Surgical supplies demand forecasting

Master thesis

Industrial Engineering and Management

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August 16, 2021

isala UNIVERSITY OF TWENTE.

Title page

Document

Title:	Surgical supplies demand forecasting
Date:	August 16, 2021
Place:	Zwolle
Edition:	Fourth
Number of pages:	59
Number of appendices:	6
Reference:	UT/IEM-05.04-16.08.2021

This thesis was written as part of the Master of Science of Industrial Engineering and Management graduation.

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Management Summary

In a hospital, logistics play a significant role, especially regarding the supply of goods. For this supply, hospitals often have tight schedules and agreements with suppliers. However, hospitals typically need to deal with unpredictable circumstances, which causes them to sometimes deviate from the agreements. This deviation usually occurs when an item is out of stock but is needed immediately, resulting in that an employee orders the item with urgency. Such so-called emergency orders disrupt the hospital's operations because employees need to shift their focus and take additional actions for these emergency orders. In Isala hospital in Zwolle, disruptions due to emergency orders increase the hospital's costs. Therefore, this research will investigate the causes, frequency, and costs of emergency orders within Isala hospital in Zwolle.

Research goal

A root cause analysis shows that two of the core problems that cause emergency orders are (1) the behaviour of employees and (2) the hospital does not forecast the demand for items. Therefore, this research aims to study the literature to find a relationship between the behaviour of employees and emergency orders. Furthermore, it aims to forecast the demand for surgical items in Zwolle based on the operating room (OR) schedule, to prevent emergency orders from happening. Research is needed to address both core problems because employees first need to be aware of the impact of emergency orders before they are willing to cooperate in reducing emergency orders by forecasting demand. The research question that follows from this will therefore need to be twofold:

"How does the behaviour of employees influence the emergency orders, and how can the number of emergency orders be reduced by forecasting the demand for surgical items based on the operating room schedule?"

Approach

To outline the current situation of the supply chain, we observe the logistics department and OR department. Then we search literature about the behaviour of employees regarding emergency orders. We analyse historical data about emergency orders to determine which department, items and suppliers cause the most emergency orders in the hospital. With this data, we also analyse the frequency of emergency orders and the costs of emergency orders separated in terms of costs charged by suppliers and costs paid by the hospital for employees working on emergency orders. The forecasting model to forecast demand for surgical items is built, verified, and validated with the department that causes most emergency orders. Finally, we draw conclusions and recommendations.

Emergency order analysis

From the analysis, we conclude that the OR department causes most emergency orders of all hospital departments. The most ordered items with urgency are daily used by each hospital department.

The total costs of emergency orders per year were €82,239.10 in 2019 and €84,706.69 in 2020, of which 73% of these total costs per year were the costs for involved employees and 27% of the total costs were costs charged by suppliers.

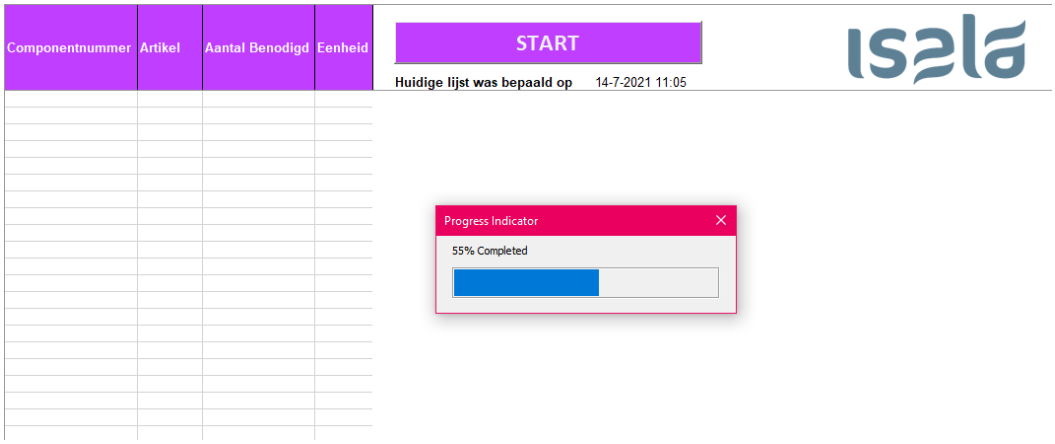
Risk-avoidance behaviour plays a significant role in the ordering of emergency orders. This behaviour causes more emergency orders because the employees want the certainty of the item delivered in time and surgeons prefer equipment that they are accustomed to. Both are a form of passive risk-avoidance. From this, we conclude that there is a relation between emergency orders and risk-avoidance behaviour.

The awareness of the employees towards the effects of emergency orders is essential. When they are aware of the impact, they are more likely to prevent it or change their behaviour. Employees should be motivated by the board of the hospital to change their behaviour. When motivating employees, every employee has to share the same goal and vision. Furthermore, the employees should get the freedom to act, try out their ideas, broaden their knowledge with training, and be responsible for producing results. Also, the hospital should take into account the wage and rewards they give the employees.

Forecast model

We develop a forecast model with two inputs (1) the preparation lists to prepare surgeries and (2) the OR schedule. Preparation lists and surgeries in the OR schedule both consist of codes, such as 'HEUPG', that indicate the type of surgery. By combining the code of the preparation list to the same code of the surgery, the model can link the two inputs.

An employee can click on the dashboard's 'START' button to initiate the forecasting process. This button starts a count of the various surgeries stated in the OR schedule. Hereafter, the system searches for each of these surgeries in the data of the preparation lists. Whenever the model finds a corresponding surgery, it copies each of the required items to an item list. If the model sees multiple lists for the same surgery, some surgeons require specific items. In this case, the model chooses the item list bound to the surgeons' staff number. By multiplying the required number of items per surgery with the respective number of scheduled surgeries, the model determines the total number of items needed. When the item list with corresponding quantities is complete, it is sorted and copied to the dashboard.



The dashboard is the forecast model's output. This output contains a list of items with corresponding quantities needed for the surgeries in the OR schedule. The employee of the OR logistics department can order the items on the list to reduce the cases in which there is a shortage of items when preparing the surgeries.

For the verification and validation, we used data of the specialism orthopaedics. We chose this specialism together with relevant stakeholders. After putting the data into the forecasting model and checking the results, we conclude the model is verified and validated.

Conclusion and recommendations

Hospitals can forecast surgical supplies based on an OR schedule by combining preparation list codes for surgeries with the same codes for the type of surgery in the OR schedule. In this way, the model searches for the preparation list belonging to a surgery. This preparation list includes all items needed for that surgery. When the model finds for each surgery in the OR schedule a corresponding preparation list, it can overview the required items for these surgeries. The model is generic, which means that the OR department can use the model in the future for each specialism.

The risk avoidance behaviour of employees influences the number of emergency orders. Employees avoid risks by taking the easy way out, i.e. by placing an emergency order. Also, due to the unawareness of the effects of emergency orders, employees place an emergency order when they need an item and do not look for alternatives. Due to the employees' unawareness and risk avoidance behaviour, the emergency orders increase, so this behaviour of employees does influence the emergency orders.

The recommendations for the hospital, which also give direction to future research, are:

- Implement the forecasting model to gain insight into the needed items for surgeries, which we expect to reduce emergency orders in the future.
- Gain insight into the supply between the hospital in Zwolle and Meppel. Only in this way the hospital can optimise its supply chain.
- Consider an ERP system that keeps track of the emergency orders of Isala. This tracking may give valuable insights.
- Reduce the number of items in the assortment of the OR department, which makes inventory management less complicated.
- Reduce the number of employees who have the authority to place an emergency order. When an employee has to ask permission from someone with authority, the threshold for placing an emergency order is higher.

Acknowledgements

In front of you is my thesis, which I wrote to complete my master's degree in Industrial Engineering and Management at the University of Twente.

I would like to take the opportunity to thank some people. In particular, I would like to thank Christa Baas of Isala hospital. She made it possible for me to have an almost regular internship despite corona. She was always willing to make time for me when I needed her, a good sparring partner, and always let me know that she was happy even with the slightest results and insights of the research.

I am also grateful to all the employees of the operating room department, logistics department and purchasing department for their enthusiasm about the assignment, which motivated me to keep the goal in mind. They also provided me with much valuable data and information during the research.

Of course, I would also like to thank my supervisors at the University of Twente, Erwin Hans and Gréanne Maan-Leeftink, for their guidance during the research. They have provided me with much helpful feedback and helped me think through the sometimes tough choices in this research. It was nice that they put so much time into me and my thesis.

Finally, I would like to thank my parents, boyfriend and friends for their support during this period. The interest they showed in me and my research kept me believing in myself and ensured that I kept my eyes on the goal.

I hope you enjoy reading my thesis!

Bente Muller
Zwolle, August 2021

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Glossary

Word	Abbreviation	Explanation	Introduced at page
Emergency order	-	An order delivered within 16 working hours, outside the regular (periodical) deliveries. For these emergency orders, the supplier and employees of Isala have to take additional actions. As a rule of thumb, instead of precisely measuring 16 hours, the order should be delivered the same day or the next day.	13
Emergency department	ED	-	43
General Data Protection Regulation	GDPR	A legal framework that consists of guidelines for the processing of personal data in the European Union.	35
Healthcare Information eXchange	HiX	HiX is an electronic patient file produced by Chipsoft.	18
Hospital Logistics	HL	Logistics service provider (LSP) with warehouse facilities.	16
Isala	-	Name of the hospital.	12
Logistics service provider	LSP	A provider that manages a company's warehousing, distribution and transportation of freight.	13
Operating room	OR	-	12
Premium pay	PP	Supplement on top of wages for employees who work irregular hours, such as holidays, evenings, weekends, etc.	30
Purchase item	-	Items that are supplied from suppliers. Sometimes these items go from the supplier via a cross-dock at HL to the hospital.	16
Preparation list	-	A list containing all necessary items per type of surgery with corresponding quantities	36
Request for order	RFO	A request internally sent within the hospital to obtain items. The request is a formal document made by a department that gives the purchasing department the exact information of which items are needed.	19
Scan relevant item	-	This item only occurs in departments where surgeries are performed, such as in the treatment centre, cardiac catheterisation rooms, operating rooms, etc. The item has a barcode and can therefore be scanned. This type of item is, for example, an implant.	16
Stock item	-	Items that are daily used by each hospital department and supplied from the logistics service provider (LSP) with warehouse facilities.	16
Theory of Planned Behavior	TPB	A helpful framework for understanding employees' beliefs and intentions to support organisational change (Jimmieson, Peach, & White, 2008).	25

1 Introduction

In a hospital, logistics play a significant role, especially regarding the supply of goods. For this supply, hospitals often have tight schedules and agreements with suppliers. However, hospitals typically need to deal with unpredictable circumstances, which causes them to sometimes deviate from the agreements. This deviation usually occurs when an item is out of stock but is needed immediately, resulting in that an employee orders the item urgently. Such so-called emergency orders disrupt the hospital's operations because employees need to shift their focus and take additional actions for these emergency orders. In Isala hospital in Zwolle, disruptions due to emergency orders increase the hospital's costs. Therefore, this research will investigate the causes, frequency, and costs of emergency orders within Isala hospital in Zwolle.

This chapter introduces the organisational context of the research, Isala hospital (Section 1.1); the motivation of the research (Section 1.2); the goal of the research (Section 1.3); and the research questions (Section 1.3).

1.1 Research context

The organisation in which the research takes place is the purchasing department of Isala hospital located in Zwolle. Isala is a top clinical hospital and has around 6,716 employees (4,946 FTE's) in Zwolle. As a top clinical hospital, Isala is part of STZ (Samenwerkende Topklinische opleidingsZiekenhuizen, in English: Collaborating Top Clinical Training Hospitals), with which they collaborate to improve high-quality patient care, top clinical treatment, top referral care, and the innovation of care. The hospital's mission is to optimally recover, maintain, and enhance the patients' quality of life. They want to reach this based on three core values: professionalism, openness & transparency, and heart & soul (Isala, 2021b).

Isala has other locations in Meppel, Steenwijk, Kampen and Heerde, of which Steenwijk, Kampen and Heerde are used for outpatient appointments, superficial treatments, health checks, and blood and X-ray tests. Zwolle and Meppel also have inpatient appointments, and therefore, surgeries only take place in Zwolle and Meppel. Zwolle has fourteen clinical operating rooms (ORs) and six day treatment ORs, whereas Meppel is smaller with five ORs. These surgeries require many different items and equipment. The items needed for surgery depend on the type of surgery, the patient's status, and the OR team's preferences. As a result, the items required for each surgery vary greatly (Isala, 2021a). The various locations and variations of items illustrate the complexity of the supply chain, which this research should take into account.

