CHALMERS
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Analysis and Proposal for Increased Capacity at a Surgery Unit

More capacity, same resources

Master's thesis in Quality and Operations Management

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Division of Supply and Operations Management
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Gothenburg, Sweden, 2019, Master´s thesis E2019:111

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Abstract

The main purpose of this project was to provide Sahlgrenska University Hospital with suggestions for increased capacity with their current resources. The study was conducted at Östra Sjukhuset, Operation 1.

The theory used is based on the principles of operations management by Holweg et al. (2018) and research suggests that reducing non-surgery time and variation in surgery processes provides significant impact on time saved, and ultimately increased capacity.

Through observations, a work sampling study and collection of historical data from their internal software, Orbit, it was possible to build an empirical foundation of the current state, the division of labor and surgery data.

Connecting the literature review and our results to the case of Operation 1 resulted in the main recommendation of parallelization of the anaesthesia process. This is done by implementing an anaesthesia induction room such that instrument preparations can continue in parallel. The potential improvement for one of the studied surgery types was 55 minutes, which is roughly 50% of the non-surgery time. From observations and the work sampling, potential reductions of variation and wastes could be identified which in turn result in a potential 68 additional minutes saved per day. Further, it was recommended that all recommendations should be combined with a continuous improvement strategy of standardizing specific surgery types to specific weekdays.

With the implementation of these process improvements, it is possible to achieve enough spare capacity to perform an additional surgery in the same day and theatre. Therefore, yes, it is possible to increase capacity with the same amount of resources.

Keywords: capacity, surgery unit, operations management, changeover time, process theory, parallelization

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The Marathon Continues!

Edmond och Alexander, May 2019

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1
Introduction

In the following chapter, the background of this study will be presented, along with the aim and purpose, followed by objectives and research questions, and delimitations.

1.1 Background

Early 2018, the number of patients waiting for surgery were upwards of 25000 in Västra Götalandsregionen (VGR) (Sveriges Kommuner och Landsting, 2019). Out of these 25000, more than 30% wait longer than 90 days for a surgery. This puts pressure on capacity of the hospitals conducting surgeries, and the staff performing the surgeries. Perhaps even more alarming in extreme cases; patients who wait too long might suffer life-long damage by not getting surgery in time. The process of referring a patient to undergoing a surgery is rigid, and the demand for surgeries is not something that is easily affected. However, increasing capacity to handle a greater amount of surgeries is a measure that is easier to influence. The problem is most prevalent at Sahlgrenska Universitetssjukhuset (SU) in Gothenburg, where most surgeries in the region take place.

As a result of this capacity deficit, SU has initiated projects where the reduction of this deficit is a priority. For example, one of these projects has resulted in a more standardised surgery procedure for colorectal surgeries named "Fast-Track" ultimately allowing more surgeries to take place in the same amount of time. However, standardising a surgery process is a complex matter, especially since it might be a matter of life and death. While this is only one example of a measure to be taken, many more remains unexplored.

A capacity deficit in a surgery unit would constitute a lack of surgery theatres or staff members. However, at Östra Sjukhuset, part of SU, only half of them are fully utilised at any specific time. This is due to the lack of staff working with operations related to surgeries – a problem that is prevalent in many other regions in Sweden (Sveriges Television, 2017).

1.2 Purpose and Objective

Since the number of surgery theatres are not always fully utilised, the capacity constraint comes from the lack of staff working in surgery units. Attracting and keeping

experienced and educated staff is particularly difficult for surgery units. Hence, the purpose of this Master's thesis is to study the situation in detail in order to provide a solution to the capacity problem in surgery units with the same amount of resources.

To better understand how to approach the problem, an understanding of the processes and routines of a surgery unit is necessary. The objective of the first research question is to study the staff while they are working, in order to find their routines and activities. As such, the first research question is:

Research Question 1 - What are the routines and activities of the staff at the surgery unit?

Furthermore, to be able to understand which activities and routines that use the majority of staff capacity, the following research question has been formulated:

Research Question 2 - What routines and activities use the majority of staff capacity?

When knowing which routines and activities that use most of the staff capacity, feasibility and impact of changing how activities and routines will be studied. For example, it might not be feasible to change how a surgery is conducted even though it could have the highest impact on capacity, since this might jeopardise patient safety. Hence, the third research question is stated as:

Research Question 3 - Which activities are most feasible to change, and which of those have the highest impact on capacity?

