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MASTER THESIS

Reducing unused medication at Isala Zwolle by redistribution

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Abstract

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This thesis aims to improve the sustainability of a Dutch hospital by reducing medication waste. The Dutch healthcare industry is one of the most polluting industries in the Netherlands, and a large share of the pollution results from the production and use of pharmaceuticals. A large amount of medication distributed to patients admitted at Isala Zwolle remains unused and is unnecessarily disposed of. In this research, this unused medication is redistributed, while remaining cost-efficient and maintaining patient safety levels.

Prior to piloting medication redistribution in practice, a Healthcare Failure Modes and Effects Analysis is performed to determine the risks of redistributing medication. The identified risks are mitigated via double verification of medication by pharmacy assistants and nurses. Moreover, the cost-efficiency of redistributing unused medication is determined through modelling and solving a knapsack problem restricted by time. The model maximises the total returns or the total savings, while keeping the time effort within given bounds. The model outcomes show that the majority of medication can be returned within 15 minutes, while remaining cost-efficient. After a successful prospective assessment of medication redistribution, we verify the effects of medication redistribution on waste reduction in practice through a 2-month pilot in Isala Zwolle. In the pilot, unused medication is placed in return boxes and is distributed again in the next round of patient medication distribution. During and after the pilot, we measure the cost-savings, time efficiency, waste reduction, and experience of involved professionals.

The results show that within 15 additional minutes per weekday, an average of 75% (interval: 49%-84%) of medication returned to KF can be redistributed and prevented from being disposed of. The average savings when allowing for these 15 additional minutes are on average €208 to €279 per week (interval: €66-€1,258). Eight of the thirteen pharmacy assistants agree that redistributing medication requires 15 additional minutes per day.

Concluding, without additional funding or increased staffing levels, Isala Zwolle can safely and cost-efficiently redistribute more than 6,000 unused medication units per week when expanding the pilot to all wards. A waste reduction of 84% or more is possible when using the return boxes and returning all usable medication, regardless of the time limit.

Key words: knapsack problem - waste reduction - healthcare - HFMEA

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Contents

Chapter 1

Introduction

The climate crisis affects people and industries globally and a change in practices and behaviour is necessary to reduce the contribution to greenhouse gases and the negative influence on the environment. Healthcare professionals and institutions are becoming increasingly aware of the proactive role they must take to counteract the environmental problems as they are directly involved [15]. First, healthcare organisations in developed countries are responsible for 5-10% of emitted greenhouse gases worldwide [38]. Second, people are becoming ill and are catching diseases caused by the climate crisis, which puts extra pressure on healthcare organisations [27]. Additionally, the Netherlands has an aging population, which results in higher demand for healthcare [41]. Therefore, drastic change needs to happen within healthcare to make this industry more environmentally sustainable.

Several practices are already implemented by healthcare organisations that aim to reduce carbon emissions and waste, aim to prevent (the spreading of) diseases, or aim to reduce patient admissions by keeping people healthy [27]. While the healthcare industry is accountable to improve sustainability for all areas, the most industry-specific opportunity to reduce the negative effects on the environment is to reduce pharmaceutical waste. Pharmaceutical waste often ends up in the water system [36, 42]. This is undesirable, as the pharmaceutics in waste are difficult to filter and remove, which harms the quality of water [28]. Moreover, it harms the organisms living in water [42]. The negative effect of these pharmaceutics, together with an increase in usage of pharmaceutics due to the ageing population, requires healthcare organisations to reduce their pharmaceutical waste by preventing this waste to end up in the water system. It is most desirable to reduce the resulting waste, or else to prevent this waste to enter the water system and dispose the waste in a different manner [32]. More specifically, there is ample opportunity for improvement to reduce pharmaceutical waste, as a large amount of unused medication is incinerated annually [5].

In the Netherlands, the healthcare industry is quickly trying to become more sustainable, that is supported by an agreement called the Green Deal for sustainable healthcare [13]. This is an agreement between more than 300 parties involved in Dutch healthcare, including hospitals and the Dutch Ministry of Health [15]. The goal to become more sustainable is supported by four pillars [13]:

- reducing CO_2 emissions;
- improving circularity;
- reducing pharmaceutical waste in water;
- encouraging people to improve their health by offering a healthy living environment.

More information on the Green Deal for sustainable care is provided in Appendix A.

Healthcare organisations can learn from other industries with regard to the other three pillars, but the reduction of pharmaceuticals in water is highly specific for the healthcare industry [15]. Therefore, healthcare organisations have to get more acquainted with how to reduce this form of waste by sharing information with each other and putting effort into increasing their knowledge on this specific topic.

It is not possible to eliminate pharmaceutical waste all together, as people require medication [28]. Also, there is no consensus on what pharmaceutical alternatives are more or less harmful for the water quality [28]. Furthermore, for patient safety reasons, excess medication is regularly incinerated, as there is no complete certainty that the medication has been stored in the correct way which then makes it unsafe, and thus unusable [28]. During the production of pharmaceutics, tools and storage containers are cleaned with water, that results in pharmaceutical residue ending up in the water system [36]. Additionally, patients may dispose their excess medication wrongfully via the sewage system [28, 36]. In short, there are several ways for pharmaceutical waste to end up in the water system.

This research aims to reduce the pharmaceutical waste in water by decreasing medication waste. Currently, a great quantity of medication prescribed for patients at hospital wards is not administered, and all of this unused medication is destroyed [6]. The production of medication is a polluting process and follows a polluting supply chain, and by destroying unused medication, it cannot reach its final destination and purpose; to cure a patient [37]. By decreasing the quantity of unused medication, less medication is disposed and less medication has to be produced, while treating the same number of patients. Unused medication can be decreased by redistributing unused medication, as well as not preparing medication that is systematically not administered.

This research contributes to theory by providing a purpose for unused medication and a recommendation to redistribute unused medication cost-efficiently and safely. While several initiatives are already initiated to reduce excess medication [1, 31, 42, 43], there are no initiatives on what to do with the actual excess medication [6]. By redistributing unused medication, this medication eventually becomes used and therefore reaches its end goal. To support the decision to redistribute the maximum amount of unused medication while remaining cost-efficient, we develop a mathematical model to prospectively assess the optimal design of the system of redistributing unused medication.

This research contributes to practice by reducing pharmaceutical waste and lowering the impact of pharmaceuticals on the environment. Additionally, less medication is required to treat the same number of patients. Moreover, this research provides a blueprint for decision-making regarding the redistribution of unused medication. We do so by proposing a change within the current medication distribution process to include the redistribution of unused medication, and decision support tooling on how to optimally design this process. The possible risks associated with redistributing medication are assessed and quantified to ensure no harm is caused to patients. The practical applicability of our approach is demonstrated in a case study at Isala hospital Zwolle.

The remainder of this thesis is as follows. Chapter 2 reviews the initiatives with regard to environmental sustainability in healthcare found in literature. Chapter 3 provides a detailed description of the setting of this research, presents the data in this current setting, and highlights the importance of an intervention in the current setting. Chapter 4 provides several interventions, and elaborates extensively on a chosen intervention, followed by introducing the mathematical problem behind this intervention. Chapter 5 discusses the model for solving the mathematical problem and considers its performance and outcomes. Chapter 6 addresses the empirical testing in practice and compares the testing to the model outcomes of Chapter 5. And last, Chapter 7 provides the conclusion, limitations, and implications of this research.

Chapter 2

Literature review

This chapter first considers environmental sustainability in healthcare in Section 2.1. Section 2.2 concludes the literature discussed in Section 2.1 and presents the resulting literature gap. Appendix B shows the search criteria for inclusion of studies on environmental sustainable initiatives taken in healthcare.

2.1 Environmental sustainability in healthcare

Sustainability is typically divided in three types: social, economic, and environmental sustainability. These three types are called the triple bottom line, which affects people, profit, and the planet [7]. Sustainable practices can touch upon more than one type of sustainability [7], for example, by decreasing energy usage both environmental and economic sustainability come into play. In this research, we focus on environmental sustainability, while keeping in mind that initiatives do not threaten Isala's social and economic sustainability. In order to become more sustainable, organisations can improve their sustainability via different types of initiatives [7]. Common initiatives are maximising material and energy efficiency, switching to renewable resources, and aiming for a more circular economy [7, 34].

Being more energy and material efficient, as well as switching to a better source for energy are clearly environmentally sustainable initiatives [34, 32]. Regarding a circular economy, a classification system exists which prioritises strategies to become more sustainable [34, 32]. This classification is called R10-ladder and is shown in Figure 1 [32]. A lower R-number indicates a more circular economy and lower usage of resources, and is thus more preferred to follow than a strategy related to a higher R-number [32].

Healthcare institutions are aiming to make their practices and services more sustainable, for two reasons [27]. First, healthcare institutions need to ensure that their way of conducting business can continue in the future, while adhering to the constraints set by the triple bottom line [27]. Second, climate change and greenhouse emissions affect people globally and make them more ill [27, 38]. Moreover, the healthcare sector is a great contributor in the emissions causing the environmental crisis, as healthcare industries in a developed country account for 5-10% of its CO_2 emissions [38]. This creates a counter-intuitive feeling, as healthcare professionals aim to make people healthy on a daily basis, while these professionals' work environment and practices contribute to making people ill.

Most initiatives to improve the environmental sustainability of healthcare institutions focus on reducing emissions, product usage, waste, and greenhouse gases, while ensuring quality of care and safety [38]. More specifically, most sustainable initiatives can be placed in four categories, which are patient empowerment & self-care, prevention, lean service delivery, and low carbon alternatives [27]. In the following sections, we focus on lean service delivery and low carbon alternatives, as hospital decision makers have most impact on these two categories. With respect to patient empowerment & self-care and prevention, less direct impact can be achieved by these decision makers. However, by encouraging people to take care of their health and aiming to be as healthy as their circumstances let them, less people will have to visit a care provider, that in turn saves energy, materials and time [38]. Prevention of diseases starts by keeping people healthy and consequently reducing the demand for healthcare [38]. For example, promoting the use of sun screen to prevent skin cancer, and strongly discouraging tobacco use to prevent (lung) diseases can help in preventing diseases as well as empowering patients to keep control over their own health.

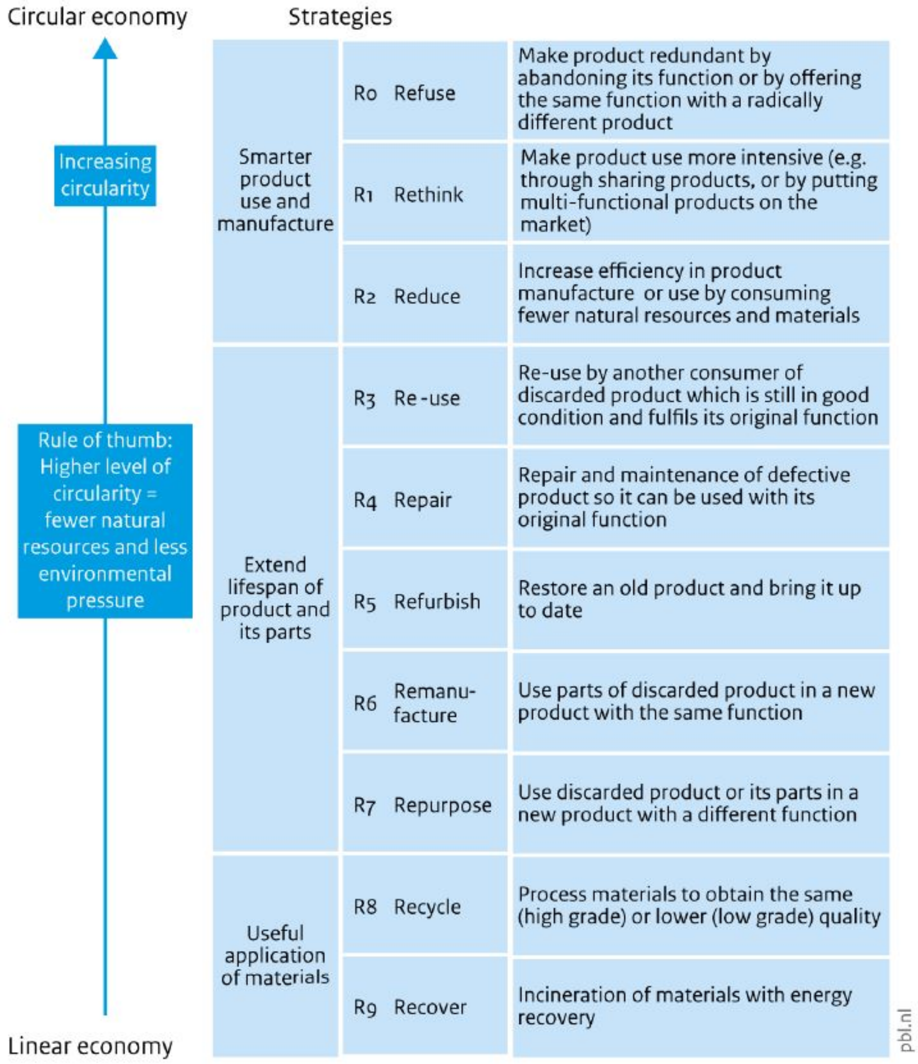

FIGURE 1: R10-Ladder (derived from Potting et al. [32])

For lean service delivery and low carbon alternatives, several initiatives are either already in use by healthcare organisations or are being initiated as shown in Sections 2.1.1 and 2.1.2 respectively. However, before organisations start to change their practices, they should first start with measuring and identifying their current practices in order to have a better picture on where to improve with regard to environmental sustainability [38].

2.1.1 Lean service delivery

Within lean service delivery, we classify the current interventions into video consultations, optimal patient planning, and patient transportation. All initiatives found aim to reduce emissions caused by patient transportation and patient treatment at the hospital site.

By providing care and consultations via (video) calls or by visiting patients, less CO_2 is emitted than when patients individually have to visit a care provider [1, 12]. For example, Allwright & Abbott [1] mention how an online consultation of 30 minutes emits approximately 200 grams of CO_2. A drive of 1.8 km by car emits an equal amount of CO_2 [1]. When a patient is considering to drive to the hospital site and the distance is more than 0.9 km, a video consultation becomes the preferred option regarding emissions. Additionally, online consultation supports the prevention of diseases [1]. By keeping people who are ill at home and away from other weak patients, spreading of diseases is prevented. Moreover, by keeping patients at the comfort of their own home, extra stress faced when visiting a hospital site is also prevented [1]. This type of consultation has been adopted widely since the corona crisis [18]. Patients who could be consulted online received this form of consultation in order to prevent the spreading of Covid-19 among both patients and care givers [18].

By planning patients in an efficient manner such that they undergo most care activities in one day, patients minimise their travel time and frequency of hospital visits [10, 12]. It is also recommended to set the appointment frequency to its possible minimum while considering the patient's needs and preferences [44]. And when situations arise where several members of a household have to visit a care provider, it is more environmentally friendly to plan all these members on the same day such that these patients can travel together [44].

While optimal planning reduces the transportation frequency and time of patients, it is further recommended to encourage patients to travel to the hospital by bicycle, public transportation, or by making use of carpooling [22]. Additionally, using a bicycle supports patients in maintaining their health.

2.1.2 Low carbon alternatives

We classify low carbon alternatives documented in the literature in four themes. The most common theme is energy and water efficiency by making changes to the building and/or equipment. Other themes involve general waste reduction or changing waste composition, switching to less polluting medication or reducing pharmaceutical waste, and food changes.

Water and energy efficiency is most frequently addressed [22, 38, 4]. Koytcheva et al. [22] show how institutions switch to a renewable or green energy source, that good and timely maintenance of the air ventilation system ensures that this system remains energy efficient, that turning off energy draining machinery during closing hours, and installing motion sensors save significant amounts of energy. A simple example that considers both the water and energy savings is a better aligned schedule to change the linnen on beds [47]. Without an aligned schedule, situations may arise where a patient's bed is changed during its standard change moment and after the discharge of this patient. By having a better aligned schedule, the change of beds only has to happen once that day [47]. This initiative reduces the amount of laundry and its accompanying water and energy usage [47]. All of these initiatives aim to reduce the required energy and water.

Waste is a second theme regarding low carbon alternatives. Most initiatives address the reduction of waste, by talking to suppliers to reduce the amount of packaging materials, switching to reusable products instead of disposable products, or reusing products more often when possible, e.g., using reusable operating room jackets instead of disposable ones [22, 25, 24, 43, 14]. Another example of waste reduction, specifically for the operating rooms, is to create custom surgical kits [22, 48]. By creating these custom kits, less surgical tools are packed before surgery and consequently, less tools are cleaned, transported and disposed of afterwards. Also, by providing surgeons and doctors with less single use tools, less untouched but opened tools need to be disposed of [47]. By reducing waste, less waste has to be transported to a waste processing facility, which saves emissions as well [1]. Besides reducing waste, the composition of products ending up in waste is altered by switching to biodegradable or greener products when possible [25, 16]. This way, although the same amount of waste remains, the fraction of the waste that is easier to recycle or dispose has increased.

The third, and often overlooked, theme regarding low carbon alternatives is the food sector within a hospital [22]. To illustrate, patients, their visitors, and employees at a hospital often have meals on-site, which results in food waste. By using this resulting waste as compost for the garden sites near or at the hospital, this waste gets a new purpose [22]. Also, serving plant-based meals more often instead of animal products is more environmentally friendly [26, 35]. This should be done with caution, however, as some patients groups may benefit more from animal products with regard to their recovery [26].

The last theme, which is also the most industry specific theme, is the reduction of medication waste. We can identify two different strategies with regard to reducing this type of waste. The first strategy is to switch to a less polluting type of medication, whereas the second strategy is to reduce the volume of medication waste. We first focus on medication switches. As a first example, anaesthetists are starting to use a liquid type of medication, called propofol, which is applied via an intravenous drip on patients [38, 48, 30]. Traditional gases used by anaesthetists are stronger greenhouse gases than CO_2, and these gases go directly into the air after being exhaled by patients [48]. When using propofol instead, the residue of it can be contained and disposed of in an environmentally friendlier manner. A second example takes place in oral care, where the usage of amalgam is discouraged and more dentists and oral surgeons are using a less polluting material [10, 11]. A third example is the medication used by COPD and asthma patients [40]. Most patients use a gas inhaler due to its ease of use, where the gases in the inhaler are greenhouse gases [40]. A powdered inhaler is a better alternative as unnecessary CO_2 equivalent emissions are prevented, but requires the patient to be fit enough to take a deep breath for this type of medication to be used effectively [40].

Before we explain the second strategy involving the reduction of the volume of medication waste, we consider the causes of medication waste. First, the manufacturing and disposal of medication is polluting, as medication (residue) ends up in water and harms the water's quality [42, 36]. Second, medication is disposed of without it being used, due to the medication exceeding its expiration date which makes it obsolete, or by providing patients with excessive medication which results in patients throwing away the excess [1, 36]. While unused medication is incinerated due to health risks, both patients and healthcare professionals feel conflicted to dispose and destroy it [6]. Also, in preparing for surgery or supplying patients in the hospital, excessive medication is prepared and provided, which results in the excess being disposed of once the patients leave the operating room or when patients are discharged [3]. Barbariol et al. [3], for example, showed that 38% of prepared and filled syringes for a surgery are discarded while remaining unused. This excess results from the standard procedure to prepare as much syringes as could possibly be needed during surgery to ensure medication can be administered as quick as possible.

