU Longgeneeskunde	3022	233	8%
VPU A5 Thoraxchirurgie	2739	165	6%
VPU Strokeunit/Neurologie	2507	131	5%
VPU MDL	2488	171	7%
Thorax IC	2628	329	13%
VPU Neurochirurgie/shortstay	2385	187	8%
Haemodialyse	1886	62	3%
ICC E	2065	206	10%
ICC D	2016	216	11%
ICC C	1907	189	10%
Eerste Harthulp	1671	97	6%
Behandelpoli	1686	190	11%
Dagbehandeling	1620	118	7%
Poli MDL/Endoscopie	1536	158	10%
Poli Radiologie	1157	58	5%
Poli Longgeneeskunde	803	73	9%
Poli Mondkaak	759	62	8%
VPU Psychiatrie/Paaz	738	106	14%
Gipskamer	623	41	7%
Poli Dermatologie	520	16	3%
Poli KNO	323	6	2%
Poli Reumatologie	266	11	4%
Poli Cardio/Cardiochirurgie	257	34	13%
Poli Interne Geneeskunde	73	29	40%
Poli Neurologie	24	0	0%

Appendix XVIII Card numbers that show a possibley error frequently

Card number	Order board	Product name	Shows the wrong status change (#)
2038	TIC	Green line verlengslang D1.0mm L300cm 714005	66
591	AIC A	Gilette scheermesje fusion 8st	45
8075	V-E5 MDLS	Zijlijnen L40cm Luer Lock, spike ref 79040	45
2131	TIC	kam middel	37
8285	V-E5 MDLS	Cyto-Ad-Wing Z/4 cytostatica toedieningssysteem	37
14397	V-E5 MDLS	Discofix 3-wegkraan met slang 10cm, LL blauw	36
8113	V-E5 MDLS	Blunt Fill opzuignaald rood 18G 40mm	34
8263	V-E5 MDLS	Plastipak spuit 20ml L excentrisch	34
10319	V-E5 MDLS	Armovertrek steriel 50cm 30st	32
8176	V-E5 MDLS	Handschoen, Style 85, Maat 6.5, 1paar	32
8252	V-E5 MDLS	Nutrisafe 2 spuit 10ml 1015.103	32
8404	V-E5 MDLS	Emerald spuit 5ml L centrisch	32
9346	AIC B	Codan spike / bereidingsspike luchtfilter 0,2pm	32
8278	V-E5 MDLS	AutoShield Duo Veiligheidspennaald 30G L5mm	31
8323	V-E5 MDLS	plastic beker 180ml wit 100st	31
325	AIC A	Noba absorberend verband 10x20cm 25st	30
8402	V-E5 MDLS	Flocare Container 1000ml	29
1213	AIC C	Zuurstofverbindingsslang 3mmx30m	28
4891	AIC C	Sunleaf Thee English blend 100 zakjes a 2gr	28
4900	AIC C	Naaldhouders Macro	28
12346	AIC A	Flocare pack set infinity Enfit 86513	27
17579	V-E5 MDLS	Perfusorspuit 50ml LL centrisch	27
8212	V-E5 MDLS	Maagsonde dubbel lumen PVC Ch16 120cm 340.16	26
8271	V-E5 MDLS	Infusomat Space line ref. 8250907SP	26
8333	V-E5 MDLS	sputumpot f-375 karton wit 42st	26
1801	TIC	Plastipak spuit 20ml L excentrisch	25
3917	P-SEH O	veiligheidsspeld nr.3 12st	25
8074	V-E5 MDLS	Toedieningssysteem Y-type ref 79052	25
10022	P-Behan	Vicryl plus ongekl 3-0 L70cm SH1 VCP219H 36st	24
14669	TIC	Innospire Masker volwassen ref.1100E	24
5411	TIC	Nutrisafe 2 spuit 60ml excentrisch 1015.603	24
1369	AIC C	HDPE plastic zak zwart 450x500mm 0.01 50st	23
6473	V-E4 S	Combidop wit 009888002 100st	23
8139	V-E5 MDLS	sputumpot f-375 karton wit 42st	23
276	AIC A	Foley catheter Ch16 m/tempsensor 12st	22
8829	AIC B	Nutrisafe 2 spuit 10ml 1015.103	22
1669	AIC C	deksel voor sputumpot f-375 blanco 42st	21
4343	P-SEH O	Vac 3ml li-hep+gel licht groen 100st	21
7692	V-E5 LONS	Combidop wit 009888002 100st	21

Card number	Order board	Product name	Shows the wrong status change (#)
8378	V-E5 MDLS	Emerald spuit 2ml L centrisch	21
3797	P-SEH S	Discofix 3-wegkraan met slang 10cm, LL blauw	20
7891	V-E5 MDLS	LoFric Sense Nelatonkatheter Ch14 L15cm	20
8109	V-E5 MDLS	Sharpsafe naaldencontainer 3L	20
9453	AIC A	Rietje buigzaam 5x210mm 250st	20
5007	AIC A	Cutisoft Kompres 4-lgs 10x10cm 100st	19
8129	V-E5 MDLS	plastic beker 180ml wit 100st	19
8274	V-E5 MDLS	Handschoen, Nitra-Tex, Maat M, 100st	19
8292	V-E5 MDLS	Nutrisafe 2 spuit 20ml excentrisch 1015.213	19
12863	P-SEH S	Anesthesie Masker Medium Adult-5	18
13594	P-Dagb O	muts baret standaard blauw 100st	18
5261	V-E5 LONS	Mondmasker met oorlus ref 47117 geel 50st	18
8090	V-E5 MDLS	bloedkweek volwassenen	18
8309	V-E5 MDLS	Dauerbinde elastische zwachtel 10cmx7mtr	18
2818	P-Behan	Lady-lux maandverband maxi 20st	17
8086	V-E5 MDLS	Green line verlengslang D1.0mm L150cm 714001	17
8127	V-E5 MDLS	Discofix 3-wegkraan, blauw	17
8390	V-E5 MDLS	I.V. Star 10 set met infusiefilter L25cm	17
914	AIC B	Sharpsafe naaldencontainer 4L	17
4643	V-CCU O	Sharpsafe naaldencontainer afvoerdoos	16
4992	AIC A	E-swab Regular roze dop / voorheen Culturette	16
707	AIC B	Receptalliner 2l G902A52 blauw	16
8166	V-E5 MDLS	Combidop wit 009888002 100st	16
8373	V-E5 MDLS	Microclave gesloten connector 011-C3300 100st	16
10540	V-E4 S	Verblijfskatheterset 1891CE	15
17576	V-E5 MDLS	LoFric Origo Nelatonkatheter Ch14 L40cm	15
4337	P-SEH O	Soffban synth. watten 15cmx2.7m 12st	15
5297	V-E61 O	Sunleaf Thee English blend 100 zakjes a 2gr	15
7730	V-E5 LONS	Nutrisafe 2 spuit 20ml excentrisch 1015.213	15
8069	V-E5 MDLS	Plastipak spuit 20ml L excentrisch	15
8190	V-E5 MDLS	Insyte Autoguard IV katheter 22G L25 mm	15
9968	V-E61 O	Posey anti-slip sokken maat Standaard oranje	15
14668	TIC	Innospire Masker volwassen ref.1100E	24
14541	TIC	Innospire Sidestream disposable kit ref.4448	17
14669	TIC	Innospire Masker volwassen ref.1100E	15