Isala's purchasing department deals with procurement processes for all purchases with an invoice, except for temporary staff. The department also ensures that various items are available from which the departments can order items. These items concern, for example, syringes, disposable gloves, etc. The essential point of this, relevant to the research, is that purchasing is centralised, and the ordering of items is decentralised. The departments can place typical orders, or emergency orders when an item is not in stock and has to be delivered the same or the next day. The purchasing department in Zwolle is

responsible for the purchasing for all locations of Isala. An organigram of this department with its various sub-departments, referred to as desks, is given in Appendix A.

1.2 Motivation of research

The motivation for Isala to start this research is that the purchasing department has to deal with many emergency orders for items. This research defines an *emergency order* as an order delivered within 16 working hours, outside the regular (periodical) deliveries. For these emergency orders, the supplier and employees of Isala have to take additional actions. As a rule of thumb, instead of precisely measuring 16 hours, the order should be delivered the same day or the next day.

The additional actions described mean that emergency orders cost extra time and money. When an item is 'missing', an employee considers an alternative or decides to place an emergency order. This decision has to be made ad hoc, so without any formal approval process, and other activities are postponed or delayed as a result. When an employee places an emergency order, the following steps have to be done: the supplier or a logistics service provider (LSP) brings the item directly to the hospital; the logistics department's employee gets the just delivered item to the hospital's proper place. Also, these employees need to shift their focus. This time, transport, etc., have to be paid, and therefore an emergency order is expensive. Furthermore, emergency orders come at a high rate, and consequently, the hospital has to reduce these as much as possible.

1.3 Research goal

This research aims to study the literature to find a relationship between the behaviour of employees and emergency orders. Furthermore, it aims to forecast the demand for surgical items in Zwolle based on the operating room (OR) schedule to prevent emergency orders from happening. We scope these items for surgeries only, so we exclude items for anaesthesia and recovery. Our data analyses ensure that Isala gains more insight into the volume of (unnecessary) emergency orders and the department or items that cause them. As a result, the hospital may prevent emergency orders.

Research is needed to address both the behaviour and the forecasting problem because employees first need to be aware of the impact of emergency orders before they are willing to cooperate in reducing emergency orders by forecasting demand. The research question that follows from this will therefore need to be twofold:

"How does the behaviour of employees influence the emergency orders, and how can the number of emergency orders be reduced by forecasting the demand for surgical items based on the operating room schedule?"

1.4 Research questions

Research questions support achieving the research goal. Under each research question, we state how we gathered the knowledge and where to find the answer.

1. How is the supply chain of emergency orders organised within Isala?

1.1. Which types of items does the hospital have?
1.2. How are the departments supplied in the current situation?
1.3. How are the ORs in Zwolle supplied in the current situation?
1.4. When will the OR schedule be finalised?
1.5. How often does the OR schedule change after it has been finalised?
1.6. What causes these emergency orders?
1.7. Which steps are needed to place an emergency order, and which employees are involved?

We obtained the answer to these questions during orientation days at the logistics department and OR department. The knowledge has been acquired by observing and interviewing employees, which means there is no direct contact about the research with the hospital's patients. All information required for the research we obtained through the employees of Isala. The interviews with the employees are semi-structured, for which we drew up several questions in advance. These questions could be deviated from, for example, by questioning the answers given by the employees. Appendix B provides a questionnaire for this interview (Dingemanse, 2015). Chapter 2 answers Research question 1 and Questions 1.1 to 1.7.

2. How does the behaviour of employees influence the number of emergency orders?

2.1. What provides the literature about the relationship between emergency orders and the behaviour of employees?
2.2. How to make an employee aware of the consequences of an emergency order?
2.3. How can the behaviour of employees be changed best?
2.4. How to motivate the employees of a hospital to change their behaviour?

We searched for the behaviour of employees concerning emergency orders in the literature. Chapter 3 provides a literature study with the answers to Questions 2.1 to 2.4.

3. What are the number and costs of the emergency orders per year?

3.1. What are the costs that a provider/supplier charges for an emergency order?
3.2. How much does the hospital pay for employees who deal with an emergency order?
3.3. Which department causes the most emergency orders?
3.4. Which items cause the most emergency orders?

To be able to answer these questions, several data is needed. First, we request the costs for one emergency order from the LSP and the suppliers to make a cost overview for emergency orders. Second, the time spent by an employee on one emergency order has to be measured and converted into costs. Third, to determine which department and items cause the most emergency deliveries,

historical information on emergency orders is required. To this end, we scheduled an appointment with the data analyst of the support desk. The data used in the research is from location Zwolle and the years 2018, 2019, and 2020. Due to Covid-19, the research should consider that not all data from 2020 is 100% accurate. The data is complete and audited by an employee of the support desk.

With the gained data, we executed an analysis to find the total number of:

- Items ordered with urgency
- Orders placed with urgency
- Emergency orders per day
- Emergency orders per month
- Emergency orders per item
- Emergency orders per department
- Emergency orders per supplier

With this data, the costs of the emergency orders are calculated and given in Chapter 4. This chapter also answers Questions 3.1 to 3.4.

4. How can a model that forecasts supplies for surgeries be made based on an OR schedule?

4.1. What are the design principles for hospital software?
4.2. How does a good interface look like for a forecasting model?
4.3. How do employees experience the interface of this new model?
4.4. How to verify and validate a forecasting model?

This research question helps to build to forecasting model. The literature searches for the design principles for hospital software and the essential elements of a good forecasting model interface. This literature answers questions 4.1 and 4.2. To ensure that the model is reliable in the long term, the model should be adaptable to changing circumstances. A scheduled meeting with the employees who will work with the model in the future answers Question 4.3. During this meeting, we discuss the interface, usability, clarity, etc., of the model. After we create the model, it has to be validated. The research uses data from the department that causes the most emergency orders to validate the model to check whether the forecast performs as expected, which directly answers Question 4.4. Chapter 5 answers these questions and gives an overview of how we built the forecasting model.

This report concludes with Chapter 6, which provides the conclusion and discussion of the research, and gives recommendations to the hospital.

2 Context analysis

Emergency orders are part of the goods flow within Isala. Therefore we analyse how the hospital currently organises the flow of goods (Section 2.1), particularly the supply of the nursing departments and OR department. The forecasting model is made based on the OR schedule, so it is essential to know how the OR schedule is made (Section 2.1.3). Section 2.2 discusses the causes of the emergency orders given in a problem cluster, from which the core problem follows. Finally, we present conclusions in Section 2.3.

2.1 Process description

This section discusses the three types of items the hospital uses (Section 2.1.1), the supply of nursing departments (Section 2.1.2) and the OR department (Section 2.1.3), and the process of an emergency order (Section 2.1.4).

2.1.1 Types of items

There are three types of items: stock, purchase and scan relevant items. *Stock items* are daily used by each hospital department and supplied from the logistics service provider (LSP) with warehouse facilities, named *Hospital Logistics (HL).* Other suppliers supply the *purchase items*. Nevertheless, sometimes the purchase items go from the supplier via a cross-dock at HL to the hospital.

Scan relevant items occur only in departments where surgeons perform surgeries, such as in the treatment centre, cardiac catheterisation rooms, ORs, etc. The item has a barcode, and an employee can therefore scan the item. This type of item is, for example, an implant. Most of the time, scan-relevant items are costly; hence, the hospital should keep a low stock level for these items. A low stock level means that the chance of running out of stock is more significant than with a higher stock level. The low stock level is one of the reasons why the hospital decided to scan these items. By scanning, the system reduces the stock of the item by one and a new item is automatically ordered to replenish the stock. Furthermore, implants should be linked to an individual patient so that if there is ever a problem with an implant, it is known which implant is in which patient (Ministerie van Volksgezondheid, 2018).

In the hospital pantries of nursing departments, without scan relevant items, two colours indicate the item type. Namely, white with a yellow back for stock items and blue for purchase items. The departments that also have scan relevant items indicate the different items with yellow, blue and white. However, the departments do not use the colours the same way; for two departments, a specific colour might indicate another item type. For example, the OR department has white for stock items, yellow for purchase items, blue for scan relevant items, and the cardiac catheterisation department uses yellow for stock items, blue for purchase items, and white for scan relevant items.

2.1.2 Supply of the nursing departments

The logistics department consists of several disciplines. The most critical disciplines in the supply process are goods receipt, fine distribution and transport.

Figure 1 - Delivery by HL with three containers

Goods receipt receives all goods delivered on a day. For example, HL comes four times a day with a delivery (7:00, 10:00, 13:00, 16:15); see Figure 1. Every container delivered by HL has a barcode and a paper that clarifies to which wing and floor it belongs. Goods receipt scans all the barcodes on the containers so that the system registers the received goods. The goods receipt receives an e-mail from the purchasing department about every item that departments have ordered with urgency. They check whether HL has delivered all these emergency orders, which are often in a separate container. If not all emergency orders are delivered, goods receipt contacts the purchasing department.

After goods receipt has scanned all containers, they sort the containers per wing. An employee of transport attaches these sorted containers to a trolley, which can handle a maximum of 6 containers at a time. The courier drives through a corridor under the hospital to the correct wing. When all containers of that wing arrived, the employees take the containers to the correct floor with the elevator. The transport employee stores the containers in a room behind the elevator, to which only employees have access.

The other suppliers deliver at other times. The couriers of these suppliers report to the goods receipt reception desk so that a goods receipt employee can receive the packages and register them. Goods receipt sorts all the boxes from the suppliers per wing of the hospital. The sorted packages from the suppliers are taken away by transport or by goods receipt themselves.

Fine distribution scans and stows the stock and purchase items of the departments except for the OR department and the treatment centre. Every department has its scan and stowage times, of which the logistics departments stores an overview in Excel. Appendix C gives an example of this overview. The logistics department adapted the scan and stowage schedule to the type of department, which means that some departments are scanned and stowed every working day, and some only twice a week. When fine distribution scans, they scan the yellow cards for the shelves per pantry. The nursing staff in that department turns the cards and are therefore yellow. This way, the logistics department employee knows which items they have to order according to the department. The items from which they scan the cards are also the items that the system orders.

For the stowing of the goods, the fine distribution employee picks up the containers in the storage room behind the elevator, where transport left them, and takes the containers to the pantries. When the fine distribution employee stows the goods in the pantries of the departments, the fine distribution employee turns the yellow cards back to white. There are also blue cards, which are the purchase items. The

delivery time for these often is longer. That is why they put a red note behind it with the date that they ordered that item.

The number on the scan cards is the minimum that should be in stock in the pantry of that item. If the compartment is almost empty, fine distribution scans the card twice, which causes that the system orders the item twice. Two times the number on the ticket is the maximum that the employee can order. The number on the card is also the order quantity. The use of the item determines these numbers. They are not revised regularly, but only when it happens a few times that the item is out of stock while needed.

2.1.3 Supply of the OR department

The decentralised planners make the OR schedule in *HiX*, which stands for Healthcare Information eXchange and is an electronic health record and hospital information system produced by Chipsoft (ChipSoft, 2021). HiX updates the OR schedule automatically to the ERP programme SAP. The OR schedule can therefore be downloaded to, for example, Excel from SAP. Surgeons have a significant say in this schedule, which means that the planning changes regularly. If it is more convenient to swap one surgery with another that week, they decide that the schedule changes. Officially, the planning for a day is finalised at noon the day before. After this, minor adjustments can still be made if necessary, but this has to be done by contacting the planner at the OR department.

As described in Section 1.1, both locations in Zwolle and Meppel have ORs. The supply of the OR departments differs because Meppel has an internal warehouse, while Zwolle receives its supplies through HL. Furthermore, Zwolle has more ORs than Meppel, so more supplies are delivered, and there are more pantries than only one. The pantries in Zwolle are divided by specialism to make it easier to find items.

Figure 2 shows a pantry with scan relevant items. The supply of the scan relevant items is automated, so no scan cards can be seen in the picture. These items are immediately scanned by an OR assistant when used in the OR. As a result, the system links the item to the patient in HiX. Furthermore, the stock reduces with one, which causes an automatic order for a new item.

Figure 2 - Pantry with scan relevant items at the OR department

The OR department has its own logistics employees. These employees order the stock and purchases items. Unlike the rest of the hospital, the employees verify whether they need to replenish an item. In the OR department, therefore, no cards are turned by nurses, surgeons, etc. In Meppel, the logistics department employee scans the sterile pantry items five times a week and those from the non-sterile pantry and the pharmacy twice a week. In Zwolle, all the items, except those in the coffee corner and the vascular

storage, are scanned five times a week. Scanning takes place in the morning at 7:00, after which the items are delivered the same afternoon at 13:00. The coffee corner and vascular storage in Zwolle are scanned three times a week between 10:30 and 12:00, and these items are delivered the following day at 7:00.