To address these causes of pharmaceutical waste, a few initiatives are already in place. For example, by creating a strict collection system to collect pharmaceutical waste, it is less likely to end up in the sewage system [47, 42]. To do this, remaining medication at the hospital is collected by the hospital itself, and discharged patients are encouraged to hand-in unused medication at a pharmacy [47, 42]. Furthermore, it is recommended to lower the doses and units of medication handed over to patients, surgeons and/or anaesthetists such that less medication remains afterwards [1, 42, 31]. For example, Van Norman and Jackson [43] found that by lowering the contents of a bottle of propofol, less medication was disposed afterwards as the remainders in the bottle are smaller. Moreover, by monitoring the expiration date of medication, less medication close to the expiration date is given to patients [1]. By doing so, expired medication is incinerated in a correct way by the pharmacy and not by patients, as patients tend to dispose expired medication incorrectly [1]. Finally, given that patients often take too much medication [42], a decrease in total medication use reduces the production of medication and corresponding waste streams.

2.2 Conclusion

To conclude, an increasing number of initiatives are adopted to reduce the negative impact on the climate crisis within the healthcare industry. We classify these initiatives in four themes, which are energy & water efficiency, general waste reduction, dietary switches, and medication related waste reduction. The first three themes transcend the healthcare sector since other industries aim to improve their sustainability as well. Reducing medication waste, however, is specifically related to the healthcare sector. It is also a theme that receives least attention in the Netherlands, but where healthcare decision makers have most impact [15]. More specifically, there are already initiatives adopted that reduce excess medication given to patients and care givers. However, we identify a gap in the literature that addresses the remaining excess and unused medication. Unused medication is most often incinerated, and by doing so, both patients and healthcare professionals feel conflicted to watch perfectly fine medication go to waste [6]. It is uncertain to what extent excess medication can be redistributed safely within a hospital, and when redistributed, what its consequences are regarding a reduction in medication waste (in %).

Chapter 3

Empirical setting and data

In Section 3.1, we describe the research setting at the Clinical Pharmacy department of Isala Zwolle. In Section 3.2, we describe the data used in this current setting.

3.1 Case study at Isala Zwolle

Isala Zwolle is part of a larger hospital group that also operates in Meppel, Steenwijk, Kampen, and Heerde. The entire hospital group has over 1,250 beds, 25 operating rooms, and 640,000 citizens living in the catchment area [19]. Isala aims to continually improve their hospital, this includes their environmental sustainability [19]. Therefore, they are involved in the Green Deal, and started several green teams. These green teams operate at various departments and aim to improve the environmental sustainability of their department. One of these teams operates at the Clinical Pharmacy (KF) department. KF aims to contribute to the improvement of Isala's environmental sustainability by aiming to decrease pharmaceutical waste. This department is responsible for the production and preparation of medication for Isala's admitted patients [21]. KF distributes oral, rectal and transdermal medication directly for admitted patients. We will first describe the current distribution process of medication at Isala Zwolle. Isala Meppel is not included in the case study and corresponding data analysis. KF also prepares and distributes medication for patients admitted at Isala Meppel, and this distribution process follows the same steps as the other wards.

3.1.1 Current medication distribution process

Each patient that is admitted to the hospital and who spends at least one night at the ward has two medication drawers assigned to their bed. One drawer is present near the patient and contains the medication for the coming day or weekend. The other drawer is located at KF and is prepared with a new set of medication for the following day. Each workday at 17:00, the drawers are switched and the newly filled drawer is placed near the patient, and the returned drawer is prepared at KF for the next day. Appendix D contains photos of one of the filling units and a medication cart with patient drawers.

The replenishment of a patient's medication drawer at KF works as follows. A pharmacy assistant collects one patient drawer from a cart filled with drawers of one ward. The wards are supplied from filling units and a large apothecary cabinet at KF. One filling unit supplies several wards and there are a total of seven filling units for the wards located at Isala Zwolle. When a drawer still has contents left in them when the drawer is returned, the contents are disposed of in a black waste bin. The pharmacy assistant then starts preparing the drawer for a new distribution cycle. The specific patient's medical file is opened and the prescribed medication is displayed. The pharmacy assistant collects the required units per medication type and scans each type before placing it in the drawer. Scanning medication ensures no incorrect medication is placed in a drawer. All medication remains in its original seal when placed in the drawer to ensure its safety, and to provide transparency to patients on what is administered to them. The drawer contains four sections where each section is linked to a time slot during the day to indicate when a patient needs what medication. When all medication for a patient is collected, the pharmacy assistant returns the newly filled drawer to the cart and proceeds with the next drawer of this cart. At 17:00 each workday, the filled carts are transported to the wards. When a cart is prepared on a given workday, the same cart is processed again two workdays later. For example, the cart processed and transported on Monday is returned on Tuesday after 17:00 and then filled again on Wednesday.

When the drawers arrive at the ward, the nurses place the drawers near the patient. During the assigned time slots for prescribed medication, a nurse scans each pill or plaster before administering it to the patient. This way, a detailed time stamp is logged for all administered medication and an extra verification is in place to ensure no medication is forgotten, given multiple times, or administered incorrectly.

The process of patient medication distribution between a ward and KF is displayed in Figure 2. The verification of correct medication is highlighted in this process, as well as the process steps where unused medication is disposed of. The starting and ending event for both departments occurs when a cart arrives or returns.

3.1.2 Unused medication causes

Within the distribution process at Isala Zwolle, situations exist that result in large quantities of unused medication. While it is certain that one of the situations results in unused medication to be returned to KF, it is not known for each individual case why medication is not administered. The following situations are most common to result in unused medication:

- The patient's clinical state has changed and they do not require the medication anymore. For example, beta blockers become redundant when a patient already has a low blood pressure.
- A patient is discharged from Isala and is therefore not present at the ward anymore. Consequently, the patient's medication at the ward becomes unnecessary.
- The patient brought medication from home and that medication is used first. The medication transported from KF becomes redundant.

In these situations, unused medication remains in the patient's drawer and this drawer is returned to KF. At KF, all returned and unused medication is collected in a black waste bin. When this waste bin is full, it is incinerated together with its contents. In some instances, the wards dispose unused medication in black waste bins themselves instead of returning it to KF. However, a great majority of unused medication is disposed of at KF.

Another stream of medication waste at KF results from expired medication. KF currently assesses the expiration dates of medication each month. When a box reaches its expiration date in the coming three months, it is marked. When a box is already marked and it reaches its expiration date between the current review period and the next review period, the box is disposed of into the black waste bin.

3.2 Data on medication distribution and usage

3.2.1 All wards at Isala Zwolle

At Isala, all medication is scanned before being placed in a patient drawer and scanned again before being administered to a patient. Each scan results in information regarding the medication unit being scanned. Information is available on date of distribution, date of administration, medication unit price, type, patient code, speciality, wards, rooms and more. This detailed data set is analysed for all oral, rectal and transdermal medication distributed in September 2022.

In September 2022, KF distributed 656 different types of medication, for example pantoprazol and diclofenac, to 25 different wards within Isala Zwolle. In September 2022, 2,043 patients were supplied by KF and the average length of stay was 3.43 days. There were 7,013 admission days in September 2022 in total for which KF distributed medication.

In September 2022, 87,302 units of medication were distributed to the wards at Isala Zwolle, of a total value of €28,328. This means that each admitted patient in September 2022 received on average 12.4 units per day with a total value of €4.04 per day in their patient drawer. Figure 3 displays the total number of units distributed per day. It highlights

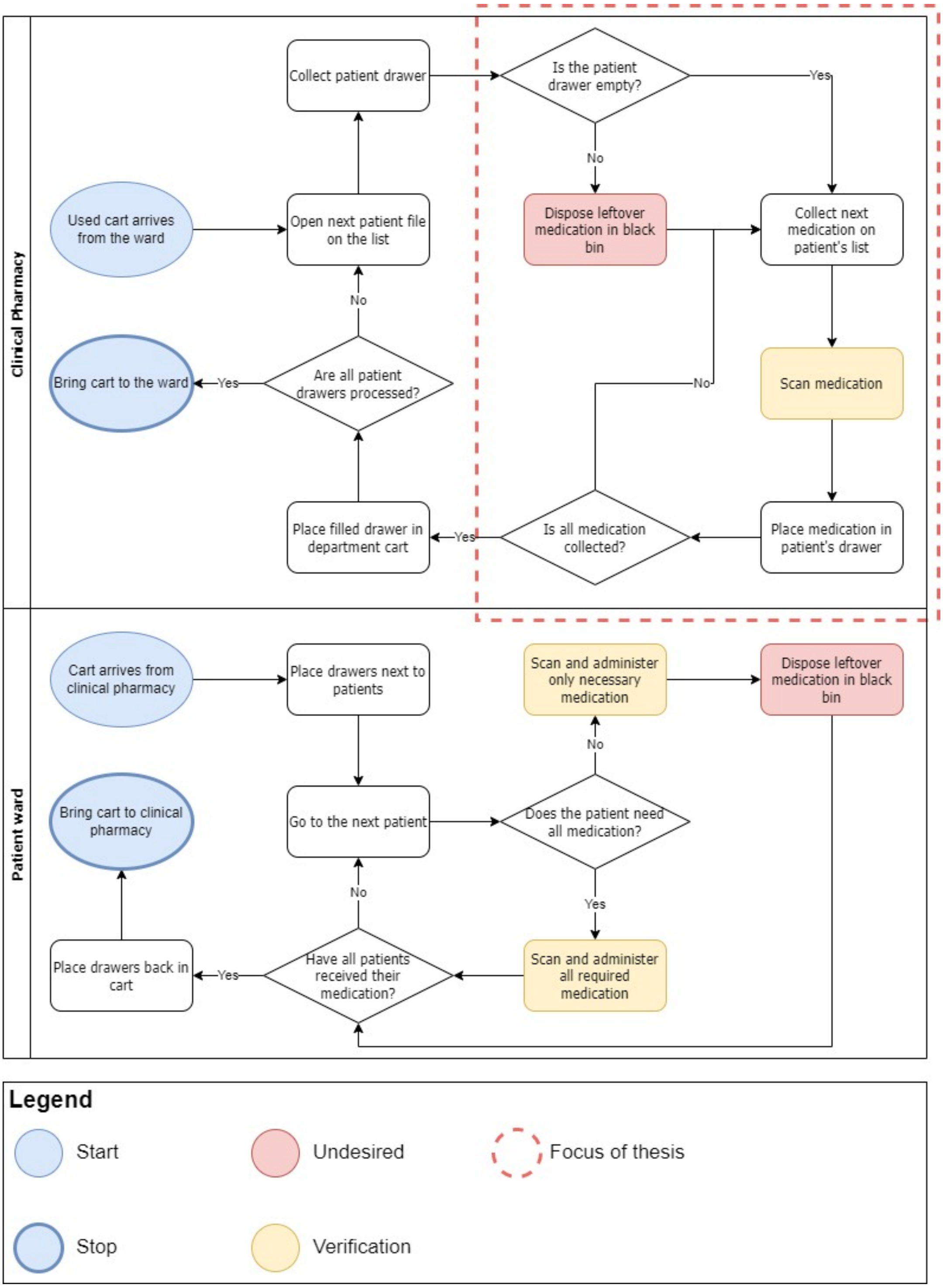

FIGURE 2: The current process of medication distribution

the distinction between the units administered and the units remaining unused. The administered and unused medication together account for the total quantity distributed. Figure 3 shows peaks on Fridays. These peaks can be explained by medication distributed on Fridays having to cover the weekend administration as well.

As visualised in Figure 3, 67% of all units distributed were administered. However, the remainder of the distributed medication was left unused. In September 2022, a total of 29,048 (33%) units remained unused and the unused medication had a total value of €9,337 (33%). For each admitted patient in September 2022, 4.1 units remained unused per day with a total value of €1.33. This medication was returned to KF via the carts and was disposed of when the cart was processed again. The largest quantity of medication returned to KF on a weekday resulted from medication distributed on Fridays. This returned medication was disposed of on Tuesdays. Figure 4 displays the quantity returned to KF during the given time period. Table 1 displays the distributed and unused quantity per weekday in terms of units, percentages, and a 95% confidence interval (CI) for unused units.

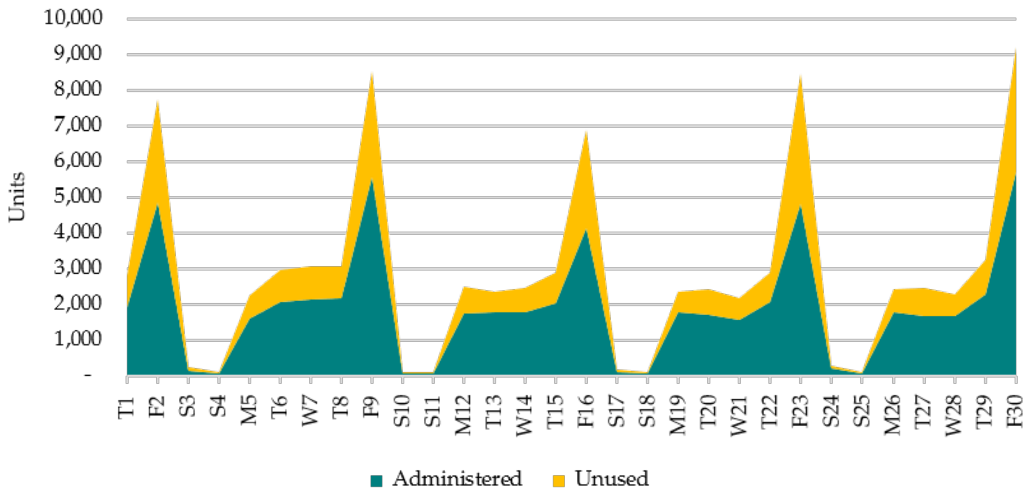

FIGURE 3: Total amount of medication distributed to all wards per day (September 2022, n=87,302)

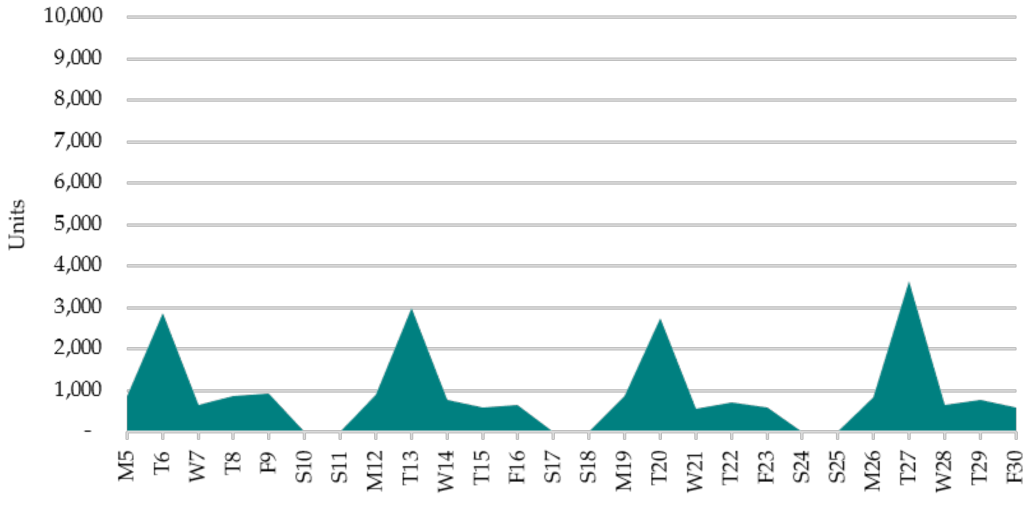

FIGURE 4: Arrival of unused medication at KF per day (September 2022, n=24,561)

Table 2 provides an overview per filling unit regarding the total quantity and value distributed, administered, and remaining unused for September 2022. Of the 25 wards supplied by KF, seven wards present in the data were not assigned to a filling unit due to incoherence in the data set. Therefore, these wards were grouped together.

Besides speciality, quantity, and value of the medication distributed in September 2022, we also consider two additional characteristics of each medication type. The first characteristic considers the presence of a bar code on each medication unit. Since all medication is scanned before being placed in the drawer or administered to the patient, all medication requires a code available for scanning. When a unit packaging does not contain a bar code yet, KF prints and places a 2D label that is scanned instead. Of the 656 medication types distributed in September 2022, 388 medication types already contained a bar code on each

TABLE 1: Distributed medication per weekday (September 2022, n=87,302)

Day	Distributed (n)	Unused (n)	Unused (%)	95% CI
Monday	9,643	2,643	27	25-30
Tuesday	10,275	2,947	29	26-31
Wednesday	10,080	2,799	28	26-29
Thursday	15,011	4,445	30	29-30
Friday	40,937	15,774	39	36-41
Saturday	859	285	35	28-41
Sunday	497	155	31	20-41

TABLE 2: Overview of quantities and values distributed per filling unit (September 2022, n=87,302)

Filling unit	Speciality	Distributed (n)	Used (n)	Unused (n)	Distributed (€)	Used (€)	Unused (€)
1	Internal medicine Oncology	8,547 (100%)	5,657 (66%)	2,890 (34%)	€ 6,170.52 (100%)	€ 4,784.82 (78%)	€ 1,385.70 (22%)
2	Nephrology Gastroenterology	8,478 (100%)	5,450 (64%)	3,028 (36%)	€ 2,647.94 (100%)	€ 1,668.58 (63%)	€ 979.36 (37%)
3	Orthopedics Plastic surgery	15,014 (100%)	10,639 (71%)	4,375 (29%)	€ 4,078.53 (100%)	€ 2,824.25 (69%)	€ 1,254.28 (31%)
4	Surgery Trauma surgery	11,456 (100%)	7,135 (62%)	4,321 (38%)	€ 3,764.08 (100%)	€ 2,101.63 (56%)	€ 1,662.45 (44%)
5	Urology Gynecology	9,520 (100%)	5,528 (58%)	3,992 (42%)	€ 2,121.68 (100%)	€ 1,242.71 (59%)	€ 878.97 (41%)
6	Neurology Pulmonology Acute admissions unit	12,850 (100%)	9,052 (70%)	3,798 (30%)	€ 3,692.10 (100%)	€ 2,513.76 (68%)	€ 1,178.34 (32%)
7	Cardiology	17,609 (100%)	12,163 (69%)	5,446 (31%)	€ 4,896.01 (100%)	€ 3,215.39 (66%)	€ 1,680.62 (34%)
N.A.	Remaining wards	3,828 (100%)	2,630 (69%)	1,198 (31%)	€ 957.87 (100%)	€ 640.71 (67%)	€ 317.16 (33%)
	Total	**87,302 (100%)**	**58,254 (67%)**	**29,048 (33%)**	**€ 28,328.73 (100%)**	**€ 18,991.85 (67%)**	**€ 9,336.88 (33%)**

individual unit of packaging. The other 268 types therefore required the 2D label. In terms of quantities distributed, 17,793 (20%) of 87,302 units required an additional 2D label. 6,651 (23%) of the 29,048 unused units had a 2D label.

The other characteristic considers the location of the medication type. While a cart is filled at a filling unit, not all medication collected is present at this assigned filling unit. More expensive and less frequently demanded medication is located in a large apothecary cabinet. The drawers can therefore contain medication from both the assigned filling unit and the apothecary cabinet. A filling unit contains between 204 and 304 medication types, whereas the apothecary cabinet contains 1,793 medication types. Regarding the quantities distributed in September 2022, 5,641 (7%) of 87,302 units originated from the apothecary cabinet. 2,080 (7%) of the 29,048 unused units originated from the apothecary cabinet. Table 3 displays the total unique medication types located in each filling unit and apothecary cabinet, and how many of these types were required in September 2022.