Appendix XIX Number of errors per order board

Order board	Normal status change (#)	Wrong status change (#)	Ratio	Normal status change (#)	Wrong status change (#)	Ratio
AIC A	1322	173	13%	1145	384	34%
AIC B	1552	174	11%	1379	217	16%
AIC C	1147	152	13%	1003	283	28%
AOA A6 O	1368	83	6%	1297	197	15%
AOA A6 S	601	12	2%	592	23	4%
AOA BG O	519	54	10%	464	36	8%
AOA BG S	2032	67	3%	1967	198	10%
P-Behan	1531	152	10%	1397	309	22%
P-Cardio	257	8	3%	246	7	3%
P-Dagb LS	426	23	5%	401	25	6%
P-Dagb O	497	53	11%	444	78	18%
P-Dagb RS	593	30	5%	564	21	4%
P-Derm	520	57	11%	467	58	12%
P-GIPSK	583	33	6%	552	63	11%
P-HEMO O	33	1	3%	32		0%
P-HEMO S	1757	159	9%	1604	281	18%
P-Intg	44	39	89%	5		0%
P-KNO	322	16	5%	297	11	4%
P-Longf	764	94	12%	657	82	12%
P-MDL O	651	40	6%	613	37	6%
P-MDL S	779	81	10%	712	67	9%
P-MOKA	759	71	9%	684	77	11%
P-Neuro	24	1	4%	24	0	0%
P-Reuma	266	14	5%	252	14	6%
P-Rontg	1120	77	7%	1037	114	11%
P-SEH O	2031	150	7%	1869	284	15%
P-SEH S	1320	56	4%	1241	176	14%
TIC	2101	240	11%	1850	430	23%
V-A5 O	1244	89	7%	1139	174	15%
V-A5 S	1431	115	8%	1315	195	15%
V-A61 O	1143	54	5%	1094	103	9%
V-A61 S	1343	58	4%	1291	144	11%
V-B4 AO	259	17	7%	242	10	4%
V-B4 AS	36	5	14%	33	0	0%
V-B4 BO	334	20	6%	311	9	3%
V-B4 BS	106	5	5%	100	3	3%
V-C4 O	1370	116	8%	1254	221	18%
V-C4 S	1812	71	4%	1742	196	11%
V-C61 O	1024	90	9%	930	163	18%
V-C61 S	1315	64	5%	1251	102	8%

Order board	Normal status change (#)	Wrong status change (#)	Ratio	Normal status change (#)	Wrong status change (#)	Ratio
V-CCU O	794	63	8%	734	142	19%
V-CCU S	454	37	8%	419	63	15%
V-E4 O	1375	101	7%	1267	157	12%
V-E4 S	2136	107	5%	2027	387	19%
V-E5 LONO	1155	87	8%	1066	95	9%
V-E5 LONS	1780	152	9%	1620	632	39%
V-E5 MDLO	522	22	4%	498	22	4%
V-E5 MDLS	1785	216	12%	1559	1266	81%
V-E61 O	1274	102	8%	1161	237	20%
V-E61 S	2196	63	3%	2128	282	13%
V-EHH S	282	11	4%	273	40	15%

Appendix XX Remaining improvements

(1) Response time

The response time is the time interval between the moment of request and the moment of completion of this request. This requests can be an urgent order, creating a new order card, location change, or bin value change. In the ideal situation the response time is equal to the execution time. That means there is no waiting time between the execution steps. When customers need something, they do not want to wait long for that.

Communicate digitally

One of the causes of the waiting time is how the communication is organized. To decrease the waiting times between the process steps we think the communication needs to be digitally. With digital communication it make no sense where a deliver employee is located. In the current situation the communication is organized by paperwork and oral consultation. That is not direct communication and that ensures the long waiting time. Besides, we now know that the central warehouse will move to Hengelo. We observe that mostly the deliver employees are checking if a request can be carried out. When the backoffice is moving to Hengelo, the distance between the backoffice and the deliver employees becomes much larger. We expect that the waiting time will increase because the paperwork and oral consultation become more complicated.

With digital communication we mean that when the backoffice get a request, the backoffice employees can sent a digital message to the deliver employees who can read it directly on their mobile phone. This communication can be done by text message, but we also expect an app can be useful. This app make it possible for every deliver employee to read the message at the same time. The deliver employee who is located closely to the request department and has time can respond on this app that he/she will check the request. At the same time, the other deliver employees can read the request is being treated. On both locations, wifi is present. For that reason, when the app is developed it will not ensure extra costs per month.

More logistics employees should be educated to work with Alltrack

Another cause of the waiting time between the process steps is that only one employee is educated to create new order cards. The system in which the order cards are created is called Alltrack. Most often the order cards are created on Tuesday. To decrease the waiting time we think more employees need to be educated to work with Alltrack. We expect that when more employees can work with this program, order cards can be made at more times during the week. We think the other backoffice employees need to be educated to work with Alltrack. Besides, we also think the deliver employees need to be educated to work with Alltrack. The deliver employees are also checking if the request can be carried out. It will be helpful when they can create order cards by themselves so that one process step can be skipped, namely the step that the deliver employee communicates with the backoffice that the request can be carried out.

(3) Stock level in department warehouses

(3.2) Deliver reliability

In the ideal situation is at least 95% of the orders delivered completely. In every company it happens that an order cannot be delivered complete because there is not enough stock for one product. For that reason we determine the ideal situation at least 95%.

Ensure a stable order demand per day

We find a correlation between the number of orderlines on an order and the probability that the order is not completely delivered. We think that orders with a small number of orderlines will increase the rate of completely delivered orders. The solution therefore is to get a stable order demand per day. Now we observe on Monday the average number of orderlines on an order is very high. When this number is the same as on other days, we expect the rate of complete delivered orders will increase.

Correct minimum and maximum value central warehouse

Another solution we find to increase the rate of completely delivered orders is to get a correct minimum and maximum value in the central warehouse. We measure the fill rate per product. The fill rate can help to determine if the minimum and maximum value in the central warehouse is correct.

(3.6) System reliability

The system reliability depends on the performance of the system. To get the ideal situation all errors need to be tackled directly when these appear.

Second internet connection

We discuss the connection of the order board with the central warehouse. The order boards are connected by internet. However, we observe there is one internet connection available. Because all hospital departments are dependent on this connection we think it is good to have a second connection. When the first connection fails, the hospital has a backup connection.

(4) Workload

The workload of warehouse employees means how much time they need for each process. It also shows the time they are working and the time they are waiting. The ideal situation is that the warehouse employees are using the working time efficiently so without waiting time and without extra workload.

