IMPACT OF THE WEEKDAY-EFFECT ON STROKE CARE IN SLINGELAND HOSPITAL

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Management summary

Problem definition

This project investigates the impact of the day of the week in stroke care at Slingeland Hospital. Slingeland is a regional hospital in the East of the Netherlands with 283 beds, 2030 employees, and 9 operating rooms. The stroke care chain consists of three departments: the Stroke Care Unit (SCU), the Acute Care Unit (ACU) and the Neurology clinic. The team of Integral Capacity and Transfer Management perceive that there are weekday differences in the stroke care chain: fewer transfer or discharge possibilities and less (specialized) care. This extends their length of stay (LOS): their time spent on a department or in the hospital.

Research approach

We will present a literature study, data analysis, and a simulation study to research the existence and impact of the weekday differences. We will study the routes patients take and their probabilities as well as the lengths of stay and their probability distributions. We use a discrete-event simulation to assess the impact of weekday differences.

Results

In the literature and data analysis we find weekday differences in the care of stroke patients. Besides care, the arrival of stroke patients is also dependent on the moment in the week. There are more arrivals on Mondays and fewer in weekends.

We use the simulation model to assess the impact of the following interventions: constant availability of paramedical care, constant visiting rounds, and constant discharge to nursing homes. This shows that:

- interventions removing weekday differences on the neurology department could decrease LOS and bed occupancy by 12,7% and 10,9% respectively.
- interventions that remove the weekday differences on the SCU, ACU and Neurology clinic potentially decrease the total LOS by 11,5% and potentially decrease bed occupancy in the Neurology department by 12,7%.
- aiming for the ideal protocol route, SCU-Neurology, does not lead to a smaller LOS.

Conclusion

There exist weekday differences in the care of stroke patients in Slingeland. Removing them could decrease length of stay and bed occupation. From a patient's perspective we advise to implement the proposed interventions since it decreases the LOS by 11,5%. Further research is needed to see if the benefits of the interventions way up to the costs and efforts. Also, further research could show whether other departments could benefit from the interventions.

Discussion

The team of integral capacity and transfer management expected these results, but is very satisfied with the numerical proof. They see it as a starting point of slowly convincing personnel of the impact of the weekday effect, starting by neurologists. Also the arrival pattern of stroke patients stood out. According to the transfer manager old stubborn people in the region do not call in with complaints but wait for the availability of their GP on Monday. The hospital will investigate with the regional GPs what they can do to limit or prevent this.

Foreword

This thesis presents my bachelor assignment for the study Industrial Engineering and Management at The University of Twente. It was a project in collaboration of the University of Twente and Slingeland Hospital Doetinchem.

I would like to thank Erwin Hans for his great support during the whole project. The direct and critical feedback made me learn the most out of this project and experience. I was a bit shocked by the type of feedback in the beginning. But as he mentioned, this indeed made me a better writer and researcher.

Furthermore, I would like to thank the kind and welcoming people at Slingeland. In particular, Gijs Spijkers and Matthijs Blaazer for all the nice brainstorm sessions, the instant feedback, and really supporting me in this process. I would like to thank Annemijn Houwers-Buunk for supporting me in the overall process and offering me such an open and free problem case. For understanding the total transfer processes of Slingeland, I would like to thank Francis Bongers. For the problem identification, I would like to thank Lindsey Rooks for all the nice insights the stroke care chain. Finally, I would like to thank the whole team of Integral Capacity Management of Slingeland for all the help with my project and the entire experience. I really felt part of the team.

Luuk Nijs

Enschede, May 2022

Glossary of items

SCU	-	Stroke Care Unit
ACU	-	Acute Care Unit
LOS	-	Length of Stay
KPI	-	Key Performance Indicator
ICM	-	Integral Capacity Management
COVID	-	An infectious disease caused by the SARS-CoV-2 virus Pandemic active during this research
GP	-	General Practitioner
ED	-	Emergency department

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1 Introduction

This project investigates the impact of the day of the week in stroke care of Slingeland Hospital. This chapter introduces Slingeland and the problem that motivated this research. This research uses the framework of the 'Managerial Problem Solving Methodology (MPSM)' by Heerkens & Van Winden (2012) to structure the approach and report.

This chapter is structured as follows. Section 1.1 presents the context of this research: the Slingeland Hospital and its Integral Capacity Management department and neurology department. Section 1.2 gives the motivation of this research and explains the problem description. Section 1.3 presents the research objective and approach.

1.1 Slingeland hospital

This project is within the department of Integral Capacity Management (ICM) at the Slingeland Hospital in Doetinchem. Slingeland is a regional hospital in the East of the Netherlands with 283 beds, 2030 employees, and 9 operating rooms. It originates from a fusion from the Wilhelmina Hospital and the Sint Jozef Hospital in 1975, both situated in Doetinchem. In 2020 Slingeland registered 68098 first outpatient clinic visits and 21271 hospital admissions (Slingeland Ziekenhuis | Kwaliteit en behandelresultaten, 2021).

Since COVID hit our society and affected the hospital heavily, capacity management has gained a bigger role of importance in the hospital. Therefore, Slingeland decided in July 2020 that capacity management, which was done on an irregular basis, is a managerial function that is continuously needed. To this end, the ICM department was started, which further developed capacity management within the hospital. The department gives solicited and unsolicited capacity and planning advice to clinics and other departments in the hospital.

Within Slingeland the department of neurology is situated. A team of 7 neurologists, 1 neurosurgeon and 2 nurse specialists work on disorders of the central and peripheral nervous system, brain, spinal cord and muscles.

1.2 Research motivation and problem description

Because the ICM department was developing, more and more complicated requests were received from different departments. The project we will investigate was requested by the department of transfer management, but the case was under attention for a long time.

The ICM department perceives that the care chain of stroke patients is not efficient. If there are capacity issues, the patient does not travel the ideal route. As a result, other departments need to buffer for stroke patients. It also appears that patients who arrive on different days of the week have different care paths and lengths of stay. It is suspected that on weekend days there is less urge to transfer or discharge patients, which extends their length of stay (LOS): their time on a department or in the hospital. We will investigate the extent that this happens, and the impact hereof on capacity usage.

The hospital would also like to have more insight into the care paths of stroke patients. They would like to know to what extent the care path and LOS can be predicted upon arrival. Such an improved prediction could improve the patient's experience and the number of FTEs and beds needed in the departments.

Chapter 2 gives an elaborate problem analysis.

1.3 Research objective and approach

In Chapter 2, we thoroughly analyse and demarcate the problem and conclude that we want to show to the hospital what the effects of the admission day are to the LOS of a stroke patient. These insights need to show the factors that affect the LOS of the patient and the capacity usage of the hospital. If we find these factors, we want to investigate how to minimise the difference of these effects. We formulate the following main research question:

To what extent are there weekday differences in treatments of stroke patients. How can we standardise treatments and what would be the expected impact on lengths of stay?

We use a problem-solving approach (Robinson, 2014) to answer the research question and solve the associated problem. The approach splits up into 5 chapters. Below we will discuss these research questions and the expected deliverables per chapter.

Chapter 2 – Analysis of current situation in Slingeland hospital

This chapter answers the following question:

How does the current care of stroke patients in the Slingeland hospital take place?

This chapter analyses the current care chain of stroke patients in the Slingeland Hospital. We approach this on three levels: process, planning and control, and performance. With the use of a problem cluster, we will demarcate to the core problem.

Chapter 3 – Interventions needed to remove the effect of the day of the week

This chapter answers the following question:

What interventions are needed to remove the effect of the day of the week?

We investigate how stroke patients in other hospitals are treated, what other care paths they travel, and the division of their lead-time per department. To this end, we execute a benchmark research amongst other hospitals and doctor inside Slingeland. Furthermore, we investigate the literature regarding treatment protocols for stroke care, and evidence for differences in stroke patient characteristics per day of the week.

Chapter 4 – Analysis of the impact of removing the weekday effect

This chapter answers the following question:

What is the impact on capacity usage of removing the weekday effect?

This raises the question how to quantitatively assess this. In Chapter 4 we will argue that a computer simulation model is suited for this purpose. Hence, in Chapter 4 we design a conceptual model to understand the real world-system and make a non-software specific description of the computer simulation model. The conceptual model is a simplified representation of the real-world system, which translates the real world into a model that can be used by any simulation software. To realise the conceptual model, we need more data. This includes all the data needed as input for the simulation model and are directly divided from the conceptual model. The model is coded in the simulation software according to the model design. We pay attention to the input- and output variables, which are determined in Chapter 2. When the model is coded, we choose the right warm-up length and number of replications. Thereafter, the process of verification and validation starts, which ensures that the model is sufficiently accurate (Robinson, 2014).

Chapter 5 – Experiments and findings

This chapter answers the following question:

> *What is the expected impact of the interventions?*

In this chapter we design interventions, a set of measures taken within the hospital, that remove the weekday effect. These interventions will be implemented in the experiments that should be simulated. After that, these experiments will be run and adapted if necessary to get the desired results. An overview of the outputs of the different runs will be delivered. Based on the results, further research is done on the possible causes of these results and we will discuss the findings.

Chapter 6 – Conclusion and recommendations

This chapter answers the following question:

> *How can the weekday effect in the care of stroke patients in the Slingeland hospital be removed?*

The last chapter discusses the results and draws conclusions from them. The research process will be evaluated and the hospital will receive recommendations based on our findings. An implementation plan with recommendations to Slingeland will be delivered.

2 Analysis of the current situation

This chapter analyses the Slingeland hospital. The chapter is structured by the steps of process (Section 2.1), management (Section 2.2), and performance (Section 2.3). After that, we take the problem given by the hospital and further demarcate to the core problem (Section 2.4).

Figure 2-1 Entrance Slingeland Hospital

2.1 Processes within the hospital

In this section discusses the hospital by means of a visual representation of the patient flows. Figure 2-2 depicts the most common routes a patient can travel within Slingeland. Every department is explained below.

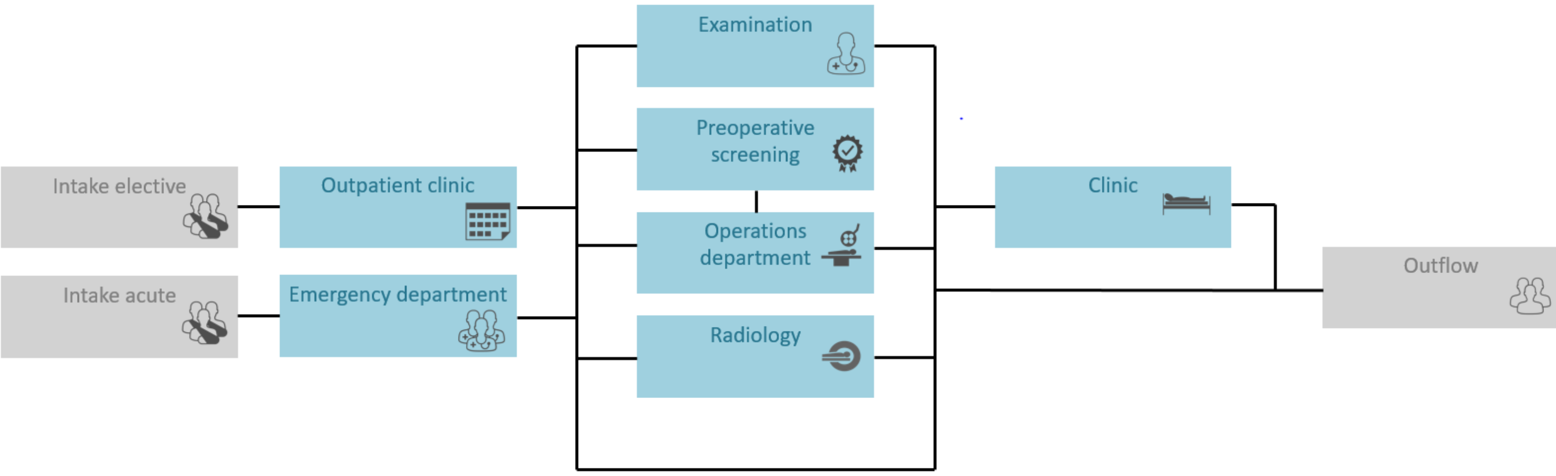

Figure 2-2 Patient flows within Slingeland Hospital (Source: Slingeland; December 2021)

Intake

There are two types of patients: elective and acute patients. Elective patients are planned patients, referred to the hospital by for example a general practitioner (GP) to make an appointment for further examination or treatment. Acute patients are unplanned and typically have more urgency for treatment. They can also be referred by the GP but also by for example an ambulance.

Outpatient clinic

Slingeland has 16 outpatient clinics where patients can come for medical consultation or a small treatment. A total of 100 specialists work here.

Table 2-1 Number of specialist working per outpatient clinic (Source: Slingeland; December 2021)

Outpatient clinic	Number of specialists
Internal medicine	7
Rheumatology	6
Geriatrics	5
Cardiology	9
Neurology	8
Lung diseases	5
Surgery	10
Orthopaedics	8
Ophthalmology	4
Dermatology	6
Otolaryngology	3
Urology	3
Stomach bowels liver	8
Plastic surgery	2
Gynaecology and obstetrics	7
Paediatrics	9

Emergency department

The emergency department takes care of all unplanned patients that need urgent care. A team of E.R. doctors, Acute Care doctors, and nurses take care of the first treatment. If hospitalisation is necessary, the patient transfers to the Acute Care Unit (ACU). At the ACU, diagnostics is done and it is determined to which clinic the patient needs to be transferred.

Examination

There are five examination departments within the Slingeland: cardiology, internal/stomach-bowels-liver, lung diseases, neurology, and vascular diagnostics. Further planned and unplanned examination is done here.

Preoperative screening

Before surgery, a patient visits the preoperative screening. This starts with a talk with a pharmacist's assistant, anaesthetist, and a nurse. All preparations and admission to the hospital are discussed.

Operations department

This is the department where all surgeries are done. There are 7 clinical operation rooms and 2 operative daycentres.

Radiology

The department of radiology plays an important role in the determination of the disease. This is done with for example X-rays, images using sound waves (ultrasound) and magnetic fields (MRI). A team of 10 radiologist work here.

Clinic

The clinic is where patients stay in the hospital for a longer treatment. The clinic divides into two clinics; the clinic internal medicine and the clinic surgical. These two clinics have sub clinics which can be found Figure 2-3. These sub clinics can swap beds if capacity issues ask for that.