After analysis of feasibility and which activities have the highest impact on capacity, recommendations to improve or change activities will be the ultimate goal of this Master's thesis.

Research Question 4 - How can impactful activities and routines be changed or improved to increase capacity?

1.3 Delimitations

This Master's thesis will be delimited to capacity constraints related to the staff and processes in surgery units. More specifically, only nurse assistants, surgical nurses, anaesthetist nurses will be studied. Additionally, the study will be conducted at Östra Sjukhuset, part of SU, in the unit ANOPIVA which is where anesthesia, surgery and intensive care is conducted.

2
Theory

In this chapter, the theoretical framework is presented. The theories and research used are based on the authors interpretation of the ten principles of operations management by Holweg et al. (2018). Capacity and efficiency is elaborated upon, and what they mean in a surgery unit. Further, theory on changeovers and variation is provided as means to use for analysis of the results. A brief explanation of work sampling theory is also provided. Last, but significantly important, theory on continuous improvement is provided

2.1 Process theory

With aspects such as organization, division of labor, education, staffing, IT, automation and planning at a surgery unit, it becomes apparent that the discipline of operations management can be useful in affecting these aspects. Application of operations management principles are frequently used in research and process improvements related to healthcare, surgery units and surgical theatres (Guerriero & Guido, 2011; Cardoen et al. 2010). However, Holweg et al. (2018) argues that operations management theories to analyze processes are non-existent, and that there is an ambiguity of which theories to use. Holweg et al. (2018) presents a *process theory* built upon 10 principles of operations management, see A.2 for the 10 principles. Holweg et al. (2018) elaborates that the *process theory* and its principles does not entail a comprehensive guide for application of the theory, but instead provides empirical evidence of parts of operations management but not of the discipline. As such, it is the *process theory* and its relevant principles, and subprinciples, that will serve as a foundation for the theories presented in this study. The choice of using a process perspective in this study of a surgical unit is further amplified by the first principle by Holweg et al. (2018) saying that *all operations are composed of processes.*

2.1.1 What is a process?

Holweg et al. (2018) describes a process as the sequence of activities that transform inputs into outputs, see figure 2.1.

As obvious as it may seem, processes also have a purpose, which is to transform the input into the desired output (Holweg et al., 2018). When transforming inputs to

Figure 2.1: The process model (Holweg et al., 2018)

outputs, the process may also produce undesired outputs such as waste like reworks or waiting (Holweg et al., 2018).

In a simplified process model for a surgery unit, the inputs are labor, medicine and the patient. The labor from the surgical team and medicine from the anaesthesia helps "transform" the patient into a better state of health. An example of an undesired output is if the surgery has not helped the patient as it intended to, which would require another surgery - a "rework".

2.1.2 Redesigning processes

Holweg et al. (2018) builds the foundation of operations management on the two first principles. However, with the purpose of this study, other principles or parts of principles are used to fit with the main purpose of this study. Hence, the foundation as interpreted by the authors of this study, will be based on the first three principles:

- **#1** All operations are composed of processes
- **#2** Variation is inherent in all process inputs, tasks, and outputs
- **#3** Work-in-process is determined by throughput rate and throughput time

It is the foundation that provides the means for going forward to redesign, measure and improve the processes (Holweg et al., 2018). Figure 2.2 illustrates that the core of operations management build upon the foundation of it.

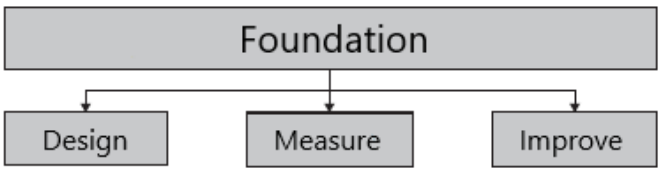

Figure 2.2: The core of operations management: to design, measure and improve processes (Holweg et al., 2018)

In this study, these principles allows for building a map of the current state and using it as the foundation. The processes, variations and their bottlenecks are mapped and described at a surgery unit in a current state map. Hence, theory on current state is provided in section 2.4.