(4.1) Extra workload

Set up consequences for hospital departments for return orders

The users are not carrying out the correct order procedure. The solution is to talk with the different departments. The aim of this conversation is to get the department aware of the return problem. Besides, it is important every user knows how to carry out the correct procedure. In these conversations it is important to find out why the users are placing the order cards too soon and find a solution together to decrease the return orderlines.

If this solution is not working we advise the hospital to set up consequences for the hospital department for a return shipment. Let the department pay an extra amount of money when an order is sent return caused by a wrong procedure.

Appendix XXI Average fill rate, total orderlines, total demand and total number of backorders per product

Article name	Average. Fill Rate (%)	Total orderlines (#)	Total demand (#)	Total backorder number (#)
Verzendcontainer voor 5 objektglazen	95	29	279	19
Flocare Universal adapter 570063	95	14	199	14
Handdoek Wit 20x34,5cm 2lgs 160st	95	178	6,050	364
Afzuigcath, 59cm Ch12 aeroflo coude 1180251744 50st	95	48	93	6
Bair Hugger Upper Body warmtedeken 52200	95	60	763	40
Flocare Container 1000ml	95	67	199	12
Dauerbinde elastische zwachtel 10cmx7mtr	95	119	286	14
Rusch Tieman katheter Ch14 ballon 10ml	95	41	82	7
Veiligheidsbril Virtua AP Blank 3M	95	22	43	5
Delta-Cast Conf, blauw 3,6m x 10cm 10st	94	16	16	1
ExacTrace Huid Electrodes met schuurpapier 30st	94	9	14	1
Novalife1 ileozak maxi open 9150-10 10st	94	12	13	1
Hot Cups SMR8 karton 240cc 50st	94	737	4,767	278
vasoview 6 1st	94	11	68	7
HDPE plastic zak grijs 70x110 0,004 25st	94	117	545	40
LoFric Origo Nelatonkatheter Ch14 L40cm	94	82	343	25
Plastic zak wit tbv cytostatica 58x100cm 25st	94	34	47	3
Mucus Specimen Trap 20ml MST-3180	94	55	385	32
Sharpsafe naaldencontainer 4L	94	333	1,279	93
Boorhoes ref 31081	93	17	200	20
Klinion gipstricot geribt 10cmx20m	93	12	17	1
Peijnenburg ontbijtkoek mono 100st	93	11	13	1
Spoelglansmiddel Sun 1l	93	42	71	6
Maagsonde dubbel lumen PUR Ch14 120cm 1340,14	93	68	196	14
Eco supergel 260ml clear	93	129	701	46
Maagsonde dubbel lumen PVC Ch18 120cm 340,18	93	20	121	9
Beademingssysteem uniflow 1,6m ref, 2900000	93	16	139	11
Scott* 600 toilet tissue rollen 2-lgs 600v 6rl	93	285	2,212	136
Vaatwaspoeder Sun 3kg	93	89	160	13
Tegaderm I,V, pleister 7x8,5cm 1633 100st	93	201	246	18
Handschoen, Nitra-Tex, Maat S, 100st	92	959	2,645	211
I-Stat G3+ cartridge 25 tests	92	59	120	9
Steri-Strip basis wondsluiting 12mmx100mm 50st,	92	49	97	8
Plastipak spuit 30ml LL centr	92	50	1,572	146
Sharpsafe naaldencontainer afvoerdoos	92	108	235	25
I,V, Star 10 set met infusiefilter L25cm	92	71	850	76
Zelfklevend afdeklaken 175x175cm	92	38	207	17
Boso medicus bloeddrukmeter	92	5	8	1

Article name	Average. Fill Rate (%)	Total orderlines (#)	Total demand (#)	Total backorder number (#)
Instrumentenveld 150x190cm abs, 75x190cm 22st	92	15	15	1
Wondkompres Algisite M 5x5cm 10st	92	7	8	1
Verbindingsslang 5mmx1,50m pvc	92	69	307	44
Microclave gesloten connector 011-C3300 100st	91	221	221	18
Satino hygienezakjes PE wit 25st	91	46	332	42
E3+ Istat cartridge 25st	91	14	23	3
Anesthesie Masker Medium Adult-5	91	128	2,548	229
Microclave verlenglijn 18cm 011-C3302	91	101	1,974	179
Schoenovertrek blauw 100st	91	30	35	5
Pro-optha oogkussen 6,2x7,2cm 25st	90	10	15	2
titanium clips 2200 horizon med, Wide 180st	90	8	12	2
Voedingssonde Levin Si Ch16 L125cm 2391,16	90	12	43	5
ideaalwindsel 120mmx5m nobalastik	90	25	317	33
Gaasdepper x-ray nr,5 steriel 10st	90	8	26	3
Red Dot monitoring Electrode 2560 5st	90	158	978	86
Nutrisafe 2 spuit 60ml excentrisch 1015,603	90	234	4,125	470
Kerlix AMD gaasverband 15x17cm 40st	90	63	89	14
Hair & Body Wash, flesje	90	198	688	86
Handschoen, Nitrile, Maat L, 100st	90	47	134	11
Camerahoes 13x250cm ref 31501	89	25	288	39
Delta-Cast Conf, wit 3,6m x 10cm 10st	89	11	11	1
LDPE boterhamzak 10x4x30 0,02 1000st	89	8	12	2
Noba elastisch netverband mt 6	89	26	27	3
Ranger Standard Flow infuusverwarmingset	89	8	70	10
Zwitsal Shampoo 500ml	89	8	13	3
laryngealmasker maat 4,0 classis lma	89	56	580	72
Evaqua 2 beademingscircuit incl,Filter	88	53	265	30
Afzuigcath, 52cm Ch12 aero-flo 8888250134	88	61	370	73
Plastipak precisiespuit 1ml L centr	88	331	16,868	2,461
Eclipse naald veiligheidsbloedafname 48st	88	50	65	11
Unimedical Nelaton katheter Ch8 L40cm blauw	88	2	9	1
Mon-a-therm foley catheter ch16 m/sensor 12st	87	12	38	11
Maagsonde dubbel lumen PVC Ch14 120cm 340,14	87	20	57	7
Infusomat Space line ref, 4182586SP	87	273	4,604	615
ActiVAC opvangbeker met gel 300ml	87	7	27	6
Batterij Duracel CR2032 knoopcel	87	3	26	8
neustampon 80mm merocel gelamineerd 10st	87	10	13	2
Curettageslang CH30 7x10mm L2,00m steriel pvc	86	20	240	40
Vac 4 ml Edta gesprayed lavandel 100st	86	92	94	13
I-Stat CG4+ cartridge 25 test	86	31	40	9