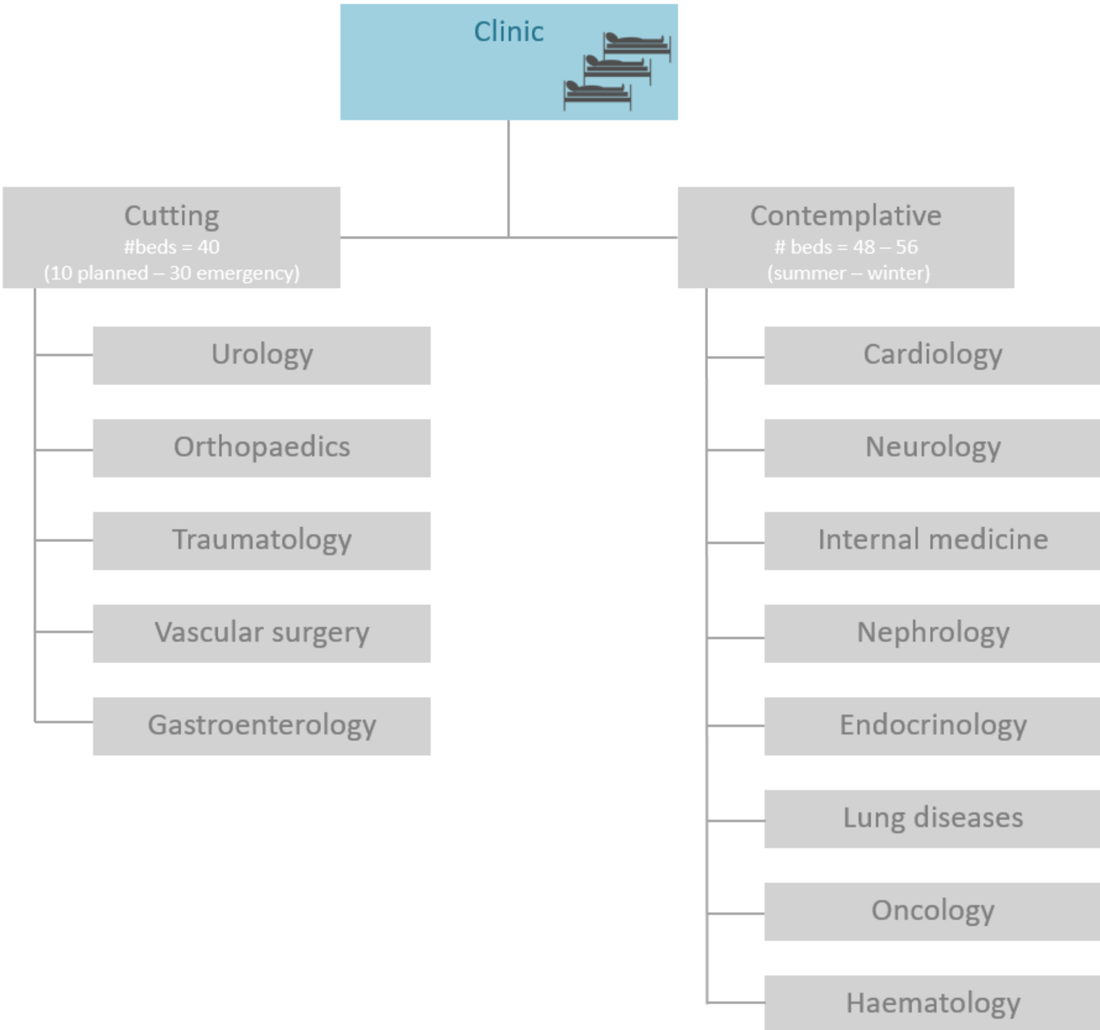

Figure 2-3 Types of clinics within Slingeland (Source: Slingeland; December 2021)

Patients can travel many routes that are depicted in Figure 2-2, in this research we are going to focus on the route of stroke patients. An interview with a neurology specialist nurse and a process-mining tool are used to determine this path. Figure 2-4 depicts the results. Below, the different routes and deviations are discussed. In Figure 2-4 we discuss the 90% most used routes in 2018 and 2019. 10% of routes travelled by stroke patients in 2018-2019 followed another route. These were divided over 35 alternative routes, which we consider as deviations that we do not take into consideration at this stage. The green line shows the route a patient should take according to the stroke protocol.

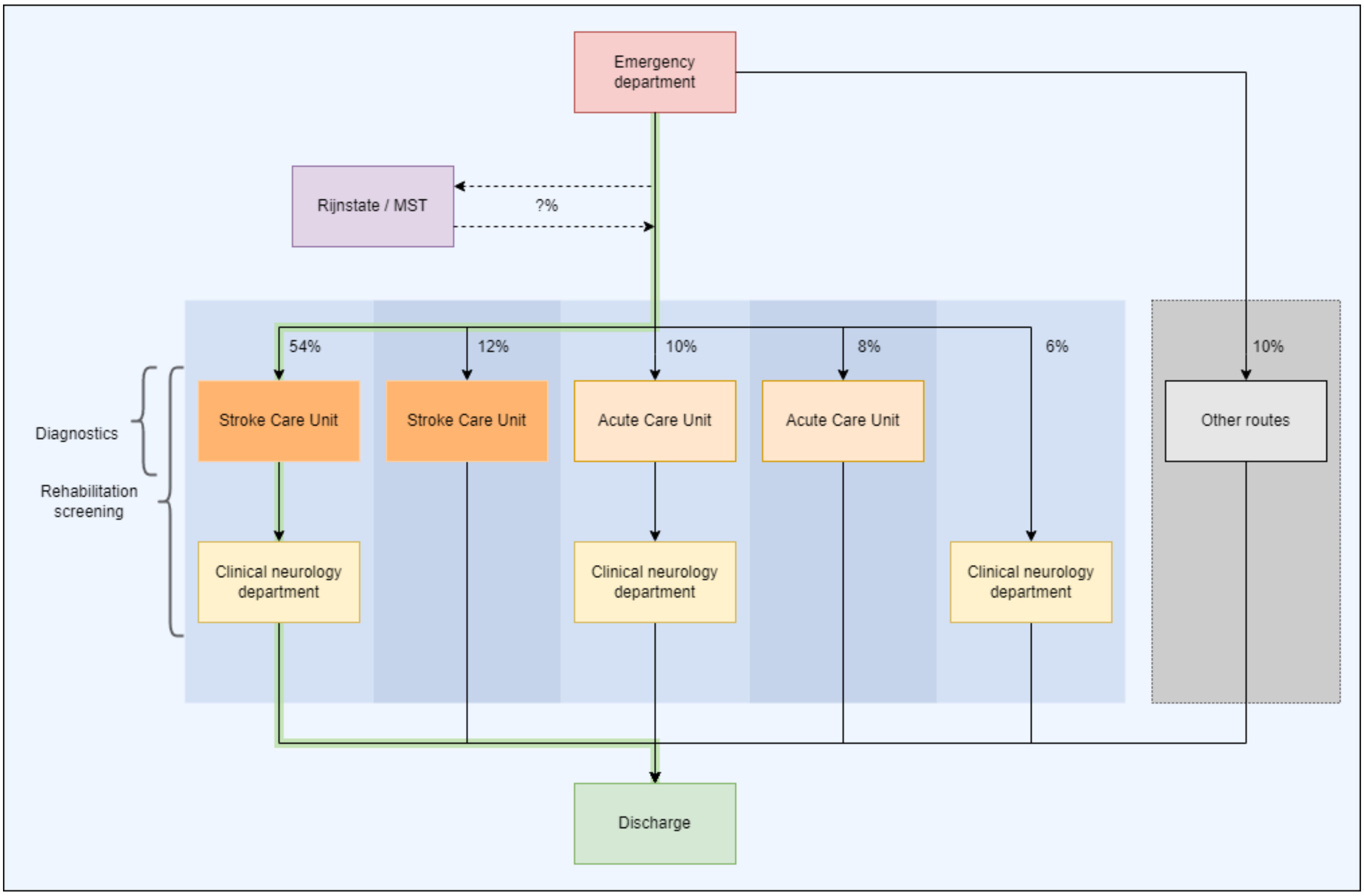

Figure 2-4 Routes of stroke patients within Slingeland (n=1149, 2018-2019, source: Slingeland process mining tool)

The ambulance or general practitioner (GP) send a stroke patient to the hospital. The patient enters the hospital through the emergency department (ED). When a stroke patient is announced to the ED, the stroke team prepares, and the CT-scan is made available. The stroke team is a specialized team with a neurologist, a stroke-nurse, and an ED-nurse. When the patient arrives a CT-scan is made. With the result of that scan, they can determine if the stroke is an haemorrhagic stroke or an ischemic stroke. Initial treatment belonging to the type of stroke starts right away at the ED and if the patient is stable, the patient is transferred. In some rare cases, the patient goes home right away if the complaints are gone.

Patients with an ischemic stroke with a clot in one of the big cerebral arteries transfer to the Rijnstate Hospital in Arnhem for intra-arterial thrombectomy. This is a specialized treatment where a catheter removes the clot. This treatment must start 6 hours after the beginning of the stroke. Patients with a haemorrhagic stroke with complications transfer to the MST for neurologic surgery. The other patients are kept in the hospital. Currently no data is available on the patients referred to the Rijnstate or MST hospital. According to the respondent, these patients always come back in the Slingeland hospital, so they are still in our data set used to determine the routes.

The patients that remain inside the hospital transfer to the stroke care unit (SCU). If the SCU is low at capacity and the patient does not need monitoring of all vital functions, the patient transfers to the acute care unit (ACU). This is a back-up option since there is less specialized neurologic care at the ACU. In some of the cases, the patient transfers directly to the neurology clinic. The respondent tells us this is strange and not according to protocol.

Patients stay on the SCU for the most acute phase of the treatment. Diagnostics are done here, and the patient's vital functions are monitored. Patients that travel the back-up route via the ACU stay there for the diagnostic phase. On both departments also the rehabilitation screening starts.

When diagnostics are done, and the patient is stable nurses and neurologist determine if the patient needs any further hospital care. When the patient needs hospital care, the patient is sent to the neurology clinic, in other cases the patient is sent home, to a rehabilitation centre or, to a nursing home.

On the neurology clinic, a patient receives specialized neurology care, but does not need the full monitoring of all vital functions. The patient stays here as long as it needs hospital care. When the patient is able to leave, it goes home, to a rehabilitation centre, or to a nursing home. Sometimes there is no capacity at the rehabilitation centre or the nursing home. The patient then must stay longer on the neurology clinic.

2.2 Management organization and structure

Slingeland has a decentralized organizational structure. Figure 2-5 depicts the organigram. The supervisory board and board of directors work on strategic level and determine the long-term vision of the hospital. Clusters are situated under the board of directors. The presence of a cluster manager and a medical cluster manager depends on the cluster. In most clusters, the cluster managers work together with the team managers to fulfil the tactical policy of the hospital. There is a lot of communication and participation of the team managers in the decision making of the cluster managers. The teams, which are led by the team managers, work on the operational level of the hospital. In some teams they work with the 'oldest present' leading principle. This means that the person who is in service the longest takes the operational management on that specific moment. The teams are at the bottom of the hierarchical structure and deliver the performance of the hospital.

This assignment is within the team of integral capacity management in the cluster operation centre and service. This team can give advice on capacity and planning issues to almost every other team within the hospital. For example outpatient clinic schedules, but even advice to the cleaning team on when beds are ready to be cleaned and what can be improved in that process.

In the treatment of stroke patients the neurologist always has the lead. From arrival until dismissal the neurologist is involved and makes the policy. The neurologist is supported by nurse specialists, nurses and other treating personnel. The nurses and nursing specialist see the patient more often and advice the neurologist. On the nursing department, the lead can also be taken by a nurse specialist. When the nurse specialist acts outside certain guidelines and/or frameworks this is supervised by the neurologist.

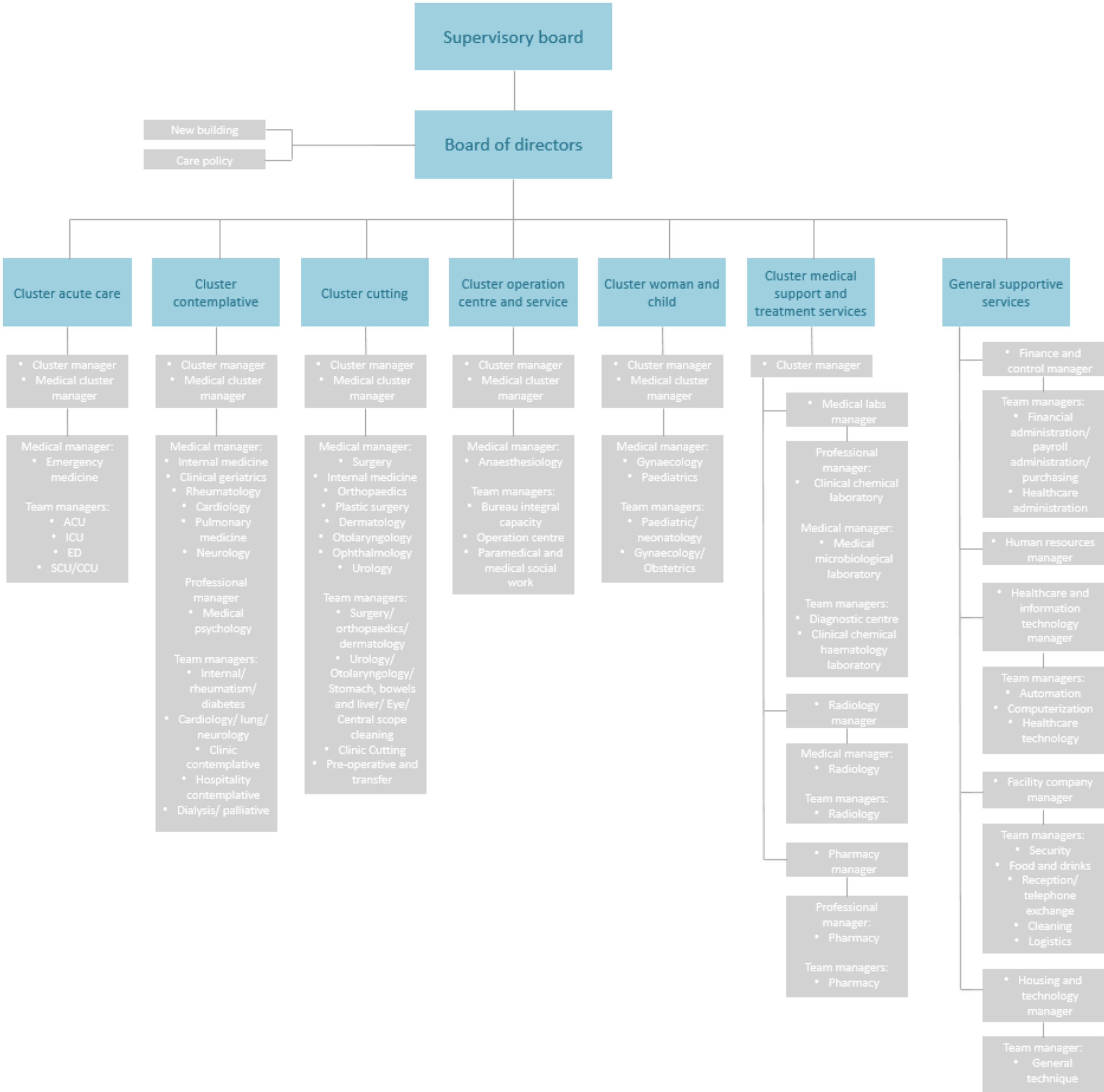

Figure 2-5 Organigram Slingeland (Source: Slingeland; December 2021)

2.3 Performance of the hospital

The performance of the hospital will be approached on the subjects of: quality of care, quality of labour, quality of service, and productivity.

Quality of care

To determine the quality of care, we use two sources that both determine a grade to represent the appreciation of the hospital. The first is ziekenhuischeck.nl. This website presents patient satisfaction based on research done by Newcom Research & Consultancy. Commissioned by The Association of Dutch Hospitals they did research on this subject. In 2020 3366 patients of Slingeland have completed their questionnaires resulting in a grade of 8,5. A second research amongst people in the Netherlands on the rural image of Slingeland resulted in a grade of 8,3 (Slingeland Ziekenhuis | Kwaliteit en behandelresultaten, 2021). The second source is zorgkaart.nl. This is a website where patients can leave a rating of healthcare based on their own experiences. 293 ratings result in a grade of 8,9 (Slingeland Ziekenhuis, 2021).

Quality of labour

The quality of labour is represented in the sick leave rate. The sick leave rate in Slingeland per year against the nationwide sick leave rate in hospitals is presented in Table 2-2.

Table 2-2 Sick leave rates (Source: Statistiek; 2021)

Year	Slingeland %	Nationwide %
2014	4,3	4,0
2015	4,2	4,2
2016	4,3	4,0
2017	3,5	4,3
2018	4,7	4,7
2019	5,6	5,0
2020	6,6	5,3

Quality of service

The quality of service is determined in terms of access times. These are specified on the outpatient clinics, diagnostics, and treatment. 0 presents an overview.

Turnover

Table 2-3 shows the turnover by the number of admissions in day nursery, clinical admissions and first outpatient clinic visits. The ICM department works hard to make the hospital more efficient. They work along with the different planning employees within the hospital to maximize efficiency. However improvement is noticeable, it is very hard to measure the real impact of the measures taken. We therefore cannot quantify the efficiency.

Table 2-3 Turnover Slingeland 2020 (Source: Slingeland Ziekenhuis | Kwaliteit en behandelresultaten; 2021)

	# per year 2020
Admissions on day nursery	8.860
Clinical admissions	12.411
First outpatient clinic visit	68.098

2.4 The care of stroke patients

The research focusses on the care of stroke patients in the Slingeland Hospital. In Section 1.1 we introduced the problem given by the bureau of integral capacity management. In this section, we:

- discuss the processes that could affect the LOS,
- demarcate to the core problem,
- and determine KPIs needed to measure the problem approach.