2.1.4 Process of an emergency order

An employee of a department places a *request for order (RFO)*, which is a request internally sent within the hospital to obtain items. The request is a formal document made by a department that gives the purchasing department the exact information of which items are needed. The employees of the order desk receive this RFO. Then, the order desk contacts the supplier and logistics department to see whether the (emergency) order can be carried out. The department places an emergency order itself. This order is made final and forwarded to HL or the supplier by the purchasing department. In some cases, the logistics department makes the order final. When the supplier or warehouse processed the order, they deliver the item to the hospital. After that, the logistics department ensures that the order arrives at the right place in the hospital.

When employees place emergency orders, it can also mean that Zwolle delivers items to Meppel and vice-versa. However, the logistics department employees have no insight into how often this happens but indicated that they regularly see an emergency order. The hospital does not register these orders. The employees often settle this among themselves over the phone.

For emergency orders of HL, logistic department employees use approximately ten minutes. Nevertheless, for emergency orders of suppliers, they need at least twenty minutes. Emergency orders of suppliers take longer because these packages cannot go with the standard transport to the wings. So, an employee has to walk or drive back and forth to the wing, especially for this one order, which takes about ten minutes more than with emergency orders of HL.

2.2 Core problem

From the interviews with purchasers and orientation days at several departments, the following issues and associated causes follow, processed into a problem cluster in Figure 3. To read the problem cluster, start at the top and follow the arrows down. One can say 'thus' between the blocks, which indicates an effect of the former block. All blocks with thick blue edges are root causes, and all blocks with purple edges indicate the problems experienced by Isala, for which this research sought causes to tackle.

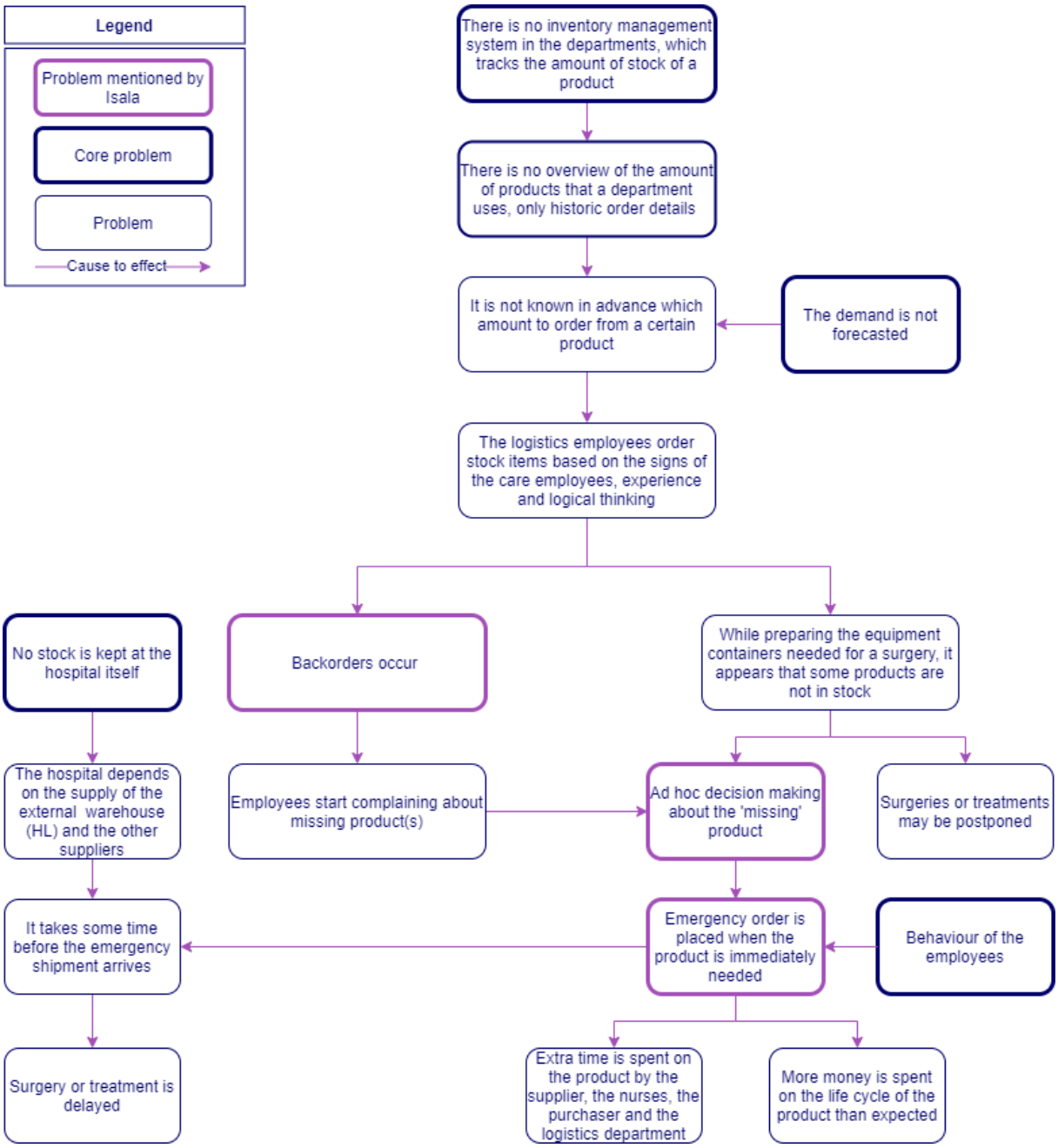

Figure 3 - Problem cluster

Figure 3 shows that there are four core problems, indicated with a thick blue border. The first core problem is that there is no inventory management system, which provides insight into an item's stock amount. For example, in a supermarket, all items that the customer purchases are scanned. When the cashier scans the item, the stock reduces by one. If the stock drops below a specific number, the system automatically reorders this item. Without this insight into an item's stock amount, the purchasers do not know how much to purchase an item, which has its effects, shown in the problem cluster. This problem occurs hospital-wide and is therefore out of the scope of this research.

The second core problem is that there is only an external warehouse in Zwolle and no internal warehouse but only pantries in the departments. The external warehouse causes (emergency) orders to take longer to get to the hospital. Moving an external warehouse to an internal warehouse can have other consequences. However, this has been the hospital's deliberate decision, for which they had several arguments. Therefore, this is not part of the research

The third core problem and one of this research's core problems is that the departments' demand in the hospital is not forecasted. The departments are responsible for their pantries, and the logistics department only estimates, for example, the minimum and maximum numbers of the scan cards when the department asks for them. The logistics department determines the number of an item in stock based on the use. No safety stock, optimal order quantity, etc., is calculated. Not calculating and not forecasting contributes to the hospital having many ad hoc decisions and emergency orders. Once the hospital has more insight into how many and where the emergency orders occur, they will be able to tackle this problem by forecasting the demand.

The fourth core problem and a core problem that this research takes into account is the behaviour of the employees. In general, employees do not know what an emergency order entails. They do not know how many people are involved, how much time they put in, and certainly not the associated costs. When they need an item, they order it with urgency. With this research, we expect to make employees aware of what an emergency order entails to deal with it differently in the future.

The causes that fall under the block 'Behaviour of employee' are explained in Table 1. The table also lists other reasons for an emergency order, which have not been included in the problem cluster to keep the figure comprehensible.

Table 1 - Extension problem cluster

Cause	**Description**
External factors	
Emergency surgery or treatment	When there is an emergency surgery, specific items are sometimes needed for this as well. These items are ordered with urgency.
Backorders	The hospital usually finds out about backorders late. As a result, employees often order alternatives with urgency.
External warehouse	The external warehouse causes (emergency) orders to take longer to get to the hospital. Therefore, often emergency orders are placed to make sure the item is there in time.
The wrong item is delivered	Sometimes the supplier or the external warehouse delivers the wrong item. When the stock was already low and not supplemented, the department would place an emergency order to get the item after all.

Working method OR department	
Too many employees are authorised to place an emergency order	Many employees in Isala have the authority to place an emergency order. The department gave this authority because, most of the time, it suits their job. However, some employees once had this authorisation in their previous job and can still use it. This means that too many people have this authorisation, making it uncomplicated for the employees to place an emergency order.
Employees replace scan cards too late	When employees replace scan cards too late, the logistics department employee cannot scan the card, and in that way, the system does not order the item when an employee scans the card. This causes the inventory to decrease, which has to be supplemented, which happens with emergency orders.
The items are ordered by someone else every day	In this way, the logistics department employee does not get a 'feeling' about the items in the pantry. They also do not see backorders occur. When one person constantly scans the same pantry, they see that the item is not delivered although they ordered it the day before. A new person just thinks the item is almost out of stock and orders new ones.
The minimum and maximum number of an item in stock is not calculated with historical data	The use of the item determines the minimum and the maximum number of the item in stock. So, no safety stock, optimal order quantity, etc., is calculated with data.
Behaviour of employees	
The pressure of surgeons on the logistics department employees	Sometimes a surgeon lays pressure on the logistics department employee because that specific item has to be there before the surgery.
Lack of willingness to use other items/alternatives	It is well known from the literature that clinical staff have strong preferences regarding surgical items. This may stem from factors relating to technology or sales/services. Sometimes also from factors related to vendor and implant's cost/financial considerations (Burns, Housman, Booth, & Koenig, 2018). In Isala, also the educational background is mentioned. All these various items cause an extensive assortment in the hospital with items the employees work with.
Employees do not know the effects (costs and time) of an emergency order	This results in emergency orders when the orders are not needed. Sometimes the same item is available on another floor or department.

The OR assistant does not scan the scan relevant items when the surgeon uses the items	When the OR assistant does not scan the item, the system does not automatically reorder the item. Most of the time, of the more expensive items, only one item is in stock. So, when the item is needed again, it becomes an emergency order. The reason the OR assistant does not scan the item can have several causes: - After scanning, the scanned item is not already in the system. The scan has to be accepted by hand by clicking on a button. - Some employees are not computer literate. - Sometimes they forget.
The certainty that the item is there in time	The purchasing department cannot always guarantee that HL or the supplier delivers the item in time. Then, the employee who orders the item decides to order it as an emergency order to ensure it is there in time, for example, with items needed for surgery.
The purchaser relies on the employee who places the emergency order	Employees also order syrup, batteries, garbage disposal bags, etc., with urgency in the current situation. These are items that a department can wait for a bit longer or borrow from another department. The purchasing department accepts the RFO with urgency placed for these items because they trust that it is needed when an employee orders an item.

2.3 Conclusion

Isala has challenges with backorders, ad hoc decision making, and emergency orders placed when the item is immediately needed. A root cause analysis shows that these challenges are caused by:

- having an external warehouse instead of an internal warehouse
- no inventory management systems which tracks the stock of items
- the behaviour of employees
- the demand is not forecasted

The first two are outside the scope of this research. Therefore, this research focuses on forecasting the demand and the behaviour of employees concerning emergency orders. To do so, we will forecast the demand for the department that causes the most emergency orders. The analysis in Chapter 4 provides this department, but first Chapter 3 tells more about the theory on emergency orders regarding the behaviour of employees.

3 Theory on emergency orders concerning employees' behaviour

This chapter executes a literature study to find a relation between the emergency orders in the hospital and the behaviour of employees. The topics 'emergency orders in hospitals' and 'the employees' behaviour' are both extensively discussed in the literature. Nevertheless, the literature does not state a link between those topics yet. To our knowledge, this research is the first attempt to state the relationship between emergency orders and the employees' behaviour.

3.1 Risk-avoidance behaviour

Table 1 discusses that one of the causes of an emergency order can be due to the behaviour of employees. One of the causes mentioned in this appendix is that employees want the certainty that their order is there in time. For example, an employee orders a stock item with urgency on Monday for a surgery planned on Friday. HL or the supplier then delivers the item on Monday or Tuesday, so at least three days in advance. If the employee had placed a regular order, the item would have been there on time, too, before the surgery. This behaviour falls under risk-avoidance behaviour. Another cause of emergency orders related to risk-avoidance behaviour is the surgeons who have strong preferences regarding surgical items. They avoid the risk of working with other items than they are accustomed to, to guarantee the quality of their work.