Article name	Average. Fill Rate (%)	Total orderlines (#)	Total demand (#)	Total backorder number (#)
Green line verlengslang D1,0mm L300cm 714005	85	113	5,950	874
Nutrisafe 2 sonde PUR Ch6 L75cm 1363,062	85	17	250	35
Beschermkit echo transducer ref 87106 12st	85	27	44	7
Dufour Blaaskatheter 3-weg Ch20 50ml 2340-20	85	10	70	22
Mepitel 12x15cm 5st	85	53	139	32
Handschoen, Nitrile, Maat XL, 100st	84	35	69	12
Patient neutraal electrode klem/kabel 4,6mtr	84	9	13	2
Dental kit	83	130	520	100
Objektglazen Superfrost + matrand 50st	83	16	48	9
Ecolab Into spray 750ml	83	22	25	4
Oogdop universal 7,5x6,5cm	83	3	60	10
Swann-Morton mesje nr,11 100st	83	4	4	1
Wondkompres Algisite M 10x10cm 10st	83	4	9	2
Zebra polsband wit 25,4x279,4 mm cartridge	82	104	202	25
Connector aansluiting spuit-grote beker 801,00D	82	71	855	353
Delta-Cast Conf, zwart 3,6m x 10cm 10st	82	14	14	3
Symphony Afkolfset disp, met membraan maat L	82	45	681	143
Broxo onthardingszout 25kg	80	18	126	30
CABG Tray	80	16	110	21
ideaalwindsel 60mmx5m nobalastik	80	20	346	58
Medisavona handzeep 500ml	80	321	1,513	329
Delta-Cast Conf, groen 3,6m x 10cm 10st	80	7	7	2
Nilodor ruimte-deodorant	80	6	12	6
Centrifugeerbuis Conisch PP 15ml	78	88	280	72
Tegaderm I,V, pleister 6x7cm 1624W 100st	78	6	6	2
Broxomatic Onthardingszout 1kg	78	73	277	89
Handzeep Soft Care Fresh 800ml	77	39	345	65
handschoen katoen large maat 13 1paar	77	3	26	6
Collafoam seton halskraag small	75	3	7	3
Tube 8,0 Taperquard 18780 10st	75	2	8	2
ACT Kaolin 25st	73	22	94	22
Handschoen, Nitrile, Maat S, 100st	73	45	158	47
Pocketmasker (voor reanimatiekoffer)	72	33	109	34
Coloplast irrigatie conus klein 1110	72	10	19	6
Handschoen, Nitrile, Maat M, 100st	70	73	293	112
HS carpulenaald 27G L42mm 100st	70	17	31	10
Spoelkatheter Ch14 L18cm ref,02017182	70	60	928	299
Urinepotjes met geïntegreerd afnamepunt 100st	68	32	35	12
Klinion prepareerdepper x-ray 6x6cm 5st	67	9	68	10
Navulcontainer elektrodenspray 5000 ml	67	3	7	4

Article name	Average. Fill Rate (%)	Total orderlines (#)	Total demand (#)	Total backorder number (#)
shunt bulb 1,75mm l14mm clearview 5st	67	1	6	2
Shunt Sensor CDI500 for use with system 500	66	5	76	21
Afzuigcath, 51cm Ch10 aeroflo coude 1180251736	65	11	50	21
KC toiletbrilreiniger 400ml transparant	65	3	50	14
centimeter op rol 1,50m	64	20	43	20
Posey anti-slip sokken maat L groen	62	88	637	245
Afnameset E-swab MRSA	62	18	206	76
Theelepeltje es-85 metaal 115mm	62	4	600	228
Frova tube introducers met Rapi-Fit Adapters 14Fr L70cm	61	12	79	29
Gatdoek 75x90cm gat D6cm zelfklevend	60	106	2,427	1,034
Urinebokaal, Fles vierkantig 1l	59	8	44	18
Microscoophoes Zeiss 122x300cm 326071 5st	57	12	24	6
Fluido standaard 20st	53	9	12	3
Bak D101mm 500ml karton wit 50st	50	4	7	1
Sunleaf thee apple cinnamon 20 zakjes a 2gr	50	8	49	2
Sunleaf thee green tea mint 20 zakjes a 2gr	50	5	7	2
Tiger reserve closetborstel wit	49	57	424	271
Posey anti-slip sokken maat Standaard oranje	42	74	609	366
Maagsonde dubbel lumen PUR Ch12 120cm 1340,12	40	17	85	57
Microscoophoes 122x209cm 306070M 10st	38	5	5	2
Nutrisafe 2 sonde PVC CH8 L125cm 3620,82	28	2	102	73
Vulling Kimberly Clark Zen luchtverfrisser	20	1	40	32
Probe Cover, VIP film, Gel and Rubber bands E6346 13x61cm	7	4	104	97
Suma CoffeecLean koffieapp, reiniger 2ltr	0	2	2	2
Tube 6,0 RAE nasaal cuff gebogen 119-60 10st	0	1	1	1

Appendix XXII Average waiting time backorders per product

Product name	Average delivery time (d)
Tube 6.0 RAE nasaal cuff gebogen 119-60 10st	54.5
Suma CoffeecLean koffieapp. reiniger 2ltr	40.5
Afzuigcath. 51cm Ch10 aeroflo coude 1180251736	39.5
Dansac gordel beige 1.50m	36.5
Collafoam seton halskraag medium	34.3
Nutrisafe driewegkraan	25.2
Maagsonde dubbel lumen PUR Ch12 120cm 1340.12	25.1
Boso medicus bloeddrukmeter	20.0
neustampon 80mm merocel gelamineerd 10st	17.0
Wondkompres Algisite M 10x10cm 10st	16.0
Fluido standaard 20st	14.3
Centrifugeerbuis Conisch PP 15ml	13.6
Probe Cover, VIP film, Gel and Rubber bands E6346 13x61cm	13.0
Voedingssonde Levin Si Ch16 L125cm 2391.16	13.0
Posey anti-slip sokken maat Standaard oranje	12.8
Zebra polsband wit 25.4x279.4 mm cartridge	12.1
Boorhoes ref 31081	12.0
Noba elastisch netverband mt 6,borst baby	12.0
Shunt Sensor CDI500 for use with system 500	11.3
Unimedical Nelaton katheter Ch8 L40cm blauw	10.3
ActiVAC opvangbeker met gel 300ml	9.0
Oogdop universal 7.5x6.5cm	9.0
Wondkompres Algisite M 5x5cm 10st	9.0
Connector 5-in-1 8888-271007	8.7
Curettageslang CH30 7x10mm L2.00m steriel pvc	8.0
Pro-optha oogkussen 6.2x7.2cm 25st	8.0
Tegaderm I.V. pleister 6x7cm 1624W 100st	8.0
Microscoophoes 122x209cm 306070M 10st	7.8
Theelepeltje es-85 metaal 115mm	7.5
centimeter op rol 1.50m	7.4
Kerlix AMD gaasverband 15x17cm 40st	7.3
Nutrisafe 2 sonde PUR Ch6 L75cm 1363.062	7.3
Ecolab Into spray 750ml	7.3
Tiger reserve closetborstel wit	7.0
Cutisoft 12-lgs 10x10cm 75st 92422	7.0
Gaasdepper x-ray nr.5 steriel 10st	7.0
Klinion prepareerdepper x-ray 6x6cm 5st	7.0
Swann-Morton mesje nr.11 100st	7.0
handschoen katoen large maat 13 1paar	6.5
Sharpsafe naaldencontainer afvoerdoos	6.5