2.4.1 Processes that affect the length of stay of a stroke patient

Several processes influence the LOS of a stroke patient. Below we discuss the ones that stood out the most.

Initial diagnostics and treatment

This is the process of the intake and the first examinations at the ED. As discussed in the previous section this determines the route that the patient takes and treatment that the patient receives. The respondent indicates that there is almost no delay at the process of intake. Steps are according to a strict protocol and all stakeholders work fluently together. In addition, no effect of the day of the week is noticeable.

Diagnostics of treatment complications

The process of diagnostics entails all examination done outside of the acute phase. The neurologist visits the patient daily. Other specialists like the vascular surgeon and cardiologist can visit the patient based on the complications that occur after the stroke. The diagnostics can be done on all departments but are meant to be done in the diagnostic phase at the SCU or ACU.

According to the respondent, this process should be the same on every day of the week, but on weekend days, there could be some difference. Most specialist work with weekend shifts. A specialist targets at making a visit round every day, but it is unknown if this is done on strict regular basis.

Rehabilitation screening

Whenever the patient is stable, the rehabilitation screening should start. This is possible on every department. Depending on the patient's complaints specialist visit. This can be a physiotherapist, an occupational therapist, a speech therapist, a dietitian, or a rehabilitation doctor. These are external partners, who often do not work on weekend days. According to the respondent, the moment the screening starts has a lot of effect on the LOS. The urge of the screening is different on different departments. For example, on the ACU there is no neurology nurse, so there is less knowledge of this process. The screening is of importance in the transfer to the external partner of the patient. This process is one of the causes of the so-called 'Wrong bed patients', patients who occupy a hospital bed when they do not need that care anymore but cannot be transferred to an external partner.

The process of rehabilitation screening is the problem that comes up the most during the interview with the respondent. Because external partners do not work on weekend days, most patients who cannot go home and need to go to a rehabilitation centre stay in the hospital during the weekend. A patient that according to schedule is ready to transfer on

Saturday remains inside the hospital until Monday. A small number of patients transfers on Saturday to a particular nursing home, but this is an exception of the regular transfers. On Mondays the rehabilitation specialists catch-up on the delay made in the weekend. Data backs this; it shows a peak on Mondays and Tuesdays in admission numbers.

Daily checks

Nurses constantly monitor the patient. Depending on the department, a neurology specialist nurse does this. According to the respondent, this could cause delayed action if the nurse is not specialized on neurology. This could happen on the ACU since there are no neurology nurses there. This could also happen if the SCU and neurology clinic are over capacity and using 'cardiology beds'. The neurologist pays daily visits to all stroke patient, independent of its location. The patient's status is discussed together with the responsible nurse. This considers complications and associated treatments, status of the rehabilitation screening, and dismissal. The neurologist is responsible, but the nurse can react to the decisions made. The respondent thinks the weekend does not influence this process. The visit time and frequency may differ, but this should not affect the LOS of the patient according to the respondent.

Transfer management

When a patient is ready to transfer to the next department, the nurses of the corresponding departments discuss the transfer possibilities. When a bed is available, the patient transfers. When there are no beds available the patient remains on the current department. The nurses then discuss alternative options like early dismissal or early transfer to the external rehabilitation partner.

According to the respondent, the availability of a bed on the next department in the care chain has a lot of influence on the LOS of the patient. This disturbs the process of having the patient on the right department at the right moment in the treatment. Patients stay on departments with more care than necessary and the other way around patients stay on departments with less care than necessary with carry-on devices.

2.4.2 Demarcation to the core problem

We made a problem cluster to find the core problem. When selecting these problems, we pay attention to 4 rules; only the problems that really exist are put in the problem cluster, why a problem has not been resolved does not matter, what you cannot influence does not matter, and if more than one problem remains, choose the one that makes the impact.

The problem cluster displays the multiple causes of the total capacity problem of the stroke care chain. Appendix C depicts the problem cluster.

One of the main consequences of the capacity problems is the buffering of other departments. This causes again capacity problems and means that there is less specialized care. Overall, this causes patients to stay longer at the hospital. The end problems that come up are:

1. **The predetermined care path is not used**
   Only 49% of the time the ideal route is used which means that in other cases some of the time the patient does not receive specialized care.

2. **The admission day of the week affects the length of stay of the patient**
   The preliminary research has pointed out that there is a difference in the average LOS depending on the day of admission. The weekend could be a cause for this.
3. **There is too little capacity in the following department**
   This problem occurs in every department in the chain. Assumed is that a capacity problem at one department immediately affects the others.
4. **There is no capacity at the external partner in the care chain**
   This means that a patient cannot be transferred from the hospital to the nursing home or rehabilitation centre.

Problem 1 and 3 would be very interesting to investigate and improve. The insight on the total capacity of the care chain would have the preference of the hospital. Eventually, they would like to apply this to other care chains. Unfortunately, the eventual product of this bachelor assignment would be too dynamic to be useful for the hospital. Every change in the number of beds or FTE would need to be implemented in the model and therefore this would not be ideal for a bachelor assignment. We do not have influence in solving problem 4. Therefore, we choose problem 2 as our core problem. The insight into this problem could make an impact in the approach of 24/7 hospital care and would be a static usable product.

2.4.3 KPIs needed to measure the problem approach

To dive further into the core problem, we determined the average LOS in the hospital minus the time on the ED for stroke patients in 2018-2019. Although these values still have a large standard deviation, we can still use them as an indicator to determine to get a more reliable result we subtracted the outliers and ‘wrong bed’ time from the data set. Figure 2-6 depicts the averages and standard deviations found. The absolute difference per day with the total average currently exceeds a maximum of 9,26. We want to reduce that to a maximum of 5. We also want to investigate if we can give further specification the KPI ‘length of stay’ and do not depend on averages only.

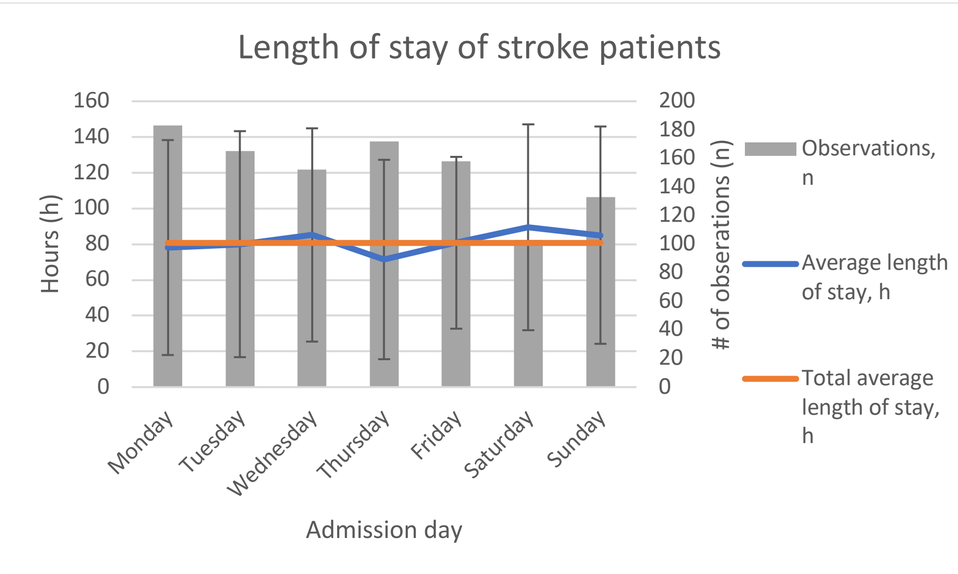

Figure 2-6 Length of stay of stroke patients within Slingeland (n=1149, 2018-2019, Source: Slingeland)

Furthermore, we want to use the number of stroke patients present on every specific department within the care chain of stroke patients as an indicator within the research. This gives a good indication of the number pressure on the capacity, wrong routes, and possible patterns.

Now that we have analysed the current situation we are going to search for explanations of the findings and causes in the literature in Chapter 3.

3 Stroke characteristics and care throughout the week

This chapter answers the following question:

What interventions are needed to remove the effect of the day of the week?

We want to get a good understanding of methods that remove the effect of the day of the week in stroke care. Therefore, we need to understand the influences within stroke care. This is split up into the internal and external factors of stroke treatment. We search for evidence in the literature for differences in stroke patient characteristics per day of the week in Section 3.1. We investigate the literature regarding the so-called 'weekend-effect' caused by the hospital or other caretakers in Section 3.2. To get an understanding of the impact of interventions in stroke care, we want to learn more about the relationship between LOS and capacity. We will search the literature for this matter in Section 3.3.

3.1 Patient characteristics per day of the week

In this section, we are going to answer the following question:

Is there a difference in stroke patient characteristics per day of the week?

In the problem analysis, we found data that showed us that there are differences in the number of strokes that come to Slingeland on different days of the week. We could not directly find a cause for this. However, we want to know whether there are any identifiable causes for this pattern. Appendix D depicts the search strategy.

In search for stroke characteristics depending on the day of the week, we mostly find research specified on the weekend-effects caused by hospitals reducing (qualitative) care in the weekends. From those publications, we derive six articles that discuss patient specific characteristics upon arrival.

Bachner & Zuba (2021), Angerer et al. (2019), and Saposnik et al. (2007) tell us that stroke patients arriving in the weekend are significantly older. Other baseline patient characteristics were the same with weekdays, except Saposnik et al. (2007) who tell us that more men arrive in the weekend.

Three publications present findings on the arrival of stroke patients per day of the week. Bachner & Zuba (2021) and Angerer et al. (2019) show mostly the same results: there are significantly more arrivals on Mondays and they decrease towards Friday with significantly less admissions in the weekend. Henr-Ching Lin et al. (2009) also tells us that strokes happen more often on Mondays and give a possible cause: it might be associated with the sudden build-up of stress on the first day returning to work. They also tell us that strokes happen more often on holidays.

The severity of the stroke is also dependent on the day of the week. Bachner & Zuba (2021) and Angerer et al. (2019) say that the severity of strokes increases throughout the week and peaks at the weekend. Niewada et al. (2012) also states that patients arrive in a worse status on weekend days than on weekdays. Huei-Kai Huang et al. (2019) discusses that the severity of the stroke depends on whether it is a weekday, weekend day, or a holiday. The severity increases respectively.

The findings in the different publications of age, severity, and day of the week could be related. A hypothesis could be that on weekdays more working people get a stroke, which decreases the average age and severity. However, we do not find any arguments for this in the literature.

We conclude that there is yet no widely supported explanation for the different arrival and severity patterns of stroke patients depending on the day of the week. However, we acknowledge that it happens. We therefore cannot say that there is a difference in stroke characteristics depending on the day of the week, but we can say that there is a difference in frequency and severity.

3.2 The weekend-effect

In this section, we are going to answer the following question:

How does the 'weekend-effect' affect the care of stroke patients?

In the search of answering the question of Section 3.1, we often find the 'weekend-effect'. This term represents the possible lack of (qualitative) care in hospitals during the weekend.

Searching for the weekend-effect in stroke care brings us too many publications about the influence of hospitalization in the weekend on mortality. Most of the publications focus on the mortality or clinical status of the patient because of the lack of (qualitative) acute care. Focus lays upon the acute care phase of treatment and is therefore out of the scope of this research. This is because at this stage of the research we focus on treatment outside the acute phase of the stroke and we do not take the possible improvements in the acute phase into consideration.

When we narrow down the search to the influence of the weekend on the LOS, we find six publications that tell us something about that. Appendix D2 depicts the systematic search process. These six publications present research on stroke patient populations in Scotland, the United Kingdom, Taiwan, and the United States. They explain the same: there is no significant difference in the LOS of patients who arrive in the weekend with respect to patients who arrive on weekdays. None of the articles gives us more explanation on the weekend-effect specified on the care process and LOS.

We therefore cannot find possible influences of the weekend-effect on the care of stroke patients.

3.3 Relationship between length of stay and capacity

In this section, we are going to answer the following question:

Is there an effect of bed capacity availability on patients' lengths of stay??

We want to get an understanding of the impact of interventions in stroke care. LOS and capacity are possible key performance indicators (KPIs). Therefore, we investigate the effect of bed capacity on patients' lengths of stay.

The search strategy, depicted in Appendix D3, brings various publications on process optimization in health care. Because the key terms appear in many publications of different health care topics, we choose to use strict inclusion criteria that focus only on the articles presenting a direct link between bed capacity and LOS.

Two publications present findings about the link between bed capacity and LOS. White et al. (2013) did research on the improvement of discharge efficiency of paediatric patients in the Cincinnati Children’s Hospital Medical Centre. While improving the discharge efficiency, they also shorten the LOS. As a result, they find that beds came available for unplanned admissions and postsurgical care. Bowers and Cheyne (2016) did research on the shortening of postnatal hospital stay in the UK. They present the relationship between lengths of stay and bed capacity on a certain level of service. Both levels of service show a positive linear relationship between the two variables.

One publication is dedicated to research on the impact of bed capacity on LOS. Walsh et al. (2021) did research on that subject in Ireland. They present a positive statistically significant relationship between bed supply and LOS. This means that a higher level of bed supply is associated with longer LOS. They further examine the heterogeneous effects across sexes, marital status, public/private discharge status, and for patients with different levels of comorbidities. The positive relationship between bed capacity and LOS is also observed there. They conclude that this shows that the connection between bed capacity and LOS can flow in both directions. The reduction in LOS can be driven by various factors: limited bed capacity, changes in expenditure, reduced demand for care, or the shift of care to another setting. As discussion, Walsh et al. (2021) tell us that the implications of low bed capacity go beyond LOS and affect patient outcomes more generally. Covid-19 is a clear example of that. As a result, the quality of care could decrease, and readmission rates could increase. They also discuss that the health care system in Ireland is somewhat different from the rest of Europe, a combination of private and general hospitals, and therefore these results cannot be generalized.

In the relationship between lengths of stay and bed capacity also other factors are of importance. Many publications write about the effects of more expensive treatment which causes shorter lengths of stay. For example, Kalthoft et al. (2011) talk about this subject with the use of laparoscopic surgery. The surgery is assumed to be more expensive but has less impact on the patient. Therefore, patients stay less long in the hospital afterwards. Workers in Slingeland hospital also tell us that constantly focussing on the expected discharge date of a patient has a lot of effect on the LOS. This method makes sure all caretakers have to constantly evaluate when a patient can leave the hospital, and therefore think about the future planning of the treatment.

We conclude that there is a positive linear relationship between lengths of stay and bed capacity. Various effects on either one of the two variables cause it. Decreasing both variables is often seen as efficient. However, it could for example have negative consequences for the quality of care. We must bear this in mind in our research.

There is still little known on the effect of the day of the week in stroke care. We cannot answer the research question with the literature. The information found on the patient characteristics in Section 3.1 explains the arrival frequency results we found in Chapter 2. Because of the limited scope of this research, we do not further search for explanations ourselves. In Section 3.2 we did not find any confirmation on the weekend-effect in stroke care we suggested in Chapter 2. Because we believe the suggested effect happens in

Slingeland, we will investigate this. In Chapter 4, we will discuss how we will further research this subject. The information we found in Section 3.3 is used in this further research.

4 Analysis of the impact of removing the weekday effect

This chapter answers the following question:

What is the impact on capacity usage of removing the weekday effect?

This raises the question how to quantitatively assess this. We therefore need to understand the real world-system first. Section 4.1 describes the real world in a conceptual model. In Section 4.2 we argue that a discrete event simulation model is best for this purpose. Section 4.3 translates the conceptual model into the simulation model. In Section 4.4 we gather and prepare the data from Slingeland for the simulation model. In Section 4.5 we verify and validate the model, which ensures that the model is sufficiently accurate.

4.1 Conceptual model

In this section we create a non-software specific description of the simulation model: the conceptual model. It consists of the following key components: objective, content, inputs, outputs, assumptions, and simplifications (Robinson, 2014). Below we will discuss each component.