Design
After the foundation has been set, redesigning processes will be easier (Holweg et

al., 2018). The purpose of redesigning processes is to ultimately make them more productive (Holweg et al., 2018). In brief, it is about redesigning a current process into a better, more efficient process in the future. Holweg et al. (2018) further elaborates on the principles and subprinciples of operations management and how to cope with different design considerations such as: eliminating unnecessary processes, standardizing processes and tasks, specializing when volume and variety is low, identifying future bottlenecks, dimensioning buffer sizes in terms of time, inventory and capacity, and at the same time designing with a holistic view to avoid sub-optimization (Holweg et al., 2018).

In this study, design considerations will be based on previous research within operations management related to surgery units and its application to increase capacity. As such, theory on efficiency in surgery units is presented in section 2.3 which present ways to design for increased capacity.

Measure
Along with the redesign of processes, Holweg et al. (2018) state that no single measure can capture the performance of a process and that you can not manage what you do not measure. With the main focus of this study being capacity, means to increase it are presented in section 2.3. It is the most intuitive measure to use in process analysis, according to Holweg et al. (2018), but previous research use different measures to achieve the increase in capacity. Hence, measures that are frequently used in operations management research for surgery units are presented by Peltokorpi et al. (2009) in section 2.3. It is these measures that will provide the basis for the analysis of this study. Although Holweg et al. (2018) does not describe or detail any work studies, breaking down the processes into smaller activities and measuring them is inherent in the principles and subprinciples. Therefore, theory on work sampling is provided in section 2.5

Improve
To actually move from the current state and redesigning it to a future desired state requires all stakeholders to be part of the change. There is a need for ownership of processes, efforts with continuous improvement and root cause analysis (Holweg et al., 2018). Holweg et al. (2018) further elaborates that it is important to dedicate resources to continuous improvements for all processes, as well as primarily focus on continuous improvements until it becomes more economically viable to instead make process investments. Hence, theory on standardization and continuous improvements, see section 2.9, is presented.

2.2 Capacity

According to Zandin and Maynard (2001), capacity is defined as the maximum customer demand that can be satisfied over a certain period of time. The capacity of an organization is based on the existing resources available such as labor, facilities and technology. From the perspective of process theory, Holweg et al. (2018) state that capacity is the most intuitive measure to be used for process analysis. Capacities

can, in most cases, be tagged to each step in a process. Hence, it is very useful in determining where bottlenecks are present or where they might occur (Holweg et al. 2018). Holweg et al. (2018) further argues that service operations are rarely analyzed systematically and as such provide opportunity for greater impact with minor changes.

As stated in the scope of this study, capacity is to be increased by using the resources available. In an earlier study by William Lovejoy and Ying Li (2002), he argues that there are two ways to relieve the largest capacity bottlenecks of a surgery unit; either by building new surgical theatres or by extending the working hours through overtime or hiring new staff members. For the case of Operation 1, surgical theatres are underutilized. The labor market for staff related to surgeries is also thin. Hence, for the purpose of this study, increased capacity is only achieved through higher labor utilization, e.g. making the processes more efficient. The key metric with regards to capacity is the utilization defined through productivity metrics, e.g. input through output, which is further described under section 2.3 (Holweg et al. 2018). With regards to labor utilization, the metric is the ratio of value-added work divided by the total labor time (Holweg et al. 2018). For a surgery unit, the value-added work is the value added to the patient, e.g. the actual surgery.

2.3 Efficiency

Two of the most basic measures for performance is the effectiveness and efficiency of a process (Holweg et al. 2018). Effectiveness deals with the customer point of view, and aims to measure if the process is able to deliver what is expected of the customer in terms of cost, quality and time. Efficiency measures how efficiently the process can convert input to output. Due to the nature of the hospitals in Sweden being tax-funded, patients receive free, high quality, surgery-related services at the cost of aligning with the queue and prioritization order. Hence, the effectiveness of a surgery unit operation in Sweden is as good as a patient can expect. It is therefore the inward-looking metric, *efficiency*, that is more interesting to look at for this study. Efficiency assesses how well a process uses its resources to create value (Holweg et al. 2018; Modig & Åhlström, 2011) and can be increased by either increasing the amount of added value with the same resources or by reducing the amount resources needed to produce the same amount of value.