The last important aspect in the distribution process of medication and the accompanying data considers employees. Medication is collected by a pharmacy assistant who receives a salary of €3,468 per month for working 156.5 hours per month on average. This means that one hour of employment costs €22.16. One pharmacy assistant is assigned to one filling unit per day.

3.2.2 Wards 2.4B and 2.5A

To further understand the system behaviour, we focus on filling unit 4 that supplies ward 2.4B and 2.5A for (trauma) surgery, since this filling unit resulted in most medication waste compared to the other filling units in September 2022.

TABLE 3: Overview of medication types per inventory group
(September 2022, n=87,302)

Location	Speciality	Unique medication types	Types used in September 2022
Filling unit 1	Internal medicine Oncology	271	157 (58%)
Filling unit 2	Nephrology Gastroenterology	291	178 (61%)
Filling unit 3	Orthopedics Plastic surgery	304	224 (74%)
Filling unit 4	Surgery Trauma surgery	251	170 (68%)
Filling unit 5	Urology Gynecology	204	146 (72%)
Filling unit 6	Neurology Pulmonology Acute admissions unit	279	185 (66%)
Filling unit 7	Cardiology	258	170 (66%)
Apothecary cabinet	Various	1,793	279 (16%)

In September 2022, a total of 11,456 units were distributed. This had a total value of €3,764. The spread of the quantity distributed is visualised in Figure 5. A few weeks display a similar pattern compared to all wards aggregated. However, differences are visible for Monday the 26th, and the week between Tuesday the 13th and Tuesday the 20th. This could be due to the Joint Commission International accreditation that occurred in this time frame, influencing the operating room schedule that strongly influences the demand on these wards. The distributed units originated mostly from filling unit 4, with a total of 10,591 (92%) of the 11,456 units originating from here. The remaining units were collected from the apothecary cabinet.

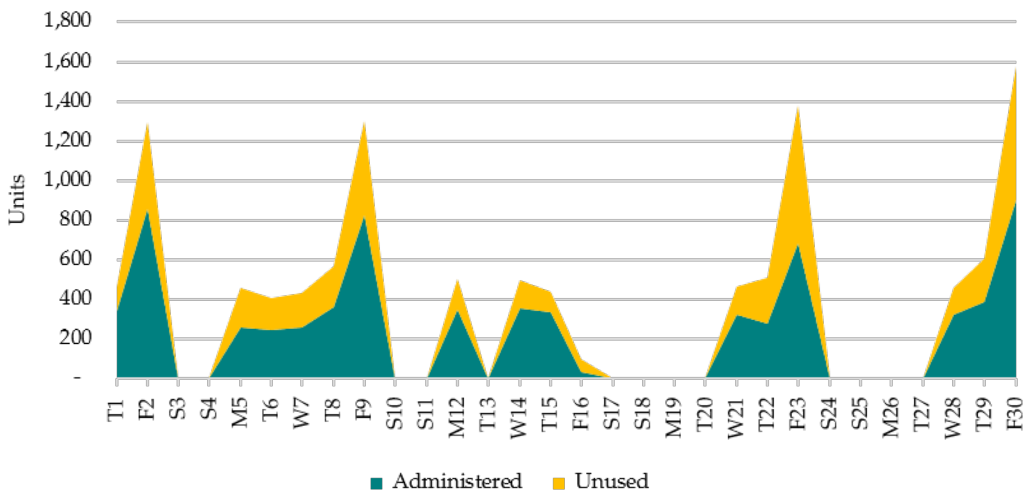

FIGURE 5: Total amount of medication distributed to wards 2.4B and 2.5A per day
(September 2022, n=11,456)

Of the units distributed to wards 2.4BA and 2.5A in September 2022, 4,321 (38%) units remained unused and this had a total value of €1,662. In terms of quantity, most unused units originated from filling unit 4 with 3,991 (92%) units of the 4,321 unused units. The total value of the unused units was €1,662, with €1,107 (67%) originating from filling unit 4. Table 4 displays an overview of the characteristics of all medication distributed from KF to wards 2.4B and 2.5A.

In September 2022, pharmacy assistants distributed medication to wards 2.4B and 2.5A on 17 days. The average units collected by pharmacy assistants was 673.88. The average time for collecting medication per day was 4.44 hours. Fridays were the busiest days in

TABLE 4: Medication distribution characteristics of wards 2.4B and 2.5A (September 2022, n=11,456)

Location	Unique medication types	Medication types with 2D label	Quantity distributed	Quantity used	Quantity unused	Value distributed	Value used	Value unused
Filling unit 4	263	68	10,591 (100%)	6,600 (62%)	3,991 (38%)	€3,029 (100%)	€1,922 (63%)	€1,107 (37%)
Apothecary cabinet	92	51	865 (100%)	535 (62%)	330 (38%)	€735 (100%)	€180 (25%)	€555 (75%)
Total	**355**	**119**	**11,456 (100%)**	**7,135 (62%)**	**4,321 (38%)**	**€3,764 (100%)**	**€2,102 (56%)**	**€1,662 (46%)**

terms of quantity collected, whereas Thursdays required on average more time to collect all medication. Table 5 displays the distribution frequency, units distributed, units unused and a 95% CI for the percentage of unused medication per day in September 2022 at wards 2.4B and 2.5A. On all Wednesdays, Thursdays and Fridays in September 2022 KF distributed medication to wards 2.4B and 2.5A. There are some Mondays and Tuesdays in September 2022 on which KF did not distribute medication to wards 2.4B and 2.5A. Again, this could be caused by the Joint Commission International accreditation that took place during one of the weeks in September 2022, as well as these wards' dependency on the operating room schedules. As a consequence, the other days could show distorted information to account for the variability on these Mondays and Tuesdays.

TABLE 5: Distributed medication per weekday at wards 2.4B and 2.5A (September 2022, n=11,456)

Day	Frequency distributed	Distributed (n)	Unused (n)	Unused (%)	95% CI	Average hours distributed
Monday	2	960	349	37	24-49	4.13
Tuesday	1	407	157	39	N.A.	4
Wednesday	4	1,852	592	32	27-37	4.31
Thursday	5	2,587	881	33	26-41	4.75
Friday	5	5,650	2,342	45	36-55	4.45
Saturday	0	0	0	N.A.	N.A.	0
Sunday	0	0	0	N.A.	N.A.	0

3.3 Conclusion

KF is responsible for the distribution of all oral, rectal, and transdermal medication for admitted patients at Isala Zwolle and Isala Meppel. The department distributed 87,302 units of medication in September 2022 for patients admitted at Isala Zwolle. Of all distributed units in September 2022, 29,048 units were not administered and therefore remained unused. All these unused units end up in a black waste bin and this bin is incinerated afterwards. We paid special attention to one filling unit, filling unit 4, that supplies wards 2.4B and 2.5A since these wards show large fractions of unused medication. These two wards were responsible for 4,321 (17.6%) units of the total of 87,302 units of unused medication in September 2022.

This data analysis highlighted the large amount of unused medication that is incinerated without a proper reason. The aim of this research is to decrease unused medication, and the data analysis highlights the motivation and room for improvement regarding the quantities of unused medication. We hypothesize that a major quantity of the currently unused and incinerated medication can be used by another patient and therefore given a purpose. As a consequence, an intervention in the current process is necessary to change the route of unused medication at KF to ensure this medication does not end up in the black waste bin, but is eventually used instead.

Chapter 4

Intervention assessment

Before piloting an intervention to alter the current distribution process, several possible intervention approaches are discussed in Section 4.1. Next, one approach is chosen based on its feasibility and possible effects on the quality of care, and this approach is discussed in more detail in Section 4.2. To determine the consequences of the chosen intervention with respect to the environmental and financial aspects, a mathematical model is discussed in Section 4.3. In this section, we will first elaborate on the problem definition in Section 4.3.1 before presenting the formal problem formulation in Section 4.3.2.

4.1 Intervention approaches

The current distribution process at KF results in excessive pharmaceutical waste. Most unused medication ends up in the black waste bin. In order to reduce unused medication, an intervention in the current distribution process is necessary to change the course of unused medication. There are several interventions that facilitate a more streamlined management of materials in a hospital [29, 9]. We will shortly discuss the following:

1. Just-in-Time delivery to patients;
2. Decentralised inventories;
3. Integrated data systems;
4. Accurate demand prediction;
5. Reuse policy development.

4.1.1 Just-in-Time delivery to patients

For this intervention, required medication is delivered to the patient right before the medication is needed and no safety inventory is present [29]. Medication that normally remains unused is not ordered anymore. Only when a patient actually needs the medication, an order is placed and KF then ensures this medication is brought to the correct ward right away. However, situations could arise where medication is required more urgently than anticipated and this intervention then endangers patient safety. A patient should always be able to receive the correct medication at the instant it is needed. When there is no medication present, patient safety is severely endangered. Therefore, this intervention is considered as inappropriate as it negatively influences the quality of care.

4.1.2 Decentralised inventories

Instead of distributing medication from KF, the inventories of the filling units are placed at the wards [29]. This way, only required medication is collected by the nurses and medication is not administrated as unused. However, this intervention counters the benefits of the pooled inventory at KF, and would require a larger total inventory at the hospital [29]. The wards at Isala Zwolle do not have the capacity to include an inventory of the size of a filling unit. Moreover, the patients present at the wards may require urgent medication. When a nurse first has to find the correct medication, the patient may be endangered and experiences the negative consequences of the intervention. Also, the total inventory in the hospital grows, while the demand for medication stays the same. As a consequence, more medication is expected to expire. Therefore, relocating medication to the wards is considered as an inappropriate intervention [9].

4.1.3 Integrated data systems

At Isala Zwolle, unused medication often results from lack of data or delayed data. Unused medication results from medication distributed to patients already being discharged, patients bringing the same medication from home, or patients whose clinical state has changed [9]. The first two situations are caused by a lack of data accuracy. When a patient's medical file is updated with the correct discharge date and moment, medication after this moment does not have to be distributed. Additionally, when patients bring medication from home, this should also be updated in the medical file to prevent the distribution of the same medication to the patient. Medication from home can be used first in this case. This is considered as an appropriate intervention to decrease unused medication. However, for this intervention to succeed, cooperation and communication from all nurses and physicians are required in order to keep the data up to date [9]. The success of this intervention is therefore strongly dependent on the effort of numerous employees from different departments. This intervention is not rejected as other interventions due to its influence on the quality of care, but due to its feasibility. We do think that improving data accuracy and integration supports a decrease in unused medication. However, instead of the support and help of the employees of one department, all departments and specialities need to cooperate for this to accurately work. The scale and scope of this intervention is outside of this research and time frame to make a clear impact. Therefore, we do not choose this intervention, but highly recommend to still increase the data integration and accuracy.

4.1.4 Accurate demand prediction

This intervention considers anticipating medication demand at the wards by analysing patient arrivals and the corresponding medication requirements [9]. Elective patient arrivals are known in advance and the procedure the patients undergo are mostly known as well. By looking into the past medication consumption and linking it to patient arrivals and patient characteristics, a better prediction of demand can be made [9]. Instead of having individual patient drawers, the carts switched between KF and the wards contain the aggregate supply of medication for that ward. This intervention, however, still requires nurses to look for the correct medication and consequently harms the patient safety.

4.1.5 Reuse policy development

Currently, unused medication returns to KF via the patient drawers. In the current situation, this medication is disposed of in the black waste bin. By returning this medication to the inventory in either the filling unit or the apothecary cabinet, this medication will be reused when new demand for this medication occurs [9]. This intervention also contains risks, such as placing it back in the wrong location, mixing up medication types, placing medication back that decreased in quality due to opened or damaged packaging, or placing medication back that contains no visible expiration date [9]. Another drawback of this intervention is that the process of placing medication back puts extra work pressure on personnel.

While the risks should be mitigated, we do consider this intervention as the most appropriate intervention. With this intervention, all unused medication that is in a perfect state receives a purpose to be reused. Medication that cannot be guaranteed to be completely safe and perfect for use can still be disposed of. The employees involved with this intervention are also the employees who directly see the benefits and decrease in unused medication, and are also the employees who are already involved in the current distribution process.

To conclude, while improving the data accuracy of the patients' medical files would be beneficial, this intervention is difficult to attain correctly and is highly dependent on numerous employees. Therefore, we focus on decreasing unused medication by placing returned medication to the inventory in the filling units and the apothecary cabinet at KF. We will elaborate more on this situation in Section 4.2.

4.2 Chosen intervention approach

The main objective of the chosen intervention is to significantly reduce the quantity of unused medication that is disposed of in the black waste bin. We believe that this can be achieved best by placing medication that is returned to KF back in the inventory in the filling units and the apothecary cabinet and reusing it. By doing so, this group of medication receives a new purpose during the next round of medication distribution, and does not end up in the black waste bin. This intervention also requires only a minor change in the current distribution process and at KF only. Therefore, the wards nor the patients are affected by this intervention. The effect on the distribution process at KF with the intervention included is visualised in Figure 6.

FIGURE 6: Ideal situation to reduce unused medication in the distribution process

The changes in the process involve placing returned medication back in the inventory. This is executed by the pharmacy assistant. Normally, all contents left in the patient drawer are disposed of in the black waste bin. In the new situation, these contents are still removed from the patient drawer, but placed in front of the pharmacy assistant. The assistant first scans medication that is still on prescription by the patient and this medication is placed in the patient drawer again. Unused medication that is not required by this specific patient anymore is placed back in the inventory. This medication cannot be placed back in its original package due to safety guidelines. Therefore, the unused and 100% usable medication is placed in a return box that is located directly in front of the original package. As a consequence, medication from the original packaging and medication in the return boxes are easily distinguishable. When the pharmacy assistant starts with collecting the rest of the list of required medication for the particular patient, medication is first collected from the return boxes before collecting medication from the original packaging to counter obsolescence of the products. By using medication from the return boxes first, attention is paid to the expiration dates. Only when the return boxes are empty, the medication is collected from the original packaging.

The chosen intervention comes with several risks. Before implementing anything, a Health Failure Mode and Effect Analysis (HFMEA) was conducted with pharmacists and pharmacy assistants at KF. HFMEA is a method to prospectively identify possible risks in order for these risk to be mitigated [17]. Appendix C contains this HFMEA, which shows three categories of most common and threatening risks:

Placing unused medication back at the incorrect inventory location. This situation will probably occur frequently since the placing back is done by an employee. However, this employee is also responsible for collecting all medication from the correct packaging and is therefore well-trained in knowing the location of each medication type and is used to reading the medication name before placing it in the patient drawer. Moreover, medication is still scanned and verified via its bar code before being placed in the drawer. If unused and returned medication is placed in the incorrect return box, this will be noticed when the medication is scanned by the pharmacy assistant. Even when the medication is wrongly placed in the patient drawer, a nurse scans the medication before administering it to the patient as well and will notice it if the medication is incorrect. Additionally, since medication is collected from the return box instead of the original packaging, the pharmacy assistant is alerted to pay more attention to verify that the medication is indeed correct. Moreover, different pharmacy assistants are assigned to a filling unit during the week. If one returned medication unit is placed back incorrectly, another pharmacy assistant is extremely likely to notice this during the next round of medication distribution. Therefore, we assume that this risk is mitigated and does not negatively affect the quality of care.

Placing unusable and unsafe medication back. When medication is returned to KF, it is possible that the individual packaging of the medication unit is damaged or opened. In that case, the medication becomes unusable and unsafe, and it should be disposed of in the black waste bin. We assume that this situation does not occur frequently. The pharmacy assistants are skilled, trained and know when medication is considered unusable. All units are checked by the pharmacy assistant before being placed in the patient drawer and all units are also checked by a nurse before being administered to the patients. Therefore, we assume that this risk will not create dangerous situations.

Placing back medication that has expired. Most medication contains expiration dates on its packaging that can be checked to ensure medication has not expired yet. However, not all medication contains this expiration date. These medication types can be given a 2D label that contains the expiration date when the medication unit is scanned. When the medication is expired, the pharmacy assistant will be notified by the program that contains the medical files of patients. Moreover, when a packaging containing several units of medication expires, this packaging as well as the units in the return box in front of it are disposed of. Therefore, it is unlikely that expired medication is administered to a patient.

The last subject to mention that is not necessarily a risk, is the issue of additional time and work load pressure on the pharmacy assistants. Placing medication back in the inventory requires additional time during a regular work day and it may put additional pressure on the pharmacy assistants. They have to do additional tasks next to their regular work without receiving additional time for it. It is uncertain how much extra time and effort the task of placing medication back into the inventory in the filling unit and the apothecary takes. Moreover, since there is a varying amount of medication returned to KF each workday, it is expected that this activity varies in its time effort for each workday. In case KF wishes to hire another full time equivalent (FTE), it may be beneficial for them to know how to spread the workload of this FTE over the week. Additionally, hiring additional FTE requires capital that has to be made free. Placing medication back may save in expenses since medication is used instead of disposed. The intervention of placing unused medication back should therefore also be cost-efficient. Even if the intervention requires a small investment in terms of funding, it may still result in an incredible long-term reduction in unused medication that goes to waste. The model therefore supports making a decision on the possible price to pay for a great reduction in waste.

4.3 Mathematical model

To ensure that KF is cost-efficient in the redistribution process of unused medication, we make use of a mathematical modelling approach. We model the problem as a knapsack problem, which is an approach that has not been considered in a pharmaceutical context before to reduce medication waste. This approach is therefore original, and highly applicable when aiming to reduce medication waste under one large restriction; to remain cost-efficient [46]. The model supports in deciding what medication is returned in order for the redistribution to be cost-efficient and results in a decrease in unused medication. Moreover, it addresses the possible additional workload the pharmacy assistants may experience when medication is redistributed. In short, we model cost-efficient returns of medication and tap upon the environmental and financial aspect of sustainability by considering the reduction in waste and the possible savings. In our modelling approach, we will first define the problem and its notation before introducing the mathematical problem formulation.

4.3.1 Problem definition

The problem of redistributing medication resembles a knapsack problem. The knapsack problem involves a knapsack that is possible to contain several items until the knapsack is full [46]. Each item has a size and a possible benefit. For each item, it has to be decided to bring it along in the knapsack or to leave it behind [46]. The goal is to bring the maximum possible benefit along, while the knapsack does not exceed its capacity [46].

In our problem, the items to place in the knapsack are the different medication types, which each have a corresponding time investment. The size of the knapsack is defined by the maximum time it may take to return all medication types selected in the knapsack to the shelves. The benefits of placing medication back in the knapsack consists of the total amount of unused medication, and the savings made from returning unused medication. To get a better picture of the characteristics of our problem, we will first discuss the medication properties, the workload properties, the decisions and the objective, and constraints.

Medication properties

Our problem is characterised by a list of medication types $p \in P$ that are distributed from an inventory type $i \in I$. Every medication type p has a monetary value V_p per unit, a daily demand rate D_p, and a daily probability to remain unused and therefore a probability to return ϕ_p to KF, with ϕ_p taking a value between zero and one. Moreover, some medication types require an additional, one time only, task that has to be performed before the medication is distributed, e.g., opening a package or marking a blister. A medication type either requires this additional task, setting indicator variable $A_p = 1$, or the medication type does not have to process this task and $A_p = 0$. Also, this additional activity only has to be processed once per medication type and unit. This means that when medication is returned to KF and placed back in the inventory, it does not have to undergo this task again.