Objective

The objective of this simulation study is to create a model of the care of stroke patients in Slingeland hospital. We want to simulate interventions which remove the effect of the day of the week that influence the LOS.

Content

The model consists of three departments: Stroke Care Unit, Acute Care Unit, and the Clinical Neurology department. Patients arrive at the hospital and then flow through these departments via various routes. The flow of patients within the simulation is depicted in Figure 4-1. Figure 4-4 depicts the logic of the steps in the simulation.

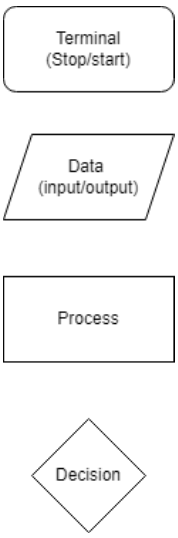

Figure 4-2 Legend for flow charts

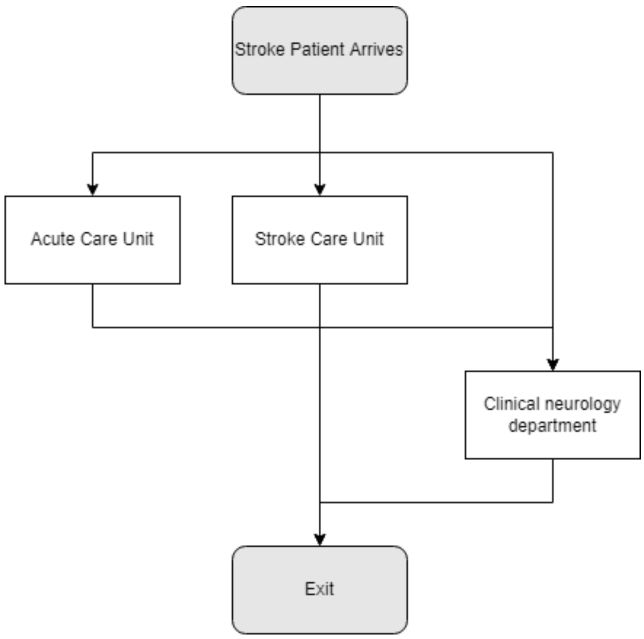

Figure 4-1 Process flow chart

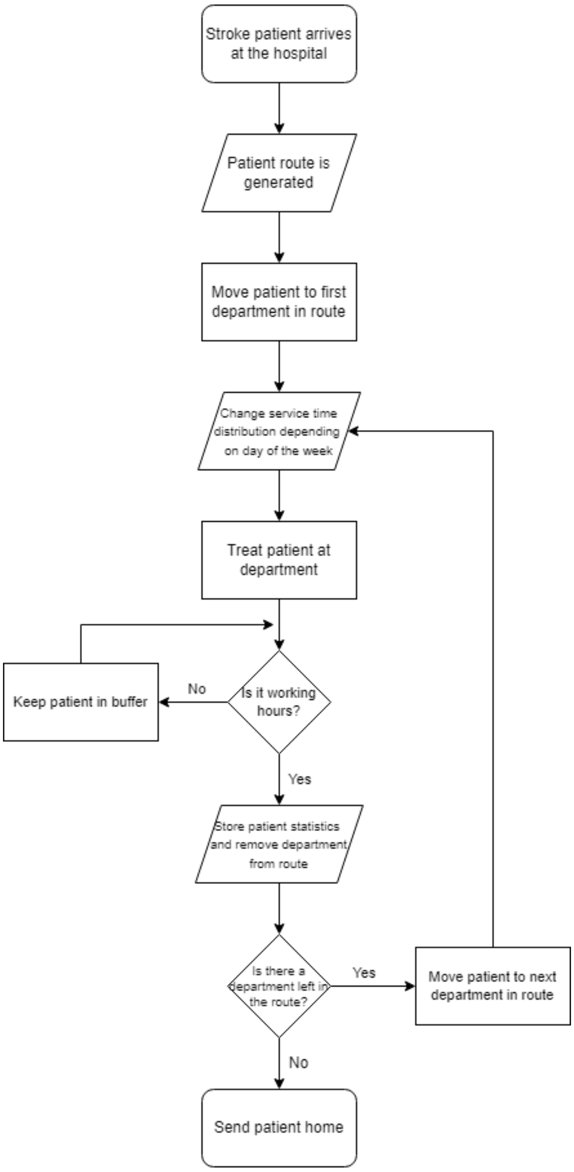

Figure 4-4 Flow chart of the simulation logic

Inputs

We use a data set containing all arrivals to Slingeland in 2018 and 2019. The derivation of the data used is explained in Appendix E. The eventual data we are going to use is depicted in Table 4-1.

Table 4-1 Input data

Arrivals	Arrival distribution	See Table 6-25
Routes	Route table	See Table 6-26
Stroke care unit	Service distribution	See Table 6-27
Acute care unit		
Neurology ward		

Outputs

The outputs of the simulation software are depicted in Table 4-2 and entail both individual patient data and general performance measures.

Table 4-2 Output data

Stroke care unit	Length of stay
	Number of occupied beds
Acute care unit	Length of stay
	Number of occupied beds
Neurology ward	Length of stay
	Number of occupied beds
Patients	Total length of stay
Departures	Distribution of departures

Assumptions and simplifications

Table 4-3 lists the assumptions and simplifications of the model, and their motivations.

Table 4-3 Assumptions and simplifications of the simulation model

Arrival	The process on the emergency department is disregarded. For the simulation we assume the throughput time to be zero.
	We have insufficient data to take into consideration whether a patient has been to Rijnstate Hospital for intravenous thrombolysis.
	We focus on differences between individual days, not weeks or months.
Patients	We have insufficient data to take the severity of the stroke into consideration.
	We have insufficient data to take the medical status of the stroke into consideration.
Departments	There is no finite capacity of beds and staff. This means that there are infinite servers because we do not want to simulate a queue.
	A change of bed within the same department is not taken into consideration, because we want to determine the bed occupation of the department as a whole.
Transfer	The effect of the fact that no patient transfers take place during the night is contained within the service times of the departments. We chose to use a service time per day and not divide this into hours. Therefore, patients can finish their service time during the night, which means they will be placed in a buffer and transferred to the next department or exit at a specified time in the morning.
	Transportation time is not taken into account, because in the data used, the discharge from one department is immediately followed by entry to the next department.
Others	Service times for departments can be dependent on the previous visit to a department. We do not take this into consideration and look at the departments independently.
	Arrival rates and service rates are based on empirical data. In reality, it is possible that patients may be transferred earlier or later than the time specified in the data. We do not take this into consideration in the simulation.

4.2 Why computer simulation?

Now that we understand the real world, we must study and use interventions in the system we describe in Section 2.4. Robinson (2014) and Law (2015) discuss methods for studying a system.

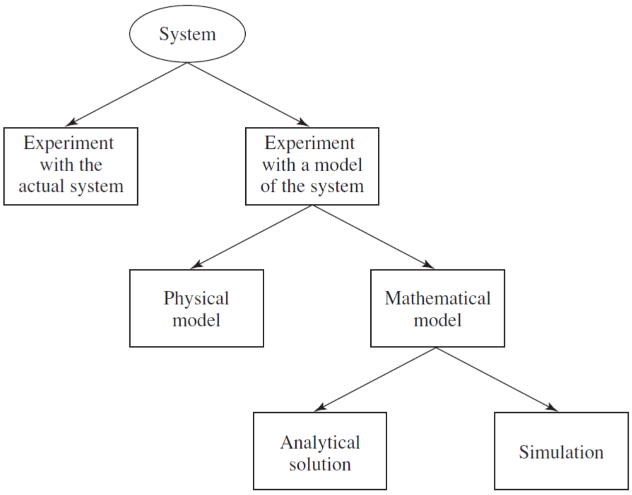

Figure 4-5 Ways to study a system (Law, 2015)

Law (2015) presents this flow diagram. Where it is possible to experiment with interventions in the actual real world system, this is always the preferred method. It shows the most accurate effect of the measures. However, often this is too disruptive or costly to do. This is also the case in the care of stroke patients in Slingeland, since this would affect the quality of care of stroke patients. Therefore, we want to experiment with a model of the system. A physical model could in theory be made, but it would be too time consuming, the reproduction of a stroke too complex, and the building of a replica hospital too expensive. We would therefore elect to use a mathematical model.

Robinson (2014) states that the use of an analytical solution or simulation depends on the three principles of operating systems: variability, interconnectedness, and complexity. When an operating system is simple, for example, if it has low variability, small components which are connected, and if such connections are not complex, the system can be analysed using analytical models. When these factors increase in complexity, the calculations and relations become more complex as well. Where this complexity becomes such that calculations are too costly, difficult or lengthy, we need to simulate the process instead. Many departments, people and external influences are involved with the care of stroke patients in Slingeland. Each of these factors have their own variables, but most of them are connected. For example, the arrival rate differs on different days of the week, each department has another average LOS, and the capacity of one department affects the others. These variables and interconnections make the system very complex. Therefore, we must conclude that the system is too difficult to study with analytical models, and a simulation study is more appropriate.

According to Law (2015), simulations have certain characteristics. A simulation can be continuous or discrete. In a continuous simulation the state constantly changes over time. For a discrete simulation the state changes at certain moments in time only. Furthermore, a simulation can be deterministic or stochastic. In a deterministic simulation there are no probabilistic components. For a stochastic simulation, (a part of) the events happen with a probability. Finally, a simulation can be static or dynamic. A static simulation represents the system in a certain point in time. Dynamic simulations represent the system as it evolves over time.

There are several simulation types. Continuous event simulation, discrete event simulation, and Monte Carlo simulation are most commonly used. Table 4-4 shows their characteristics.

Table 4-4 Simulation types and their characteristics

Type simulation	Continuous or discrete	Deterministic or stochastic	Static or dynamic
Continuous event	Continuous	Stochastic	Dynamic
Discrete event	Discrete	Stochastic	Dynamic
Monte Carlo	Discrete	Stochastic	Static

For our research we are interested in the routes patients take, the length of their stay, and the bed capacity. This only changes when a patient is moved, so an event happens. Therefore, the system is discrete. Because the routes and LOS happen with a certain probability the system is stochastic. We want to evaluate the system as it evolves over time and need a dynamic simulation model. We therefore conclude that a discrete-event simulation (DES) model fits best our case. It models a system over time by changing the (probabilistic) variables instantaneously at separate points in time. Only the points in time at which the state of the system changes are represented.

DES works with a three-phase simulation approach (Robinson, 2014). In the A-phase the time of the next event is found, and the clock is advanced to that time. The B-phase executes all time-bound events. These are scheduled state changes that occur at a point in time. Generally, these apply to arrivals or the completion of an activity. In the C-phase all conditional events are simulated. These are events that depend on the conditions in the model. These primarily relate to the start of an activity. Figure 4-6 depicts how the DES three-phase model works.

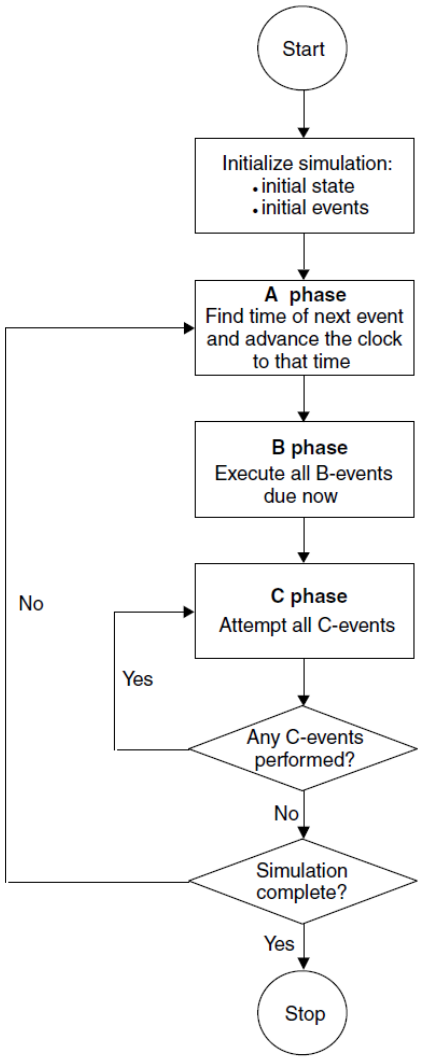

Figure 4-6 Three phase simulation approach (Robinson, 2014)

4.3 The simulation model

In this section we explain the simulation model, which was implemented in the Tecnomatix PlantSim software by Siemens. Figure 4-7 shows the operators of the simulation. In this section we discuss the elements of the simulation model.

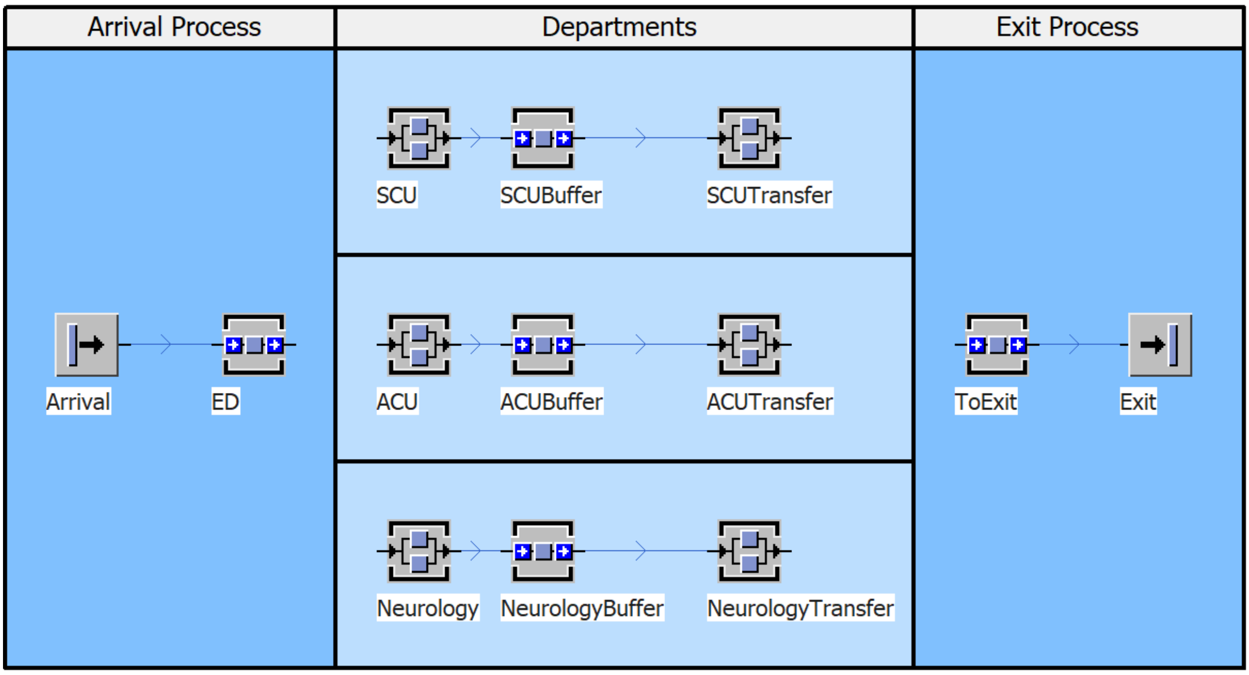

Figure 4-7 Simulation model screenshot from Tecnomatix PlantSim

Arrival and ED

As discussed in Section 3.1 and found in the empirical data, patient arrival rates depend on the day of the week. To model this, we divided the week into 14 timeslots, consisting of the day and night of every day of the week. We select the peak arrival rate of the timeslot with the most arrivals and let the arrival operator create patients at that rate. Depending on the timeslot, patients are deleted by a certain probability, which will be discussed in the next section.

Patients that are not deleted are transferred to the ED. Here, the patients are assigned a care path and transferred to the first department in this care path.

Departments – SCU / ACU / Neurology

Patients are treated at the departments. The process is split up into three operators per department. When a patient arrives at each department, the service time is assigned by the first operator, depending on the day of the week. When the service time is completed, the patient is transferred to the corresponding buffer. During working hours, the transfer operator will store the statistics of the patient, check the next department in the care path, and move the patient there.