There are activities that do not add any value to the customer or, in this case, the patient but are important to enable carrying out the value-adding activities (Liker, 2006). These activities are not deemed as a type of waste since they form the basis of value-adding activities. In the example of this case, the preparation of surgical instruments or scheduling is not value-adding to the patient. However, it is an important part of being able to carrying out a surgery. Petersson and Ahlsén (2009) presents a breakdown of three types of activities:

- **Value-adding activities** - Activities that add value to the product/patient and which customers/patients are willing to pay for

- **Necessary non-value adding** - Activities that do not add value to the customer/patient but are necessary to be able to carry out the process
- **Non-value adding activities** - Activities that do not add value to the product/patient and that the customers/patient are not willing to pay for

With this categorization, it becomes evident that in order to increase the amount value-adding activities, *non-value adding* activities have to be eliminated. Furthermore, making the *necessary non-value adding* activities more efficient will also allow more time for value-adding activities to be carried out.

2.3.1 Efficiency in a surgery unit

Research related to efficiency in surgery units are often related to primarily cost-efficiency due to the surgery unit bringing in much of a hospitals revenue, but also due to surgery unit operations being very costly (Sandberg et al., 2005; Peltokorpi et al., 2009). While the primary goal of Swedish hospitals is not profit, efficiencies achieved in cost-related process improvements share the same process analysis and improvement work as other efficiency measures. Efficiency measures in previous research vary depending on the purpose of the research. However, Peltokorpi et al. (2009) have reviewed efficiency measures related to surgery services and identified four types, among which *Capacity utilization and time measures* is one.

Capacity utilization and time measures are the efficiency measures used most frequently in operations management studies related to surgeries (Peltokorpi et al. 2009). There are five metrics in this type:

- *Surgical theatre raw utilization rate* is equal to the time that the patient is in the surgical theatre in relation to the staffed surgical theatre hours.
- *Non-surgery time* is the time between two consecutive surgeries.
- *Changeover time* is the time between surgeries when there is no patient in the surgical theatre.
- *First surgery start time* is the time it takes to set up the first surgery of the day, alternatively the actual time of day.
- *Overused or underused surgical theatre time* provides a measure of how well balanced the planning and control of resources are. Overused time is defined as time between end of office hours to the time where the last patient of the day leaves the surgical theatre. Underused time is defined as the idle time resulting from the last patient of the day leaving the surgical theatre prior to the end of office hours.

In section 2.2, value-added work was defined as the actual surgery performed on the patient. In order to increase the value provided, the non-surgery time has to decrease, since it is non-value adding. As presented in section 2.3, activities during non-surgery time could be either necessary or unnecessary. The non-surgery time consist of changeover time, the patient time in the surgical theatre prior to the surgery, e.g. inducing anaesthesia, and postoperative time related to emerging the

patient from anaesthesia and transferring the patient out of the surgical theatre - all of them necessary non-value adding activities, see figure 2.3. Consequently, reducing non-surgery time means also reducing the changeover time or the start time for the first surgery of the day. Hence, surgery changeover and preparation times will have a large focus in this study as means to increase capacity, see 2.6.

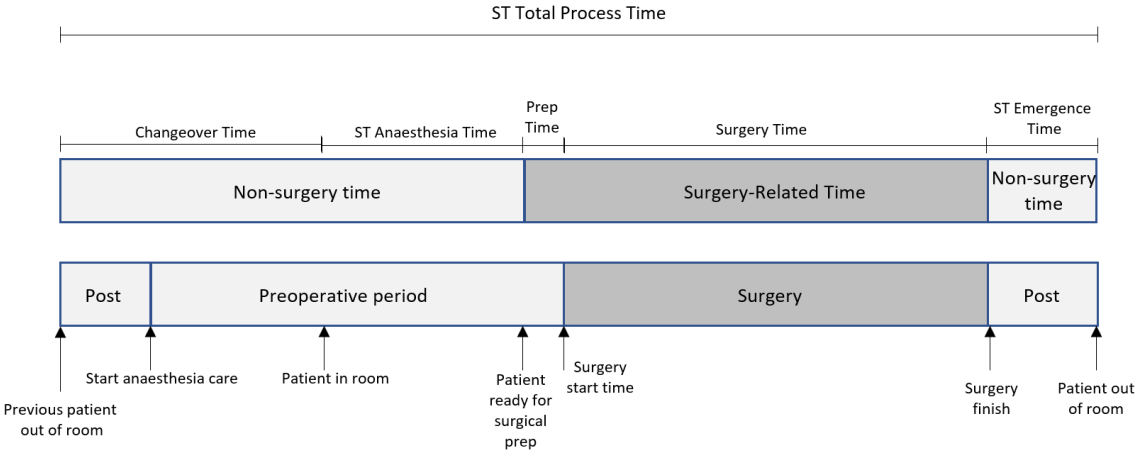

Figure 2.3: Process intervals for typical surgery (Sandberg et al., 2005)

In figure 2.3, "ST" stands for "Surgical theatre", while "Non-ST" stands for "Non-surgery time". From the figure, it is clear that by reducing the non-surgery time, more surgery-related time can be achieved.