Workload properties

Each medication type is collected from one inventory type $i \in I$. When medication type p is collected from inventory i, it is noted that this medication is located on location $L_{p,i}$ and this value is set to 1. For example, when medication 1 is located in inventory 2, $L_{1,2} = 1$ and $L_{1,i \neq 2} = 0$. A certain medication type p is collected from one inventory type i only. Time to return medication to inventory i takes on average LT_i seconds. The additional activity takes an average of AT seconds. Next, time to return unused medication is represented in price.

This price is equal to the salary of one pharmacy assistant, which is S euros per second. The total time it takes to return medication to the inventory is $TotalTime$ in seconds.

Decisions and objective

Our research aim is to decrease unused medication while remaining cost-efficient. Therefore, we have two objectives to strive for. First, we aim to maximise the total quantity of unused medication to be returned to the shelves. Second, we aim to do so while remaining cost-efficient, meaning the value of medication to be returned has to exceed the costs of returning. In order to reach these goals, we have to decide for each medication type p whether it is worth it to place place this medication back on the shelves. This decision is denoted as X_p. When $X_p = 1$, this medication type is returned to the inventory. When $X_p = 0$, the medication type is disposed of instead. We expect that the decision to return medication follows a clear pattern, since the knapsack problem can be easily solved by ordering $benefit_p/cost_p$ in decreasing value and adding medication until the capacity is reached [46]. However, when there is randomness in the decisions of the model, it would mean that the pharmacy assistant has to decide for each returning medication unit whether it can be placed back in the inventory or not.

Constraints

The decision to return certain medication types to the shelves is subject to multiple constraints. The first constraint ascribes a value to the total time spend on returning medication to the inventory. $TotalTime$ consists of the time spend returning medication either to the original inventory or the complementary inventory and the time possibly saved by not having to perform the additional task again since this task has been processed already. Second, there is limited time available to place medication back, denoted as $TimeCapacity$ that should be equal to or larger than $TotalTime$. Third, placing medication back should always be cost-efficient, meaning the costs of placing medication back should be lower than the profits made from reusing medication that would otherwise be disposed of. By doing so, KF is assured to have enough resources in terms of FTE and funding to implement the intervention without having to find additional funding. The fourth and fifth constraint considers the value restrictions on the binary decision variable X_p and non-negative integer $TotalTime$.

4.3.2 Problem formulation

The problem formulation consists of sets, (decision) variables, parameters, an objective function, and constraints.

Sets

$p \in P$	Medication type p, where $p = 1, 2, ...P$
$i \in I$	Inventory type i, where $i = 1, 2, ...I$

Parameters

V_p	Value of one unit of medication type p in euros
D_p	Daily demand in units of medication type p
ϕ_p	Daily probability to return to KF of medication type p
A_p	1 if medication p requires a one-time only task, 0 otherwise
$L_{p,i}$	1 if medication p is located in inventory i, 0 otherwise
LT_i	Time to return medication to inventory i in seconds
AT	Time to perform the additional activity in seconds
S	Salary of one pharmacy assistant in euros per second
$TimeCapacity$	The time capacity to return medication in seconds

Variables

X_p	1 if medication type p is returned to the inventory, 0 otherwise
$TotalTime$	Total time spend to return medication to the inventory in seconds

Objective function

Our goals are two-fold. First, we wish to maximise the total amount of unused medication to be placed back in the inventories. This objective is denoted in Equation 1. Second, we wish to maximise the profits made from returning unused medication to the inventory. This objective is denoted in Equation 2.

$$\text{Max} \sum_p X_p D_p \phi_p \tag{1}$$

$$\text{Max} \sum_p X_p D_p \phi_p V_p - S \times TotalTime \tag{2}$$

Constraints

The constraint in Equation 3 ascribes a value for the total time spent returning medication back to the inventory. It consists of two parts. The first part calculates the time spent on placing medication back. The second part calculates the time saved from not having to perform the additional task again.

$$\sum_i \sum_p X_p D_p \phi_p L_{p,i} LT_i - \sum_p X_p D_p \phi_p A_p AT \leq TotalTime \tag{3}$$

The total time spent cannot exceed the time capacity. This is denoted in Equation 4.

$$TotalTime \leq TimeCapacity \tag{4}$$

Constraint 5 ensures that the costs of returning medication do not exceed the savings.

$$\sum_p X_p D_p \phi_p V_p \geq TotalTime \times S \tag{5}$$

Last, Constraint 6 and Constraint 7 provide the boundary restrictions for the (decision) variables.

$$X_p \in [0,1] \; \forall \; p \in P \tag{6}$$

$$TotalTime \geq 0 \tag{7}$$

4.4 Conclusion

In this chapter, we first discussed several possible interventions to reduce unused medication that is currently disposed of at KF. The chosen intervention involves returning unused medication back into the inventory at KF in order to use this medication in the next round of medication distribution. To support the decision to return medication or not, the problem is modelled as a knapsack problem. The benefits consist of either the quantity of medication that is reused, or the value of the medication that is reused. The volume restriction considers the time capacity since it takes time to return medication to the shelves. The model provides a clear decision on what medication to return and the financial and environmental consequences of returning this medication. It supports pharmacies in deciding whether it is worth-wile to return medication to be reused or to dispose of it instead.

Chapter 5

Model performance and outcomes

Chapter 5 considers the performance and outcomes of the model presented in Chapter 4. In Section 5.1, we first discuss the model initialisation and the different instances used for running the model. Section 5.2 presents the outcomes.

5.1 Model initialisation

We consider three instances based on data provided by KF from Isala Zwolle from September 2022, of medication distributed to wards 2.4B and 2.5A. The three instances consider an average week of medication distribution from and returns to KF, a worst case scenario with maximum returns, and a best case scenario with minimum returns. The wards are filled from one filling unit and complemented by more expensive medication from the apothecary cabinet. If expanding this research to the other wards, it is recommended to perform the analysis for each filling unit individually. The filling units have equal characteristics and the model itself does not have to be altered to perform the analysis.

5.1.1 Sets

There are two sets. First, the set containing the list of medication types $p \in P$ consists of 312 medication types that are distributed from KF to wards 2.4B and 2.5A in September 2022. These medication types can originate from one of the inventory types $i \in I$. In our case, there are two different inventory types where $i = 1$ indicates the filling unit and $i = 2$ indicates the apothecary cabinet.

5.1.2 Parameters

The following values are deterministic and given by the historic data. The value V_p is derived from the data set of distributed medication in September 2022. The additional, one time only, task A_p consists of labelling medication types that do not contain a bar code on their packaging yet, and the location of medication type p in the filling unit $L_{p,1}$ or in the apothecary cabinet $L_{p,2}$ is provided by a data set containing information on medication types. The salary per hour for one pharmacy assistant is €22.16, which makes the salary S per second €0.006.

The average times to label medication, to place it back in the filling unit, or to place it back in the apothecary cabinet are estimated by the pharmacy assistants to be 7, 5, and 120 seconds respectively, making $AT = 7$, $LT_1 = 5$, and $LT_2 = 120$. Placing medication back in the apothecary cabinet takes significantly longer due to having to alter the inventory level in the data system and having to find the location of the medication type in the apothecary cabinet.

The value V_p, the task A_p, locations $L_{p,1}$ and $L_{p,2}$, salary S, and processing times AT, LT_1, and LT_2 are deterministic for all instances.

The daily demand D_p is the maximum daily demand, the average daily demand, and the minimum daily demand for the instances considering the worst case, average case and best case instances respectively. These values are derived from the data of medication distribution of September 2022. As mentioned in Chapter 3, medication is distributed for one

Tuesday in this time frame only. Therefore, the values from this Tuesday are used for the average case instance. The values for the worst case and best case daily demand for Tuesdays are derived based on the average increase and decrease of the other weekdays.

The return probability ϕ_p varies per weekday and per instance. For the average case instance, the average return probability is used from the historic data of September 2022. For the worst case instance, the maximum return probability of September 2022 is used, and for the best case instance, the minimum return probability is used. For the Tuesday return probabilities, the single available data point of September 2022 is used for the average case instance. The worst case and best case instance probabilities are derived from the average increase and decrease of the other weekdays regarding the return probabilities.

Table 6 displays an example of ten medication types distributed on a Monday for the three instances with their corresponding demand rate and return probability.

TABLE 6: Example instance of ten medication types distributed on a Monday

Medication type p	**Daily demand** D_p			**Return probability** ϕ_p		
	Worst	Average	Best	Worst	Average	Best
1	13	12	11	0.36	0.22	0.08
2	1	1	1	0.20	0.05	0.00
3	2	1	1	1.00	0.67	0.50
4	3	3	2	0.67	0.38	0.00
5	3	2	1	0.50	0.17	0.00
6	7	4	1	0.50	0.42	0.00
7	15	6	2	0.14	0.13	0.00
8	4	3	1	0.33	0.25	0.00
9	5	4	3	0.33	0.15	0.00
10	7	6	3	0.86	0.59	0.00

Preliminary analyses showed that running the model with the constant return speed of 5 seconds per unit for the filling units returns and 120 seconds per unit for the apothecary cabinet returns, we find that it takes an exceptionally long time to return all medication on a given day. Also, we consider that it is unrealistic to expect every unit to take 5 (120) seconds, while it is possible that more units of one medication type returns from a drawer. Economies of scale may increase the average speed per unit. Therefore, we create a weighted return time $WLT_{i,p}$ where the speed depends on the number of units of one medication type p to return. The processing speed increases until more than six units of one medication type are returned. When returning six or more units, the average processing speed remains constant and the total processing speeds increases linearly as the total units of one medication type increases. Equation 8 shows the growth factor of 0.85 per extra unit of one medication type placed back. The cut-off value of six units ensures that the average processing time per unit decreases, whereas the total time to place all medication types of one unit back increases.

$$WLT_{i,p} = \begin{cases} LT_i \times 0.85^{D_p\phi_p - 1}, & \text{for } D_p\phi_p \leq 6 \\ LT_i \times 0.85^6, & \text{otherwise} \end{cases} \quad \forall\, p \in P \;\forall\, i \in I \tag{8}$$

5.1.3 Experiment setup

To experiment with the model, we make use of different settings. The objective function is to either maximise the total returned quantity or the total savings. Next, the time capacity on a given day increases by 15 minutes until we reach the total time of 3 hours. Table 7 displays the setup of the 24 experiments. Every experiment is performed for each workday of the week and for all three instances.

Moreover, we run the LP relaxation where the decision X_p is not restricted to a binary value, but may take all values between 0 and 1 [46]. We do so for each experiment, workday, and instance. The LP relaxation provides an upper bound to the optimal solution to maximise either the total medication returned to the shelves, or the maximum possible savings [46]. It facilitates the comparison of our results with the LP relaxation results.

TABLE 7: Experiment instances

Experiment	Time capacity (sec)	Objective function	Experiment	Time capacity (sec)	Objective function
1	900	Maximise returns	13	900	Maximise savings
2	1,800	Maximise returns	14	1,800	Maximise savings
3	2,700	Maximise returns	15	2,700	Maximise savings
4	3,600	Maximise returns	16	3,600	Maximise savings
5	4,500	Maximise returns	17	4,500	Maximise savings
6	5,400	Maximise returns	18	5,400	Maximise savings
7	6,300	Maximise returns	19	6,300	Maximise savings
8	7,200	Maximise returns	20	7,200	Maximise savings
9	8,100	Maximise returns	21	8,100	Maximise savings
10	9,000	Maximise returns	22	9,000	Maximise savings
11	9,900	Maximise returns	23	9,900	Maximise savings
12	10,800	Maximise returns	24	10,800	Maximise savings

5.2 Model outcomes

After running the 24 experiments for five workdays and three instances, we analyse the results applicable for both objective functions. We consider the average time per day to place medication back, the returns in terms of quantity and monetary value per day, and the decisions made to place mediation back or not. When discussing the results, we analyse the average outcomes, and provide an interval that contains all values, providing the minimum and maximum of the three instances considered. Lastly, we consider the performance of both objective functions with regard to their LP relaxation. Appendix E contains the results of all experiments.

5.2.1 Time effort

For the objective to maximise the total units returned to the shelves, the average additional time required for returning medication distributed on Mondays to Thursdays varies between 52 and 66 minutes (interval: 43-180 minutes). The average time for returning medication distributed on Fridays is 161 minutes (interval: 112-180 minutes). Figure 7 displays the average additional time required per day and per instance. Mondays and Tuesdays require on average more time to return medication for the best case instance than for the average case instance. This can be explained by less medication units having to be returned that contain a 2D label. Not having to label medication again saves more time than it takes to return the medication to the filling unit. It is therefore possible that there are fewer units to be returned, while taking more time to return medication.

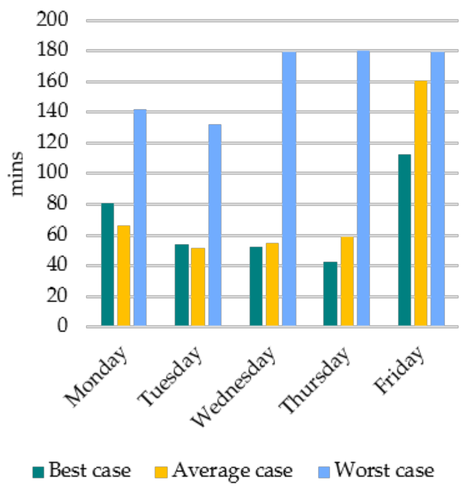

FIGURE 7: Additional time per instance when maximising returns

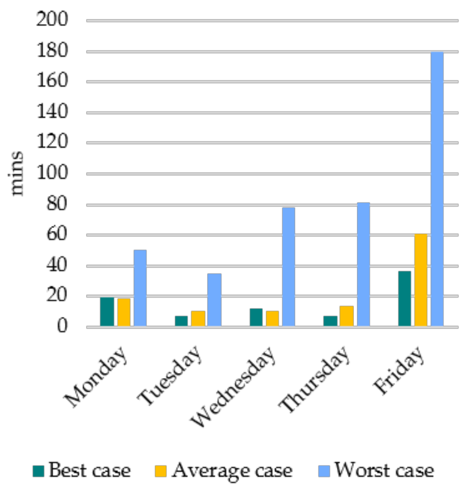

FIGURE 8: Additional time per instance when maximising savings

Medication distributed on a given weekday returns to KF two weekdays later. For example, medication distributed on Mondays returns to the shelves on Wednesdays. The weekend is not included, as medication is not distributed via the carts during these days. Figure 9 displays the average daily workload for the pharmacy assistants when returning medication to the shelves is incorporated in this daily workload. As visualised, the busiest days were Thursday and Friday, but the peak workload has shifted to the Tuesdays when returning unused medication is incorporated.

The average additional time required to return medication distributed on Mondays to Thursdays when maximising the savings varies between 10 and 18 minutes (interval: 7-81 minutes). For Fridays, the average time to return medication is 61 minutes (interval: 37-180 minutes). Figure 8 displays the average time required per day and per instance. Mondays and Wednesdays require more time for the best case instance than for the average case instance, due to less medication with a 2D label to be returned to the inventory. Figure 10 displays the average daily workload with returning unused medication incorporated and shows that Tuesdays are the new busiest days in the week.

FIGURE 9: Average daily workload when maximising returns

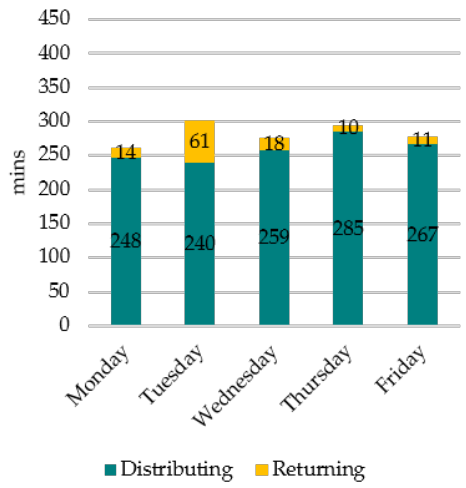

FIGURE 10: Average daily workload when maximising savings

5.2.2 Returns

We consider both objective functions separately with regard to the results. We start with analysing the results of the objective to maximise the total units returned. Next, we discuss the results when aiming to maximise the net savings.

Maximising returns

Within 15 additional minutes per weekday for one pharmacy assistant, an average of 920 units (interval: 301-3676 units) can be returned to the shelves per week. More specifically, allowing 15 minutes per day for Mondays to Thursdays, an average of 552 units (interval: 180-2,153 units) can be returned during these four days. Medication distributed on Fridays has an average of 368 units (interval: 121-1,523 units) to be returned in 15 additional minutes. An average of 84% (interval: 67%-84%) of medication that returns to KF in a week can be placed back in the filling unit and apothecary cabinet when allowing 15 additional minutes per day. When there is no daily time capacity, an average of 1,098 units (interval: 446-4,674 units) can be returned per week. Figure 11 displays units returned over an increasing time capacity when maximising total units to be returned.

The average savings, already accounting for time compensation for the pharmacy assistants, varies between €191 and €239 (interval: €44-€1,321), depending on the available time capacity. Figure 12 displays the savings over an increasing time capacity when maximising total units to be returned. The average value of the units returned per week varies between €235 and €379 (interval: €93-€1,597).

For all instances and days, the available time capacity is first filled with returning medication to the filling units. As more time becomes available, more medication is returned to the apothecary cabinet. Medication is selected based on the total returns of one medication type; the medication type with most units returned is placed back in the filling unit first. Figure 13 displays the percentage of returned medication placed back in the filling unit and the apothecary cabinet within 15 minutes per day. Figure 14 displays the average percentage of returned medication that does (not) contain a label.