Exit

The patient leaves the simulation at the exit.

4.4 Input data

This section discusses the data processing required to make the data usable in the simulation software.

Arrival data

We assume the arrival of stroke patients to be a Poisson process. This means that all arrivals are individual and independent. The empirical data set contains arrivals of stroke patients in 2018 and 2019. We created an arrival policy with blocking rates to model the different arrival rates depending on the day of the week, and whether it is day or night. Time slots are designated (08:00-20:00 / 20:00-08:00) based on the plotted graph of arrival data (Figure 6-3). The highest arrival rate of each of the timeslots is selected, this sets our peak arrival rate. Based on the empirical arrivals of the other timeslots, blocking rates are determined. In the simulation software, this means that with a certain probability, arrivals are blocked to create the realistic weekday effect in the arrival of stroke patients. The arrival and blocking rates can be found in Appendix E, Table 6-25.

Departments – SCU / ACU / Neurology

Empirical data of the total lengths of stay in a department in 2018 and 2019 is input in our dataset. Only those stays which occurred in the routes discussed in Section 2.4 are used. In order to ensure simulations are unique, we fit a distribution to the empirical data. We first look at the distribution of the empirical data and remove extensive outliers from the dataset. This results in removing 4 SCU data points, 1 ACU data point, and 4 Neurology data points.

In Python we use the package 'distfit' (Taskesen, 2022) to determine the probability distribution which best fits the data. This tool fits the most suitable distribution in its library to your data. Unfortunately this did not result in an adequate visual representation. Therefore we used web-tool, which is also Python-based, but is more visual (Raoniar, 2022). In this tool you insert data, select the number of bins you want to use, and the distributions you want to fit. The simulation software restricts the type of distributions that can be used, and the desired parameter change. It is only possible to use a set of commonly known distributions within this software. Furthermore, we want to change the parameters of the distributions based on the day of the week, which is only suitable for certain distributions.

The tool selects the best fitting distribution based on the sum square of the errors, the difference between the empirical data bin and the distribution. This results in a Cauchy distribution for the SCU and Neurology department, and a Laplace distribution for the ACU. While this is unfortunately not the best fitting distribution out of all existing distributions, it is the most usable one. Figure 4-8 depicts the plotting of the Cauchy distribution on the SCU LOS. The plotted graphs of the ACU and Neurology are in Figure 6-4 and Figure 6-5 respectively in Appendix E.

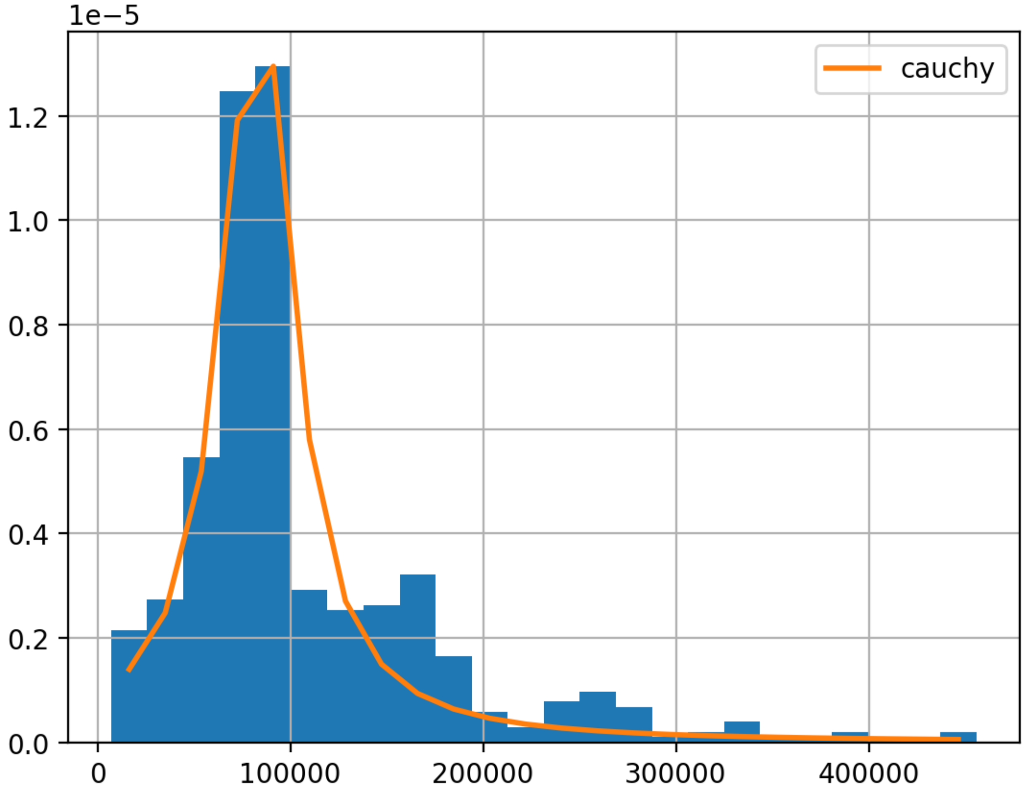

Figure 4-8 Cauchy distribution plotted on SCU LOS histogram

The empirical dataset is then used to adjust the parameters. Based on the boxplot, median, and mean value we select an 'in-between value' for every day and department. This is defined as the value between the median and mean value. We calculate the percentage difference with the total data set 'in between value' for each day, and use this as a scalar for the parameter of the distribution. The results are depicted in Appendix E, Table 6-27.

4.5 Verification and validation

In this section we set up the warm-up length and number of replications of the simulation model. It is subsequently verified and validated with the white- and black-box method.

Warm-up period

We used a Marginal Standard Error Rules (MSER) Heuristic tool to determine the warm-up period. The total maximum number of occupied beds per day of 10 years was used as input data with 20 replications. The tool plotted the graph in Figure 4-9 and gave a warm-up period of 9 days.

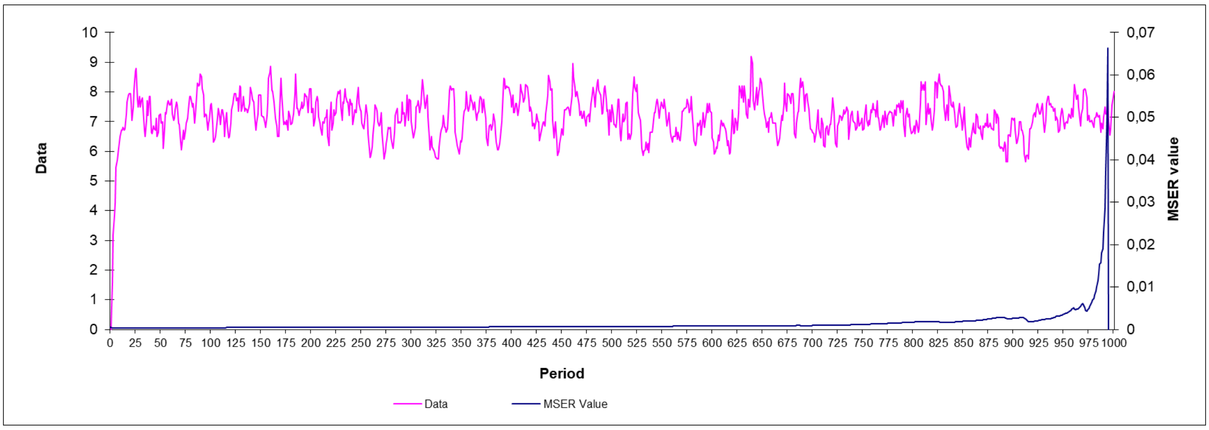

Figure 4-9 MSER Heuristic graph for determining the warm-up period.

Number of replications

We use a paired t-test to determine the number of necessary replications. The total LOS of a patient was used as a KPI. With a 95% confidence interval only 1 replication was needed. We next increased the confidence interval to 98% and 99%, which resulted in 5 and 9 necessary replications respectively. Due to the relatively short running times, we can manage a higher number of replications, which is why we elected to run 9 replications per experiment.

Verification

In the process of verification, the simulation model is compared to the conceptual model. The process checks whether the simulation model meets the requirements of the conceptual model. There continues to be a match between the two models, which means the model is verified.

White-box validation

According to Robinson (2014), white-box validation checks the validity of the separate parts of the simulation model. The outputs of the constituent parts of the simulation model, which are based on distributions, are compared to the empirical data.

With a simulation of 10 years, the arrival process gives on average 6% fewer patients per day compared to the empirical data. Regrettably, the division between day and night is also inaccurate. We suspect that this effect is a result of an inter arrival time that is almost equal to the timeslots at which the blocking rate changes. This is therefore identified as a limitation of the simulation model.

The LOS of the SCU and ACU perform as desired and resemble the empirical data. The boxplots and paired t-tests with a 95% confidence interval show us the distribution has a good fit.

The LOS of the Neurology department performs as expected based on the distribution we used, but is not sufficiently visually similar to the empirical data. There are fewer high values, and the other observations are more concentrated around the median. The paired t-test with a 95% confidence interval shows us the distribution has a good fit. However, we still think the visual inspection of the data displays a limitation of the neurology operator, and therefore it has to be acknowledged that it simulates shorter lengths of stay than in real life experiences.

Black-box validation

According to Robinson (2014), black-box validation checks the validity of the overall simulation model, i.e. whether the overall result sufficiently represents the real-world model. We therefore compare the bed occupations of the departments, which are based on the routes and the service distributions, with the empirical data.

A paired t-test on the max bed occupation per day per department and max total bed occupation per day shows there is a significant difference between the data sets with a 95% confidence interval. Only the ACU data is accepted with a 95% confidence interval. The simulation model performs worse than the real world. On the total LOS we see a mean LOS which is 20% larger than the empirical data. We see this as a limitation of the model but accept it since it is preferable making the model too optimistic, and the LOS results are worse than the real world model.

Now that we have designed and validated the model, we can design and run interventions to see the impact of weekday differences and its removal in Chapter 5.

5 Impact of the interventions

This chapter answers the following question:

What is the expected impact of the interventions?

In Section 5.1 we will design the interventions, a set of measures to be taken by the hospital to remove the effect of the week. The impact of these interventions will be discussed in Section 5.2. In Section 5.3 we discuss how we translate the experiments into interventions in the real world. Section 5.4 discusses alternative experiments.

5.1 Design of the experiments

The main objective of this research is to see which effect the day of the week has on the care of stroke patients. According to the interviews conducted in Chapter 2, this effect is caused by the different planning of nurses, the lack of para-medical care in the weekend, and the restriction that patients can only be transferred to nursing homes on weekdays. According to the principal, this causes longer patient LOS and a higher bed occupation than necessary.

It is difficult to translate the quoted events directly into experiments in the simulation model. We therefore choose to select a method that represents the effect of removing any weekday effect in the care of stroke patients. To implement this, the service time distribution parameters (LOS of patients) are changed. In the base model a patient gets a service time assigned by a probability distribution, which is based on the day of arrival at that department. In the experiments, we use the day with the distribution that has on average the shortest LOS, and assign that distribution to every patient on all days. To mitigate against the limited data points for the ACU on Saturday, and the fact that it is a weekend day, we choose the second smallest LOS for the ACU. This results in the location parameter of the distributions of the LOS in Table 5-1. The yellow cells are the new distribution parameters for the departments.

Table 5-1 Parameters of the experiment (in hours)

	Total	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
SCU	23,08	24,13	25,01	21,83	**20,98**	23,10	23,18	23,23
ACU	24,85	28,64	**22,90**	24,19	20,74	25,77	16,52	30,02
Neurology	80,66	**59,03**	107,14	70,44	90,99	98,33	72,01	69,09

These experiments will be toggled by Boolean 'weekday-effect' parameters in the simulation. There will be a separate Boolean parameter for each department. Thus, we perform an analysis of the impact of removing the weekday effect on the different departments, since we expect the 'weekday-effect' on the SCU and ACU to exist due to undeclared bias.

Table 5-2 depicts the experiments run by the simulation software where experiment 1 resembles the current situation.

Table 5-2 Experiments in the simulation model

EXPERIMENT	SCU WEEKDAY-EFFECT	ACU WEEKDAY-EFFECT	NEUROLOGY WEEKDAY-EFFECT
1	True	True	True

2	True	True	False
3	False	False	False

5.2 Results of the experiments

This section presents the result of the experiments conducted in the simulation model. We use the bed occupation and LOS as the main output KPIs.

Bed occupation

Table 5-3 depicts the results of the average maximum number of beds per day of the experiments.

Table 5-3 Average of the maximum number of beds of the experiments

	SCU		**ACU**		**Neurology**	
	# Beds	**% Change**	**# Beds**	**% Change**	**# Beds**	**% Change**
Experiment 1	1,22		0,44		4,11	
Experiment 2	1,22	0%	0,33	-25,0%	3,66	-10,9%
Experiment 3	1	-18,0%	0,22	-50,0%	3,22	-21,7%

The results of experiment 2 are not as expected for the SCU and ACU. We would expect the same results as the current system, experiment 1. There is a difference in the averages and interquartile range of both departments displayed in Figure 6-6 and Figure 6-7 in Appendix F. The difference may be explained by the use of the probabilistic variables and therefore caused by random bias. Since the difference is not significant, we ignore this bias. The results of experiment 3 are as expected. The averages decrease slightly for both departments, and the maximum of the ACU department shown in Figure 6-7 in Appendix F is decreased to 1 bed.

The bed occupation of the Neurology department is depicted in Figure 5-1. The results from experiment 2 in relation to the bed occupation in the neurology department is as expected. As shown in Table 5-3 the average decreases by 10%. Also, the interquartile range decreases and shifts down. The result of the interquartile range in experiment 3 is as expected, it decreases and shifts down. Also, the reduction of the average is as expected. On the other hand, the maximum is larger than expected. The removal of the effect of the day of the week on the SCU and ACU might have more incidental effects on the neurology department than we expected. It could be caused by variability in the routes and arrival pattern that cause potential outliers to increase.

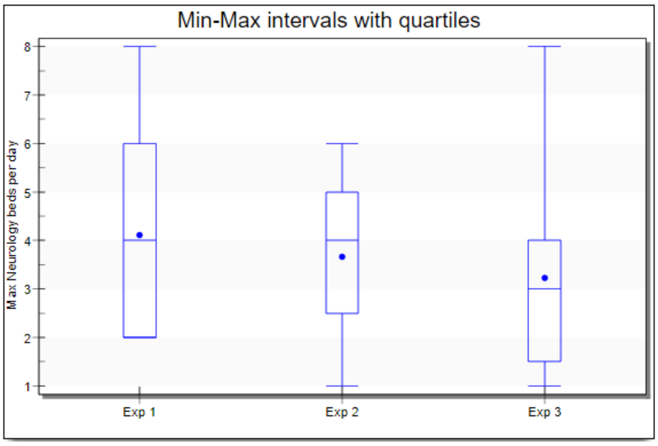

Figure 5-1 Neurology bed occupation min-max interval of the experiments

Length of stay

Table 5-4 depicts the results of the average LOS in hours of the experiments.

Table 5-4 Average LOS in hours of the experiments

	Total		SCU		ACU		Neurology	
	LOS	% Change	LOS	% Change	LOS	% Change	LOS	% Change
Experiment 1	116,7		29,9		30,4		114,1	
Experiment 2	105,5	-9,6%	29,9	0,1%	30,4	-0,1%	99,6	-12,7%
Experiment 3	103,3	-11,5%	28,0	-6,3%	27,2	-10,7%	99,4	-12,9%

The experiments have the expected results for the SCU and ACU based on Table 5-1. There is no significant impact. There is little difference between experiment 1 and 2. Experiment 3 also creates a minimal impact on the LOS on that department. The decrease on the SCU is line with expectations based on Table 5-1. The reduction on the ACU differs somewhat from what is expected based on Table 5-1. We assume that this is caused by the variability in the daily parameter values of the ACU when the weekday effect is present. The plotted results can be found in Figure 6-9 in Appendix F.