Product name	Average delivery time (d)
KC toiletbrilreiniger 400ml transparant	6.0
Klinion gipstricot geribt 10cmx20m	6.0
Ranger Standard Flow infuusverwarmingset	6.0
titanium clips 2200 horizon med. Wide 180st	6.0
Hair & Body Wash, flesje	6.0
Coloplast irrigatie conus klein 1110	5.7
Navulcontainer elektrodenspray 5000 ml	5.5
Camerahoes 13x250cm ref 31501	5.3
Posey anti-slip sokken maat L groen	5.2
Collafoam seton halskraag small	5.0
ExacTrace Huid Electrodes met schuurpapier 30st	5.0
Handschoen, Style 85, Maat 8.5, 1paar	5.0
Maagsonde dubbel lumen PUR Ch14 120cm 1340.14	5.0
Mucus Specimen Trap 20ml MST-3180	5.0
Nutrifit verbindingstuk trapconnector	5.0
Reanimatie set volw ballon 1.5l masker ref.7152000	5.0
CABG Tray	4.8
Dauerbinde elastische zwachtel 10cmx7mtr	4.6
Afzuigslang PVC Ch27 6x9mm L3.50m	4.5
Delta-Cast Conf. groen 3,6m x 10cm 10st	4.5
Koppelsysteem + naald vrij A2581NF SPACE	4.5
Urinepotjes met geïntegreerd afnamepunt 100st	4.5
Pocketmasker (voor reanimatiekoffer)	4.3
Rusch Foley katheter Ch16 10ml L41cm 170605-16	4.1
Handzeep Soft Care Fresh 800ml	4.1
Afzuigcath. 52cm Ch12 aero-flo 8888250134	4.0
Broxo onthardingszout 25kg	4.0
Eclipse naald veiligheidsbloedafname 48st	4.0
Nutrisafe 2 sonde PVC Ch6 L50cm 361.062	4.0
Oasis dry suction thoraxdrainagesysteem	4.0
Rusch Tieman katheter Ch14 ballon 10ml	4.0
Spinale naald 22G 3,5 inch 0,7x90mm zwart	4.0
Spoelkatheter Ch14 L18cm ref.02017182	4.0
Urinebokaal, Fles vierkantig 1l	4.0
Nutrisafe 2 spuit 60ml excentrisch 1015.603	3.9
CVC-set triple lumen 7Fr/160mm	3.5
Eco supergel 260ml clear	3.5
Flocare Universal adapter 570063	3.5
laryngealmasker maat 4.0 classis lma	3.5
Maagsonde dubbel lumen PVC Ch14 120cm 340.14	3.5
Microclave 3-weg koppelsyst.octopus met klem	3.5

Product name	Average delivery time (d)
Zwitsal Shampoo 500ml	3.5
Symphony Afkolfset disp. met membraan maat L	3.4
Afnameset E-swab MRSA	3.4
Scott* 600 toilet tissue rollen 2-lgs 600v 6rl	3.4
Dental kit	3.3
Delta-Cast Conf. zwart 3,6m x 10cm 10st	3.3
Gatdoek 75x90cm gat D6cm zelfklevend	3.3
Patientline hoofdtelefoon zwart met kabel, 2.5m	3.2
bloedkweek volwassenen	3.2
Microclave gesloten connector 011-C3300 100st	3.2
Broxomatic Onthardingszout 1kg	3.1
Dufour Blaaskatheter 3-weg Ch20 50ml 2340-20	3.0
E3+ Istat cartridge 25st	3.0
Eclipse injectienaald groen 21G 40mm	3.0
Handschoen, Nitrile, Maat M, 100st	3.0
Hemofiltratie set	3.0
HS carpulenaald 27G L42mm 100st	3.0
LaproCare Urine opvangzak 2ltr L115cm steriel	3.0
Micro Mist vernevelaar masker kind ref.41894	3.0
Micropore Chirurgische pleister 2,5x9.1m 12st	3.0
Microscoophoes Zeiss 122x209cm 326070 5st	3.0
Nexcare Comfort strips 19mm 100st.	3.0
Nilodor ruimte-deodorant	3.0
Noba tricotzwachtel 15cmx4m steriel	3.0
Peijnenburg ontbijtkoek mono 100st	3.0
Plastic zak wit tbv cytostatica 58x100cm 25st	3.0
Rusch TUR zak 4ltr L120cm	3.0
Symphony Afkolfset disp. met membraan maat M	3.0
Verkade biscuit volkoren San Francisco 250gr	3.0
Medisavona handzeep 500ml	2.9
Red Dot monitoring Electrode 2560 5st	2.9
Innospire Sidestream disposable kit ref.4448	2.8
Evaqua 2 beademingscircuit incl.Filter	2.8
Frova tube introducers met Rapi-Fit Adapters 14Fr L70cm	2.8
Braun proscan hoesjes oorthermometer 200st	2.8
Connector aansluiting spuit-grote beker 801.00D	2.7
Mon-a-therm foley catheter ch16 m/sensor 12st	2.7
Satino hygienezakjes PE wit 25st	2.7
Handschoen, Nitrile, Maat S, 100st	2.5
Schoenovertrek blauw 100st	2.5
Scott handdoeken Multifold Airflex 1lgs wit	2.4

Product name	Average delivery time (d)
HDPE plastic zak grijs 70x110 0.004 25st	2.4
Flocare Container 1000ml	2.3
Zelfklevend afdeklaken 175x175cm	2.3
Green line verlengslang D1.0mm L300cm 714005	2.3
I.V. Star 10 set met infusiefilter L25cm	2.3
ProSafety I.V.katheter 20Gx1 1/4 11x32mm 50st	2.3
Toedieningssysteem Y-type ref 79052	2.3
Microclave verlenglijn 18cm 011-C3302	2.1
Nutrisafe 2 spuit 20ml excentrisch 1015.213	2.1
Handschoen, Nitrile, Maat XL, 100st	2.1
Tegaderm I.V. pleister 7x8.5cm 1633 100st	2.1