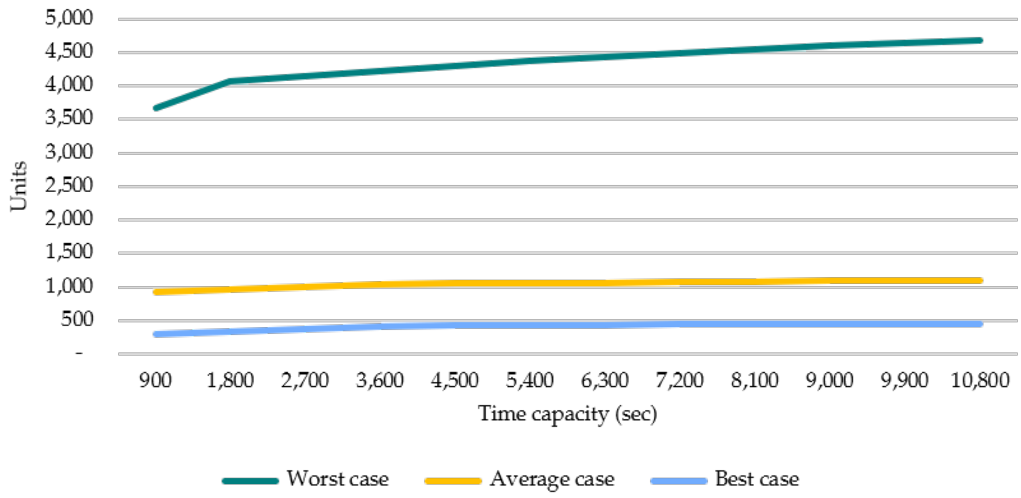

FIGURE 11: Returns per week over an increasing time capacity when maximising returns

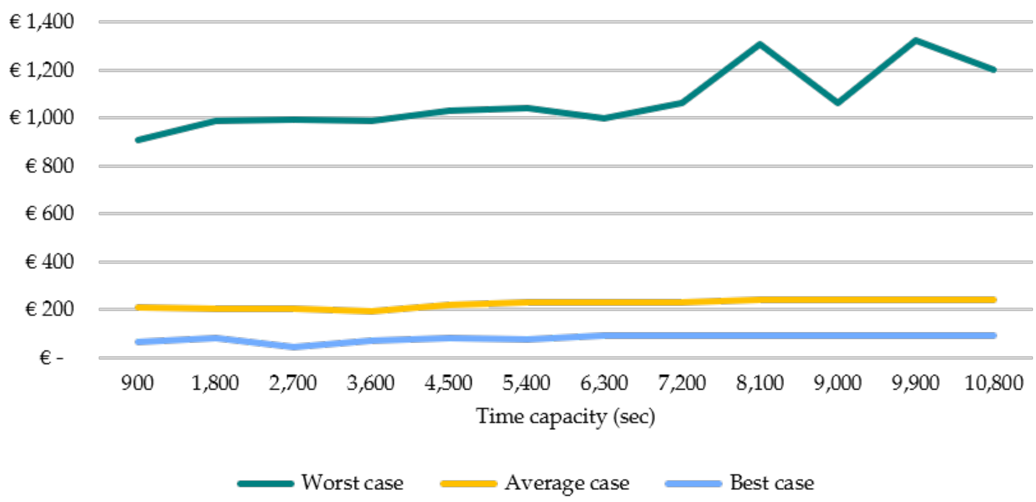

FIGURE 12: Savings per week over an increasing time capacity when maximising returns

Maximising savings

An average of 826 units (interval: 273-2,533 units) can be returned when allowing 15 additional minutes per day per pharmacy assistant when aiming to maximise savings. On Mondays to Thursdays, an average of 533 units (interval: 162-1,752 units) in these four days can be returned to the filling units and apothecary cabinet in 15 additional minutes per day. For

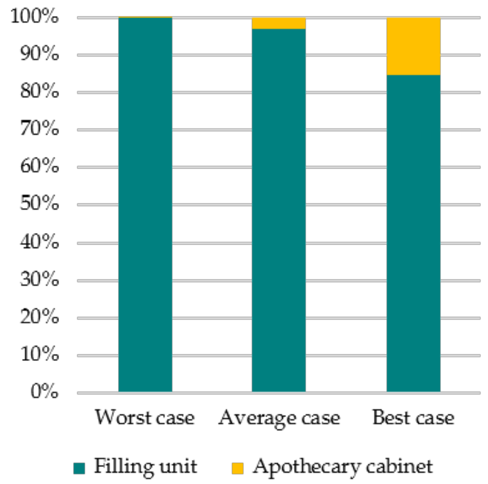

FIGURE 13: Location of units returned within 15 minutes when maximising returns

FIGURE 14: Labels of units returned within 15 minutes when maximising returns

Fridays, the average units returned are 293 units (interval: 111-781 units). When taking these 15 additional minutes per day, an average of 75% (interval: 49%-75%) of the units returned to KF can be placed back in the correct inventory. When time capacity is not taken into account, an average of 936 units (interval: 297-4,299 units) can be returned to the apothecary cabinet and filling unit. Figure 15 displays the units returned per week over an increasing time capacity when the objective is to maximise the savings.

The average savings per week vary between €279 and €300 (interval: €141-€1,658) when compensation for the pharmacy assistants time is already included. As the time capacity increases, the savings per week increase. Figure 16 displays the average savings per week over an increasing time capacity when maximising savings. The average value of the returned units varies between €302 and €341 (interval: €161-€1,810) per week.

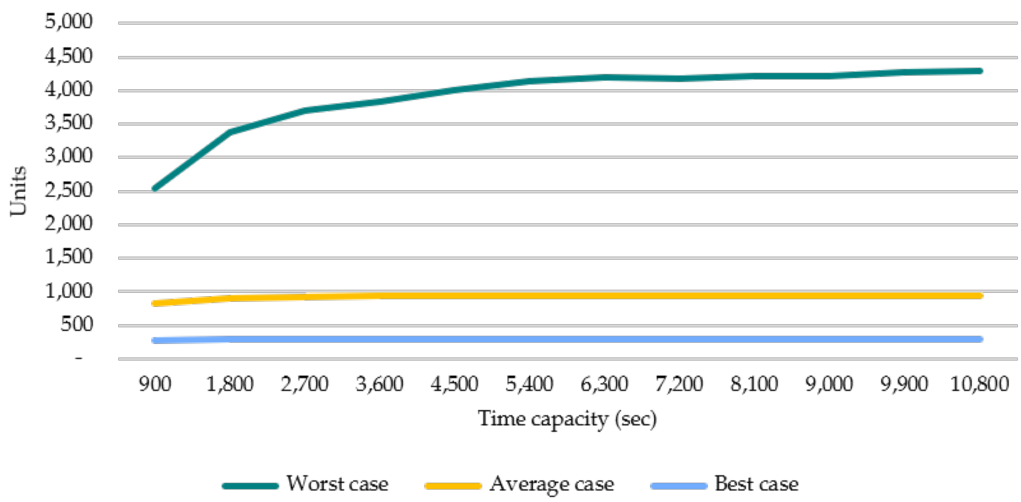

FIGURE 15: Returns per week over an increasing time capacity when maximising savings

Most units originating from the filling unit are returned first, with remaining seconds being filled with more expensive medication from the apothecary cabinet. There are a few selection criteria whether medication is returned or not. First, medication from the filling unit is always returned when it has a value of €0.03 per unit or more. Medication from the apothecary cabinet is returned when it has a value of €0.70 or more per unit. Figure 17 displays the percentage of returned units located in the filling unit and apothecary cabinet when allowing 15 minutes per day. Figure 18 displays the percentage of units returned within 15 minutes per day containing a label.

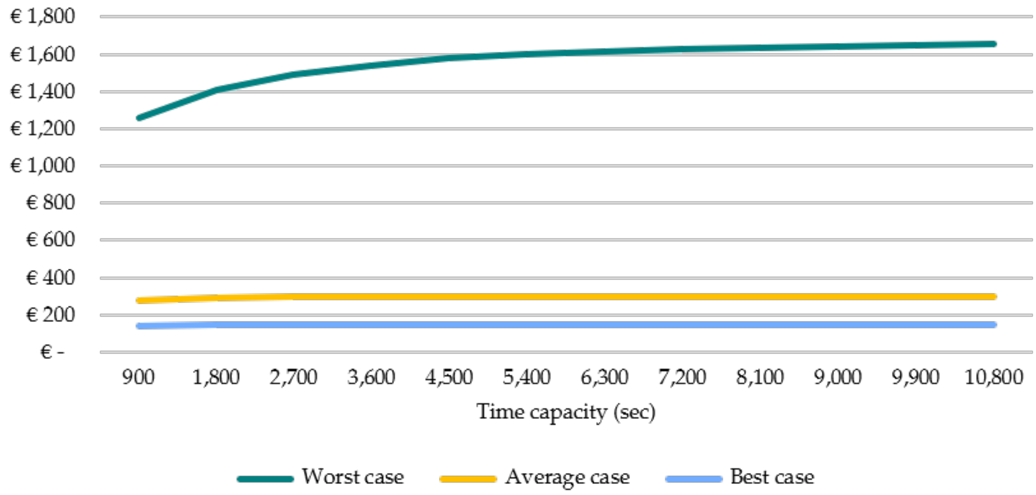

FIGURE 16: Savings per week over an increasing time capacity when maximising savings

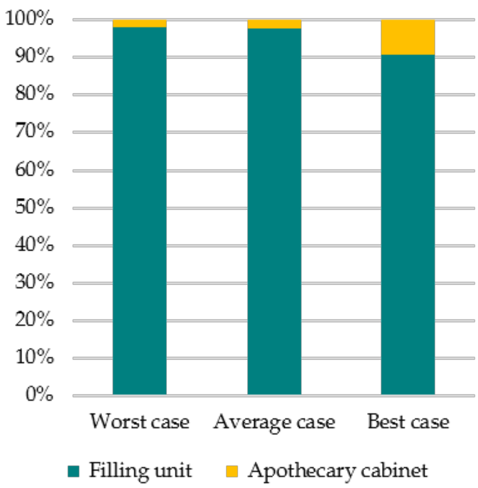

FIGURE 17: Location of units returned within 15 minutes when maximising savings

FIGURE 18: Labels of units returned within 15 minutes when maximising savings

5.2.3 Overall decision and consequences

Returning medication results in savings in terms of waste reduction and cost-savings, regardless of the objective to maximise savings or returns. Figure 11 and Figure 15 display the returns per week over an increasing time capacity and these highlight that within 15 minutes per day, unused medication is always saved from the waste bin. Figure 12 and Figure 16 display the net savings per week over an increasing time capacity. As visualised, these savings are non-negative for each time capacity, indicating that returning unused medication is cost-efficient at every time capacity.

There are criteria for including medication types to return to the shelves. When maximising returns, all medication from the filling unit are returned and remaining time is filled with returning medication from the apothecary cabinet. When maximising net savings, all medication in the filling unit is returned with a value of €0.03 per unit or more. Medication from the apothecary cabinet is returned when it has a value of €0.70 per unit or more. Table 8 displays an overview of the inclusion criteria per objective function.

TABLE 8: Decision criteria for returning medication

Objective function	Filling unit	Apothecary cabinet
Maximise returns	Return all	Include max $D_p \phi_p$
Maximise savings	$V_p \geq$ €0.03	$V_p \geq$ €0.70

Whether aiming for maximum returns or maximum savings, a waste reduction of at least 49% is possible in terms of medication units disposed of when allowing 15 minutes per day to place medication back in the inventory. While allowing theses 15 minutes per day, the net savings are at least €66 per week. More specifically, when maximising returns, at least 67% of unused medication units can be saved from the waste bin per week when allowing 15 minutes per day, with net savings of at least €66 per week. With maximising savings, a minimal waste reduction of 49% per week is possible with 15 minutes per day, with net savings of €141 or more per week.

5.2.4 LP relaxation

We run the LP relaxation in order to have an upper bound to the solution value [46]. The model solution cannot exceed the LP relaxation solution [46]. It facilitates an easy comparison to the model outcomes and the LP relaxation outcomes. The difference between the two outcomes is the integrality gap, which we calculate as the model solution minus the LP relaxation solution. By changing the variable $X_p \in [0, 1]$ to $0 \leq X_p \leq 1$, we receive the LP relaxation of our problem. We run this version for the three instances and two objective functions.

When maximising returns, the average deviation is 2 units per week (interval: 1-5 units). The savings, however, have larger gaps. The savings for the average and best case instances are at most €17 per week and €29 per week, respectively. For the worst case instance, a deviation of €3,534 is found. This results from the large quantities returning in this instance, especially on Fridays. When the total quantity of one medication type is too large to be returned within the time capacity, it is not returned at all in our model. However, in the LP relaxation, a large part of the quantities can still be returned since X_p can take any value between 0 and 1, indicating not all medication of this specific type has to be returned. Still, the objective is to maximise the returns and the model solution approaches the upper bound given by LP relaxation.

The difference between the LP relaxation and the model with regard to maximising savings results in an average deviation of 2 units per week (interval: 1-49 units). The gap between the LP relaxation savings and model savings is small, as this is at most €1 per week for all three instances. The model solution is therefore extremely close to the upper bound provided by the LP relaxation.

Overall, the solutions provided by our model are optimal. Returning medication is beneficial regardless of the time capacity, objective, and instance, and supports waste reduction while remaining cost-efficient.

5.3 Conclusion

In Chapter 5, we first initialise the model, run it, and then analyse the outcomes. A total of 312 medication types are analysed for five days in the week, with twelve time capacities, two objective functions, and for three instances. When spending 15 additional minutes per day, at least 49% of unused medication that returns to KF can be returned to the inventory again with at least €66 in savings per week. More specifically, when maximising returns, an average of 84% of returned medication can be prevented from being disposed of with an average of €191 saved per week, when taking 15 additional minutes per day. When maximising the savings, an average of 75% of the unused medication can be prevented from being disposed of, with average savings of €279 per week, taking 15 minutes per day to return medication to the shelves. While the model outcomes are promising with regard to the waste reduction and cost-efficiency of returning unused medication, it is beneficial to perform a pilot to return medication in practice to compare whether the actual time to return medication resembles the model output.

Chapter 6

Empirical testing in practice

Chapter 6 discusses the pilot executed for the filling unit serving wards 2.4B and 2.5A. Section 6.1 discusses the design of the pilot. Next, Section 6.2 discusses the pre-intervention state, and Section 6.3 discusses the post-intervention state. Then, Section 6.4 compares the results of the pilot with the model outcomes of Chapter 5.

6.1 Pilot design

In Chapter 5, we conclude that returning unused medication strongly decreases the total quantity of unused medication at KF that is disposed of, while remaining cost-efficient and being restricted by time. Even when only a few minutes per day are available to return unused medication to the shelves, a difference is present in terms of quantities of unused medication and investments saved from the black waste bin. Therefore, we advise to test it in practice and we do so by creating a pilot for the filling unit serving wards 2.4B and 2.5A.

Before starting the pilot, we first analyse medication that returns to KF and is disposed of at the end of the day. The baseline measurement consists of medication that returns to KF from wards 2.4B and 2.5A and is disposed of at the end of the day. This leftover medication is counted by one of the pharmacy interns. A total of two counts are held, where one count is performed for a workday with medication distributed for another workday and one count is performed for medication that was distributed on a Friday for Friday, Saturday and Sunday. By considering a regular workday and a Friday, a difference in quantities returning is visible as there is a large difference in quantities distributed on these days.

When the returned and disposed medication is counted, the quality of the medication is assessed to verify that medication is indeed in a perfect state and completely safe to use for the next distribution round. A large share of the returned contents should be in this perfect state in order for the pilot to commence.

After verifying that medication does return in excessive quantities and is usable, the pilot is prepared. The pharmacy assistants receive clear instructions on how to assess the state of returned medication, and how to return, collect, and redistribute this medication. All medication types receive a return box that is placed in front of the original packaging. Appendix D contains a photo of a selection of medication types together with their return boxes. The assigned pharmacy assistant on pilot days is notified who to contact or alert in case the process does not go as supposed to. Moreover, it is emphasized that it is possible to stop placing returned medication on the shelves when the workload becomes too large. Medication is then disposed of instead, as how it happened before the pilot.

A few days after the start of the pilot, new counts are held. We have a count on at least one Tuesday to account for the large quantities disposed of after the weekend to verify a great reduction. Another count is held for another weekday to verify that there is a waste reduction for regular weekdays as well. Counts are held at the end of the day, after the medication cart has been filled and the pharmacy assistant is finished with all distribution tasks on that particular day. The counts are held by a pharmacy intern, who counts all medication that is still disposed of at the end of the day, while usable medication has been returned to the shelves. These counts after the start of the pilot should verify that there is indeed a waste reduction in % on the days where returned and usable medication is returned to the inventory. All medication that is disposed of on these days are assessed on their quality.

Next, the pharmacy assistants are surveyed in order to get a clear picture on their experience with the new process. We consider both the experience with the intervention in terms of effort, workload and attitude towards the change, as their opinion regarding job satisfaction. The survey is based on the Job Satisfaction Survey developed by Spector [39]. Appendix F shows an overview of the questions asked and the given answers. The results of the survey are analysed and discussed with the department of KF to highlight possible issues and to facilitate a discussion on how to further improve the process.

6.2 Pre-intervention

The pre-intervention counts happened on Tuesday, November 8th 2022 and Wednesday, November 16th 2022. The drawers analysed on Tuesday were the ones distributed on Friday, November 4th 2022 and the drawers analysed on Wednesday were distributed on Monday, November 14th 2022.

Table 9 displays the characteristics of the returned medication. A total of 589 units returned to KF and this had a total value of €127.39. Of these 589 units, 560 (95%) units were still in perfect state. 453 (77%) of the returned units originated from the filling unit. Also, 143 (24%) units had a 2D label. A clear difference in quantities returned is visible between the two days. The returned quantities that were initially distributed on a Friday is 2.25 times larger than the quantities that were initially distributed on a Monday. This follows our hypothesis; more medication is distributed on Fridays and consequently more medication is returned.

TABLE 9: Results of the pre-intervention counts
(November 2022, n=589)

Count date	Distribution date	Quantity unused	Value unused	Units with 2D label	Units from filling unit	Units from apothecary cabinet	Units reusable
Tuesday Nov. 8th	Friday Nov. 4th	408	€ 85.95	90	312	96	388
Wednesday Nov. 16th	Monday Nov. 14th	181	€ 41.43	53	141	40	172
Total		**589**	**€ 127.39**	**143**	**453**	**136**	**560**

Worth mentioning is that returned and counted medication hardly overlapped with medication registered as 'unused' in Isala's database. There are several causes that could result in this discrepancy. First, patients may be transferred to another ward. The medication located at the patient then follows the patient to the new ward and therefore does not return to KF via the ward's cart. Second, it could be the case that medication is left behind at the ward when the carts are switched and unused medication returns to KF with a delay. Third, patients may also bring medication from home and this medication is used first. Medication is then registered as administered, but it is a different unit than prepared and distributed by KF. Fourth, nurses may be in a rush and take medication from the ward's inventory instead of the medication supplied by KF. The unit is then again registered as administered, yet the unit originated from a different inventory than that of KF.

While it is difficult to know the exact quantities of unused medication from all wards that is returned to KF on a daily basis, this is not considered a major issue. Unused medication eventually returns to KF, either on a different day and/or at a different filling unit. Before the pilot starts, all unused medication is disposed of in the black waste bin, while 95% of this unused and returned medication is in a perfect condition to be used by a patient.

6.3 Post-intervention

We consider counts after the pilot and the results of the survey sent to pharmacy assistants.

6.3.1 Counts

Three counts are held on Thursday November 24th 2022, Tuesday December 6th 2022 and Monday December 12th 2022. Table 10 shows the characteristics of the counted medication. A total of 82 units remained unused at the end of the three days with a total value of €55.79. 63 of these 82 units were still in the same state as when they initially left KF.

TABLE 10: Results of the post-intervention counts (November & December 2022, n=82)

Count date	Distribution date	Quantity unused	Value unused	Units with 2D label	Units from filling unit	Units from apothecary cabinet	Units reusable
Thursday Nov. 24	Tuesday Nov. 22	15*	€ 5.59	10	6	8	6
Tuesday Dec. 6	Friday Dec. 2	33	€ 41.55	18	3	30	24
Monday Dec. 12	Thursday Dec. 8	34	€ 8.65	25	8	26	33
Total		**82**	**€ 55.79**	**53**	**17**	**64**	**63**

*Of which one unit was unidentifiable

Most remaining medication originated from the apothecary cabinet. This could be a reason why this type of medication remained at the end of the day. Returning medication to the apothecary cabinet requires more effort and time. After the counts, pharmacists and pharmacy assistants were still able to return some medication to the apothecary cabinet. Therefore, it could be that the final quantities that were disposed of are smaller than displayed in Table 10.

6.3.2 Employee experience survey

The survey is conducted in the period between January 23rd and February 1st 2023, after the pilot ran for eight weeks. Appendix F contains the survey questions and the aggregated answers given.