However, the results are not in line with the expectations of the respondent interviewed for the problem identification in Chapter 2. The respondent expected a big delay caused by the ACU in comparison with the SCU. This is not evident in our data and results.

If the experiments are translated into interventions they impact the Neurology LOS. The average LOS decreases in both experiments by almost 13%. The min-max intervals shown in Figure 6-10 in Appendix F more or less keep the same dimensions, but shift down. Table 5-4 displays an almost equal reduction for experiment 2 and 3. Based on Table 5-1 we expected a larger decrease here since the difference between the weekday parameter and the average parameter is larger.

The impact on the total LOS shown in Figure 6-11 in Appendix F and Table 5-4 show expected results in the decrease of the LOS. The decrease is in line with the individual departments. However, the sum of the averages of the individual departments is not in line with the average value of the total LOS. This could be caused by the occurrence of outliers that infrequently occur after one another, which increase the average. In effect, this means that a patient who has a large LOS in their first department very rarely has a further large LOS in their second department as well.

5.3 From experiment to interventions

In this section we gather the conclusions from the experiments, and their implications for the hospital.

Interventions

in Section 2.4, we discussed the processes that differ on weekend days with a nurse. Interventions that are required to remove the weekday differences are:

1. **The availability of paramedical care**
   Services like rehabilitation and speech training are the same on every day of the week.
2. **Visiting rounds of doctors**
   Every day has an equal number of visiting moments by the Neurologist.
3. **Transfer to nursing homes**
   The availability of patient transfers out of the hospital is constant.

Intervention 1 and 2 have to be executed internally, intervention 3 has to be dealt with externally.

Looking critically at the results of the interviews and experiments we conclude that there is no significant improvement to focus on with regards to removing the weekday effect on the SCU and ACU. The reduction of the bed occupation and LOS is minimal compared to the effort the interventions require. This is in line with the results of the interview with a nurse, who indicated that the SCU is working efficiently.

Based on the results, we conclude that removing the weekday effect can result in a significant improvement in the Neurology department. We conclude that a reduction of 0,55 bed occupation (-10,9%) on average and a reduction of almost 14 hours (-13%) of the LOS are beneficial for both the hospital and patient. However, such interventions to remove the weekday effect would affect all departments. Implementing them in one department ensures that it is implemented on the other. This is due to the general presence of personnel. So, if the interventions were to be implemented, all departments we have discussed would benefit from them. As a consequence, we conclude that a of 21.7% reduction in the bed occupation is feasible, which would result in an average reduction of 0.89 beds in the Neurology department.

This research focuses on stroke patients. The specified interventions could also improve the LOS of other patients, as well as the bed occupancy on both departments discussed in this paper, as well as others, since other patients can also benefit to the presence of paramedical personnel, more consistent visiting routes, and consistent discharges to nursing homes.

5.4 Additional experiments

Based on the results we devised other experiments we could implement in the simulation model. The principal stated that alternating from the ideal route, SCU-Neurology, also led to extended LOS, so we added this to the model. In order to take this into account, a Boolean operator toggles division of the routes within the simulation. The operator 'ideal route' is false when the routes in Section 2.4 are used and true when only the routes 'SCU-Neurology' and 'SCU' route are used.

Table 5-5 Routes in the current situation and ideal situation used for the additional experiments

#	ROUTE	CURRENT SITUATION	IDEAL ROUTE
1	SCU-Neurology	60%	78%
2	SCU	13%	22%
3	ACU-Neurology	11%	0%
4	ACU	9%	0%
5	Neurology	7%	0%

We ran the experiments mentioned in Section 5.1 again with the added route Boolean.

In every experiment the total LOS is worse than in the original experiment. There is a decrease in bed occupation on the ACU department, but that is counteracted by an expected increase in the SCU and Neurology department. On average the reduction of the ACU beds leads to a higher combined average bed occupation on the SCU and Neurology department.

The results could be biased, however, since the simulation model does not take the consecutive effects of different departments into consideration. In the real world, patient treatment on the neurology department could be delayed if treatment in the previous department had not started well, but this is currently not reflected in the simulation model.

With the above results, we can translate our findings into conclusions and recommendations for Slingeland in Chapter 6.

6 Conclusion and recommendation

This chapter answers the following research question:

> *How can the weekday effect in the care of stroke patients in the Slingeland hospital be removed?*

The objective of this research was to answer the following research question:

To what extent are there weekday differences in treatments of stroke patients. How can we standardise treatments and what would be the expected impact on lengths of stay?

> We conclude that there are weekday differences in the treatment of stroke patients. We can standardise these treatments by ensuring constant paramedical care, constant visiting rounds by neurologists, and a constant availability of transfers to external nursing homes.

6.1 Conclusions

This section discusses the conclusions of the research.

Significant weekday differences in the treatment of stroke patients exist.

> The literature, interviews, and data analysis show that there is a significant weekday effect in stroke care. This is mainly expressed in the weekend, and just after the weekend. In the weekend there is less (specialised) care available, and Mondays are used to catch up.

In the clinical Neurology department, bed occupancy can be decreased by 21,5% and LOS by 12,9%.

> The simulation study shows us that, in the Neurology department, a significant reduction in both bed occupation and LOS can be achieved by removing weekday differences. This would result in a reduction of 0,89 occupied beds on average, and a reduction of 14,7 hours LOS in the Neurology department.

Interventions to remove weekday differences affect all involved neurology departments.

> The interventions needed to remove weekday differences affect personnel who work in all departments discussed in this research. Additionally, external partners would require interventions, but their interventions also affect all discussed departments.

Total LOS of the patient can be reduced by 16,4 hours, which is equal to a reduction of 11,5%.

> Since removing weekday differences affects all involved neurology departments, the total LOS is reduced for stroke patients.

Removing weekday differences decreases the variability of the bed occupation on the Neurology department, which makes forecasting less complex.

> The results of the experiments show that the interquartile range of bed occupation in the Neurology department decreases. Therefore, bed occupation is more steady between intervals and therefore easier to forecast.

There are weekday differences in the occurrences of a stroke.

The empirical data and literature show that there are differences in the number of strokes occurring at different moments in the week. The incidence of strokes is remarkably higher on Mondays, compared to the weekend.

The use of the protocol route only (SCU-Neurology) does not have the desired impact on LOS.

Using only the protocol route does not lead to the expected decrease in length of stay.

6.2 Recommendations

This section discusses the recommendations of the research.

From a patient perspective, we recommend removing weekday differences in stroke care.

Since removing the weekday differences decreases the LOS of the patient, based on a patient perspective we suggest executing the proposed interventions.

We recommend doing a cost-benefit analysis of the proposed interventions.

Further research is needed to determine if the reduction in bed occupation and LOS is more beneficial than the costs and efforts of these interventions.

We recommend doing further research on the proposed interventions and their impact.

Since the proposed interventions affect additional non-stroke patients and other departments, the impact could be greater. This, in turn, could affect the cost-benefit analysis. We therefore suggest performing more integrated research on removing weekday differences.

We recommend doing further research on the effect of 'wrong-bed' patients.

Since there are big outliers in the data set, believed to be caused by 'wrong-bed patients', we suggest that this would benefit from further research. It is possible that the earlier discharge to nursing homes could be beneficial for more patients and departments.

We recommend doing further research on the effect of routing in stroke care.

The impact of the routes taken on LOS of patients is not taken into consideration in this research, but we suspect it is of importance. The dependency could cause either delays or improvements.

6.3 Discussion

This section discusses what Slingeland is going to do with the results of this research.

The presentation of the results to the team of integral capacity and transfer management shone a new light on the case. They are not too surprised with the results since they expected there to be a weekday effect, but they find the numerical proof very helpful. They only question whether paramedical care is the cause of this effect. According to the team, making paramedical care more consistently available would not remove the weekday effect. This is primarily due to the advice paramedical care gives about the state of the patient. According to the transfer management, one of the tasks of paramedical personnel is to advise the nurses and neurologist on whether a patient is in adequate shape to leave the hospital. However, the issue with such a process is that the neurologist has to conduct the final examination, taking into account the advice provided by the paramedical personnel. According to the transfer management this occurs less frequently during weekends, or potentially not at all.

The team of integral capacity and transfer management are going to use the results of this research as a starting point in persuading the personnel involved of the benefits of a constant workflow and the subsequent removal of the weekday effect. The numerical evidence will be shown to the neurologist to illustrate the impact of removing the weekday effect on only a small group of patients. It is a starting point for the process of slowly convincing involved parties of the effect of removing the weekday effect. The eventual goal is to broaden this research to other departments and thereby see what the impact could be for the hospital as a whole.

The results of the arrival pattern of stroke patients found in the literature and data also stood out for the team of transfer management. They strongly suggested that the peak of arrivals on Mondays and the decline during weekends, could also be caused by the stubbornness of people in the region. According to the team, the older people in the region tend to wait with their complaints until their own GP is available on Monday morning, even when complaints start on for example Saturday, when their GP isn't available. They are therefore contacting GPs in the region to establish what can be done to prevent this, and to supply improved information.

Appendix A. Bibliography

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Appendix B. Access times

Outpatient clinic

Table 6-1 Outpatient clinics access times (source: (Slingeland Ziekenhuis | Kwaliteit en behandelresultaten, 2021))

	# days
Anesthesiologie / Pijnbestrijding	49
Cardiologie	28
Chirurgie	35
Chirurgie - Liesbreuk	35
Chirurgie - Proctologie	21
Chirurgie - Vaatchirurgie	28
Dermatologie	49
Dermatologie - Oncologie (verdachte plek)	49
Gynaecologie	42
Gynaecologie - Incontinentie vrouw	42
Gynaecologie - Infertiliteit	42
Interne geneeskunde	42
Interne geneeskunde - Endocrinologie	42
Interne geneeskunde - Nefrologie	35
Kindergeneeskunde	7
Klinische geriatrie	63
KNO	7
Longgeneeskunde	35
Maag, darm en leverziekten	49
Mammapoli / Borstonderzoek	2
Neurologie	49
Neurologie - Hernia nek	49
Neurologie - Hernia rug	21
Oncologie	35
Oncologie - Plastische Chirurgie	7
Oogheelkunde	45
Oogheelkunde - Staar	7
Orthopedie	10
Orthopedie - Heupklachten	10
Orthopedie - Knieklachten	10

Orthopedie - Rugklachten	10
Orthopedie - Schouderklachten	10
Orthopedie - Voet en/of enkelklachten	10
Plastische Chirurgie	24
Reumatologie	42
Urologie	42

Diagnostics

Table 6-2 Diagnostics access times (source: (Slingeland Ziekenhuis | Kwaliteit en behandelresultaten, 2021))

	# days
Baarmoederhalsafwijkingen uitstrijkje GYNAECOLOGIE	42
Botdichtheidsmeting DEXA meting RADIOLOGIE	17
Colonscopie MAAG DARM EN LEVERZIEKTEN	42
CT RADIOLOGIE	5
Echografie RADIOLOGIE	20
Gastroscopie MAAG DARM EN LEVERZIEKTEN	42
Mammografie RADIOLOGIE	2
MRI hersenen RADIOLOGIE	33
MRI heup(en)/ onderste extremiteit(en) RADIOLOGIE	29
MRI nek RADIOLOGIE	21
MRI rug RADIOLOGIE	25
MRI schouder(s)/bovenste extremiteit(en) RADIOLOGIE	16
Röntgen RADIOLOGIE	1
Slaapapnoe diagnostisch onderzoek / screening KNO LONGGENEESKUNDE NEUROLOGIE	91
Slaaponderzoek / Polysomnografie KNO LONGGENEESKUNDE NEUROLOGIE	91

Treatment

Table 6-3 Treatment access times (source: (Slingeland Ziekenhuis | Kwaliteit en behandelresultaten, 2021))

Baarmoederverwijdering GYNAECOLOGIE	42
Besnijdenis UROLOGIE CHIRURGIE	56
Borstreconstructie PLASTISCHE CHIRURGIE	56
Carpaal Tunnel Syndroom - operatie CHIRURGIE PLASTISCHE CHIRURGIE ORTHOPEDIE	7
Carpaal Tunnel Syndroom - zenuwbehandeling NEUROCHIRURGIE	21
Dupuytren operatie	21

PLASTISCHE CHIRURGIE	
Galblaasverwijdering CHIRURGIE	28
Goedaardige aandoeningen van de anus operatie CHIRURGIE	21
Hartkatheterisatie CARDIOLOGIE	35
Hernia operatie / kanaalstenose ORTHOPEDIE NEUROCHIRURGIE	28
IUI GYNAECOLOGIE	42
Kijkoperatie knie ORTHOPEDIE	28
Liesbreukoperatie CHIRURGIE	28
Meniscus en/of kniebanden operatie ORTHOPEDIE CHIRURGIE	28
Middenoorbeluchtingsbuisjes plaatsen KNO	35
Navelbreuk operatie bij volwassenen CHIRURGIE	28
Neustussenschot operatie KNO	35
Niersteen vergruizing UROLOGIE	42
Niersteenverwijdering (percutane) UROLOGIE	28
Ooglidcorrectie OOGHEELKUNDE	18
Spataderen endovasculaire behandeling DERMATOLOGIE CHIRURGIE	56
Spataderen vaatchirurgische behandeling CHIRURGIE	35
Staaroperatie OOGHEELKUNDE	18
Sterilisatie man UROLOGIE CHIRURGIE	56
Sterilisatie vrouw GYNAECOLOGIE	42
Tonsillectomie en/of adenotomie KNO	35
Totale heupvervanging (initiële) ORTHOPEDIE	42
Totale knievervanging (initiële) ORTHOPEDIE	42
Triggerfingerrelease PLASTISCHE CHIRURGIE	21
Urine-incontinentie en/of blaasverzakking operatie bij man UROLOGIE	56
Urine-incontinentie en/of verzakking operatie bij vrouw GYNAECOLOGIE	42
Vergrote prostaat operatie UROLOGIE	56

Appendix C. Problem cluster

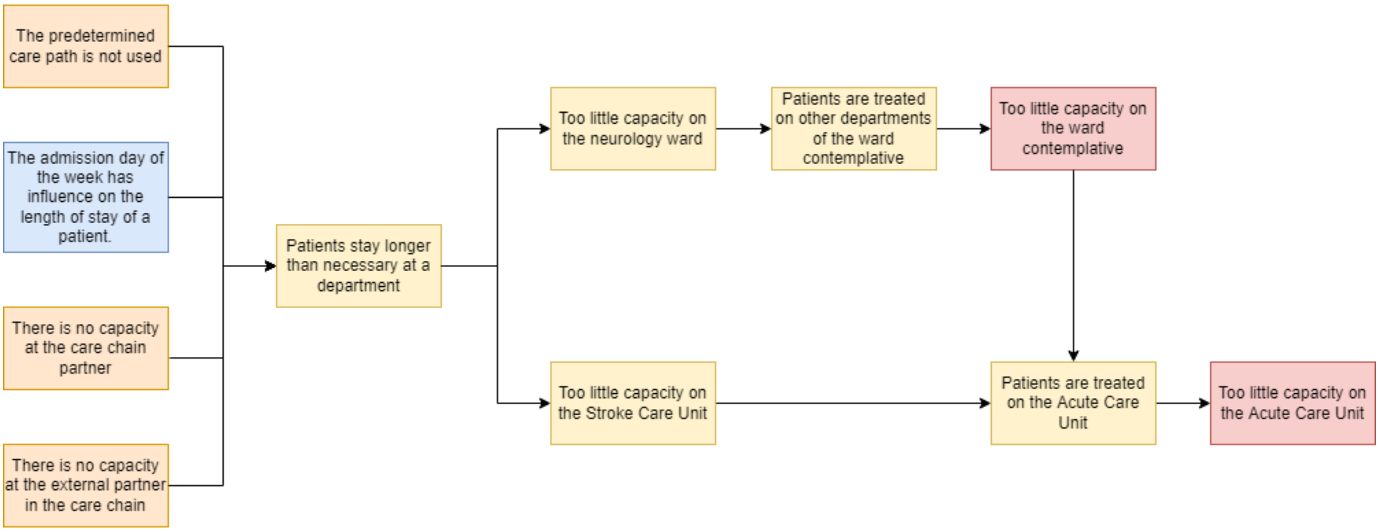

Figure 6-1 Problem cluster capacity issues within care chain of stroke patients

Appendix D. Systematic literature search

Appendix D1 Section 3.1

Table 6-4 Inclusion criteria Section 3.1

	Inclusion criteria	Reason
1	Keywords: stroke, characteristics, day, difference, seasonality	We want to search for stroke characteristics which have a different behaviour on different days of the week.
2	Subjects: stroke, disease course, and remarkable stroke characteristics	We want to learn more about the disease course of a stroke and know what remarkable characteristics are.