Optimizing the surgical theatre total process time through reducing non-surgery time by making necessary processes more efficient is the generally main focus of efficiency in surgery-related research (Cardoen et al., 2010). However, it is important to also consider a more holistic perspective in order to reduce the risk for sub-optimization between processes (Holweg et al., 2018). For a surgery unit, this also entails the planning and scheduling of the surgeries, theatres and staff (May et al., 2011). As presented in section 2.3, this could be considered as a necessary non-value adding activity. In this study, improving and highlighting issues related to planning and scheduling will be considered as means to increase capacity, see section 2.7. Hence, necessary non-value adding activities, in the case of a surgery unit, occur mainly during non-surgery time as presented in figure 2.3 and during planning and scheduling.

Unnecessary non-value adding activities during non-surgery time are wastes, such as waiting for the surgeon or the patient while the surgical theatre is ready (Harders et al., 2006; Cardoen et al., 2010). Reduction of wastes caused by undesired variation during non-surgery time will enable a reduction in non-surgery time, and ultimately allow more time for value-adding activities. This is further elaborated upon in section 2.8.

2.4 Current state mapping

As concluded by Holweg et al. (2018), the foundation and defining a current state map is important in order to develop an organization and its processes. The first step is to find out in detail how the current state of the process looks (Petersson & Ahlsén, 2009). This step is very important because if there is no correct picture of the current state, there is a great risk that the improvements will improve the wrong things.

Circling back to the first three principles by Holweg et al. (2018), it is possible to draw a current state map on these. In detail, the first step is to map all producing, supporting, and overhead processes including tasks, inputs, outputs, resources and controls. Second, with regards to variation, determine customer needs for quality, quantity and timing for every customer process. For every process, averages and variation in quality, quantity and time should be measured. Also, buffers in the form of time, inventory and capacity should be identified for every current process. Third, the throughput of the system of processes is controlled by bottlenecks. Hence, one should also identify bottlenecks that are present in the current processes. These steps, based on the three first principles by Holweg et al.(2018), provide a current state description - a foundation - which can be used to redesign, measure and improve the processes.

2.5 Work Sampling

Work sampling is a method used to measure different activities in a process and gives a total time on how the work is divided between different activities (Freivalds, 2009). This is done by observing at a random or predetermined time interval, which will result in an approximation of observed activities and the total number of observations performed (Freivalds, 2009). This method is advantageous to use when you want to see or determine how much time and value adding staff or a machine has.

While the method is based on random sampling, it emphasizes the importance of ensuring the statistical significance. Hence, it is important to determine the least amount of observations required to ensure that this is achieved (Almström, 2012). The formula below can be used, see equation 2.1.

$$n = \frac{z^2 s(1-s)}{f^2} \tag{2.1}$$

Equation 2.1: Formula for number of observations required, Almström (2012)

n = the least amount of observations needed
z = the number of standard deviations
s = the probability of a certain activity to occur during the moment of observation
f = the accepted error of margin

After the work sampling is done, the error margin for each activity can be calculated with equation 2.2:

$$f = \pm z\sqrt{\frac{s(1-s}{n}} \tag{2.2}$$

Equation 2.2: Formula for error margin, Almström (2012)

2.6 Changeovers

Generally, changeovers are mentioned when speaking of processes in manufacturing. Henry (2017) defines changeover as the whole process of changing a machine, line or any other manufacturing process from producing one type of product to another product. If there is a high variety of products manufactured, the changeover can make up a significant time of the total process time.

Developed by Shiego Shingo, the *Single-Minute Exchange of Die* (SMED) method is used for reducing waste in manufacturing processes. The concept of converting tasks during a changeover from *internal* to *external* was one of SMED's important contributions (Henry, 2017). The internal tasks are the tasks done when the production has halted, while external tasks are those able to be performed while the production is running. This is the concept of *externalization*. While externalization of internal tasks could eliminate tasks, and even reduce labor required, that must not necessarily be the case. Hours might increase as well as some tasks, due to parallel work, but it still allows the production line to keep running with fewer interruptions.