A total of thirteen pharmacy assistants responded, ranging in their experience with placing returned medication back. Four assistants have placed medication back during more than ten shifts already, six pharmacy assistants have placed it back during three to four shifts, and three pharmacy assistants placed medication back during at most two shifts. They somewhat agree that there is an increase in workload, with five respondents remaining neutral, five agreeing that workload increased, and three pharmacy assistants (strongly) disagreeing that workload increased. The indicated additional time as perceived by the pharmacy assistants to place medication back varies between 5 minutes to at most 60 minutes, but centers around 15 minutes. The busiest day experienced with regard to distributing and returning medication is the Friday, followed by the Tuesday.

Twelve of the thirteen pharmacy assistants (strongly) agree that returning medication is going well. With regard to their job satisfaction, the (new) operating procedures receive an average score of 3.3 out of five. The most disliked aspects of the operating procedure are having too much paperwork and too much to do at work, and the best scoring statement is that rules and procedure do not make their work difficult. The nature of the work is highly valued with an average score of 4.5. They all agree (very) strongly that their work is enjoyable and that they feel proud in doing their job.

To get more in depth in the survey answers, we also consider the individual responses. The more experienced pharmacy assistants who have returned medication during most shifts mention that the additional perceived workload on a day ranges between 5 and 10 minutes. When asked what their opinion was on placing returned medication back, they all agreed that it is a good idea and results in less waste. Moreover, the pharmacy assistants that place medication back on several days in the week and who have placed medication back for ten or more shifts agree that Tuesday is the busiest day of the week experienced when including the new activity to return medication.

A point for improvement is to switch to transparent return boxes since it is difficult to see if the return boxes have contents in them. Especially for shorter pharmacy assistants, it is difficult to check whether the return box contains medication.

Another mentioned point for improvement is to place a few more medication types at the wards and to stop distributing these medication types from KF. There is already a list of medication types that are not distributed by KF, e.g., paracetamol, and these types are located at the wards instead. A pharmacy assistant recommends to add a few more medication types to this list, and to keep the list equal for all wards at Isala Zwolle and Isala Meppel.

Last, one pharmacy assistant mentions to place a more general box in the filling unit as well for collecting unused, returned and 100% safe medication. In case there is too much workload on a given day, the remaining medication can be placed in this box. The contents can be returned in the correct location in the filling unit or the apothecary cabinet later during the week when there is less workload.

To conclude, returning medication is going very well and the experienced additional workload varies between 5 and 60 minutes extra per day. The busiest days experienced when including returning and distributing medication are the Tuesdays and Fridays. It is recommended to use transparent return boxes to be able to quickly see whether there is medication present in the return box.

6.4 Comparison pilot and model

We compare the pilot results with the model outcomes of Chapter 5. We discuss the daily additional workload, the busiest day in the week, the reduction of medication waste, and the decisions made when returning medication.

6.4.1 Daily additional workload

By allowing 15 additional minutes per day, an average of 84% of unused medication can be returned to the shelves according to the model outcomes. It is expected that more time may be needed on Tuesdays for returning unused medication, as the quantity returning to KF on these days is significantly larger than on other weekdays. These 15 additional minutes and the 84% reduction in medication waste are comparable to the survey outcomes and the count results. The perceived additional workload centers around these 15 minutes. Moreover, the pre-intervention counts show 589 units to be disposed of afterwards, and the post-intervention counts remain with 82 usable units to be disposed of, indicating a waste reduction of 86%.

The extreme cases presented in the model, however, are not mentioned or found in the pilot. The pharmacy assistants experience a maximum additional workload of one hour, whereas the worst case instance of the model presents situations where three hours may be needed to return unused medication. More specifically, whereas most medication can be returned in 15 additional minutes per day, the model suggests that an average of 50 minutes to one hour are required to return all medication to the inventory for medication distributed on Mondays to Thursdays, and at least two hours are necessary to return medication distributed on Fridays. The model therefore shows a flaw with regard to the actual time it takes to return medication. A better approximation of the parameters with regard to the time to return medication may improve the results and comparability of the model with the pilot.

6.4.2 Busiest day

The pharmacy assistants perceive Fridays and Tuesdays as the busiest days of the week. The model outcomes suggest that Tuesdays are indeed likely to become the busiest days of the week when returning and distributing medication, followed by Thursdays and Fridays. The more experienced pharmacy assistants support the perception that Tuesdays are the busiest. Therefore, we expect that Tuesdays are indeed the busiest days, followed by Fridays. Thursdays are not considered to have a larger workload than other days by the pharmacy assistants. This is logical, as medication distributed on Thursdays is slightly more than distributed on Mondays, Tuesdays and Wednesdays, and the total medication to be returned to the shelves on Thursdays is the smallest number of medication to be returned of the week.

6.4.3 Reduction in medication waste

Within 15 minutes extra per day, an average 84% of returned units can be returned to the inventory per week and therefore saved from the black waste bin, when looking at the model outcomes. More specifically, a waste reduction between 49% and 84% is possible according to our model. The pre- and post-intervention counts indicate a a reduction of 86% is possible over a few days. When we compare the count results of medication distributed on Fridays alone, we see a reduction from 408 returned units to 33 units, indicating a waste reduction of 92%.

Therefore, a clear reduction in unused medication ending up as waste is indeed visible. The model, however, assumes that all unused and returned medication is still perfectly usable, whereas this is not the case for the pilot. In reality, medication remaining at the end of the day might not be usable anymore and are therefore still disposed of. On the two pre-intervention counts, 95% of the returned medication was perfectly usable. The remaining 5% was considered unusable due to opened or damaged packaging or a missing expiration date. Therefore, a total reduction of 100% is unattainable, but a reduction of 95% is definitely possible. Moreover, the waste reduction currently achieved is significant.

6.4.4 Decisions to return medication

In reality, the pharmacy assistants return all unused and still perfectly usable medication to the filling unit and to the apothecary cabinet. They do not decide or check during returning medication if the value of the medication to be returned is high enough for this medication type to include. All medication is returned, unless there is indeed no time left to return medication. Verifying the value of the medication would require more time of the pharmacy assistants, and therefore does not occur; it is simply returned.

The model provides strict criteria to return medication. When wanting to maximise the returns, simply all medication is returned to the shelves. When wanting to maximise savings, medication is only considered worth-wile to be returned when the medication exceeds a certain value. To incorporate the time to verify the value of medication, the model could be extended to provide some sort of penalty for this verification. However, this may make the model unnecessarily difficult.

6.5 Conclusion

Returning medication is tested in practice for one filling unit. Before testing in practice, counts are held to verify medication returns to KF and is disposed of. Afterwards, counts are held again to verify less medication is disposed of and the pharmacy assistants are surveyed for their opinion and attitude towards the return process. A significant reduction in medication waste is present. Returning medication is perceived to require 15 additional minutes per day on average with a maximum of one hour, as mentioned by the pharmacy assistants. The pharmacy assistants agree that returning medication is going well and results in a visible reduction of medication waste. One point for improvement is to use transparent return boxes. Overall, returning medication is going very well, results in a significant decrease in medication waste, and does not constrain the pharmacy assistants too much with regard to the workload.

Chapter 7

Conclusion

Chapter 7 draws the conclusions of this research, discusses the outcomes, and provides future research directions. Section 7.1 provides the conclusion and main findings of this research. Section 7.2 discusses this research and the corresponding findings. Section 7.3 provides recommendations and opportunities for further research.

7.1 Conclusions

The healthcare industry is responsible for 5-10% of emitted greenhouse gases [38]. The industry aims to care for and cure people, whereas the effects of climate change do the opposite [27]. Moreover, the demand for healthcare increases, especially in an aging population [41]. Stopping to provide healthcare is not an option, but making healthcare more sustainable is [13]. Within the Netherlands, healthcare institutions are collaborating to make the Dutch healthcare industry more sustainable via the Green Deal for sustainable care [13]. This Green Deal consists of four pillars, with one of these being to reduce pharmaceutical waste in water [13]. There are several ways in which pharmaceutics end up in the water system, and these all harm water quality and the organisms living in it [36, 42, 28].

Several initiatives are already in place to reduce pharmaceutics in water. First, a stricter collection systems ensures medication waste is incinerated instead of disposed of via the sewage system [47, 36]. Second, total doses per package are reduced to decrease excess medication waste [1, 42, 31]. Third, the expiration date is monitored to ensure patients are able to use all medication before it expires [1]. Fourth, prescribing less medication results in less medication waste [36].

In the mentioned initiatives to reduce medication waste, there is still a great quantity of unused but usable medication. Patients and physicians are left with this medication, and this is incinerated afterwards. This medication is often still usable, and it would be better to find a purpose for this medication instead of incinerating it. Therefore, this research aims to reduce unused medication by redistributing it to ensure no unused but usable medication is disposed of.

Our research is tested in practice at Isala hospital in Zwolle. Before our intervention is implemented, a great amount of medication distributed to admitted patients remained unused and was consequently disposed of afterwards. Given the polluting production and supply chain of medication, disposing such quantities without a reason cannot be justified. Moreover, there is an increasing list of scarce medication types, emphasizing the illogical decision to dispose medication. The pharmacists and pharmacy assistants agree that something needs to happen to reduce the great amount of usable medication that was disposed of daily before the implementation of our intervention. Therefore, we research the possibility to reduce unused medication to prevent this medication from being disposed of and incinerated afterwards.

Before any change is made in the medication distribution process at Isala Zwolle's department of KF, we first analyse medication that remains unused. 33% of distributed medication to admitted patients is not administered to patients. This fraction is comparable to other Dutch hospitals that analyse their medication waste, but this does not justify the act to dispose of unused medication [20]. Medication remains unused either due to a change in the patient's clinical state and the medication becoming redundant, the patient having brought medication from home, or the patient being released and not present anymore. These causes are in line with the main cause found in the literature that results in unused medication; too much medication is provided to patients. The unused medication eventually returns to KF and this medication was previously disposed of in a black waste bin for medication waste, and this bin is incinerated afterwards. However, at least 95% of this returned and unused medication is still usable and in a perfect condition to be distributed again.

To reduce unused medication waste, we implement the intervention to place returned and usable medication in return boxes in the inventory. During the next round of medication distribution, medication is collected first from these return boxes. Before we make any changes in the process, we perform a prospective risk analysis and determine ways to mitigate risks. Possible risks include unusable and opened medication to be placed in the return boxes, medication placed in the incorrect return boxes, and medication expiring in the return boxes. An experienced and trained pharmacy assistant verifies medication is still usable before locating it in a return box. Second, since all medication is scanned before leaving the department of KF, and before being administered to a patient, no incorrect medication is redistributed or administered to a patient. Third, medication in the return boxes is included in the monthly check for expired medication, and all medication contains its expiration date on the packaging. Also, by prioritising the distribution of medication in the return boxes, medication follows a first expired, first out process. The possible risks accompanying the process to redistribute unused medication are therefore mitigated, and the intervention to redistribute this medication can safely be implemented at Isala Zwolle.

We conclude that redistributing unused medication has no negative consequences for patient safety and quality of care. Next, we study if it is possible to redistribute the unused medication cost-efficiently and indeed reducing unused medication waste all together. We formulate a knapsack problem that supports the decision to return certain medication types. The objective of the model is to either maximise the total returns to reduce medication waste, or to maximise the possible savings by redistributing medication. The model is restricted by a time capacity, since returning unused medication requires additional time by the pharmacy assistants. For both objectives, it should be possible to reduce unused medication while also being cost-efficient.

The formulated model is run for five workdays, a daily time capacity between 15 and 180 minutes, the objectives to maximise returns and to maximise savings, and for a worst case, average case, and best case situation. For each workday, time capacity, objective, and situation, it is beneficial to redistribute unused medication. In each possible configuration, there is a reduction in medication waste, and there are savings. Within 15 minutes per day, an average of 84% of returned medication can be redistributed with average savings of €191 per week. More specifically, within these 15 additional minutes, at least 49% of unused medication can be redistributed, with savings of at least €66 per week. The outcomes of the model suggest that redistributing unused medication therefore always results in a reduction in medication waste.

The prospective risk analysis indicates that there are no negative consequences for patient safety and quality of care when redistributing unused medication. The model and its outcomes suggest that under any circumstance, a reduction of unused medication waste is possible while remaining cost-efficient. The next step is to verify these results by the means of a pilot. This pilot is considered very successful and a clear reduction in waste is visible. For example, leftover medication distributed for a weekend reduced from 408 units to 33 units. This is a waste reduction of 92%. Therefore, the pilot concludes that indeed a reduction in medication waste is possible by redistributing unused medication.

After the start of the pilot, we survey the thirteen pharmacy assistants who have worked during shifts where unused medication is returned to the return boxes. They perceive the additional time required to return unused medication to center around 15 minutes. They also agree that medication waste reduced by redistributing unused medication. Moreover, they agree that the implementation is going very well. There is one major point for improvement, namely to use transparent return boxes. Overall, the perception of the pharmacy assistants towards redistributing unused medication is very positive and again emphasizes that redistributing unused medication results in less medication waste.

To summarize, medication waste negatively influences water quality and overall has a negative effect on climate change. At Isala Zwolle, a large fraction of medication waste results from unused medication. This unused medication can be redistributed in order to be used. By redistributing this medication, medication waste decreases without negative consequences for the patients, while being cost-efficient, and not putting too great of a burden on the employees involved with the redistribution process. We conclude that returning medication in the return boxes is always a cost-efficient and waste reducing decision.

The practical contribution of this research is visualised in the case study at Isala Zwolle. By redistributing unused medication, less medication is used to treat the same number of patients, less unused medication is disposed of and incinerated afterwards, and savings are made. Importantly, patients experience no negative consequences, and involved employees agree that the new process is going well. Overall, the new process supports Isala hospital Zwolle in becoming more sustainable.

The theoretical contribution of this research is an initiative to reduce medication waste and finding a purpose for unused medication. Moreover, a model is developed and presented to ensure that redistributing unused medication is cost-efficient and indeed reduces medication waste.

7.2 Discussion

While this research indicates that it is possible to safely and cost-efficiently reduce medication waste, there are a few points in our research that need to be discussed. First, there is a discrepancy between the data on returned and unused medication and the actual returned and unused medication. We do believe that unused medication eventually returns to KF and can therefore be saved from the black waste bin. However, it would have been better to have more overlap between actual returned medication and the database's list of medication to verify that the process of how medication returns to KF is correct and realistic. Currently, we cannot be 100% certain that all unused medication indeed arrives at KF. Moreover, we also do not know the exact reason why medication remains unused and returns to KF. When the causes are known, it may be possible to distribute less medication all together, and therefore reduce unused medication. For example, when the discharge date is accurately updated, medication is not distributed anymore for the time after this date.

Second, we have no clear overview of the activities and ways of working at the wards. As a consequence, unused medication does not return to KF and other medication appears that has never been distributed, which is one of the causes for the discrepancy mentioned. Visiting the wards and discussing with the nurses may support a better streamlined distribution process where unused medication always returns to KF instead of disposing it at the wards to ensure no perfect medication is disposed of. It would also be appreciated to survey the nurses on their experience with redistributing unused medication to verify that the intervention also works properly at the wards.

Third, the model parameters could be estimated more accurately. The maximum time to return all possible medication exceeds the time mentioned by the pharmacy assistants. By timing the activities at KF, a better estimation could be made for the parameters. However, timing the pharmacy assistants is not desirable, since observing them could make them feel uncomfortable.

Fourth, the model considers all returned medication to be 100% perfectly usable for redistribution. This is obviously not the case, as medication medication returns with opened packages, lost 2D labels, or medication returns that was never distributed by KF. Expanding the model to account for the possibility that medication is unusable would make it more accurate.

Fifth, the model considers one daily batch of unused medication to be returned to KF. In reality, the pharmacy assistants process small batches of returned medication via the patient drawers. There are situations where medication is returned and has to be distributed again right away, since the patient still has a prescription for this medication. In these situations, the process of collecting this specific medication is not required, and the medication simply has to be scanned again and placed in the drawer. This is faster than returning medication to the inventory and this could speed up the complete process. By considering the batches in the patient drawer, another parameter could be added to the model with a probability of medication still being on prescription.

7.3 Recommendations and further research

With regard to the intervention and its implementation, we recommend to return all usable medication that is returned to KF via the patient drawers. By doing so, a reduction in medication waste is ensured and in all cases, it is cost-efficient to do so. Furthermore, we recommend to use transparent return boxes for quick observation whether medication is present in the return box.

For further research, we recommend to expand the model formulation to resemble reality more. Instead of using batches from a medication cart, the model uses the batches from a patient drawer. Additionally, it is recommended to add a probability that medication is still perfectly usable when returned to KF. Also, the model accuracy would improve by adding a probability that medication is still on prescription when returned via the patient drawer. When medication is still on prescription, it does not have to be returned to the inventory location and the processing of it is faster than returning it.

Next, we recommend to analyse the distribution process beyond the borders of KF. By researching the process at the wards and including a reason why medication is not administered in the first place, data accuracy could be significantly be improved. By doing so, it may be worth-wile to distribute less medication overall.

Finally, when implementing the intervention at other hospitals or pharmacies, it is recommended to survey the pharmacy assistants before the implementation as well. By doing so, their view towards sustainability and efforts to become more sustainable, job satisfaction, and possible disadvantages or obstacles of returning medication are known beforehand. It makes comparing the pre- and post-intervention states easier, and it may increase employee involvement and participation.

Appendix A

The Green Deal for sustainable care

The first version of the Green Deal for sustainable healthcare was presented in the Netherlands in 2015, which encouraged involved organisations and groups to make Dutch healthcare more environmentally sustainable [23]. The motive to do so is equal to that of other institutions, being the large influence and effect healthcare has on national carbon emissions and the negative consequences of the climate crisis on people's health [38, 23]. Via the Green Deal, involved organisations start to see the importance of environmentally sustainable healthcare and they are encouraged to quickly improve their sustainability [15]. The Green Deal has evolved over the past years and more parties became involved with becoming more environmentally sustainable. The last version of the Green Deal is version 2.0 and it has over 300 involved parties, which all aim to become more sustainable in line with the following four pillars:

- CO_2 emission reduction;
- improving circularity;
- reducing pharmaceutical waste in water;
- encouraging people to improve their health by offering a healthy living environment.

For all pillars, the initiatives and practices followed are similar to the ones mentioned in Section 2.1. There are, however, a few additional initiatives mentioned by gray literature published about the Green Deal. One of these initiatives is the usage of urine bags by patients who take highly damaging medication such that residue does not end up in the sewage system [15]. Another one is to capture gases used by anaesthetics such that these gases do not roam straight into the air and its residue can afterwards be disposed in an environmentally friendlier way [8].

Within the themes of the Green Deal, carbon reduction receives most attention, whereas reduction of pharmaceutical waste receives least [15]. The reasoning behind this difference is that for carbon emission reductions, a concise and clear goal is set, whereas the reduction of pharmaceutical waste is merely a goal to strive for and to keep in mind [15]. Moreover, the reduction of CO_2 is a general sustainable practice where initiatives can be copied from other industries who also focus on sustainability, whereas the reduction of pharmaceutical waste is an initiative which is specifically for healthcare and can be directly influenced by care providers.

Appendix B

Systematic literature review on sustainable initiatives in healthcare

The systematic literature review with regard to sustainable initiatives in healthcare is performed via the database of PubMed, as this search engine focuses on topics directly related to the healthcare industry. The search string used in this review is:

("environmental sustainability") AND healthcare AND (practice OR initiative*)*

The initial search results in 97 articles. These results are filtered in the following order. First, all articles used are published within the last 10 years such that all information is relevant and findings are up to date. Next, the results are filtered such that all remaining articles are written in Dutch or English. The species selected is set to humans such that all articles with regard to medication is relevant and medication switches are medically safe for humans. Next, articles are filtered on their accessibility such that they can be fully read with a license from the University of Twente. Last, articles are excluded in case their topics are irrelevant for this research. An overview of this filtering process is displayed in Table 11.