Risk avoidance behaviour happens a lot in hospitals. According to Chang et al. (2012), benchmarking programs can lead to risk-avoidance behaviour on some surgeons and hospitals that lack confidence in risk adjustment to improve their ranking (Chang e.a., 2012). Benchmarking between hospitals is done a lot because the data is simple to obtain. Data such as turnover, mortality rates, number of medical specialists, etc., are published publicly. Due to benchmarking between hospitals being simple causes hospitals to want to perform at their best, which in turn causes them to engage in even more risk-avoidant behaviour.

There are two types of risk-avoidant behaviour, namely active and passive. According to Huber et al. (2014, p.444): *"Decision-makers intending to avoid risk in a decision situation can choose a less risky alternative (passive risk avoidance) or intervene actively in an alternative applying a risk-defusing action (active risk avoidance)"*. The two causes discussed are passive risk avoidance. For example, the risk for surgeons is making a mistake during a surgery. They choose the easiest solution to reduce this risk, a less risky alternative, namely using items they are entirely accustomed to. If items of this kind are not available, they have to be ordered urgently before that surgery. Surgeons could also actively consider an alternative. For example, they can teach each other how to use all items. If they can work well with all items, there is no need to place an emergency order if an item is not available. Then they can use a similar item as an alternative. Surgeons working well with all items ensure that the surgeons and the purchasing department can reduce the assortment. The smaller assortment makes it less complicated to manage stock, and therefore fewer emergency orders are needed (Zhang & Rajaram, 2013).

The cause for emergency orders about the certainty of having an item before the surgery has the risk: the item will not be there in time for the surgery. When keeping in mind the lead times of items, the logistics department employee does not have to order the items urgently. In almost every case, the item can be ordered without urgency and be there on time. Just ordering the item with urgency means that they did not actively consider an alternative but went for the less risky one. In both cases, they react instead of trying to be one step ahead of the risk.

Huber et al. also state: "*The observed differences between active and passive risk avoidance and risk-taking demonstrate once more that decision theory should take into consideration that decision-makers often attempt to actively defuse the risk of an alternative when it has attractive outcomes"* (Huber, Huber, & Bär, 2014, p.451). Therefore, we conclude that the OR department should be more actively considering attractive alternatives when facing possible risks.

3.2 Awareness employees of costs emergency orders

One of the biggest causes of emergency orders is that employees are not aware of an emergency order's effects (costs and time). Therefore, they order items with urgency while it is not necessary. The staff's answer to the question "What do you do if the compartment of an item is empty?" is placing an emergency order. To the following question: "Do you ever check if the item is available on another floor/department, or consider another solution?, the answer was: no, not always. Asking why the employees did not consider another solution, they answer that ordering the item with urgency is the easiest and fastest way. It became transparent that they never thought of doing it differently because it has always been this way, which worked well. According to Galbreath and Rogers (1999), the answer 'because it has always been this way' is unacceptable (Galbreath & Rogers, 1999). Therefore, employees should be aware of the effects of emergency orders. The awareness will help them realise that the current working method is not working as well as they think and should be changed.

To make the employees aware of the cost of an emergency order, the hospital should be transparent with the data on emergency orders. Publicly posting the number and costs of emergency orders will make employees aware of the problem (Litzky, Eddleston, & Kidder, 2006). However, being transparent with the data is only possible if this data is available. This research has collected this data and can now be published.

After making the employees aware of the effects of emergency orders, their behaviour toward emergency orders still has to adjust. Therefore, the Theory of Planned Behavior (TPB) framework can be used. *TPB* is a helpful framework for understanding employees' beliefs and intentions to support organisational change (Jimmieson e.a., 2008). With this framework, the hospital finds out what their employees think about specific issues and whether they are open-minded to changing their working methods. The open-mindedness of the employees and the desire to change their behaviour can be motivated by the hospital. The following section discusses how to motivate employees.

3.3 Motivation of employees to change their behaviour

Davidescu et al. (2017, p.40) say: *"Hospital performance is deeply influenced by the quality of human resources, and can be directly influenced by the improvement of employees' skills, and indirectly by increasing employee motivation"* (Davidescu, Tania, & Eid, 2017). The first step to increase this motivation is to make sure the employees share the same vision and goal. In this case, that could, for example, be: 'Reducing the emergency orders with x%'. The second step is to create an environment of action and learning. Moving the decision making down the hierarchy to a local level creates this environment. In this way, the employees get the freedom to act, try out their ideas, and be responsible for producing results (Galbreath & Rogers, 1999).

Furthermore, employees are motivated by their wages and rewards. In the research from Davidescu et al. (2017), the employees mentioned that responsibility and knowledge/training are essential factors that could improve their motivation. On the other hand, they found the financial component demotivating, namely the wage and rewards, because they were too low. From this, we conclude that wages and rewards are the main drivers of motivating employees in hospitals. Nevertheless, the focus should also be on non-financial components such as the knowledge and information of employees to increase their motivation (Davidescu e.a., 2017).

3.4 Conclusion

Risk-avoidance behaviour plays a significant role in the ordering of emergency orders. This behaviour causes more emergency orders because the employees want the certainty of the item delivered in time and surgeons prefer equipment that they are accustomed to. Both are a form of passive risk-avoidance. From this, we conclude that there is a relation between emergency orders and risk-avoidance behaviour.

The awareness of the employees towards the effects of emergency orders is essential. When they are aware of the impact, they are more likely to prevent it or change their behaviour. Getting insight into the employees' beliefs and the intention to support this change can be obtained by the TPB framework (Jimmieson e.a., 2008). After that, employees should be motivated by the hospital to change their behaviour. When motivating employees, every employee has to share the same goal and vision. Furthermore, the employees should get the freedom to act, try out their ideas, broaden their knowledge with training, and be responsible for producing results. Also, the hospital should take into account the wage and rewards they give the employees (Galbreath & Rogers, 1999; Davidescu, Tania, & Eid, 2017).

4 Number and costs of the emergency orders

Now we know that risk avoidance behaviour and the employees' unawareness of the impact of emergency orders increase emergency orders, we want to analyze the size of the emergency orders in Isala hospital. This chapter, therefore, provides an answer to the research question: "*What are the number and costs of the emergency orders per year?*". We answered this question with the help of the sub-research questions 3.1 to 3.4. These sub-research questions divide this chapter into several sections. The chapter starts with the most significant contributor to emergency orders in terms of departments, items and suppliers (Section 4.1), followed by the expenses charged by HL or suppliers for one emergency order (Section 4.2). After that, a flowchart for the process of emergency orders and the costs for employees working on emergency orders is given in Section 4.3. Then Section 4.4 describes the number and costs of emergency orders over 2018, 2019, and 2020. Finally, Section 4.5 presents the conclusions of this chapter.

4.1 The most significant contributor to emergency orders

To determine who/what causes the most emergency orders for departments, items and suppliers, we execute an analysis for stock items with data from HL and the other items with data from the ERP system SAP. This analysis consists of two datasets; therefore, the results are split into two sections: stock items (Section 4.1.1) and purchase and scan relevant items (Section 4.1.2).

4.1.1 Stock items

HL keeps detailed records per year of which items the hospital orders with urgency, what type of emergency it is, the date of the order, which department the emergency order came from, etc. With this detailed data, we execute the analysis.

First, the research considered the most significant contributor in terms of departments. Figure 4 shows the top ten departments in 2019 and Figure 5 in 2020. The colours indicate the departments and items which appear in the top ten in both years. The grey departments have no overlap in these two years.

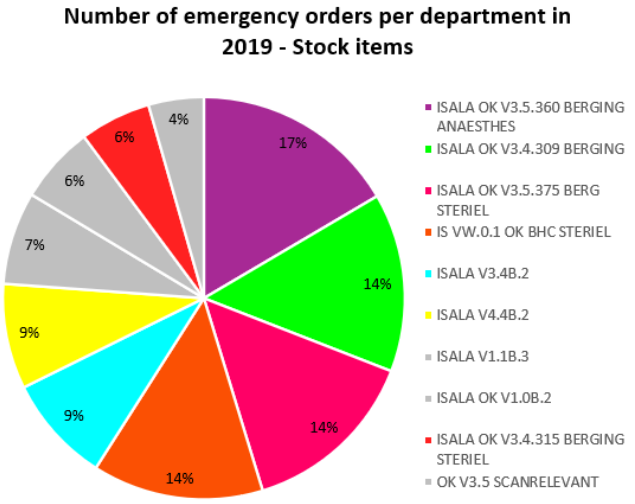

Figure 4 - Number of emergency orders per department in 2019 (n = 7669, and source = data HL)

As shown in Figure 4 and Figure 5, the 'OK' (in English: OR department) is seven times in the top ten in 2019 and five times in 2020. After calculating, the conclusion is that the OR department causes 43.6% of the emergency orders of the stock items in 2019 and 35.3% in 2020. With these percentages, we conclude that the OR department causes most emergency orders in the hospital.

The analysis not only considered the departments as a contributor but also the items. Seven of the same items are in the top ten of both years. Examples of these items are disposable jackets, syringes with other volumes (mL), etc. Each hospital department uses these items on a daily basis. Therefore, we conclude that the items most ordered with urgency are those items that each hospital department daily uses.

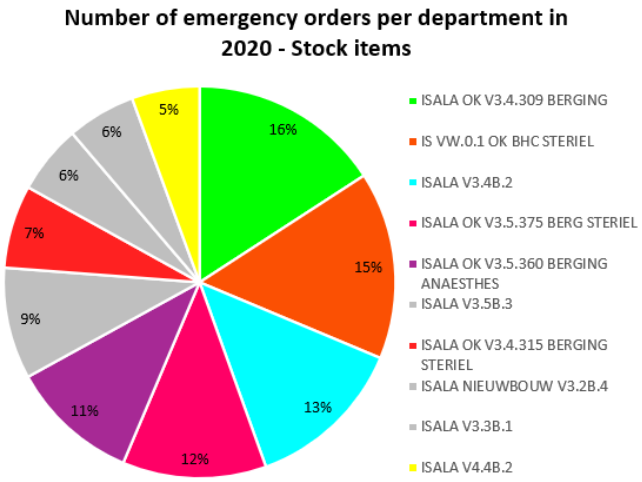

Figure 5 - Number of emergency orders per department in 2020 (n = 6838, and source = data HL)

4.1.2 Purchase and scan relevant items

The data for purchase and scan relevant items ordered with urgency is not documented as well as HL did for the stock items. Isala cannot keep track of whether an order is regular or urgent. For this research, the data was obtained from the hospital's ERP system SAP to be helpful for the analysis but not 100% accurate. We acquire the information by sorting the orders per year in SAP according to freight costs. Almost every emergency order has extra costs, which are called freight costs. However, some suppliers do not charge any costs if the employees order the item before a specific time. So, the data does not include these items.

Furthermore, these data also include items with shipping costs. Shipping costs are also part of the freight costs, but items with only shipping costs are not emergency orders. We filtered the items with shipping costs out of the data by looking at the order and delivery date. The item has to be delivered either the same day or the next day. Otherwise, we assume the item is not an emergency order. The research only focuses on Zwolle (indicated by location 1000 in the dataset). Thus all items ordered for Meppel (location 4500) have been removed from the data.

This filtered data from SAP determines which items from the purchase and scan relevant items cause the most emergency orders. From this, we conclude that the items that appear in the top ten of emergency orders in several years are either daily used items that run out quickly or hardly ever used/available items, so they have to be ordered with urgency if they are suddenly needed. Some examples of these items are disposable vacuum tourniquets, bulb 3.5V xenon heine, magnetic window A4, etc. The conclusions made for stock items, purchase and scan relevant items are the same; namely all items ordered with urgency are items that each hospital department daily uses.

The analysis also showed from which suppliers the employees order most emergency orders, namely Roche diagnostics Nederland BV, Cook Netherland BV, and Sigma Aldrich Chemie BV. Roche diagnostics Nederland BV is a strategic supplier due to the large purchase volume; because the average order volume is already high, the chance of emergency orders with these specific suppliers is also

higher. This high purchasing volume may explain the overlap of suppliers between multiple years. Other causes can be a critical process so that an employee has to place an emergency order faster or that the employee in charge in the department does not have the stock of a specific item in control, and therefore often has to place an emergency order at the same supplier. The following section discusses the emergency order costs charged by the suppliers and HL.

4.2 Costs charged by HL and suppliers for one emergency order

The costs of an emergency order consist of the costs the supplier or HL charges per order and the costs for the hours an Isala employee spends on this order. This section discusses the costs of the supplier or HL, and the following section elaborates about the costs of employees involved in emergency orders. The costs charged by a supplier or HL differs for each emergency order. For example, some suppliers do not charge any costs when the employees order an item before a specific time. Others always charge costs. Table 2 contains the costs that HL charge per type of emergency.