Appendix XXIII Average delivery time per extern supplier and order moments

Supplier	Average delivery time (d)	Monday	Tuesday	Wednesday	Thursday	Friday
Surgical Company BV	14.3	N	Y	N	Y	N
VWR International BV	13.6	Y	N	N	N	N
Smith + Nephew Nederland BV	12.5	Y	Y	Y	Y	Y
ICT Spirit	12.1	Y	Y	Y	Y	Y
Terumo Europe N.V.	11.3	Y	Y	Y	Y	Y
Simovision	9.0	Y	N	N	N	N
D-Care	7.6	N	N	Y	N	Y
MST CLeancare	7.3	N	Y	N	Y	N
GD Medical Pharma	6.3					
Indomo BV	6.2	Y	N	N	N	N
MediReva	5.7	N	Y	N	Y	N
Vygon Nederland	5.7	Y	Y	Y	Y	Y
Medtronic	5.3	Y	Y	Y	Y	Y
Schinkel Medical BV	5.2	N	N	Y	N	Y
BMA B.V	5.0	Y	N	N	N	N
Medico Care	4.8	Y	N	Y	N	N
Carel Lurvink BV	4.3	Y	Y	Y	Y	Y
Lohmann & Rauscher BV	4.2	N	N	Y	N	Y
Brenntag Nederland B.V.	4.0	Y	N	N	N	N
Dispo Medical BV	3.8	N	N	N	Y	N
Plastimed V.o.f.	3.8	Y	N	N	N	N
Medela Benelux BV	3.4	Y	N	N	N	N
Lab Micta (Microbiologie)	3.3	N	N	Y	N	Y
Medline	3.3	Y	N	N	N	N
Vandeputte Medical	3.3	N	Y	N	N	N
Patientline BV	3.2	Y	Y	Y	Y	Y
Intersurgical Nederland BV	3.1	N	N	N	N	Y
Henry Schein Dental	3.0	N	N	Y	N	Y
LivaNova Nederland N.V.	3.0					
Maquet Netherlands BV	3.0	N	Y	Y	Y	Y
Pluripharm Distrimed	3.0					
Rembrandt Medical	3.0	N	Y	N	Y	N
Teleflex Medical BV	3.0	N	N	Y	N	Y
Huuskes	2.9	Y	N	N	N	N
Medica Europe	2.9	N	N	N	Y	N
Brocacef Intramuraal	2.8	N	N	N	N	Y
Cook Nederland/Shared Service Center	2.8	Y	Y	Y	Y	Y
Fisher & Paykel Healthcare SAS	2.8	Y	N	N	N	N
Romedic BV	2.8	Y	N	N	N	N
3M Nederland BV	2.7	N	Y	N	N	Y
Mediq BV (Medeco BV)	2.7					
BSN Medical BV	2.4	Y	N	Y	N	N
Molnlycke Health Care	2.4	Y	Y	Y	Y	Y
Codan BV	2.3	N	N	Y	N	Y
Medlon BV	2.2	N	Y	N	Y	N

Supplier	Average delivery time (d)	Monday	Tuesday	Wednesday	Thursday	Friday
Stopler BV	2.1	N	Y	Y	Y	Y
Becton Dickinson BV	2.0	N	Y	N	Y	N
Braun Medical BV	2.0	N	Y	N	Y	N
C.R. Bard Netherlands Sales BV	2.0	N	Y	N	Y	N
Smiths Medical Nederland BV	2.0	Y	N	N	N	N
Technische Unie BV	2.0	Y	Y	Y	Y	Y
Argon Medical Devices Netherlands BV	1.8	N	N	Y	N	Y
Microtek Medical	1.7	Y	N	N	N	N
Dentsply Sirona	1.6					
Twepa Enschede	1.6	Y	Y	Y	Y	Y
Labeldiscounter	1.5					
Abena BV	1.2	N	N	Y	N	Y
Beukenhorst Koffie	1.2	N	Y	N	Y	N
Arjo Huntleigh Healthcare	1.0	Y	N	N	N	N
Hollister BV	1.0	N	Y	N	Y	N
Paul Hartmann BV	1.0					
Sita	1.0	Y	N	N	N	N
VE-Systems BV	1.0	N	Y	N	Y	N

Appendix XXIV The average delivery time of a product with the supplier information

Supplier	Product name	Average delivery time (d)
Surgical Company BV	Fluido standaard 20st	14.3
VWR International BV	Centrifugeerbuis Conisch PP 15ml	13.6
Smith + Nephew Nederland BV	Wondkompres Algisite M 5x5cm 10st	9.0
	Wondkompres Algisite M 10x10cm 10st	16.0
ICT Spirit	Zebra polsband wit 25.4x279.4 mm cartridge	12.1
Terumo Europe N.V.	Shunt Sensor CDI500 for use with system 500	11.3
Simovision	Oogdop universal 7.5x6.5cm	9.0
D-Care	Dental kit	3.3
	Hair & Body Wash, flesje	6.0
	Posey anti-slip sokken maat L groen	5.2
	Posey anti-slip sokken maat Standaard oranje	12.8
MST CLeancare	Ecolab Into spray 750ml	7.3
GD Medical Pharma	ActiVAC opvangbeker met gel 300ml	9.0
	VAC Simplace Small Dressing Kit	1.0
Indomo BV	Schilmesje 6cm	1.0
	Theelepeltje es-85 metaal 115mm	7.5
Vygon Nederland	Connector aansluiting spuit-grote beker 801.00D	2.7
	Maagsonde dubbel lumen PUR Ch12 120cm 1340.12	25.1
	Maagsonde dubbel lumen PUR Ch14 120cm 1340.14	5.0
	Maagsonde dubbel lumen PVC Ch14 120cm 340.14	3.5
	Maagsonde dubbel lumen PVC Ch18 120cm 340.18	2.0
	Nutrifit verbindingstuk trapconnector	5.0
	Nutrisafe 2 / ENFit adapter	1.0
	Nutrisafe 2 sonde PUR Ch6 L75cm 1363.062	7.3
	Nutrisafe 2 sonde PUR Ch10 L125cm 1362.1022	1.0
	Nutrisafe 2 sonde PVC Ch6 L50cm 361.062	4.0
	Nutrisafe 2 sonde PVC CH8 L125cm 3620.82	2.0
	Nutrisafe 2 spuit 10ml 1015.103	1.9
	Nutrisafe 2 spuit 20ml excentrisch 1015.213	2.1
	Nutrisafe 2 spuit 60ml excentrisch 1015.603	3.9
	verbindingsstuk 881.47 vygon steriel	1.0
	verbindingsstuk 881.77 vygon steriel	1.7
	Voedingssonde Levin Si Ch16 L125cm 2391.16	13.0
MediReva	Coloplast irrigatie conus klein 1110	5.7
Medtronic	Afzuigcath. 52cm Ch12 aero-flo 8888250134	4.0
	Afzuigcath. 59cm Ch12 aeroflo coude 1180251744 50st	1.0
	Connector 5-in-1 8888-271007	8.7
	DLP intra cardiale sump 20Fr lengte 38cm	2.0
	Kerlix AMD gaasverband 15x17cm 40st	7.3
	Mon-a-therm foley catheter ch16 m/sensor 12st	2.7