Table 6-5 Exclusion criteria Section 3.1

	Exclusion criteria	Reason
1	Non-Dutch or non-English literature	Otherwise, we cannot read the article.
2	Medical specifications on strokes which do not have different effects on different days of the week.	We are only interested in factors of the disease course that affect the process.

3	Diseases other than stroke.	We only focus on stroke patients for this research and exclude for example TIA.
4	Other definitions of stroke than the medical one.	We only focus on the stroke definition of "Cerebrovascular accident".
5	Weekday influences caused by the hospital.	We only focus on effects caused by influences outside the hospital.
6	Research where baseline characteristics of stroke patients are made the same.	We want to focus on the characteristics on the stroke and not take the generalized base of stroke patients.
7	Seasonality, meteorological or geographical influences.	We want to focus on effects based on the 7 days of the week.

Table 6-6 Databases used Section 3.1

Database	Reason
Scopus	Multidisciplinary
Web of science	Multidisciplinary
PubMed	Medical

Table 6-7 Search terms version 1 Section 3.1

Search string	Database	Scope	Number of entries
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND seasonality*	Scopus	Abstract title, abstract, keywords	105
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND "weekend effect"	Scopus	Abstract title, abstract, keywords	81
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND ("day of the week" OR "calendar day")	Scopus	Abstract title, abstract, keywords	141
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND seasonality*	Web of science	Topic	98
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND "weekend effect"	Web of science	Topic	96

("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND ("day of the week" OR "calendar day")	Web of science	Topic	96
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND seasonality*	PubMed	All fields	80
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND "weekend effect"	PubMed	All fields	67
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND ("day of the week" OR "calendar day")	PubMed	All fields	85
Total			**849**

Because this were too many articles we narrowed down the search terms and added the (characteristics* OR effects*) term.

Table 6-8 Search terms version 2 Section 3.1

Search string	Database	Scope	Number of entries
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND seasonality*	Scopus	Abstract title, abstract, keywords	34
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND "weekend effect"	Scopus	Abstract title, abstract, keywords	32
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND ("day of the week" OR "calendar day")	Scopus	Abstract title, abstract, keywords	48
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND seasonality*	Web of science	Topic	29
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND "weekend effect"	Web of science	Topic	31
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND ("day of the week" OR "calendar day")	Web of science	Topic	39
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND seasonality*	PubMed	All fields	29

("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND "weekend effect"	PubMed	All fields	27
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND (characteristics* OR effects*) AND ("day of the week" OR "calendar day")	PubMed	All fields	51
Total			**320**

Table 6-9 Funnel Process Section 3.1

Narrow down step	Number of articles remaining
Total search	320
Removing duplicates	157
Selecting last 10 years only	96
Scanning abstracts on inclusion and exclusion criteria	19
Reading on inclusion and exclusion criteria	6

Table 6-10 Article set Section 3.1

Source	Article	Authors (year)	Relevance
1	The weekend effect in stroke mortality: evidence from Austrian acute care hospitals	Bachner & Zuba (2021)	About weekend effect and admissions per day of the week.
2	The weekend effect revisited: evidence from the Upper Austrian stroke registry	Angerer et al. (2019)	About weekend effect, admissions per day of the week, and severity per day of the week.
3	Holiday Season and Weekend Effects on Stroke Mortality: A Nationwide Cohort Study Controlling for Stroke Severity	Huei-Kai Huang et al. (2019)	About the severity on weekdays, weekend days, and holidays.
4	Weekend versus weekday admissions in Polish stroke centres – could admission day affect prognosis in Polish ischaemic stroke patients?	Niewada et al. (2012)	About patient status on admission on weekdays vs. weekends.
5	Weekends: A Dangerous Time for Having a Stroke?	Saposnik et al. (2007)	About weekend characteristics of patients.

6	Weekly Pattern of Stroke Onset in an Asian Country: A Nationwide Population-Based Study	Hern-Ching Lin et al. (2009)	About the frequency of strokes happening on different days of the week and in the holidays.

Table 6-11 Conceptual matrix Section 3.1

Concepts ***Articles /***	**Weekend effect**	**Individual day effect**	**Holiday effect**	**Severity**
1	x	x		x
2	x	x		x
3	x		x	
4	x			
5	x			
6		x	x	

Table 6-12 Explanatory conceptual matrix Section 3.1

Topics ***Articles /***	**Weekend effect**	**Individual day effect**	**Holiday effect**	**Severity**
1	Patients in the weekend are significantly older, but were less likely to have had a previous stroke. Further specifications do not differ.	Significantly more admissions on Monday. Tuesday till Friday almost the same. Weekends significantly less admissions.		Severity increases and peaks at the weekend.
2	Patients in the weekend are slightly older.	Significantly more admissions on Monday. Decreases towards the weekend, but stabilizes on Friday. Significantly lower in the weekend.		Severity increases and peaks at the weekend.
3	Medium severity on weekend days, low severity on weekdays.		High severity.	
4	Worse patient status on admission in the weekend.			*See weekend effect.*
5	Patients admitted in the weekend were older and more frequently male. There were no other differences in baseline characteristics,			

	including medical complications.			
6		Stroke occurs more on Mondays, might be associated with short-term changes or the sudden build-up of stress on the first day of returning to work vs the rest of the week.	Stroke occurs more on holidays, might be associated with short-term changes or the sudden build-up of stress on the first day of returning to work vs the rest of the week.	

Appendix D2 Section 3.2

Table 6-13 Inclusion criteria Section 3.2

	Inclusion criteria	Reason
1	Keywords: stroke, weekend-effect, and length of stay	We want to search for the weekend-effect in stroke care and focus on the impact on the length of stay.
2	Subjects: stroke and weekend-effect	We want to learn more about the weekend-effect in stroke care.
3	We focus on the treatment outside the acute phase.	We want to learn more about the effects inside the hospital outside the acute phase.

Table 6-14 Exclusion criteria Section 3.2

	Exclusion criteria	Reason
1	Non-Dutch or non-English literature	Otherwise, we cannot read the article.
2	Medical specifications on strokes which do not have influence on the process and/or throughput time.	We are only interested in factors that affect the process.
3	Diseases other than stroke.	We only focus on stroke patients for this research and exclude for example TIA.
4	Other definitions of stroke than the medical one.	We only focus on the stroke definition of “Cerebrovascular accident”.
5	Weekend-effect in other diseases.	We only focus on the weekend-effect in stroke care.
6	Weekend-effect in totally different treatment to stroke than Slingeland.	We cannot use the findings if the treatment is totally different.

7	Studies focussed on the acute phase of the stroke.	We assume that the acute phase does not differ in the weekend.

Table 6-15 Databases used Section 3.2

Database	Reason
Scopus	Multidisciplinary
Web of science	Multidisciplinary
PubMed	Medical

Table 6-16 Search terms version Section 3.2

Search string	Database	Scope	Number of entries
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND "weekend effect" AND ("Length of stay" OR "hospitalization length" OR "length hospital stay")	Scopus	Abstract title, abstract, keywords	28
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND "weekend effect" AND ("Length of stay" OR "hospitalization length" OR "length hospital stay")	Web of science	Topic	17
("cerebrovascular accident" OR "cerebrovascular attack" OR stroke*) AND "weekend effect" AND ("Length of stay" OR "hospitalization length" OR "length hospital stay")	PubMed	All fields	19
Total			64

Table 6-17 Funnel Process Section 3.2

Narrow down step	Number of articles remaining
Total search	64
Removing duplicates	37
Scanning abstracts on inclusion and exclusion criteria	8
Reading on inclusion and exclusion criteria	6

Table 6-18 Article set Section 3.2

Source	Article	Authors (year)	Relevance
1	Variation in quality of acute stroke care by day and time of admission: prospective cohort study of weekday and weekend centralised hyperacute stroke unit care and non-centralised services	Melnychuk et al. (2019)	Weekend-effect influence on length of stay.
2	The weekend effect for stroke patients admitted to intensive care: A retrospective cohort analysis	Mitchell et al. (2020)	Weekend-effect influence on length of stay.
3	Influence of Admission Time on Health Care Quality and Utilization in Patients with Stroke: Analysis for a Possible July Effect and Weekend Effect	Liu et al. (2021)	Weekend-effect influence on length of stay.
4	A Nationwide Analysis of Outcomes of Weekend Admissions for Intracerebral Hemorrhage Shows Disparities Based on Hospital Teaching Status	Patel et al. (2015)	Weekend-effect influence on length of stay.
5	Comprehensive Stroke Centers and the 'Weekend Effect': The SPOTRIAS Experience	Albright et al. (2012)	Weekend-effect influence on length of stay.
6	Stroke patients admitted within normal working hours are more likely to achieve process standards and to have better outcomes	Turner et al. (2015)	Weekend-effect influence on length of stay.

Appendix D3 Section 3.3

Table 6-19 Inclusion criteria Section 3.3

	Inclusion criteria	Reason
1	Keywords: bed capacity, length of stay, relationship, and impact	We want to learn more about the relationship between length of stay and bed capacity.
2	Subjects: healthcare processes	We want to learn more about the process relationships in hospitals.
3	Publications from 2008 till present.	Since this is a relatively new subject, we focus on articles written from 2008 till present.
3	Publications that specifically elaborate on the relationship between length of stay and bed capacity.	Strict inclusion criteria to find only the publications that tell

		us something about the relationship.

Table 6-20 Exclusion criteria Section 3.3

	Exclusion criteria	Reason
1	Non-Dutch or non-English literature.	Otherwise, we cannot read the article.
2	Publications focussed on patient status or care.	We do not want to focus on the patient's clinical status or the care process.
3	Publications focussed on costs only.	We want to focus on the direct relation of length of stay and capacity, cost can be helpful, but not if it is only focussed on the financial part.

Table 6-21 Databases used Section 3.3

Database	Reason
Scopus	Multidisciplinary
PubMed	Medical

Table 6-22 Search terms Section 3.3

Search string	Database	Scope	Number of entries
"bed capacity" AND "length of stay" AND (relationship OR impact)	Scopus	Abstract title, abstract, keywords	209
"bed capacity" AND "length of stay" AND (relationship OR impact)	PubMed	All fields	113
Total			322

Table 6-23 Funnel process Section 3.3

Narrow down step	Number of articles remaining
Total search	322
Selecting last 10 years	225
Removing duplicates	156
Scanning abstracts on inclusion and exclusion criteria	11

Checking on availability	8
Reading on inclusion and exclusion criteria	3

Table 6-24 Article set Section 3.3

Source	Article	Authors (year)	Relevance
1	The impact of inpatient bed capacity on length of stay	Walsh et al. (2021)	Dedicated research on relationship between length of stay and bed capacity.
2	Using quality improvement to optimise paediatric discharge efficiency	White et al. (2013)	Shortening the length of stay resulted in more available beds.
4	Reducing the length of postnatal hospital stay: implications for cost and quality of care	Bowers and Cheyne (2016)	Shows us the relation between bed requirement and mean length of stay.

Appendix E. Dataset

Derivation of data

The main data set used in this research is derived from empirical data from all admissions in Slingeland from 2018 and 2019. This is a dataset exported from HiX, a healthcare information exchange system used by the hospital. Every hospitalization of a patient has an admission number. Per admission number all visits of a patient to a certain department and room are presented. Per certain department and room we can see the start time, end time, diagnosis, and type of admission. Because diagnoses is an open text field in the data set, and therefore not consistent, we connect the admission numbers to the diagnosis-treatment combination (DBC) code to see if the patient is admitted for a stroke. The DBC code is the eventual treatment code a patient receives and therefore we can see if the admitted patient actually has had a stroke. This results in 839 admission sets visiting 2286 department and rooms.

Because of inconsistent registration we left some steps in the care of stroke patients out of the dataset and made assumptions. As mentioned in Section 2.4.1 patients enter the hospital via the emergency department (ED) and are transferred to internal departments or external hospitals. The treatment on the emergency department is assumed to be efficient and improvement is out of the scope of this research. We therefore did not add this part of the treatment to the dataset. There is no consistent registration available of patients who are transferred to external hospitals. Therefore this step is not taken into consideration. Unfortunately we therefore cannot distinguish patients who directly come from the internal ED and patients who are transferred back from external treatment. We therefore cannot take the difference in patient type and the eventual difference in following treatment into consideration.

Arrivals

Analysing the arrival data we examine patterns per day of the week and per hour of the day. We therefore wanted to use inter-arrival times per day and use time slots per day. Based on the graphs below we set different periods for the inter-arrival rates. For each period of 09:00-13:00, 13:00-18:00, and 18:00-09:00 we set the corresponding arrival rate.

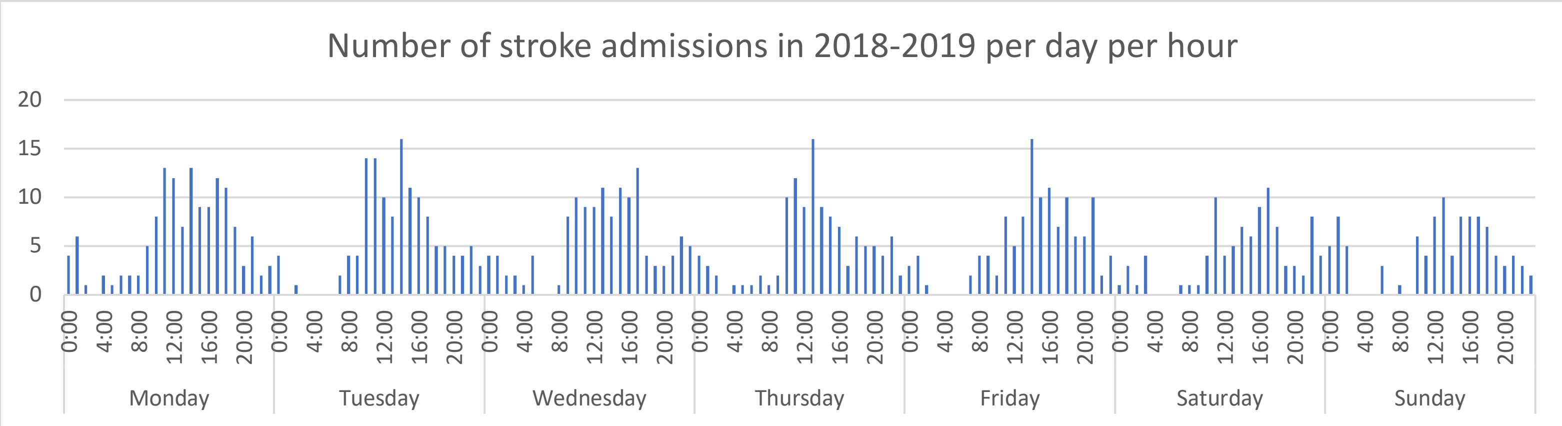

Figure 6-2 Number of stroke admissions in 2018-2019 per day per hour (n=842, 2018-2019, Source: Slingeland)

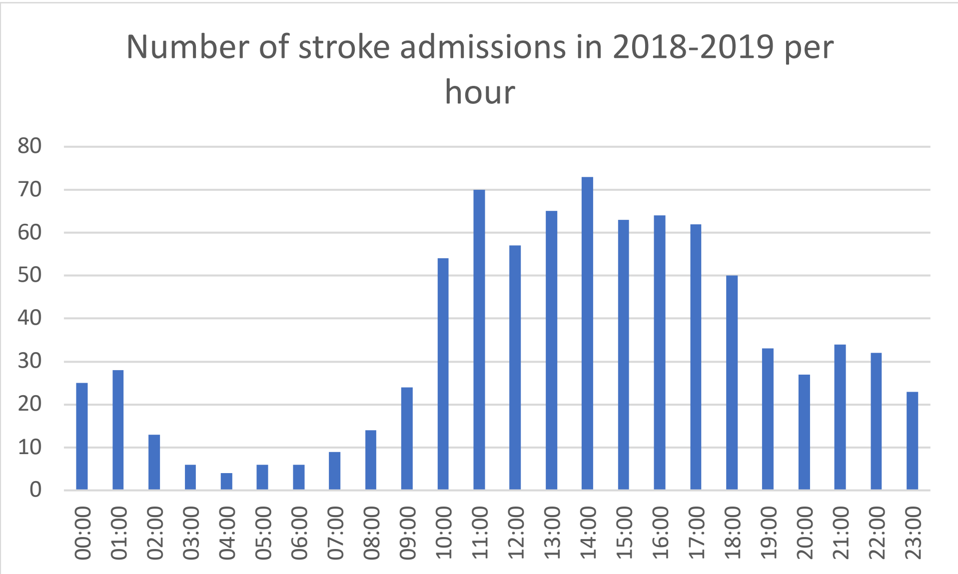

Figure 6-3 Number of stroke admissions in 2018-2019 per hour (n=842, 2018-2019, Source: Slingeland)

Arrival

Table 6-25 Arrival and blocking rates

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Day	108	109	97	88	91	68	68
Night	32	23	35	31	32	27	33
Total	140	132	132	119	123	95	101
Total #Days in 2018-2019	105	105	104	104	104	104	104

InterArrivalTime day	42000,00	41614,68	46317,53	51054,55	49371,43	66070,59	66070,59
InterArrivaltime Night	141750,00	197217,39	128365,71	144929,03	140400,00	166400,00	136145,45
Peak InterArrivalTime	41614,68						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Blocking rate day	1%	0%	10%	18%	16%	37%	37%
Blocking rate night	71%	79%	68%	71%	70%	75%	69%

Routes

With the use of a process mining tool we determined the 90% most used routes for stroke patients.