Table 2 - Costs emergency order charged by HL

Type of emergency	Costs excl. btw	Description
Scan relevant items	€0.-	The system automatically orders the scan relevant items with urgency, so the stock at Isala replenishes directly. This is an agreement made between the warehouse/suppliers and Isala.
Urgent customer	€0.-	If an employee orders with urgency at HL 1.5 hours before the truck's departure time (6:00, 9:00, 12:00, 15:15), HL carries the order without additional costs.
Urgent customer with cost	€25.-	When orders come in within 1.5 hours before the truck's departure time, HL charges additional costs.
Outside office hours	€125.- (outside office hours) + €80.- (courier cost)	For orders outside office hours, HL charges money for having someone come to the warehouse to prepare the order and for transporting the order to the hospital.

For the other suppliers, it is not possible to display these costs in the same way. As mentioned before in Section 4.1.2, Isala does not register the emergency orders. Therefore the costs per supplier and type of emergency order are not transparent. In addition, Isala has too many suppliers to discuss in this research because it would be too time-consuming. Therefore it is out of the scope of this research.

4.3 Costs paid for employees working on emergency orders

Now that the costs charged by HL are transparent, we calculate the costs paid by the hospital on wages for hours when an employee is working on an emergency order. Before this, the process steps, described in Section 2.1.4, are processed into a flow chart (Figure 6) in consultation with the employees involved in emergency orders.

Figure 6 shows the steps of an emergency order in more detail. Each step takes a certain amount of time. These times are determined and validated with the employees involved. Subsequently, we converted the minutes per step into costs. We calculate these costs with the hourly wages the hospital pays for the employees. That means an employee's hourly wage, including social charges and *premium pay (PP)*. PP is a bonus for employees who work irregular hours, such as holidays, evenings, weekends, etc. Appendix D provides how to calculate the hourly wages. Figure 6 shows the steps with corresponding times and costs.

Sometimes a few steps have to be redone when something went wrong. Rework is shown in Figure 6 by the arrow that goes from right to left instead of left to right. An example of rework is when an item is not available at the supplier or HL. It may also be when HL or the supplier has not delivered or delivered the wrong item. As a result, the flow chart allows for more than one path to be followed, namely four: no problems occur; item not available; item not delivered, or wrong item delivered; item not available AND item not delivered, or wrong item delivered. In addition, certain steps differ in time and cost for HL and suppliers. Therefore, the four other paths are split between HL and suppliers, resulting in eight other paths. Each path has its associated time and costs calculated by adding up the times and costs per path. Table 3 gives an overview.

Table 3 – Working time spend and employee costs of an emergency order in various situations

Situation	**HL**		**Supplier**	
	Costs in €	**Time in min**	**Costs in €**	**Time in min**
No problems occur	€20.39	35	€33.-	60
Item not available	€41.97	61	€62.31	101
Item not delivered, or wrong item delivered	€29.03	52	€41.64	77
Item not available AND item not delivered, or wrong item delivered	€50.61	78	€70.95	118

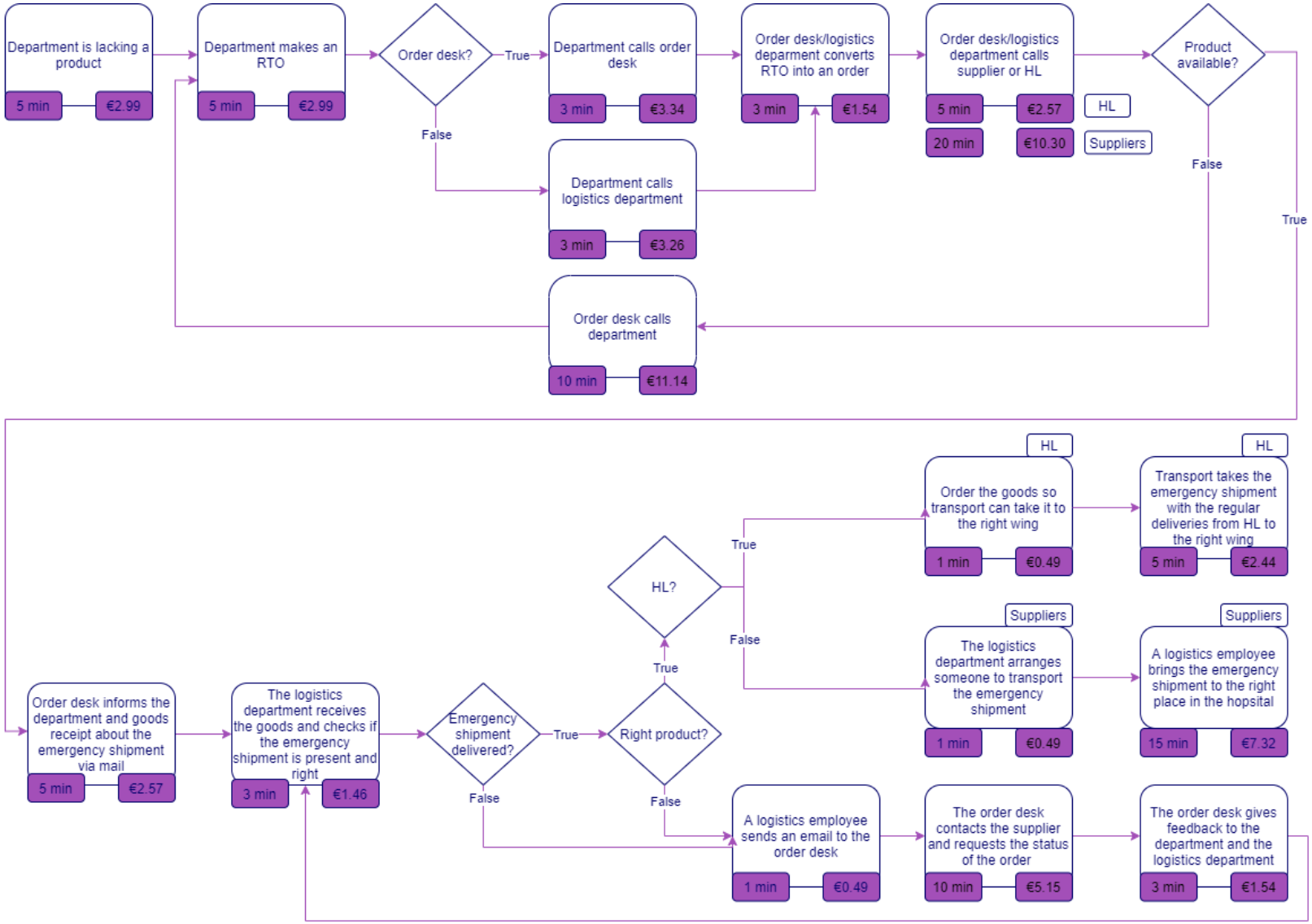

Figure 6 - Flowchart emergency order

The flow chart shows what emergency orders cost in person-hours in various situations. To determine the percentage in which the situations occur, interviews were once again conducted with employees.

According to the order desk, the initially requested item is not available in 7.5% of the cases. The logistics department indicates that in 80% of emergency deliveries, HL or the supplier delivers the correct item. That means that in 20% of deliveries, the item is not provided or is not the right item. Both cases can happen simultaneously in 0.075 * 0.2 = 0.015, which is 1.5% of the times. These percentages are the same for both HL and suppliers, and we consider these percentages when calculating the approximate time and costs for an emergency order from HL and suppliers. Appendix E gives these calculations.

The costs for hospital employees working on an emergency order from HL, takes an additional 37 minutes of work, resulting in an additional cost of €21.66. The same applies to deliveries from suppliers; in this case, the additional time investment is 62 minutes, which cost €34.50 per order.

The following section discusses the number of emergency orders over the years 2018, 2019, 2020 and the total costs charged by HL and the suppliers. That section uses the average costs calculated in this section to supplement the total costs with the costs paid by the hospital for the employees.

4.4 Total number and costs of emergency orders per year

This section answers research question 3: "*What are the number and costs of the emergency orders per year?*" Figure 7 and Figure 8 show the number of (emergency) orders over multiple years and the total costs charged by HL and the suppliers. We calculate the total costs for HL with invoices and the suppliers by adding the costs per order. The research made a distinction between the number of items ordered with urgency and the number of orders. An order often contains numerous items, and the suppliers charge emergency costs per order.

Stock items

Number of.. / Year	Total items	Emergency items (n)	Emergency items (%)	Total orders	Emergency orders (n)	Emergency orders (%)	Total costs charged by HL for emergency orders
2018	455487	-	-	43162	-	-	€ 2.692,25
2019	441284	15026	3,41%	43570	2057	4,72%	€ 2.426,05
2020	409036	14813	3,62%	21915	2555	11,66%	€ 6.771,17

Figure 7 - Costs and number of emergency orders of stock items

Purchase and scan relevant items

Number of.. / Year	Total items	Emergency items (n)	Emergency items (%)	Total orders	Emergency orders (n)	Emergency orders (%)	Total costs charged by suppliers for emergency orders
2018	120771	562	0,47%	59158	373	0,63%	€ 25.961,19
2019	117007	655	0,56%	58014	404	0,70%	€ 21.328,03
2020	48735	346	0,71%	26820	241	0,90%	€ 14.288,77

Figure 8 - Costs and number of emergency orders of purchase and scan relevant items

The figures show that there is a decrease in the number of orders from 2019 to 2020. Earlier, section 4.1.1 indicated that the OR department is the largest purchaser of emergency orders. However, by 2020, the hospital reduced surgeries significantly due to Covid-19. As there were few surgeries, there were also few items needed (with urgency). This reduction in surgeries explains the decrease in emergency orders from 2019 to 2020. However, for the stock items in 2020, the figures show that the costs of emergency orders are more than twice as high as in the previous years. We can explain this high value because in 2020, again due to Covid-19, daily used items were scarce, such as mouth masks, disposable gloves, etc. Due to the scarcity, items had to be bought from other suppliers, sometimes at a greater distance, making transport costs increase.

As mentioned before, the costs of an emergency order contain the costs charged by HL or the supplier combined with the costs for the hours an Isala employee spends on this order. As calculated in Section 4.3, the employee per emergency order costs around €21.66 for orders from HL and €34.50 for orders from suppliers. This amount is multiplied by the number of emergency orders in 2018, 2019, and 2020. After that, add to the 'Total costs charged by HL/suppliers for emergency order' of Figure 8 and Figure 9 to give the final costs spent on emergency orders per year. Table 4 presents these calculations and expenses.

Table 4 - Total costs spent on emergency orders per year

Year	Total costs for employees who spent time on emergency orders	Total cost emergency orders
2018	€8314.14 *0 (unknown for 2018) + 241 * €34.50 = €8314.14*	€36,967.68 *€8314.14 + €2692.35 + €25,961.19 = €36,967.68*
2019	€58,485.02 *2057 * €21.66 + 404 * €34.50 = €58,485.02*	€82,239.10 *€58,485.02 + €2426.05 + €21,328.03 = €82,239.10*
2020	€63,646.75 *2555 * €21.66 + 241 * €34.50 = €63,646.75*	€84,706.69 *€63,646.75 + €6771.17 + €14,288.77 = €84,706.69*

For 2018 the costs of HL are missing, which causes lower total costs than it is in reality. Taking the costs of 2019 and 2020, the costs for employees are 71.1% and 75.1% of the total costs, respectively. Taking the mean of these percentages, we conclude that around 73% of the total costs for emergency orders per year are the costs paid for employees who work on these emergency orders.

4.5 Conclusion

In summary, Section 4.3 showed that the employee per emergency order costs around €21.66 for orders from HL and €34.50 for orders from suppliers. We multiplied this amount by the number of emergency orders in 2018, 2019, and 2020. After that, we add it to the total costs charged by HL and the suppliers for emergency orders. Therefore, the total costs of emergency orders per year were €36,967.68 in 2018, €82,239.10 in 2019, and €84,706.69 in 2020. For 2018 the costs of HL are missing, which causes lower total costs than it is in reality. From these numbers, we conclude that around 73% of the total costs for emergency orders per year are the costs paid for employees who work on these emergency orders.

This chapter also analysed the department, items and suppliers that cause the most emergency orders. The conclusion for stock items, purchase and scan relevant items is the same: all items ordered with urgency are items that each hospital department daily uses. The OR department causes most emergency orders, with 43.6% of the emergency orders of the stock items in 2019 and 35.3% in 2020. Therefore, the forecasting model built in Chapter 5 will be for the OR department.