Supplier	Product name	Average delivery time (d)
Medtronic	neustampon 80mm merocel gelamineerd 10st	17.0
	Patient neutraal electrode klem/kabel 4.6mtr	2.0
	shunt bulb 1.75mm l14mm clearview 5st	2.0
	Tube 8.0 Taperquard 18780 10st	2.0
Schinkel Medical BV	Boso medicus bloeddrukmeter	20.0
	centimeter op rol 1.50m	7.4
	handschoen katoen large maat 13 1paar	6.5
	muts baret standaard blauw 100st	1.5
	Posey Foam polsband 2st	1.0
	Schoenovertrek blauw 100st	2.5
BMA B.V	ExacTrace Huid Electrodes met schuurpapier 30st	5.0
Medico Care	Camerahoes 13x250cm ref 31501	5.3
	Kaakset MST	1.0
	Microscoophoes 122x209cm 306070M 10st	7.8
	Microscoophoes Zeiss 122x209cm 326070 5st	3.0
	Microscoophoes Zeiss 122x300cm 326071 5st	2.0
Carel Lurvink BV	Handzeep Soft Care Fresh 800ml	4.1
	KC toiletbrilreiniger 400ml transparant	6.0
	Satino hygienezakjes PE wit 25st	2.7
	Scott handdoeken Multifold Airflex 1lgs wit	2.4
	Scott* 600 toilet tissue rollen 2-lgs 600v 6rl	3.4
	Spoelglansmiddel Sun 1l	1.0
	Tiger reserve closetborstel wit	7.0
	Vaatwaspoeder Sun 3kg	1.9
	Vezeldoeken Vileda Microroll wit 35x25cm 200st.	1.8
	Vulling Kimberly Clark Zen luchtverfrisser	1.0
Lohmann & Rauscher BV	Dauerbinde elastische zwachtel 10cmx7mtr	4.6
	Mollelast fixatie windsel 6cmx4mtr 20st	1.0
	Pro-optha oogkussen 6.2x7.2cm 25st	8.0
Brenntag Nederland B.V.	Broxo onthardingszout 25kg	4.0
Plastimed V.o.f.	Eco supergel 260ml clear	3.5
	Navulcontainer elektrodenspray 5000 ml	5.5
Dispo Medical BV	Afzuigslang PVC Ch27 6x9mm L3.50m	4.5
	Curettageslang CH30 7x10mm L2.00m steriel pvc	8.0
	Mucus Specimen Trap 20ml MST-3180	5.0
	Verbindingsslang 5mmx1.50m pvc	1.6
	Verbindingsslang 5mmx30m pvc	1.0
Medela Benelux BV	Symphony Afkolfset disp. met membraan maat L	3.4
	Symphony Afkolfset disp. met membraan maat M	3.0
Vandeputte Medical	Gaasdepper x-ray nr.5 steriel 10st	7.0
	ideaalwindsel 60mmx5m nobalastik	1.5

Supplier	Product name	Average delivery time (d)
Vandeputte Medical	ideaalwindsel 120mmx5m nobalastik	1.0
	Noba absorberend verband 10x20cm 25st	1.7
	Noba elastisch netverband mt 6,borst baby	12.0
	Noba tricotzwachtel 15cmx4m steriel	3.0
	wattenstok met gaas steriel	1.5
Lab Micta (Microbiologie)	Afnameset E-swab MRSA	3.4
	bloedkweek volwassenen	3.2
Medline	Gatdoek 75x90cm gat D6cm zelfklevend	3.3
Patientline BV	Patientline hoofdtelefoon zwart met kabel, 2.5m	3.2
Intersurgical Nederland BV	Beademingssysteem uniflow 1.6m ref. 2900000	1.0
	Inter-Therm filter L poort steriel ref1341000S	2.0
	Pocketmasker (voor reanimatiekoffer)	4.3
	Reanimatie set volw ballon 1.5l masker ref.7152000	5.0
Henry Schein Dental	HS carpulenaald 27G L42mm 100st	3.0
LivaNova Nederland N.V.	Hemofiltratie set	3.0
Maquet Netherlands BV	Oasis dry suction thoraxdrainagesysteem	4.0
	vasoview 6 1st	1.0
Pluripharm Distrimed	Nilodor ruimte-deodorant	3.0
Rembrandt Medical	Dufour Blaaskatheter 3-weg Ch20 50ml 2340-20	3.0
Teleflex Medical BV	Anesthesie Masker Medium Adult-5	1.5
	Braun proscan hoesjes oorthermometer 200st	2.8
	CVC-set triple lumen 7Fr/160mm	3.5
	laryngealmasker maat 4.0 classis lma	3.5
	Micro Mist vernevelaar masker kind ref.41894	3.0
	Rusch Foley katheter Ch16 10ml L41cm 170605-16	4.1
	Rusch Tieman katheter Ch14 ballon 10ml	4.0
	Rusch TUR zak 4ltr L120cm	3.0
	Swann-Morton mesje nr.11 100st	7.0
	titanium clips 2200 horizon med. Wide 180st	6.0
Medica Europe	Handenwasborstel 25st	1.0
	Medisavona handzeep 500ml	2.9
	Microclave 3-weg koppelsyst.octopus met klem	3.5
	Microclave gesloten connector 011-C3300 100st	3.2
	Microclave verlenglijn 18cm 011-C3302	2.1
	Mondmasker met oorlus ref 47117 geel 50st	1.0
	Mondmasker PFRP2 respirator ref 62408 50st	2.0
	Probe Cover, VIP film, Gel and Rubber bands E6346 13x61cm	13.0
	Toedieningssysteem Y-type ref 79052	2.3
Huuskes	Broxomatic Onthardingszout 1kg	3.1
	Peijnenburg ontbijtkoek mono 100st	3.0
	Sunleaf thee apple cinnamon 20 zakjes a 2gr	2.0

Supplier	Product name	Average delivery time (d)
Huuskes	Sunleaf thee green tea mint 20 zakjes a 2gr	2.0
	Sunleaf thee tropical fruit 20 zakjes a 2gr	1.0
	Verkade biscuit volkoren San Francisco 250gr	3.0
	Zwitsal Shampoo 500ml	3.5
Romedic BV	Innospire Sidestream disposable kit ref.4448	2.8
Fisher & Paykel Healthcare SAS	Evaqua 2 beademingscircuit incl.Filter	2.8
Brocacef Intramuraal	Flocare Container 1000ml	2.3
	Flocare Universal adapter 570063	3.5
Cook Nederland/Shared Service Center	Frova tube introducers met Rapi-Fit Adapters 14Fr L70cm	2.8
Mediq BV (Medeco BV)	Ecolab Brialspray 750ml	1.0
	Klinion buikgaas 45x70cm 10x2st	2.0
	Klinion gipstricot geribt 10cmx20m	6.0
	Klinion prepareerdepper x-ray 6x6cm 5st	7.0
	Klinion protectiejas XL 145cm 10st	1.0
	Pillow-paw pantoffel maat 42-46 bruin 1pr	1.0
	Plastic zak wit tbv cytostatica 58x100cm 25st	3.0
	Sharpsafe naaldencontainer 3L	1.0
	Sharpsafe naaldencontainer 4L	1.8
	Sharpsafe naaldencontainer afvoerdoos	6.5
	Spoelkatheter Ch14 L18cm ref.02017182	4.0
3M Nederland BV	Bair Hugger Full Access warmtedeken 63500	1.0
	Bair Hugger Upper Body warmtedeken 52200	1.8
	Durapore hechtpleister 25mm 12st	1.0
	Micropore Chirurgische pleister 2,5x9.1m 12st	3.0
	Nexcare Comfort strips 19mm 100st.	3.0
	Ranger Standard Flow infuusverwarmingset	6.0
	Red Dot monitoring Electrode 2560 5st	2.9
	Steri-Strip basis wondsluiting 12mmx100mm 50st.	2.0
	Tegaderm I.V. pleister 6x7cm 1624W 100st	8.0
	Tegaderm I.V. pleister 7x8.5cm 1633 100st	2.1
BSN Medical BV	Cutisoft 12-lgs 10x10cm 75st 92422	7.0
	Cutisoft Kompres 4-lgs 10x10cm 50x2st 45849	1.3
	Delta-Cast Conf. blauw 3,6m x 10cm 10st	2.0
	Delta-Cast Conf. groen 3,6m x 10cm 10st	4.5
	Delta-Cast Conf. wit 3,6m x 10cm 10st	2.0
	Delta-Cast Conf. zwart 3,6m x 10cm 10st	3.3
	Fixomull stretch zelfklevend 5cmx10m	1.0
	Soffban synth. watten 10cmx2.7m 12st	1.0
Molnlycke Health Care	CABG Tray	4.8
	Instrumentenveld 150x190cm abs. 75x190cm 22st	2.0
	Mepilex 10x12cm 5st	1.3