For a surgery unit, the "production line" is represented by the actual surgery, and the changeover is the time between surgeries in order to prepare for the next patient. And with SMED-theory in mind, externalizing internal tasks such as instrument

preparation could be done while a surgery is ongoing, by other staff members - in order to reduce the changeover time for the next patient.

2.6.1 Changeover time in a surgery unit

Previous research such as Meredith et al. (2011) has studied changeover times and activities for elective orthopaedic surgeries. In their study, they found five factors that defined if a changeover was slow or fast, see figure 5.1.

	Faster	Slower
Process archetype	Patient preparation and instrument preparation concurrently	Patient preparation and instrument preparation in series
First case setup timing	Long first case setup	Short first case setup
Prepare surgical instruments	Two stage preparation, start of day and during changeover	Complete preparation during changeover
Surgeon availability	Surgeon in theatre during changeover	Surgeon arrives after patient is ready for operation
Theatre layout	Set up room adjacent to theatre for patient preparation	No set up room - all processes occur in theatre

Figure 2.4: Summary of activities which make faster or slower changeovers (Meredith et al., 2011)

With these factors considered by Meredith et al. (2011), five hospitals were studied and their surgery and changeover processes. For the same type of surgery, one hospital had 38 minutes of changeover time while another had 59 minutes, e.g. 55% higher. The main reason was that the slow hospital had *serial processing*, meaning that the patient preparation took place after the preparation of surgical instruments.

The faster hospital had *concurrent processing*, meaning that the preparation of surgical instruments could take place during the same time as the patient preparation. As described by the SMED-theory - it does not necessarily mean that tasks are eliminated or that labor hours are reduced, but it allows the "production line" to keep running. Meredith et al. (2011) illustrates the process flow for both the slow and fast hospital. The figures are presented in figure 2.5 and in figure 2.6.

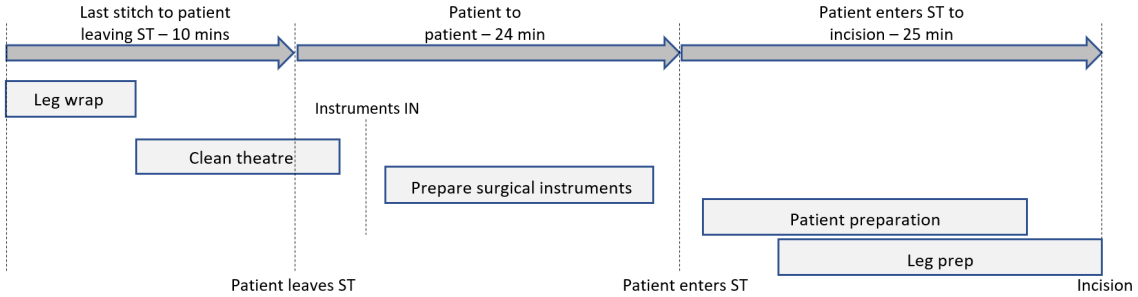

Figure 2.5: Hospital with serial processing (Meredith et al., 2011)

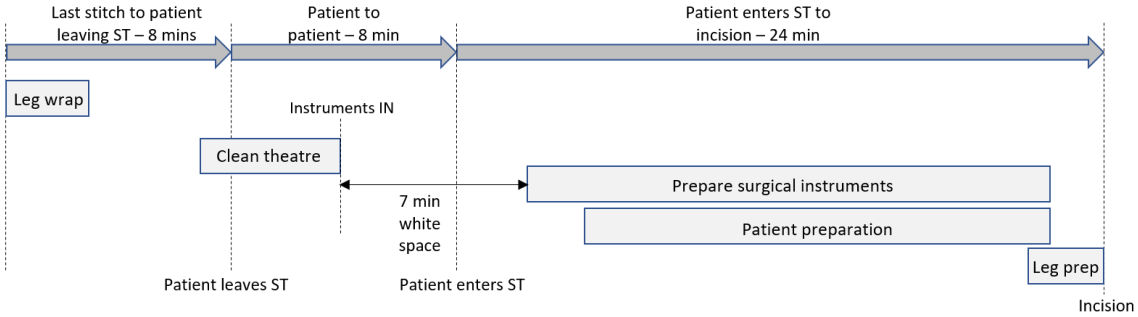

Figure 2.6: Hospital with concurrent processing (Meredith et al., 2011)