TABLE 11: Overview of search results on sustainability in healthcare

Keywords	**Number of sources**
PubMed database *("environmental sustainability") AND healthcare AND (practice* OR initiative*)*	97
Exclusion criteria	
Published more than ten years earlier	-12
Language is not English or Dutch	-1
Species focused on is not human	-9
Article is not fully accessible	-9
Topic is not relevant for this research	-41
Total remaining sources used	**25**

The common themes in the remaining 25 articles are video consultations, optimal patient planning and patient transportation for lean service delivery, and energy & water efficiency, general waste reduction, reducing medication waste, and food changes for low carbon alternatives. An overview of the found papers together with their discussed topics is displayed in Table 12.

TABLE 12: Overview of themes discussed in literature review

Source / Topic	**Video consultation**	**Optimal planning**	**Patient transportation**	**Energy & water efficiency**	**General waste reduction**	**Medication waste reduction**	**Diet switch**
Koytcheva et al. [22]			x	x	x	x	
Lyne et al. [25]					x		
Allwright & Abbott [1]	x					x	
Duane et al. [10]	x	x			x	x	
Duane et al. [12]	x	x	x				
Spruell et al. [40]	x					x	
Mendoza-Vasconez et al. [26]							x
Lister et al. [24]				x	x		
Evans [16]	x			x	x		
Wohlford et al. [47]				x	x	x	
Yates et al. [48]	x			x	x		
Petre & Malherbe [31]	x		x	x	x	x	
Thomas & Depledge [42]						x	
Van Norman & Jackson [43]					x	x	
Duane et al. [11]					x	x	
Richie [36]					x	x	
Bajgoric et al. [2]					x		
Richie [35]			x				x
Barraclough et al. [4]			x	x	x		
Petre et al. [30]				x	x	x	
Barbariol et al. [3]						x	
Eleftheriades et al. [14]					x	x	
White et al. [45]				x	x	x	
Ranjbari et al. [33]					x	x	
Wainer [44]	x	x	x				

Appendix C

Health Failure Mode and Effect Analysis

Before implementing the intervention to place returned medication back on the shelves, a Health Failure Mode and Effect Analysis (HFMEA) is performed. This analysis aims to identify all possible risks associated with redistributing returned medication before implementing the redistribution. The HFMEA is created in contribution with the employees at KF as they are the only employees directly affected by an intervention in the current distribution process. These employees are responsible for placing medication back correctly and remaining strict and cautious when distributing medication from the return boxes. Additionally, these employees are also the people affected by the additional task of placing medication back during their regular work time and are therefore affected most by time pressures.

All steps in the process are considered together with their possible failure modes, causes, occurrence (O), severity (S), detection (D), and risk priority number (RPN). The meaning behind the values used of O, S and D are displayed in Table 14, Table 13 and Table 15, respectively. The categorisation and values behind O, S and D are adapted from the guidelines by Isala to conduct the HFMEA.

The HFMEA is displayed in Table 16. The RPN is the product of the values ascribed to O, S and D. All failure modes with an RPN score exceeding 20 are elaborated upon to decrease the RPN via measures and guidelines. Table 17 provides the measures and guidelines for these failure modes.

TABLE 13: Severity of failure modes

Severity	**Description**	**Value**
No	No consequences for the quality of the product/service. No consequences for further process steps. No consequences for the patient.	1
Minimal	Very few consequences for the quality of the product/service. Few consequences for further process steps. Light discomfort for the patient at most.	2
Small	Few consequences for the quality of the product/service. Consequences for the next process steps. Light discomfort for the patient. (for example waiting time).	3
Large	Severe consequences for the quality of the product/service. Consequences for the next process steps. Could lead to temporary consequences for the patient.	4
Catastrophic	Unacceptable quality of the product/service. Next process steps cannot be followed. Could lead to permanent severe damage for the patient or could lead to patient to decease.	5

TABLE 14: Occurrence of failure modes

Occurrence	Description	Value
Extremely low	Highly unlikely to occur (<1x/year)	1
Very low	Unlikely to occur (1-2x/year)	2
Low	Unlikely to occur often (3-6x/year)	3
Imaginable	It is imaginable to occur frequently (1x/month)	4
High	Could occur weekly or daily	5

TABLE 15: Probability of detection of failure modes

Probability of detection	Value
Will definitely be detected	1
Is likely to be detected	2
May be detected	3
Is unlikely to be detected	4
Will definitely not be detected	5

TABLE 16: HFMEA of returning unused medication

Process step	Failure mode	Cause	O	S	D	RPN
Check the drawer for usable medication that the patient has/had on prescription.	Unnecessary medication remains in the patient drawer.	The prescription has stopped.	3	3	1	9
		Medication is wrongly identified	3	3	1	9
Check the drawer for medication that can be redistributed.	Medication is not usable anymore.	(Half) opened medication.	5	4	1	20
		Medication does not contain product name.	5	4	1	20
		Printed 2D label is gone.	5	1	1	5
		Blister is empty and medication is used.	5	1	1	5
		Expiration date is unclear.	5	3	2	30
		Packaging is not representative.	5	1	1	5
Place medication back in the filling unit if medication belongs in assortment.	Medication is placed back wrongly.	Failed to pay attention or look closely.	4	5	3	60
	Medication is not placed back.	Failed to pay attention or look closely.	3	1	1	3
Collect medication for the patient from the return box.	Wrong medication is located in the return box.	Medication is placed back in the wrong box.	4	5	3	60

TABLE 17: Measures to mitigate risks

Failure mode	Description/elaboration	Measure	New RPN
Medication is not usable anymore, because it is (half) opened and distributed.	Not clinically relevant, since this is extremely likely to be detected.	None, irrelevant	<15
Medication is not usable anymore, because medication does not contain product name.	This will always be detected.	None, irrelevant	<15
Place medication back in the wrong location; in a different return box.	There is a large probability that medication is placed incorrectly. Ideally, this is detected either when medication is scanned or via a visual check. In the worst case, the nurse can catch the mistake as well when scanning or via a visual check. This situation is less preferred. Since distributing several units of one medication type only requires one scan, a work agreement is necessary to prevent this at the department of KF or at the nursing wards.	Instructions central distribution: When having more than one unit per medication administration moment, ensure that you collect a set of medication units that are attached to each other, instead of collecting several single units in order to verify that all medication that you scan are correct. When there is one or less units per administration moment, a nurse scans the medication and verifies it is the correct medication.	4x5x1
Medication is expired.	The expiration date is not always present on the unit. This applies particularly to medication labelled by KF. By using the FMD* code in the 2D labels, these medication units can still contain the expiration date and this date is checked by HiX** when scanned. Not all 2D labels placed by KF can contain this expiration date. However, the group of medication types that cannot contain these labels is small, has a high demand, and the shelf life of these pharmaceuticals is relatively long. Therefore, the issue of a missing expiration date is considered irrelevant; when this medication type does expire, there is no clinical relevant risk for the patient.	Change the 2D label procedure such that the expiration date is incorporated in the label. Caution: check the charge number before labelling, since the charge number is also included in the 2D label. Moreover, change the expiration date procedure in order to include the medication in the return boxes as well when performing the periodic check for expiration dates.	3x2x1

Appendix D

Photos of a filling unit at Isala Zwolle

For visualisation purposes, several pictures were taken at the department of KF at Isala Zwolle. Figure 19 displays a part of the filling unit. Next, Figure 20 displays a medication cart with patient drawers. Last, Figure 21 displays a close up on the medication types in the filling unit and displays the small return boxes in front of the original boxes.

FIGURE 19: One of the filling units at Isala Zwolle

FIGURE 20: A medication cart with patient drawers

FIGURE 21: A selection of medication types in original boxes and return boxes in front of these original boxes

Appendix E

Experiment results

Appendix E considers more in-depth outcomes of the model presented in Chapter 4 and analysed in Chapter 5. It presents the daily outcomes of the worst case, average case and best case instances, in terms of units returned to the inventory and savings collected by returning these units. We do so for two objective functions. In Section E.1, we consider the results of maximising the returns. In Section E.2, we turn to the results of maximising the savings.

E.1 Maximise returns

Figure 22, Figure 23, and Figure 24 display the daily returns in units for the worst case, average case, and best case instances respectively, when maximising returns. Figure 25, Figure 26 and Figure 27 display the savings per day for the worst case, average case, and best case instance respectively for maximising returns.

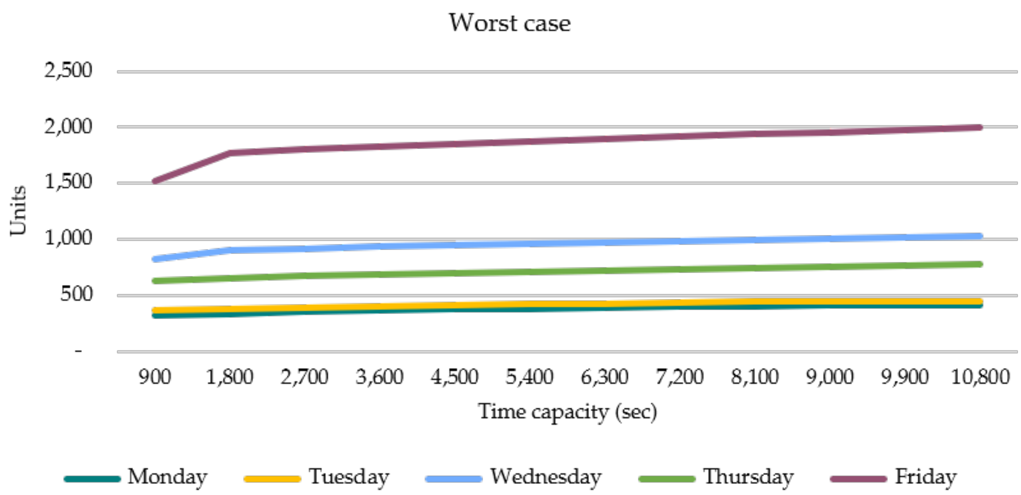

FIGURE 22: Daily returns when maximising returns for worst case instance

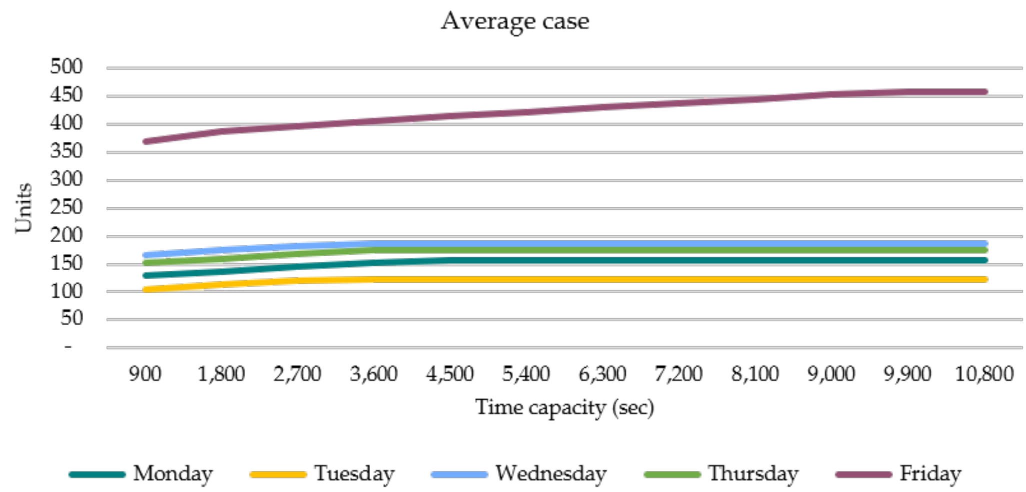

FIGURE 23: Daily returns when maximising returns for average case instance

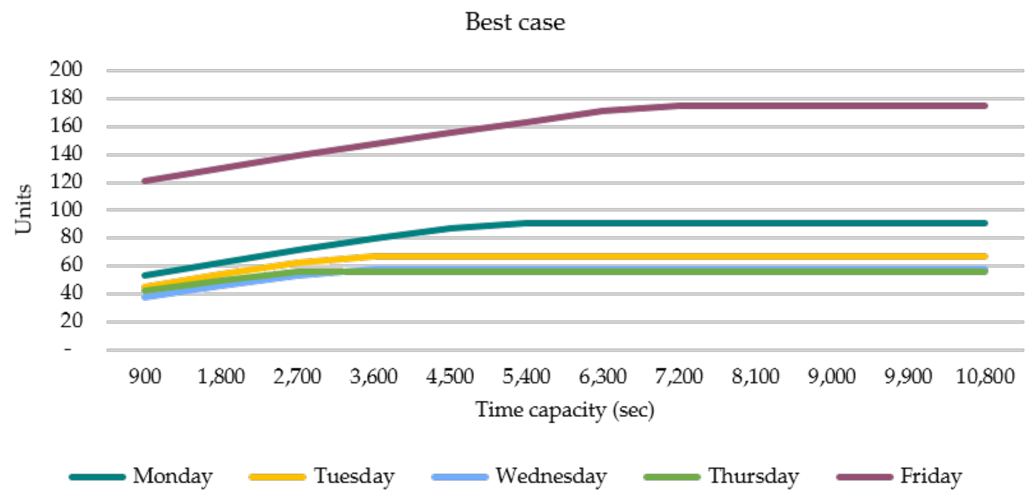

FIGURE 24: Daily returns when maximising returns for best case instance

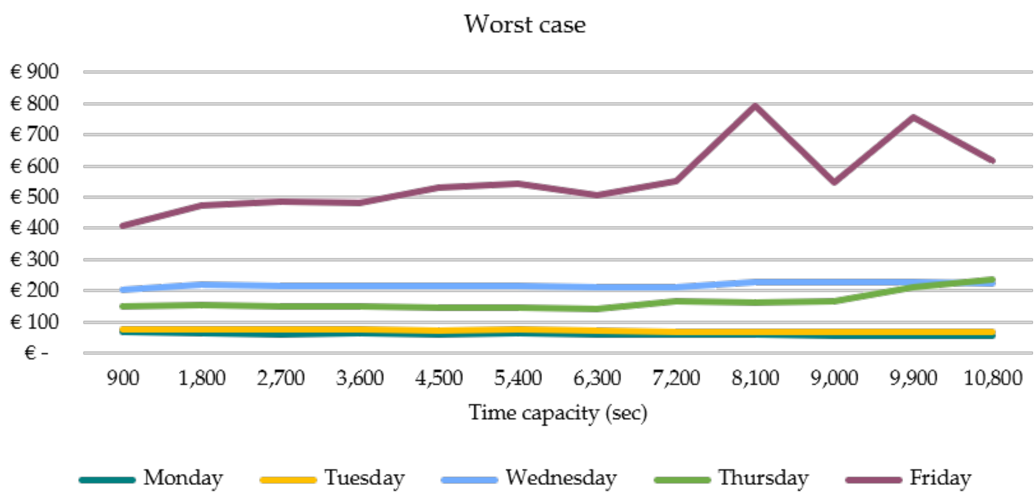

FIGURE 25: Daily savings when maximising returns for worst case instance

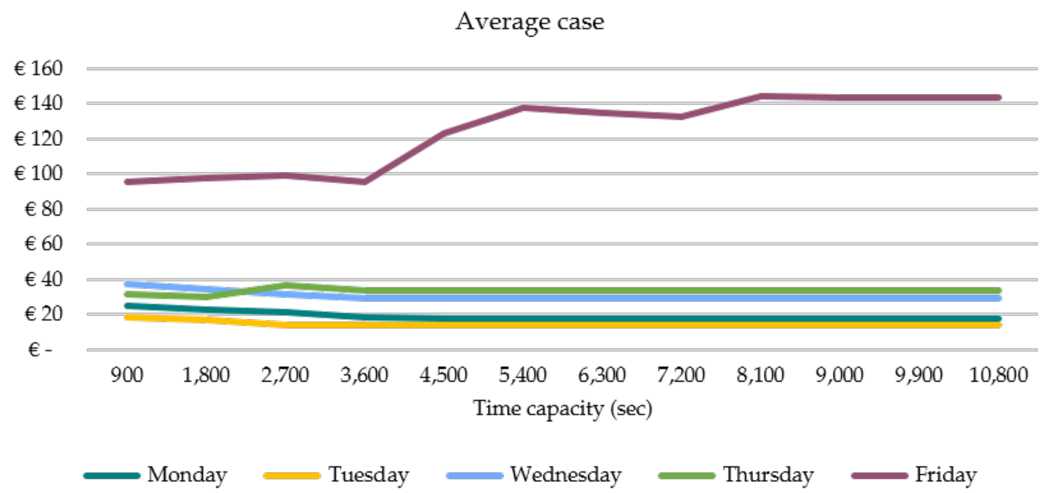

FIGURE 26: Daily savings when maximising returns for average case instance

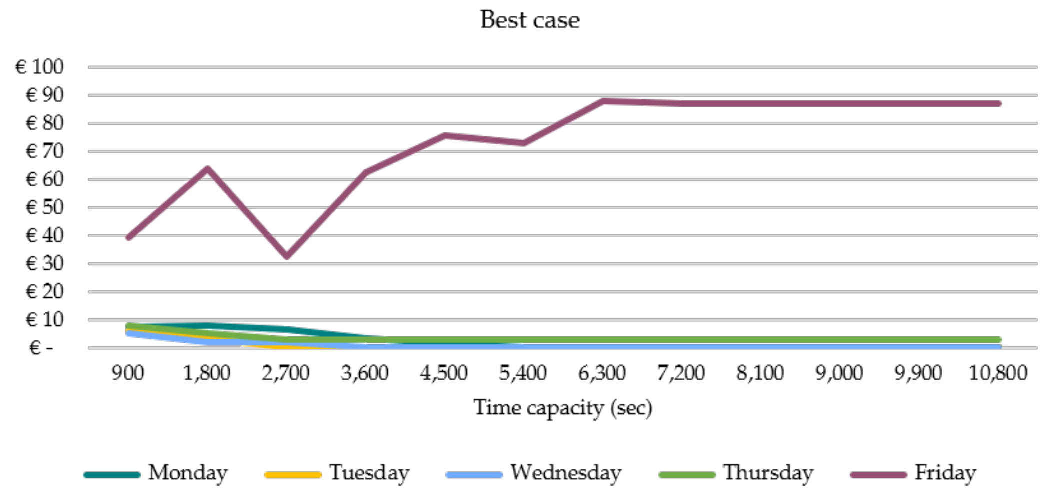

FIGURE 27: Daily savings when maximising returns for best case instance

E.2 Maximise savings

Figure 28, Figure 29, and Figure 30 display the daily returns in units for the worst case, average case, and best case instances respectively, when maximising savings. Figure 31, Figure 32 and Figure 33 display the savings per day for the worst case, average case, and best case instance respectively for maximising savings.