5 Forecast model for surgical supplies

This chapter first discusses the literature found about the design principles for hospital software (Section 5.1). After that, it describes the construction of the model (Section 5.2) and how the model's user interface should be specified (Section 5.3). Finally, the chapter ends with the verification and validation of the model (Section 5.4) and a conclusion (Section 5.5).

5.1 Design principles for hospital software

When starting to build a forecasting model, the first decision to make is for the software for the model. With software, we specifically mean programs that use a programming language, such as Delphi, Python, R, Excel, etc. The model should be created in software that meets specific requirements and hospital guidelines. This section discusses essential principles for hospital software and concludes with the chosen software to build the forecasting model for surgical supplies.

Principles to consider for hospital software are the degree of adaption, security & privacy, and extensibility. The model should be adaptable and expandable because the hospital is innovating (Bardram, 2004; Blair-Early & Zender, 2008). When the hospital innovates, the model has to innovate with it. For example, when the hospital decides to expand the specialisms with even more specialised surgeries. This decision implies that also more specialised items are needed. More various items affect the forecast of items for the surgeries and thus the model. The model should then be adaptable and expandable. These kinds of situations occur frequently, sometimes they are small decisions with little impact, but sometimes they are significant. Since changes happen often, the modification and extension of the model should be trouble-free to perform.

Furthermore, the model has to provide security and privacy when the model deals with patient data. It cannot happen that patient data used in the model leaks outside the hospital (Bardram, 2004). According to the GDPR, this data leak would violate the patients' privacy, and then the hospital is punishable (Intersoft Consulting, 2018).

Considering the principles, we decide to create the forecasting model in Excel. The people working at the hospital are familiar with this program. Therefore, the model will be accessible for every employee of Isala. Also, their willingness to use and maybe adapt the model will be more significant if they do not have to put much effort into understanding the model. Furthermore, the hospital does not have to buy new software and train the staff extensively. The hospital can lock Excel worksheets with passwords. This locking allows patient data to be invisible from people who are not authorised to see it. In this way, the hospital considers patient security and safety.

5.2 Backend

This section discusses the construction of the model. Figure 9 shows a brief overview of the backend of the model, with the input, model, and output. All the blocks of this figure are discussed and explained below in three sections.

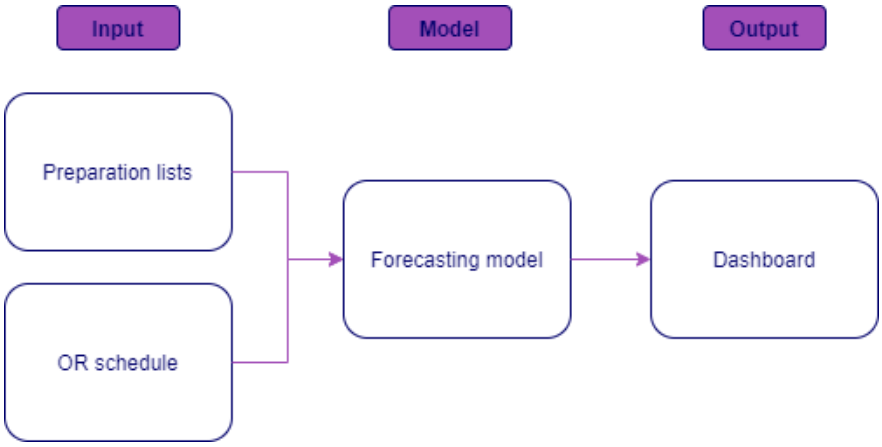

Figure 9 - Flowchart forecasting model

5.2.1 Input

The input of the model consists of preparation lists and the OR schedule.

Preparation lists

During the surgical procedure, in which the employees make the ORs ready to use for surgeries, the OR department uses preparation lists. *Preparation lists* are lists containing all necessary items per type of surgery with corresponding quantities. There are preparation lists for each specialism, and each specialism has several types of surgeries, indicated by an abbreviation of the type of surgery. For example, orthopaedics has 219 various preparation lists, one of which is 'HEUPG'. HEUP stands for hip, so this surgery is for a hip, and the G stands for gecementeerd, which is cemented. Through these codes, everyone knows what type of surgery a patient has to undergo.

Some preparation lists also contain a number after the preparation list code. This number is the staff number of a surgeon. As discussed earlier, surgeons have preferences for certain items during surgeries. There are, therefore, preparation lists for certain combinations of surgeries and surgeons, specifically for a particular surgeon. Often, this is the basic preparation list, but with one or two additional items. When there is no number after the preparation list code, that list is a basic preparation list.

The data of all the preparation lists have to be loaded into the model. When pushing the button 'Importeer klaarzetlijsten' on the sheet intended for the preparation lists, the model loads all the data into the model. Figure 10 gives an example of how the loaded data looks like. The preparation lists are updated monthly by the OR department. Therefore, an employee has to repeat the loading of the preparation lists every month. Figure 10 shows that the model links all items to an abbreviation, i.e., the preparation list code.

Component number	Item	Quantity per surgery	Unit	Preparation list code	Specialist code
6118	basisset klein	1	ST	ACHRU	1296305
6228	borensetje	1	ST	ACHRU	1296305
101436	suture retriever acufex	1	ST	ACHRU	1296305
367680	potlood diathermie 5m snoer	1	ST	ACHRU	1296305
6611	mitek setje	1	ST	ACHRU	1296305
6117	basisset algemeen	1	ST	ACHRU	1296305
363571	Proceduretray voet	1	ST	ACHRU	1296305
347573	jas disp steriel standaard maat L	3	ST	ACHRU	1296305
320608	anker quick+ G2 with panacryl	2	ST	ACHRU	1296305
332860	Slang zuig 7mmx10mm 250cm	1	ST	ACHRU	1296305
332864	Zuigbuis tip 5mm	1	ST	ACHRU	1296305
6101	lamphandvat V16 ok nieuwbouw	1	ST	ACHRU	1296305
9661	de soutter boor trauma	1	ST	ACHRU	1296305
367680	potlood diathermie 5m snoer	1	ST	ACHRU	
6611	mitek setje	1	ST	ACHRU	
6117	basisset algemeen	1	ST	ACHRU	
363571	Proceduretray voet	1	ST	ACHRU	
347573	jas disp steriel standaard maat L	3	ST	ACHRU	
320608	anker quick+ G2 with panacryl	2	ST	ACHRU	
332860	Slang zuig 7mmx10mm 250cm	1	ST	ACHRU	
332864	Zuigbuis tip 5mm	1	ST	ACHRU	
6101	lamphandvat V16 ok nieuwbouw	1	ST	ACHRU	
9661	de soutter boor trauma	1	ST	ACHRU	

Figure 10 – Example of loaded data preparation lists

OR schedule

A second input of the model is the OR schedule. The OR schedule contains data such as the date and time of the surgery, the patients' names and patient numbers, the surgeons' names and staff numbers, code for the type of surgery, etc. The code for the type of surgery is the same as the preparation list code, which ensures that in the model the preparation lists and the OR schedule can be linked. Section 5.2.2 discusses this.

The OR schedule first has to be loaded into the model, which the employee has to do manually. The employees can copy the OR schedule from the ERP programme SAP. Appendix F provides a step-by-step plan of how to load the OR schedule into the model.

5.2.2 Model

For the forecasting model, we combined the OR schedule with the preparation lists. Once the data of both are loaded into the model, an employee can click on the dashboards' 'START' button to initiate the forecasting process. This button starts a count of the various surgeries stated in the OR schedule. Hereafter, the system searches for each of these surgeries in the data of the preparation lists. Whenever the model finds a corresponding surgery, it copies each of the required items to an item list. If the model sees multiple lists for the same surgery, some surgeons require specific items that differ from the others. In this case, the model chooses the preparation list bound to the surgeon's staff number. By multiplying the required number of items per surgery with the respective number of scheduled surgeries, the model

determines the total number of items needed. When the item list with corresponding quantities is complete, it is sorted and copied to the dashboard.

5.2.3 Output

The dashboard contains the forecast and thus the output of this model. The forecast is a list of items with corresponding quantities needed for the surgeries in the OR schedule. The OR logistics department employee can order the items on the list to reduce the cases in which there is a shortage of items when preparing the surgeries.

Furthermore, the model provides a complete list of items used for a specific specialism. This output provides insight into which items are used by a specialism.

The output of the model should be understandable to the user. Therefore, we should make a straightforward user interface. The following section discusses the essential aspects of a good interface.

5.3 User interface

A critical point to the use in practice of the forecasting model is the interface of the model. Even if the model forecasts well, but has an unclear interface, no employee can or wants to work with it, and then the OR department will not use the model.

According to Blair-Early and Zender (2008), a few essential aspects considering a good user interface are listed below. Each point gives general information from the literature, and below that, how we considered the various aspects while creating the model's interface.

- Clear start
  Design an obvious starting point.
  The START button on the dashboard initiates the model, see Figure 11.
- Clear reverse
  Design an obvious exit or stop.
  The progress bar, see Figure 11, indicates when the run is almost finished, so when it stops.
- Consistent logic
  Consistent use of forms, words, colours, etc., keeps the users from wondering what, for example, a specific colour stands for.
  The model uses the colour purple, which indicates the headers and the buttons, as shown in Figure 11. The colour purple is in line with Isala hospital’s corporate identity.
- Observe conventions
  Identify and consider the impact of familiar interface convention. For example, make sure the language fits the target group.
  The language used is Dutch. All employees in the hospital speak Dutch, so the Dutch language suits the target group best. Furthermore, shown in Figure 11, the interface is made familiar by adding a logo of Isala and using the hospital's colours.
- Feedback

Design responses to user actions, for example, a progress bar.

When an employee presses one of the buttons, a progress bar (Figure 11) appears and gives the user feedback on the run's progress.

- Proximity

  There are at least three kinds of proximity: space, time, and concept. Reasonable proximity builds on users' location memory by associating content and interface. One way to ensure reasonable proximity is to cluster related objects.

  We clustered related objects on a designated sheet. For example, all information about the OR schedule is on the sheet 'OR-schedule'.

- Interface is content

  Minimise interface and maximise content.

  "Design the interface so that interaction is as direct with content as possible. Avoid interfaces that come between the content and the user. The interface serves the content, not the other way around" (Blair-Early & Zender, 2008, p.102).

  We kept the interface as simple as possible. In this way, we avoid a busy and unclear interface between the user and the content.

- Interface visualisation

  Visualising large amounts of information ensures that incomprehensible data is transformed into more understandable data. One way to do this is with colours.

  The dashboard does not have large amounts of information, so graphs are not used on the dashboard. However, the model divides the data into columns with clearly descriptive headings. In this way, the user immediately knows what is described in which column. As mentioned before, these headers are made plain by the colour purple.

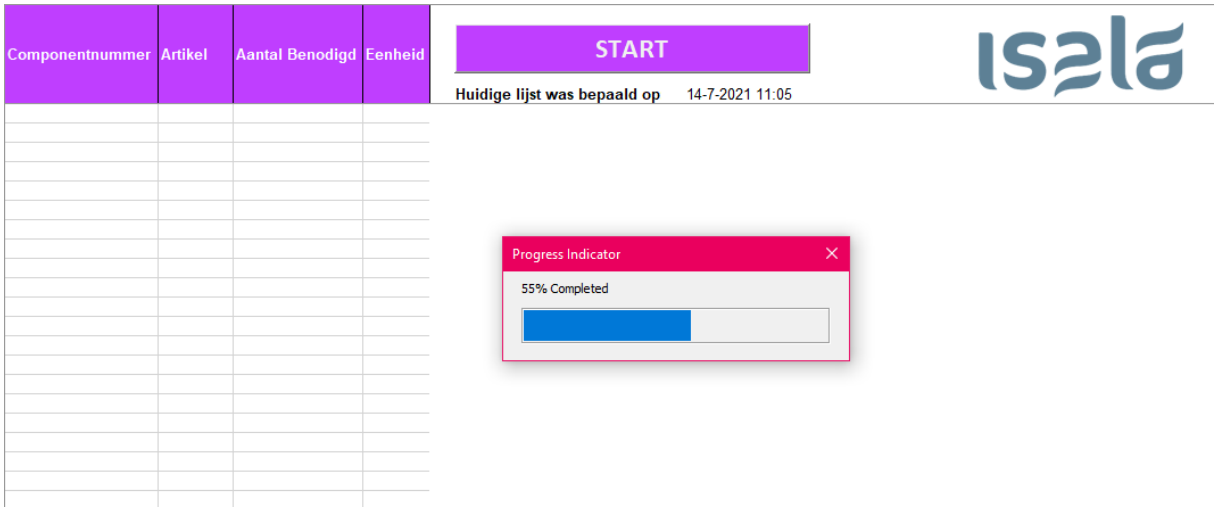

Figure 11 - Interface dashboard

Furthermore, Kanstrup et al. (2011) address four principles for building an interaction design, summarised in Figure 12.