Meredith et al. (2011) also concludes that by reducing the changeover time between surgeries, could lead to more surgeries being performed in the same amount of time. Harders et al. (2006) also present parallelization of activities as means to reduce non-surgery time. Smith et al. (2008) build upon this paralellization and suggests preparing instruments in a dedicated instrument preparation room, inducing anaesthesia in a separate anaesthesia induction room and adding an additional anaesthetist nurse that transports the patient from the surgical theatre to the post-operative unit so that the anaesthesia team can commence induction of the next patient simultaneously as the changeover takes place. Even Smith el al. (2008) found that by redesigning processes for concurrent processing, they could achieve a 50% reduction in non-surgery time. Of course, reducing the changeover time for certain procedures would not be as efficient for the whole system if only one surgery could take place during a day, e.g. more surgeries done during a day means that an equal amount of changeovers take place. Dexter and Macario (1999) elaborates on this consideration when reducing changeover times. They argue that it is optimal if the total number of reduced minutes in changeovers during a day equals the possibility of performing at least one additional surgery during the same day. In their study, they found that the possibility of this being the case was higher if the actual surgery time was less than two hours. Although, an additional surgery per day might not be achieved, the additional time saved could be used for supporting activities such as supervision of students, research and continuous improvement (Wong et al. 2010).

2.7 Planning and Scheduling

While planning and scheduling is not the primary focus of this study, it was described in section 2.3 that it has significant impact on the capacity of operations, and more specifically, in surgery units. According to Holweg et al. (2018), planning is the provision and allocation of resources such that the process can operate against a predetermined plan or schedule. This means setting the actual production schedule, procuring materials and scheduling all work so that the process can function (Holweg et al., 2018). In brief, production planning is about getting as much capacity as possible out of the process (Holweg et al., 2018). Scheduling is a part of the planning process and can be explained as the planned sequence of processes and when and where they should be finished.

2.7.1 Planning and Scheduling in a surgery unit

First, it is important to define a general classification of the patients. The patients can be divided into two categories: "elective" and "non-elective" (Cardoen et al., 2010). Elective patients are informed about their surgery in a timely manner, whereas non-elective patients are not. More specifically, non-elective patients can be further categorized into *emergency* or *urgent* surgeries. This is important to define since elective surgeries are the ones that are relatively predictable and easier to plan for. Non-elective surgeries, and specifically emergency surgeries, have a high priority and are most often not planned which could lead to disturbances of the original schedule and postponement of other surgeries. Hence, this is why the planning and scheduling function is particularly important in a surgery unit.

May et al. (2011) presents a literature review with regards to the surgical scheduling. In this review, May et al. (2011) highlights the time horizons involved with surgical scheduling issues to consider for each time horizon. The table is presented in 2.1.

Table 2.1: Time Horizons Involved with Surgical Scheduling (May et al., 2011)

Time horizon	How far in advance	Research areas	Examples of issues to be addressed
Very long term	12 - 60 months	Capacity planning, process reengineering	How many STs to construct, layout of physical resources
Long term	6 - 12 months	Capacity planning, process reengineering, surgical services portfolio, procedure duration estimation	Patient flow patterns, selection of surgical providers, block assignment
Medium term	Few weeks - 6 months	Capacity planning, procedure duration estimation	Staff assignment and scheduling
Short term	Few days - few weeks	Schedule construction	Procedures assigned to STs (particular days, parts of days), number of STs needed are determined
Very short term	24 - 48 hours before	Schedule construction	Last-minute scheduling into released unused block time; determining STs to be opened; start times
Contemporaneous	Same day	Schedule execution, monitoring and control	Assignment and scheduling of emergency procedures; reassignment of STs and rescheduling of start times as a result of emergencies, patient no-shows, cancellations, staff availability, and procedures taking more or less time than planned

As can be seen from table 2.1, long- and medium term plan trickles down to the

short-term planning. This means that changes in the short-term scheduling can significantly affect the time horizon that is one hierarchy above, if not accounted for in the long-term planning.