Supplier	Product name	Average delivery time (d)
Molnlycke Health Care	Mepilex adhesief Border Sacrum 23x23cm 5st	2.0
	Mepitel 12x15cm 5st	1.3
	Operatiejas OJ HP XL-L, 148cm Ref. 690105	1.0
	Zelfklevend afdeklaken 175x175cm	2.3
Codan BV	Green line verlengslang D1.0mm L300cm 714005	2.3
	I.V. Star 10 set met infusiefilter L25cm	2.3
Medlon BV	ACT Kaolin 25st	1.3
	Babylance Newborn 1mm	2.0
	E3+ Istat cartridge 25st	3.0
	Eclipse naald veiligheidsbloedafname 48st	4.0
	I-Stat CG4+ cartridge 25 test	1.7
	I-stat CG8+ cartirdge 25 test	1.0
	I-Stat G3+ cartridge 25 tests	1.0
	Objektglazen Superfrost + matrand 50st	1.5
	Specimen beker met schroefdop	2.0
	Test strips accucheck inform II 50st	1.6
	Urinebokaal, Fles vierkantig 1l	4.0
	Urinepotjes met geïntegreerd afnamepunt 100st	4.5
	Vac 4 ml Edta gesprayed lavandel 100st	2.1
	Verzendcontainer voor 5 objektglazen	1.0
Stopler BV	Handschoen, Nitra-Tex, Maat S, 100st	1.7
	Handschoen, Nitra-Tex, Maat XL, 100st	1.0
	Handschoen, Nitrile, Maat L, 100st	1.7
	Handschoen, Nitrile, Maat M, 100st	3.0
	Handschoen, Nitrile, Maat S, 100st	2.5
	Handschoen, Nitrile, Maat XL, 100st	2.1
	Handschoen, Style 85, Maat 7.5, 1paar	1.0
	Handschoen, Style 85, Maat 8.5, 1paar	5.0
Becton Dickinson BV	Eclipse injectienaald groen 21G 40mm	3.0
	Plastipak precisiespuit 1ml L centr	1.9
	Plastipak spuit 30ml LL centr	2.0
	ProSafety I.V.katheter 20Gx1 1/4 11x32mm 50st	2.3
	Spinale naald 22G 3,5 inch 0,7x90mm zwart	4.0
C.R. Bard Netherlands Sales BV	LaproCare Urine opvangzak 2ltr L115cm steriel	3.0
	Niagara Kit Straight Dual-Lumen Dialysis Catheters L20cm	1.0
Smiths Medical Nederland BV	Gripper Plus 20G L19mm	2.0
Technische Unie BV	Batterij Duracel CR2032 knoopcel	2.0
	Veiligheidsbril Virtua AP Blank 3M	2.0
Braun Medical BV	Infusomat Space line ref. 4182586SP	1.6
	Koppelsysteem + naald vrij A2581NF SPACE	4.5
Argon Medical Devices Netherlands BV	Drukmeetsysteem Flexi Veneus HR ref.688934	2.0

Supplier	Product name	Average delivery time (d)
Argon Medical Devices Netherlands BV	Safedraw P Thorax enkel septum ref.688420	1.8
Microtek Medical	Beschermkit echo transducer ref 87106 12st	1.7
Twepa Enschede	Bak D101mm 500ml karton wit 50st	1.0
	Europroducts facial tissues 100st	1.0
	G-label LDPE boterhamzakje 14x4x35cm 1000st	2.0
	Handdoek Wit 20x34.5cm 2lgs 160st	1.0
	HDPE plastic zak grijs 70x110 0.004 25st	2.4
	HDPE plastic zak zwart 630x700mm 0.025 50st	1.0
	LDPE boterhamzak 10x4x30 0.02 1000st	2.0
Dentsply Sirona	LoFric Origo Nelatonkatheter Ch14 L40cm	1.6
Labeldiscounter	Adresetiket MST 54x101mm rol.220st	1.5
Beukenhorst Koffie	Hot Cups SMR8 karton 240cc 50st	1.2
	Koffie Fresh Brew royal 1kg	1.0
Abena BV	Abri-Light Extra inlegverband 10st	1.5
	Abri-Soft Basic onderlegger 60x60cm 60st.	1.0
Arjo Huntleigh Healthcare	Detergent reinigingsmiddel voor pospoeler 5L	1.0
	Rinse ontkalkings/naspoelmiddel voor pospoeler 5L	1.0
Hollister BV	Novalife1 ileozak maxi open 9150-10 10st	1.0
Paul Hartmann BV	Peha-Haft fixatiezwachtel 10cmx20m	1.0
Sita	Afvalcontainer 50l met deksel blauw	1.0
VE-Systems BV	Septodry absorbtiekorrels 10 zakjes	1.0

Appendix XXV The correlation between the number of orderlines on an order and the complete rate

Number of orderlines on the order	Delivered completely	Delivered incompletely
1	100.00%	
2	93.84%	6.16%
3	92.02%	7.98%
4	91.93%	8.07%
5	89.06%	10.94%
6	87.45%	12.55%
7	87.11%	12.89%
8	86.98%	13.02%
9	84.78%	15.22%
10	84.85%	15.15%
11	80.15%	19.85%
12	85.98%	14.02%
13	81.60%	18.40%
14	76.35%	23.65%
15	69.63%	30.37%
16	76.61%	23.39%
17	74.31%	25.69%
18	75.00%	25.00%
19	74.44%	25.56%
20	71.60%	28.40%
21	72.06%	27.94%
22	64.29%	35.71%
23	66.67%	33.33%
24	61.40%	38.60%
25	71.15%	28.85%
26	63.04%	36.96%
27	67.31%	32.69%
28	63.41%	36.59%
29	62.07%	37.93%
30	55.56%	44.44%
31	61.54%	38.46%
32	58.82%	41.18%
33	60.00%	40.00%
34	61.90%	38.10%
35	52.94%	47.06%
36	68.18%	31.82%
37	64.71%	35.29%