User is: / Information is:	**Active**	**Passive**
Directed	**All in one** The user gets an overview. Support searching.	**At a glance** The user can easily follow developments. Support monitoring.
Undirected	**At hand** The user has access to information. Support browsing.	**Attention** The user is warned. Support awareness

Figure 12 - Four As model for interaction design (Kanstrup, Christiansen, & Nøhr, 2011)

We also considered Kanstrup's theory when creating the user interface. A lot happens in the model, and there are several sheets. The model presents the final result and, therefore, the overview on the dashboard. Furthermore, as mentioned earlier, there is a progress bar through which the employees can follow developments. If the model cannot find specific data, such as a preparation list for surgery, a message box appears, indicating what is wrong. In this case, the message box displays the text: 'Cannot find preparation list for ... '. These messages support awareness and warn the user that something is going wrong during the run.

So far, this section has focused on the design of the user interface using literature. However, it is also necessary to check whether the forecasted numbers are correct and if the users find the user interface as understandable, well-organised and user-friendly as it has been made out to be. This check is executed in the next section, where we discuss the verification and validation of the model.

5.4 Verification and validation of the model

Before the hospital takes the model into operation, it has to be verified and validated. The verification and validation of the model are discussed below in two separate paragraphs.

Verification and validation of the model for the entire OR department are too time-consuming. Therefore, we decide to reduce the scope to one specialism. Interviews with employees of the OR department showed that most emergency orders came from general surgery, orthopaedics, and gynaecology. For the verification and validation, orthopaedics is chosen together with relevant stakeholders. Nevertheless, the OR department can use the model in the future for each specialism.

5.4.1 Verification

Verification checks whether the model works as it should, i.e., no programming bugs, whether all data is entered in the appropriate columns, whether the model produces the expected quantities, etc.

Before verification, we have to load all data from orthopaedics. This loading includes the preparation lists and an OR schedule. A code is run to load the preparation lists. This code does not give any bugs, and we have manually checked if all the data from the preparation list files are in the correct columns in

the model. Next, we push the 'START' button on the dashboard. This code also has no bugs, and the data is in the correct columns. Next, the quantities per item need to be checked. For several items, we counted the amounts manually. The quantities are accurate. From this, we conclude that the model is verified.

5.4.2 Validation

A valid model means that the model is reliable, i.e., it gives good forecasts. This research has chosen face validation because we only consider the orthopaedic specialism and not any other specialisms. Choosing one specialism makes it challenging to count the numbers in the pantries at the OR department. The other specialisms use some of the same items, so it may happen that the counting is not correct. We spoke with five employees from the OR logistics department for face validation. In this conversation, the model was tested together and run several times. They were also allowed to try it themselves. Together, we inspected whether the outcomes are realistic. For example, when the forecasting model forecasts that only ten disposable coats are needed but forty cover sheets, it is not a realistic outcome. The five employees all independently indicated that they want to work with the model and trust the output. Trusting the output means that they will order the quantities forecasted by the model and not more.

5.5 Conclusion

The forecasting model is made in Excel because the people working at the hospital are familiar with this program. Therefore, the model will be accessible for the employees of Isala. Furthermore, the hospital does not have to buy new software and train the staff extensively. Next to that, the hospital can lock Excel worksheets with passwords. This locking allows patient data to be invisible from people who are not authorised to see it. In this way, the hospital ensures patient security and safety. Besides that, the model is made in the Dutch language because all employees in the hospital speak Dutch, so the Dutch language suits the target group best.

Hospitals can forecast surgical supplies based on an OR schedule by combining preparation list codes for surgeries with the same codes for the type of surgery in the OR schedule. In this way, the model searches for the preparation list belonging to a surgery. This preparation list includes all items needed for that surgery. When for each surgery in the OR schedule, a corresponding preparation list is found, the model can make an overview of the required items for these surgeries.

For the verification and validation, orthopaedics is chosen together with relevant stakeholders. Nevertheless, the model can be used in the future for each specialism. The model is verified by checking: if the code gives bugs; if all the data is in the correct place; and if the quantities for the provided items are accurate. In this model, there are no bugs, the information is in the proper position, and the amounts are accurate, so we can say the model is verified. For validation, face validation is used. Therefore, we spoke with five employees from the OR logistics department. In this conversation, the model was tested together and run several times. They were also allowed to try it themselves. Together, we inspected whether the outcomes are realistic. For example, when the forecasting model forecasts that only ten

disposable coats are needed but forty cover sheets, it is not a realistic outcome. The five employees all independently indicated that they want to work with the model and trust the outcome.

6 Conclusion and Recommendations

Section 6.1 answers the research question and gives the other conclusions of the research, with a discussion per conclusion. Furthermore, this chapter presents the recommendations of this research. We divide the recommendations into several sections: general recommendations (Section 6.2), recommendations for the purchasing department (Section 6.3) and recommendations for the OR department and logistics department (Section 6.4).

6.1 Conclusions

This research aims to answer the following twofold question:

"How does the behaviour of employees influence the emergency orders, and how can the number of emergency orders be reduced by forecasting the demand for surgical items based on the operating room schedule?"

The risk avoidance behaviour of employees influences the number of emergency orders. Employees avoid risks by taking the easy way out, i.e. by placing an emergency order. Also, due to the unawareness of the effects of emergency orders, employees place an emergency order when they need an item and do not look for alternatives. Due to the employees' unawareness and risk avoidance behaviour, the emergency orders increase, so this behaviour of employees does influence the emergency orders.

Hospitals can forecast surgical supplies based on an OR schedule by combining preparation list codes for surgeries with the same codes for the type of surgery in the OR schedule. In this way, the forecasting model searches for the preparation list belonging to a surgery. This preparation list includes all items needed for that surgery. When for each surgery in the OR schedule, a corresponding preparation list is found, the model can make an overview of the required items for these surgeries.

The following conclusions follow from our sub-research questions:

OR department causes the most emergency orders.

In the OR, work with an unpredictable character is carried out. Due to this unpredictability, the department may place more orders with urgency. However, the emergency department (ED) also has an unpredictable character and fewer emergency orders because ED employees are more creative with the items they use. Being creative with items is not always possible in the OR. For example, in open-heart surgery, we prefer the surgeons to use the standard set of items they are accustomed to, to provide security for a good outcome. However, if there is no 10 mL syringe left but only a 30 mL syringe, they can use the 30 mL syringe instead of placing an emergency order for the 10 mL syringe, which happens around 100 times a year in the hospital. So, we want surgeons to use one standard set of items and be more creative with the OR department items in stock.

The most ordered items with urgency are daily used by each hospital department.

The most ordered items with urgency are the items that each hospital department daily uses. It should therefore be possible to use these items from another department. However, each department has its budget from which they may order items. Suppose departments start using each other's items. In that case, the hospital has to record this use correctly, or the hospital has to find another solution, in which departments do not use each other's budget. Furthermore, the most ordered items with urgency are items for which alternatives can be found/used very well.

The total costs of emergency orders per year were €36,967.68 in 2018, €82,239.10 in 2019, and €84,706.69 in 2020.

The calculations in Section 4.3 show that the employee per emergency order costs around €21.66 for orders from HL and €34.50 for orders from suppliers. This amount is multiplied by the number of emergency orders in 2018, 2019, and 2020. After that, add to the total costs charged by HL and the suppliers for emergency orders. This adding gives the total costs of emergency orders per year. For 2018 the costs of HL are missing, which causes lower total costs than it is in reality.

73% of the total costs for emergency orders per year were the costs paid for employees who work on these emergency orders

The costs of an emergency order consist of the costs HL or the supplier charges per order and the costs for the hours an Isala employee spends on this order, as discussed in Section 4.2 and Section 4.3. A hospital's costs for the hours of an employee working on an emergency order is around 73% of the total costs for emergency orders.

The research is generalisable and reproducible

The use of preparation lists in hospitals in the Netherlands is quite common (De Geyter & Gemmel, 2009; SVN, 2015), and any hospital performing surgeries uses an OR schedule. These two items are the inputs for the forecasting model. Therefore, we conclude that any Dutch hospital that wants to forecast the demand for surgical items can use the forecasting model built in this research. When hospitals have historical order data available, they can use the analysis of this research (Chapter 4) to gain insight into their emergency order process, and the number and costs of these emergency orders.

6.2 General recommendations

Analyse both the stock and purchase items that are most often ordered with urgency

As discussed in Section 6.1, the most often ordered items with urgency are the daily used. For example, the hospital should investigate whether it is possible to increase the stock of these or if departments can use items from each other without using each other’s budget. In this way, the commonly used items are always available.

Get insight into the supply between Zwolle and Meppel

As discussed in section 2.1.2, the material flow between Zwolle and Meppel is not known. A hospital should know exactly what goes in and what goes out. Only in this way the supply chain could be optimised. So, we recommend further research into the material flow between Zwolle and Meppel.

Analyse emergency orders throughout the entire hospital

This research concludes that the OR department causes most emergency orders. Nevertheless, it also concluded that the items that are most frequently order with urgency are items that are daily used by each hospital department. So, the recommendation is to keep analysing the emergency orders, as well as on the OR department as the other departments.

Make employees aware of the effect of emergency orders

This research attempted to make the purchasing and OR department employees aware of the effects of an emergency order by talking about the costs of such an order. Nevertheless, to reduce the emergency orders, the hospital should make all employees aware of the effects. To make the employees aware of the costs and time spent on emergency orders, the hospital can use the flowchart of Figure 6. To motivate the employees to change their behaviour towards emergency orders, they can use, for example, rewards, as described in Section 3.3.

Measure the time an employee spends on an emergency order

The times in the flowchart (Figure 6) are estimated together with the employees but not measured. A rule of thumb mentioned by Stattin and Loeb is, *"To measure is to know. If you cannot measure it, you cannot improve it"* (Stattin & Loeb, 2014, p. 703). Therefore, we recommend the hospital to measure the exact time employees involved in the process of an emergency order spent on each step. For this research, measuring was too time-consuming. Nevertheless, in the future, the minutes and costs in the flowchart can be adapted by the hospital to measured numbers instead of estimated, which gives a 100% accurate flowchart.

Make a value stream map of the process of emergency orders.

In Section 4.3, we discussed a flowchart that shows all process steps of an emergency order. Not all the steps add value. When an action does not add value to the end product, the hospital should eliminate this step because it is waste (Teichgräber & Bucourt, 2012). Eliminating steps results in less time and costs spent on emergency orders. This elimination may reduce the 73%.

6.3 Recommendations purchasing department

Define what an emergency order contains for Isala

By drawing up Isala's definition of an emergency order, Isala retains control. This definition provides an overview of when an order is an emergency order or not. In the current situation, it differs for each supplier when it is an emergency order or not and therefore when they charge extra costs. If the

purchasing department pulls this together, it creates clarity for all employees. The purchasers can then include the definition in the negotiations with suppliers. In this way, Isala does not depend on what the supplier defines for the hospital.

Make an overview of which supplier charges which emergency costs

Such an overview gives insight into the costs charged per emergency order. It also allows comparing several suppliers and their prices for emergency orders, which is advantageous in negotiations.

Change the way of working of the order desk

When departments order items such as batteries or garbage bags with urgency, the purchaser can, for example, ask: "Can you use that temporarily from another department?". If necessary, the order desk can verify in SAP which other departments are also using the item. The order desk can then inform the department that they will have the items faster than waiting for the emergency order to be delivered. This delivery often takes at least three hours and walking back and forth to another department at most 15 minutes. In this way, they decide together if it is really an emergency or not. If that is not the case, the emergency order should not be made final by the purchasing department. As a result, the responsibility for an emergency order lies with two departments.

Consider an ERP system that logs the emergency orders of Isala

In the current situation, it is unknown how many emergency orders Isala places. Only HL keeps track of the number of emergency orders for the stock items. The other data is now obtained by sorting in SAP on freight costs and then on order and delivery dates. As discussed in Section 4.1.2, this data is not 100% accurate. For Isala, it is valuable to gain insight into all their emergency orders. The purchasing department is in the process of choosing a new ERP system, and the recommendation is to ensure that this ERP system also logs which orders are urgent and which are not.