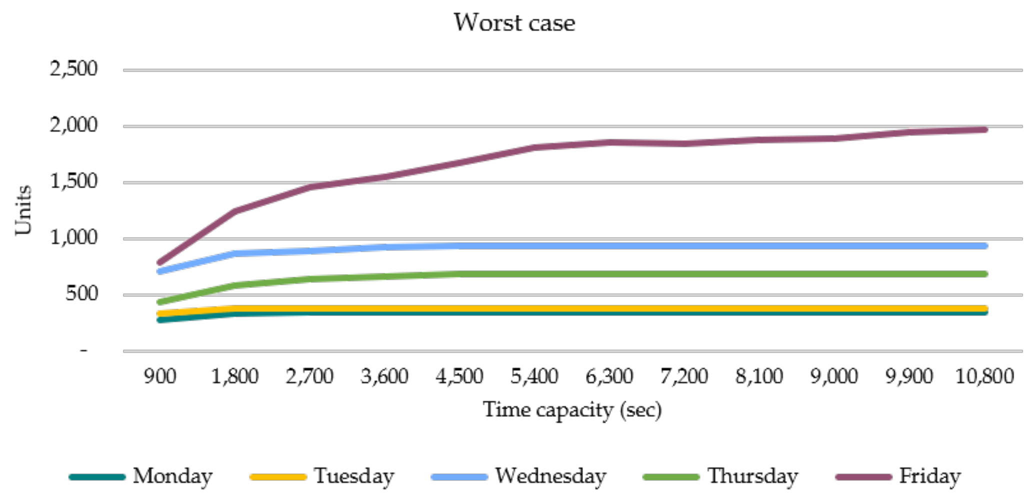

FIGURE 28: Daily returns when maximising savings for worst case instance

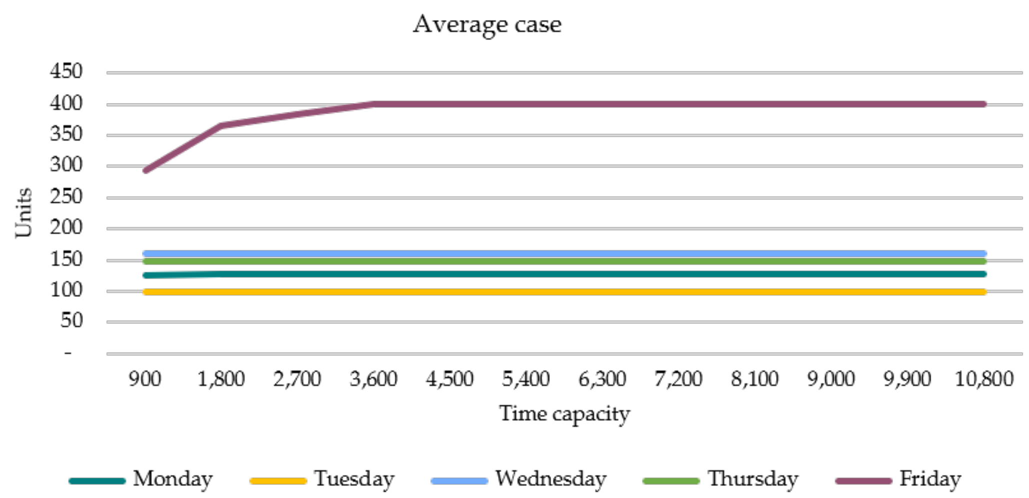

FIGURE 29: Daily returns when maximising savings for average case instance

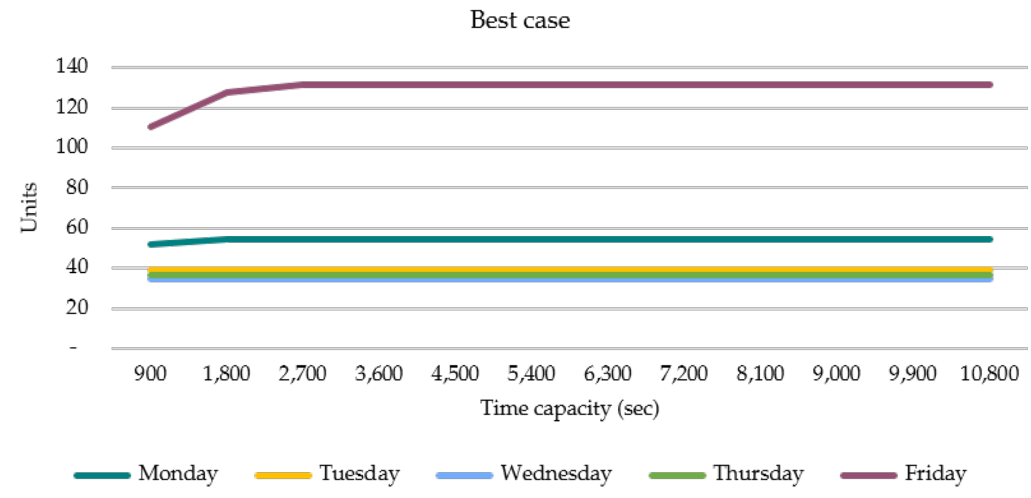

FIGURE 30: Daily returns when maximising savings for best case instance

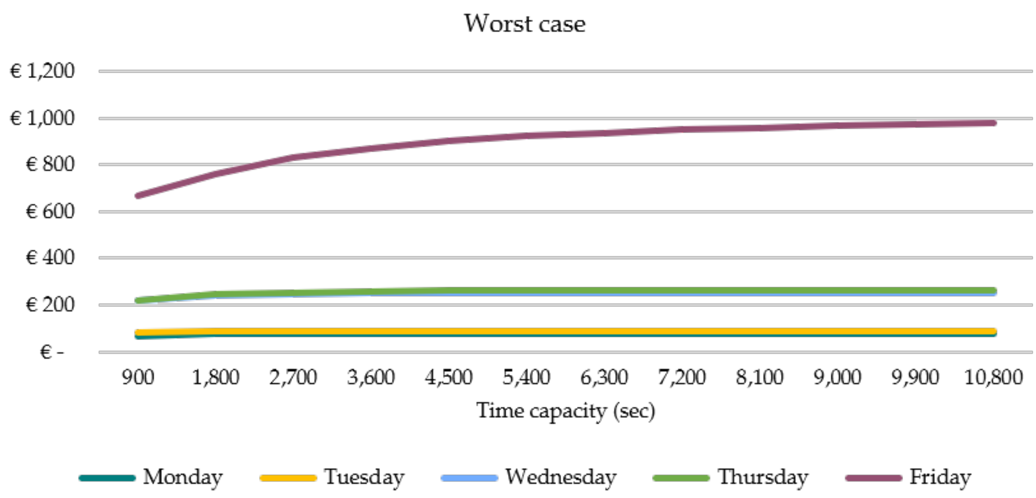

FIGURE 31: Daily savings when maximising savings for worst case instance

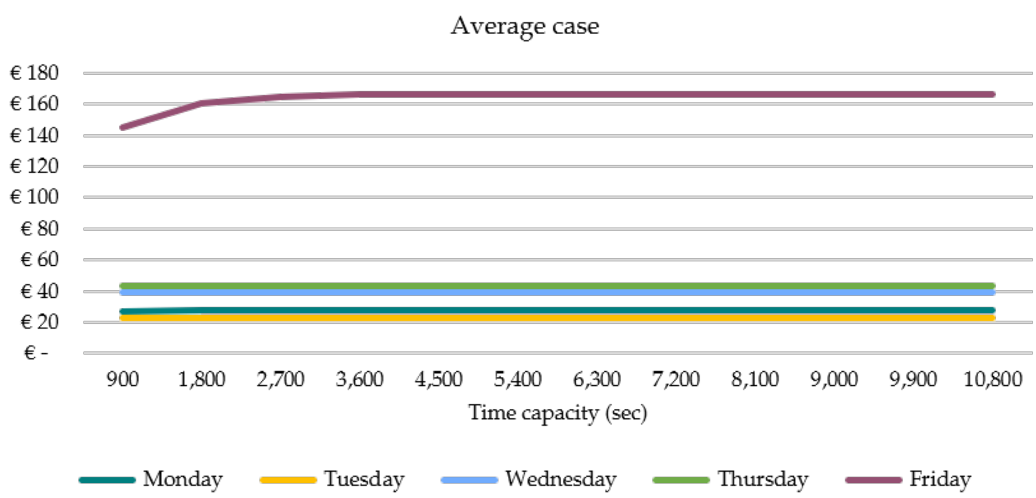

FIGURE 32: Daily savings when maximising savings for average case instance

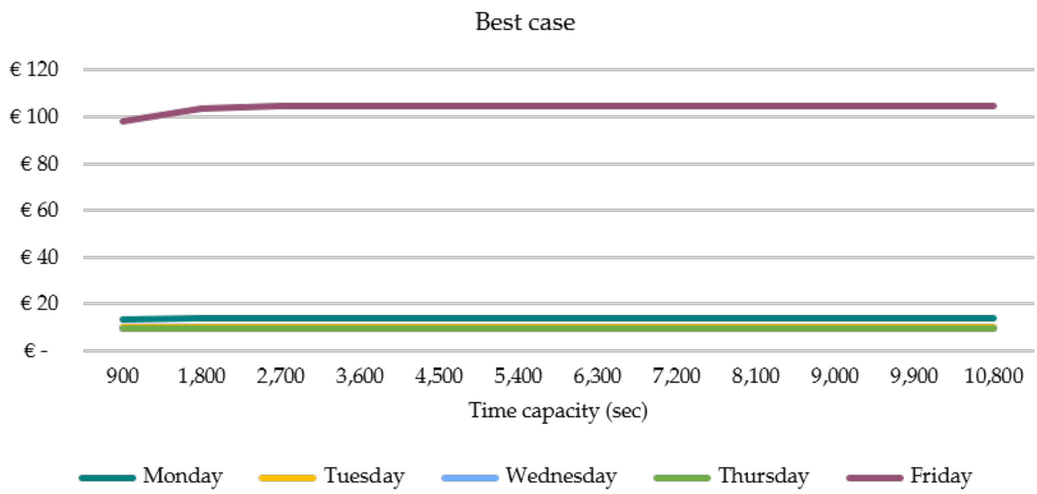

FIGURE 33: Daily savings when maximising savings for best case instance

Appendix F

Employee experience survey

This survey is conducted on the pharmacy assistants approximately one month after the implementation of the intervention to place medication back in the inventory for wards 2.4B and 2.5A. The survey is partly based on the paper by Spector [39]. The original survey involves nine sub-scales that vary in topics. We used two of these scales, namely 'operating procedures' and 'nature of work' [39]. Section F.1 contains the questions of the survey and Section F.2 displays the results of the survey.

F.1 Survey questions

The first section of the survey considers the additional workload and the experience with placing medication back in the inventories. The following questions are proposed:

1. On average, how many shifts are you planned for distributing medication?
2. How often have you placed medication back in the filling unit?
3. To what extent do you (dis)agree with the following statements?
   - I experience more workload when doing my work since we started placing medication back.
   - Placing medication back is going well.
4. On average, how many minutes more does it take you to do your work than before placing medication back?
5. This is the busiest day including placing medication back.
6. What is your opinion on the intervention to place medication back?

The second section of the survey is based on the operating procedures and the nature of work of the Job Satisfaction Survey [39]. We ask to what extent the pharmacy assistants (dis)agree with the following statements:

1. Many of our rules and procedures make doing a good job difficult.
2. I sometimes feel my job is meaningless.
3. My efforts to do a good job are seldom blocked by red tape.
4. I like doing the things I do at work.
5. I have too much to do at work.
6. I feel a sense of pride in doing my job.
7. I have too much paperwork.
8. My job is enjoyable.

F.2 Survey answers

A total of **thirteen** pharmacy assistants responded. Figure 34 displays the aggregate results of the statements based on the Job Satisfaction Survey. The scores for the Job satisfaction survey are normalised and all follow the positive dimension. For example, 'I have too much paperwork' receives a low average score. This does not mean that the pharmacy assistants disagree with the scores, it means they mostly agree that they do have too much paperwork. Figure 35 displays the answers of the pharmacy assistants with regard to their experience in returning unused medication. The answers to the open questions are discussed in Section 6.3.2.

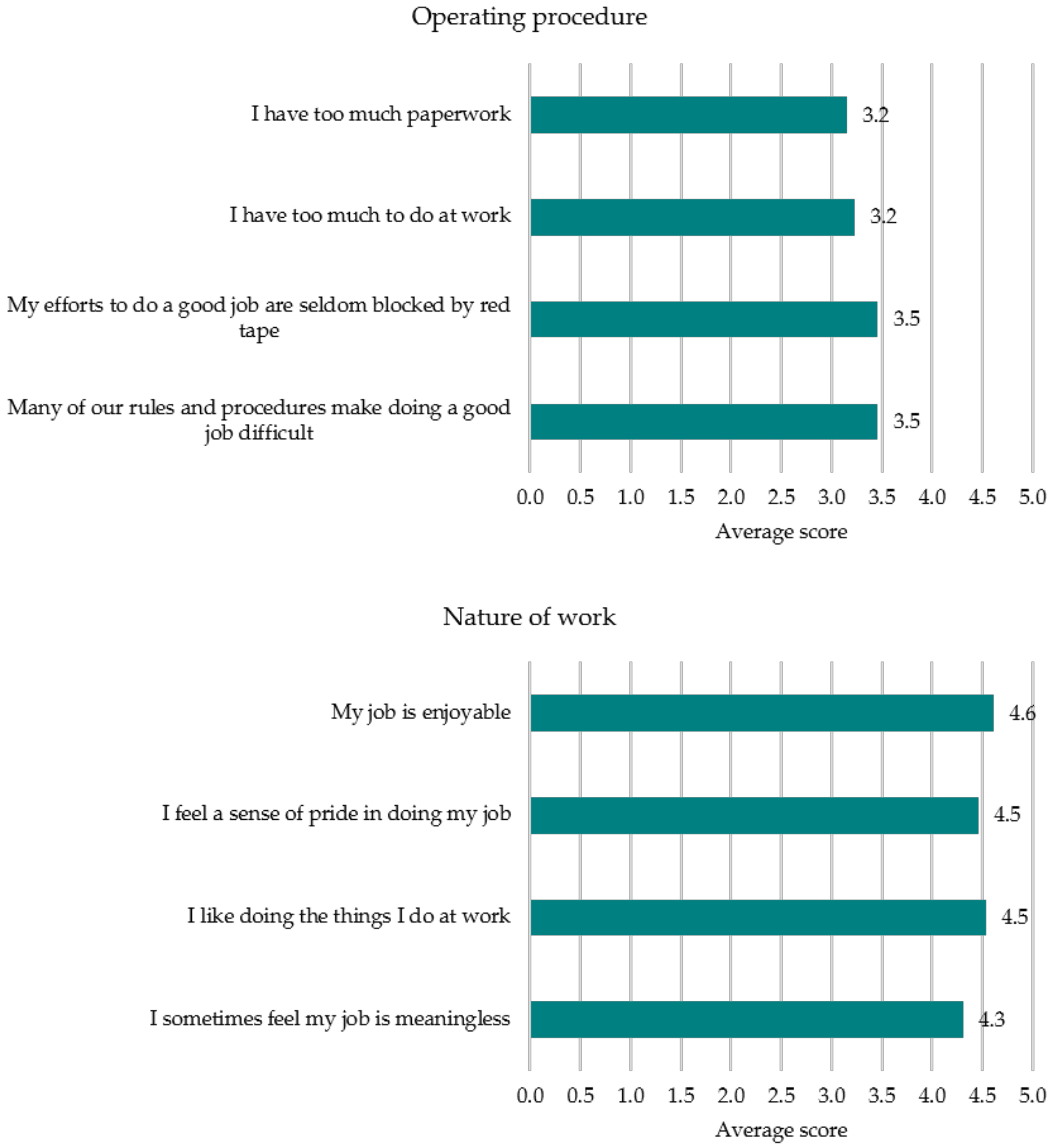

FIGURE 34: Job Satisfaction Survey results
(January & February 2023, n = 13)

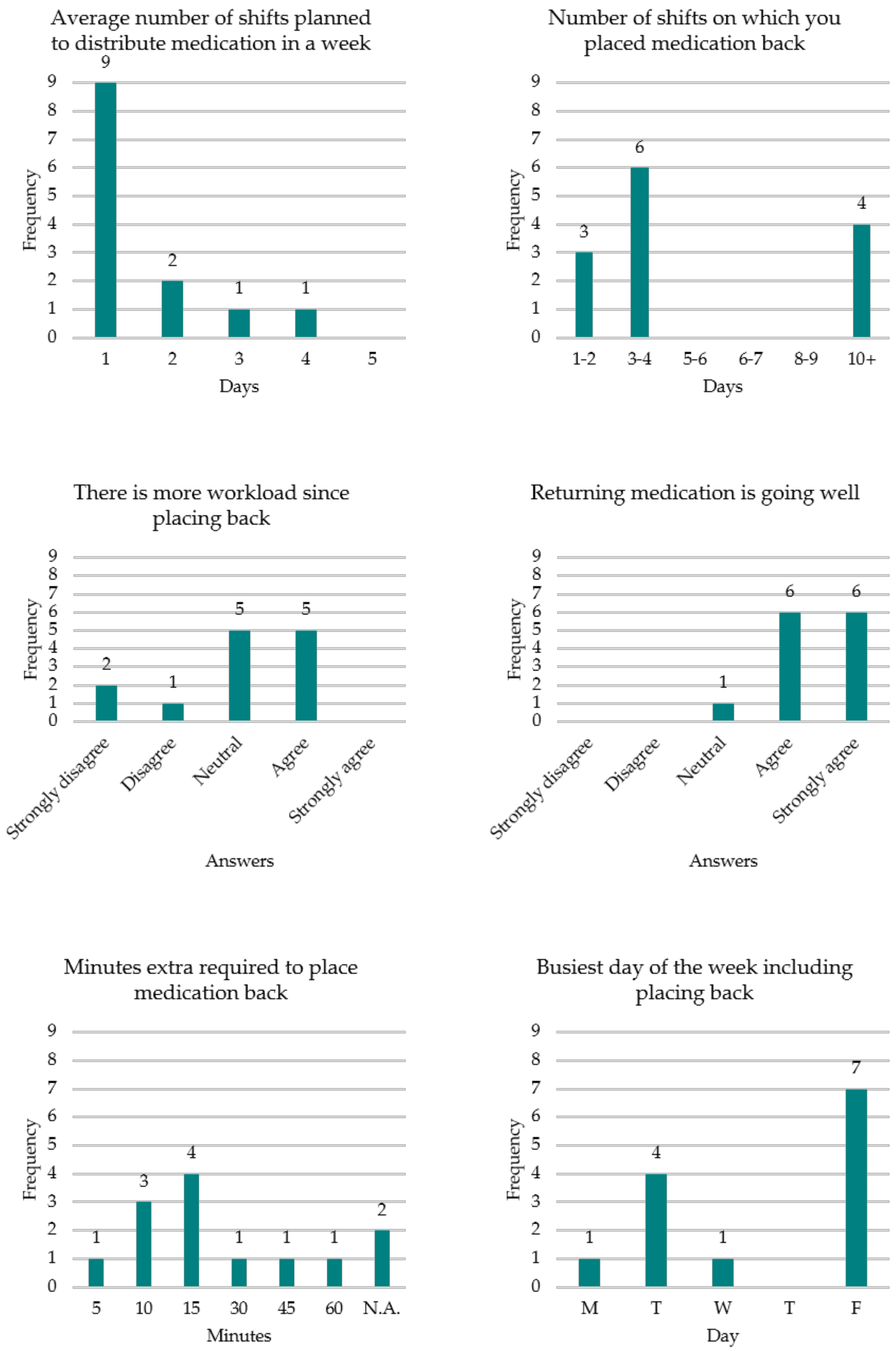

FIGURE 35: Returning medication survey results
(January & February 2023, n = 13)

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