Table 6-26 Routes of a stroke patient (n= 842, 2018-2019, Source: Slingeland)

Route #	1st visit	2nd visit	% of total routes in hospital	Normalized % used in model
1	SCU	Neurology clinic	54 %	60 %
2	SCU	-	12 %	13 %
3	ACU	Neurology clinic	10 %	11 %
4	ACU	-	8 %	9 %
5	Neurology clinic	-	6 %	7 %

Service times

Table 6-27 Service times departments in hours

SCU	Total	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average	30,55	31,15	34,64	28,12	26,40	31,33	31,44	30,83
Mean	24,13	26,03	24,60	23,60	23,30	23,39	23,47	24,22
IBT value	27,34	28,59	29,62	25,86	24,85	27,36	27,45	27,52
% difference	-	0,05	0,08	-0,05	-0,09	0,00	0,00	0,01
loc	23,08	24,13	25,01	21,83	20,98	23,10	23,18	23,23
scale	5,98	5,98	5,98	5,98	5,98	5,98	5,98	5,98

ACU	Total	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average	31,66	38,87	27,24	30,35	25,66	33,27	19,06	41,64
Mean	24,85	26,26	24,84	24,67	21,49	25,33	18,50	26,62
IBT value	28,26	32,56	26,04	27,51	23,58	29,30	18,78	34,13
% difference	-	0,15	-0,08	-0,03	-0,17	0,04	-0,34	0,21
Loc	24,85	28,64	22,90	24,19	20,74	25,77	16,52	30,02
Scale	14,12	14,12	14,12	14,12	14,12	14,12	14,12	14,12

Neurology	Total	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average	127,87	91,53	151,27	119,70	131,39	156,52	123,66	121,05
Mean	94,32	71,07	143,86	74,33	119,23	114,32	74,70	69,25
IBT value	111,09	81,30	147,56	97,01	125,31	135,42	99,18	95,15
% difference	-	-0,27	0,33	-0,13	0,13	0,22	-0,11	-0,14
Loc	80,66	59,03	107,14	70,44	90,99	98,33	72,01	69,09
Scale	48,83	48,83	48,83	48,83	48,83	48,83	48,83	48,83

Distribution fitting

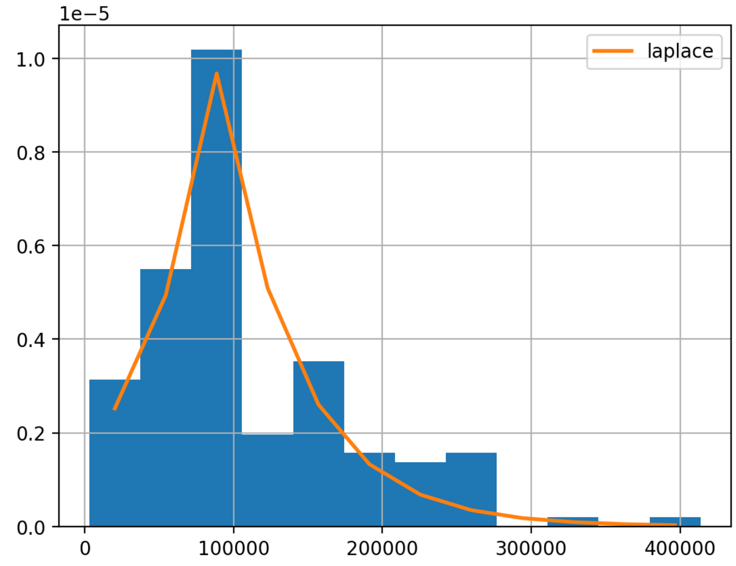

Figure 6-4 Laplace distribution plotted on ACU LOS histogram

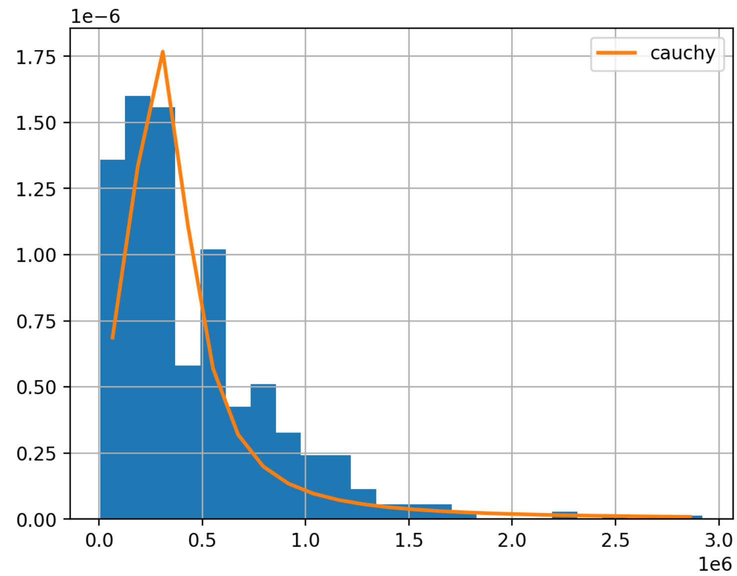

Figure 6-5 Cauchy distribution plotted on Neurology LOS histogram

Appendix F. Experiments results

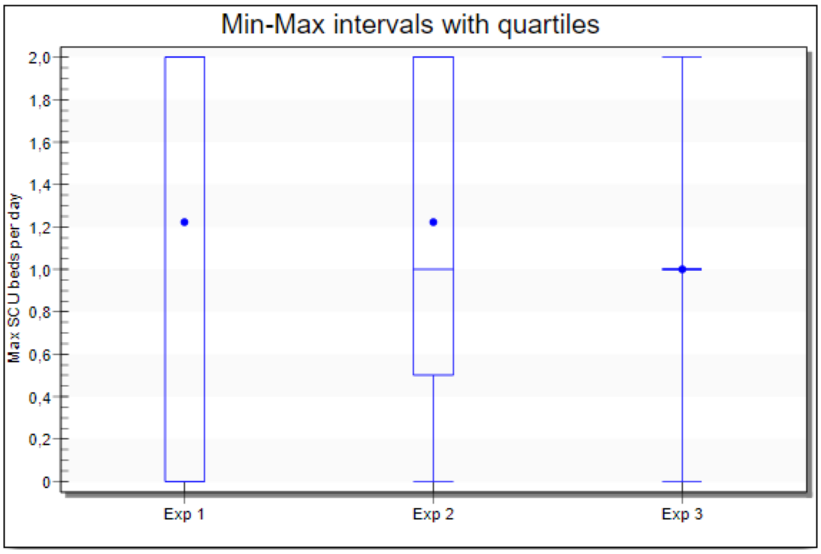

Figure 6-6 SCU bed occupation min-max intervals of the experiments

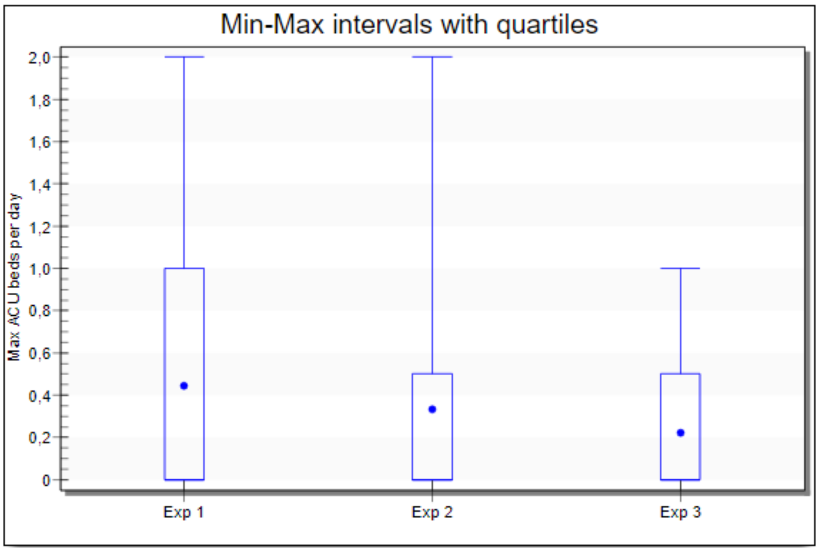

Figure 6-7 ACU bed occupation min-max intervals of the experiments

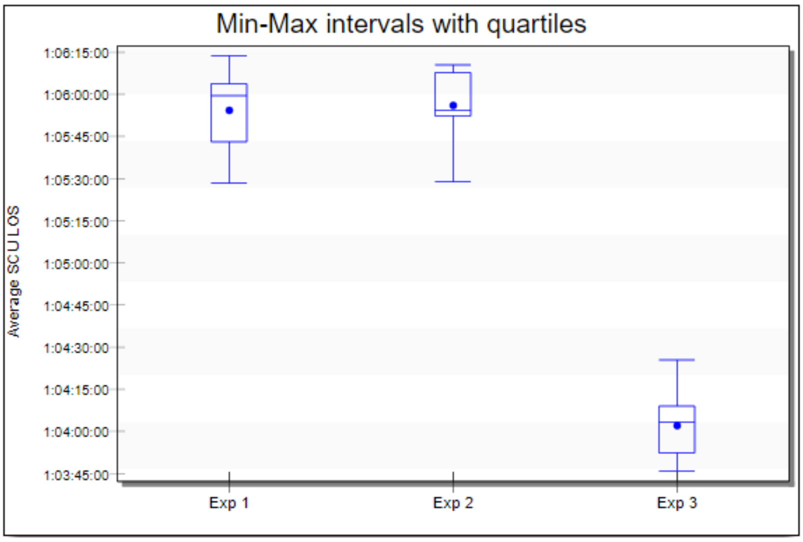

Figure 6-8 Average SCU LOS min-max intervals of the experiments

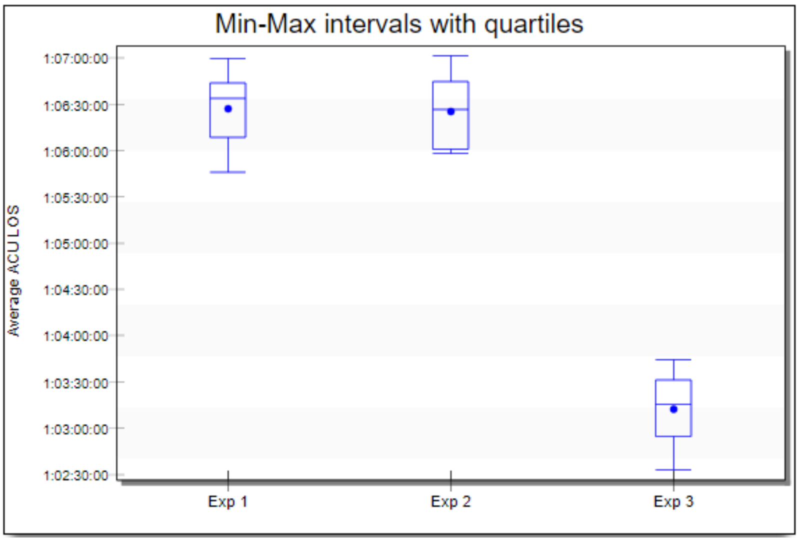

Figure 6-9 Average ACU LOS min-max intervals of the experiments

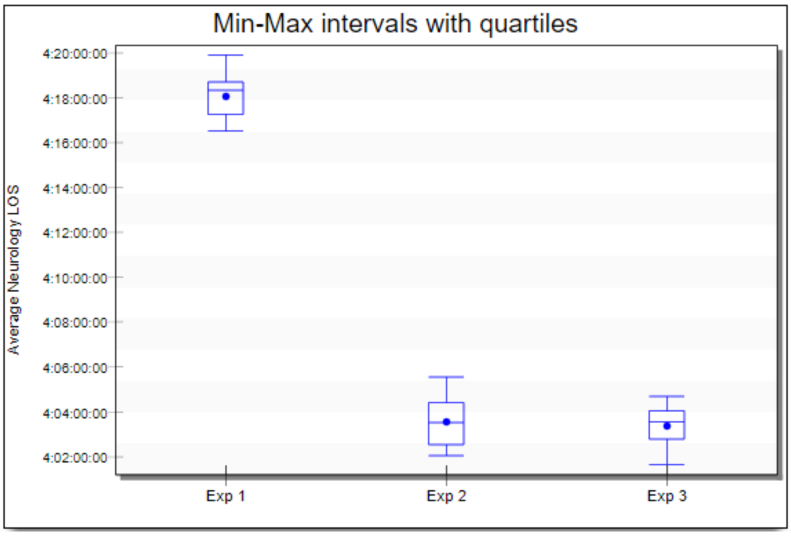

Figure 6-10 Neurology LOS min-max interval of the experiments

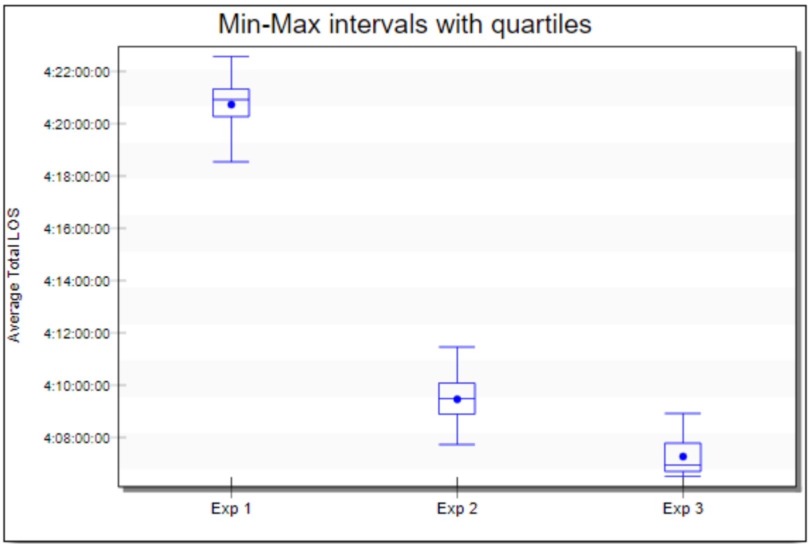

Figure 6-11 Average Total LOS min-max intervals of the experiments