Reduce the number of items in the assortment

As described in Table 1, surgeons lack willingness to use other items than they are accustomed to causes an extensive assortment. Of items with the same function, only one type needs to be present. Inventory management is less complicated when the assortment is smaller (Zhang & Rajaram, 2013). If the hospital can do the inventory management more efficiently, backorders, stock shortages, etc., will be spotted more quickly, resulting in fewer emergency orders. Therefore, the recommendation is to reduce the assortment of the OR department, together with the surgeons, such that of each item with the same function, only one type is present.

6.4 Recommendations OR department and logistics department

Implement the forecasting model

Implementing the forecasting model gives insight into the items that the OR logistic department employees should order. When the OR department decides to implement the model, it may reduce the number of emergency orders. To implement the model, two employees should manage the model. They

become responsible for updating the preparation lists and, in the future, for expanding the model to all specialisms. Furthermore, the manager has to train the logistic employees on how and when to use the model. Therefore we recommend the hospital to find two data managers and inform the manager to train and supervise the employees to use the model.

The OR logistics department employees prepare the surgeries one day before the surgeries, so then the items should be in stock. In an ideal situation, the logistic employees use the model two days before the surgeries. For example, if the surgeries are on Thursday, the employee uses the model on Tuesday and orders the items that day. HL and the suppliers then deliver the items on Wednesday. So, exact in time to prepare for the surgeries.

Make the colours that indicate the types of items the same throughout the hospital

As described in section 2.1.1, some departments use various colours to indicate the types of items. The various colours can be confusing for employees. So, it is better to pull this together and give every type of item the same colour throughout the hospital.

Reduce the number of employees who have the authority to place an emergency order

When an employee has to ask permission from someone with authority, the threshold for placing an emergency order is already higher. Isala has to ensure that the employees with authority know the possible alternatives before placing the emergency order. Then the employees are forced first to discuss how to solve the problem differently.

The OR department should be more actively considering attractive alternatives when facing possible risks

The current solution to risks is often to order an item with urgency. The OR department currently handles its risks passively. If they are more active in considering alternatives to their risks, they can avoid urgent ordering of items.

6.5 Recommendations for further research

Conduct in-depth research into the influence of employees' behaviour on emergency orders

This research concluded that the risk avoidance behaviour of employees leads to more emergency orders within a hospital. The unawareness of employees also plays a significant role in this. We recommend further research into the influence of employee behaviour on the number of emergency orders. In this way, more connections might be found between employee behaviour and emergency orders. They can use this new knowledge to improve employees' behaviour to reduce emergency orders even more.

Hospitals have to analyse their process of emergency orders

We recommend hospitals to analyse the process of their emergency orders. As mentioned in Section 6.1, the research is reproducible. Therefore, hospitals can use this research to get insight into their

emergency orders. For example, to gain insight, they can make a flow chart of the emergency order process in their hospital or analyse historical data to determine the number and costs of emergency orders in the past years. In this way, they can decide if employee behaviour needs to be modified, whether there is the need to increase/decrease stocks, or whether there are steps in the process that they can eliminate.

Resilience in hospitals

Resilience is, amongst others, about avoiding or anticipating risks/disruptions. Emergency orders create disruptions. The hospital has to anticipate risks other than avoiding them by placing an emergency order, as discussed earlier. Resilience can be a step in the right direction to avoid, survive and recover from risks/disruptions, and thus to reduce emergency orders (Madni & Jackson, 2009).

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Appendix

A. Organigram of the purchasing department

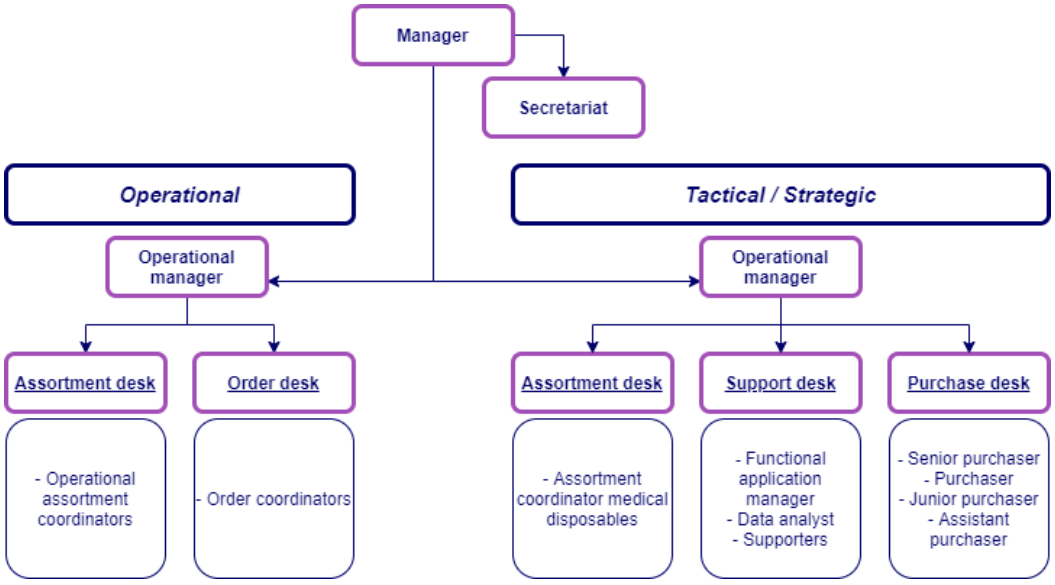

Figure A.1 - Organigram of the purchasing department

B. Interview questions for the orientation days

Logistics department

- Which tasks are there within this department?
- How are emergency orders delivered?
- What happens if an emergency order is not delivered?
- How much time do you approximately spend per emergency order?

Operating room department

- Who is responsible for the OR schedule?
- In which program is the OR schedule made/given?
- How far in advance is the OR schedule made?
- When will the OR schedule be finalised?
- How often does the OR schedule change after it has been finalised?
- Can data of the OR schedule be downloaded (to Excel)?
- What is the delivery time of the items?
- How often are those items scanned/ordered?
- Are the pantries divided per specialism?
- Which specialisation causes the most emergency orders?
- How much time do you spend per emergency order?
- What is the difference between the supply of the ORs in Zwolle and Meppel?

C. Overview scan and delivery times

Department	Scan time					Delivery time				
	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
V1.0B			12:30						13:00	
V1.1A			12:30						13:00	
V1.1B			12:30						13:00	
V1.2A			12:30						13:00	
V1.2B			12:30						13:00	
V1.3A			12:30						13:00	
V1.3B			12:30						13:00	
V2.0A	12:30		12:30				07:00		07:00	
V2.0B		12:30		12:30	12:30	07:00		07:00		07:00
V2.1A	07:00	07:00	07:00	07:00	07:00	13:00	13:00	13:00	13:00	13:00
V2.1B	12:30		12:30				07:00		07:00	
V2.2A	12:30		12:30				07:00		07:00	
V2.2B	12:30		12:30				07:00		07:00	
V2.3A		12:30		12:30	12:30	07:00		07:00		07:00
V2.3B	12:30			12:30	12:30	07:00	07:00			07:00
V2.4A		12:30		12:30	12:30	10:00		10:00		10:00
V2.4B	12:30	12:30		12:30	12:30	10:00	10:00	10:00		10:00
V2.5A	12:30		12:30	12:30			10:00		10:00	10:00
V2.5B	07:00		07:00		07:00	13:00		13:00		13:00
V2.6A	12:30		12:30				10:00		10:00	
V2.6B	12:30		12:30				10:00		10:00	
V3.0A	07:00	07:00	07:00	07:00	07:00	13:00	13:00	13:00	13:00	13:00
V3.0B	12:30		12:30				10:00		10:00	
V3.1A	12:30			12:30			10:00			10:00
V3.1B	12:30	12:30	12:30	12:30	12:30	07:00	07:00	07:00	07:00	07:00
V3.2A	12:30						07:00			
V3.2B	12:30	12:30	12:30	12:30	12:30	10:00	10:00	10:00	10:00	10:00
V3.3A	12:30	12:30	12:30	12:30	12:30	07:00	07:00	07:00	07:00	07:00
V3.3B		12:30		12:30	12:30	07:00		07:00		07:00
V3.4B	12:30	12:30	12:30	12:30	12:30	07:00	07:00	07:00	07:00	07:00
V3.5B	07:00	07:00	07:00	07:00	07:00	13:00	13:00	13:00	13:00	13:00

Figure C.1 – Overview scan and delivery times

D. Hourly wages of employees including social charges and premium pay (PP)

The gross monthly wages of employees are listed in the CAO Hospitals. The hourly wage is 1/156 part of the salary that is based on full-time employment (NVZ, 2020, p.16). Employees in the care sector work irregular shifts. So, an irregularity bonus (PP) is added to their hourly wages. The PP percentage differs per hours worked. For example, the percentage is higher at night than in the evening (Zorgwerk, 2021). The PP percentage is calculated by taking the average of these other percentages in proportion to the number of hours a certain percentage applies. This calculation results in a PP percentage of 28.65% for 2021.

In addition to the percentage of PP, there is also a percentage of social charges on top of the employees' hourly wage. The percentage of social charge is the amount that the employer pays in taxes for an employee. The social charge percentage consists of holiday allowance, year-end bonus, pension and premiums. The CAO provides the percentage of holiday allowance (8.33%) and year-end bonus (8.33%) (NVZ, 2020), and the pension regulations gives the pension percentage (8.0%) (PFZW, 2021).

The premiums are divided into Resumption of Work for Partially Disabled Persons (in Dutch: WGA), Unemployment Act (in Dutch: WW), sector fund, Health Insurance Act (in Dutch: ZVW), Work Resumption Fund (in Dutch: WHK) and WGA deductible access.

The Rijksoverheid provides the percentages of WGA (7.03%), WW (2.70%), ZVW (7.0%), and the WHK (1.36%) (Rijksoverheid, 2021). The UWV gives the percentages of the sector fund (0.79%) and WGA deductible access (0.52%) (UWV, 2021). Hospitals have sector 35 Health.

The percentage of social charges is calculated by:

% social charges = % holiday allowance + % year-end bonus + % pension + % WGA + % WW +

% sector fund + % ZVW + % WGA deductible access + % WHK

For the sector Health in the year 2021, the percentage of social charges is 44.06%.

After that, the employee's hourly wage incl. social charges and PP can be calculated by:

*Employee's hourly wage incl. PP and social charges = (Employee's hourly wage * % PP*

*+ Employee's hourly wage * % social charges) + Employee's hourly wage*

These hourly rates can be converted back to a specific number of minutes. This allows us to give the price per step of the emergency order.

E. Calculations extra time and costs for employees working on emergency orders

Costs of employees for emergency order HL=

$$\frac{(80\%*€20.39+20\%*€29.03)+(92.5\%*€20.39+7.5\%*€41.97)+(98.5\%*€20.39+1.5\%*€50.61)}{3} = €21.66$$

Minutes of employees for emergency order HL=

$$\frac{(80\%*35+20\%*52)+(92.5\%*35+7.5\%*61+(98.5\%*35+1.5\%*78)}{3} = 37 \text{ minutes}$$

Costs of employees for emergency order supplier =

$$\frac{(80\%*€33.-+20\%*41.64)+(92.5\%*€33.-+7.5\%*€62.31)+(98.5\%*€20.39+1.5\%*€70.95)}{3} = €34.50$$

Minutes of employees for emergency order supplier =

$$\frac{(80\%*60+20\%*77)+(70\%*60+30\%*101)+(98.5\%*60+1.5\%*118)}{2} = 62.4 \text{ minutes}$$

F. Step by step plan load OR schedule into model

1. Open SAP (Windows button in the lower left corner of the home screen → Financial Administration → SAP Production)
2. Log In
3. Type in the search bar: zpp_print_kzl
4. Press enter
5. At basic start-up period (basisstarttermijn), fill in the date of which you want the OR schedule (always enter the ... to ..., i.e. both)
   Enter the date with a . as separator (for example: 29.06.2021)
6. The branch (vestiging) is 1000
7. At OR code (operatiekamer code), fill in z4* to z6*.
8. At specialism (specialisatie), fill in the specialism code. For example, for orthopaedics, it is 2.
9. Press F8
10. Click somewhere in the OR schedule
11. Do: Ctrl + A
12. Do: Ctrl + C
13. Go back to the forecasting model in Excel
14. Press the button ‘Delete OR schedule’ (Verwijder OK-planning)
15. Place the cursor in cell A2 and press Ctrl + V
16. Check that the correct information is in the correct column. Otherwise, start again from step 14.