As presented by May et al. (2011), short-term scheduling aims to make sure that surgeons, anaesthetists, nurses, surgical theatres, medical supplies and equipment are allocated to a specific time slot. If the scheduling is poor, the risk increases for resource unavailability. May et al. (2011) and Cardoen et al. (2010) further elaborates on issues that could cause resource unavailability. Due to the nature of surgeries, staff and patients, it is sometimes hard to predict the time of surgeries and surgeries might take longer or shorter time than expected. Additionally, emergency surgeries might occur meaning that the short-term planned schedule must be changed. Cardoen et al. (2010) explains two types of uncertainties: *arrival uncertainty* and *duration uncertainty*. The former is related to late or early arrivals of a surgeon or an unprepared patient, while the latter is related to the uncertainty of duration of activities performed during surgery. On top of these uncertainties, resource uncertainty is also prevalent - meaning that labor or equipment might not be readily available when the patient it (May et al. 2011).

2.8 Variation

As stated by Holweg et al. (2018), variation is inherent in all process inputs, tasks, and outputs. There are two types of variations, *common cause* variation and *assignable cause* variation. The first is random and can not be predicted. The second is non-random variation which is caused by identifiable factors which are clearly defined and inherently manageable (Holweg et al., 2018).

Variation occur in three aspects: quality, quantity and timing. Variation in quality leads to dissatisfied customers and need for rework, and ultimately lowers the productivity of a process since more resources are required to produce the same unit with expected quality. Variation in quantity leads to a lack or surplus of demand or supply. If demand is higher than forecasted the system might be overburdened. If demand is lower, inventory builds up and cause extra costs. Variation in timing also leads to delays, waiting time and inventory build-up.

If workstation A produces input for workstation B, and both workstations have the same throughput time, a variation in the throughput time for workstation A will either build up inventory behind workstation B or starve workstation B of input, e.g. workstation A has to wait for B to produce build-up inventory, or workstation B has to wait for A to produce the next input. In a surgery unit, this can be exemplified by the patient being ready and prepared for surgery while the surgical theatre is not fully prepared, or vice versa. Hence, reduction of variation in processes leads to reduction in wastes such as waiting time - time which could instead be used for value-adding activities (Holweg et al., 2018).

2.8.1 Variation in a surgery unit

With variation being the cause for waiting time and delay it becomes important to reduce it or design processes to allow for variation, especially for the common cause variation. In their research, Harders et al. (2006) had the ambition of reducing the non-surgery time to under 35 minutes to allow for higher efficiency. However, variation was also present in their observed processes. They recorded the reasons for delay and their frequency when the non-surgery time exceeded 35 minutes, see table 2.2. Further, it could be noted that process-related delays accounted for 70% of delays - delays which could be reduced if the process was improved (Harders et al., 2006).

Table 2.2: Reasons for Delay when Non-Surgery Time exceeded 35 minutes (Harders et al., 2006)

Cause for delay	*Frequency (%)*
Clinical (difficult IV, difficult intubation, change in patient condition)	16
Instruments or supplies unavailable	10
No operative consent	8
Laboratory result unavailable	8
Patient late in arriving	8
Process not followed	8
Technology-related delay	7
Environmental services delayed	6
Anesthesiologist delayed	6
Surgeon delayed	6
Other	17

From the table, delays not related to the surgery process are "No operative consent", "Patient late in arriving", "Technology-related delay" and "Environmental services delayed". The reason why these delays are presented in this study is because they provide an insight of what variation in different steps of the process can cause in a surgery unit.

2.9 Standardization and Continuous Improvement

According to Liker (2006), the purpose of standardized processes is to act as a basis for continuous improvements. If processes are not standardized, the risk of improving the wrong process in a wrong way increases. Holweg et al. (2018) further elaborates on this and says that a stable process is the foundation of any process improvement.

Holweg et al. (2018) says that there two types of improvements: *continuous improvements* and *breakthrough improvements*. These two work together. Continuous improvements are achieved by worker-led initiatives on a continuous basis, such as daily team meetings, quality circles and visual management (Holweg et al., 2018).

When these improvements no longer provide the returns expected from the resources spent, it is time for breakthrough improvements such as investing in a new IT-system or changing the layout (Holweg et al., 2018).

Meredith et al. (2011) argues that changeover time should form a part of a continuous improvement strategy, and speculates that if a continuous improvement approach was used in the healthcare sector it would not be unimaginable to reach the level of SMED-theory in surgical theatres.

3

Methods

This chapter describe the methodology chosen when approaching the problem of increasing the capacity of a surgery unit. At first, the research strategy and design is presented to guide the reader of how the study has progressed. Second, the data collection methodologies are presented and how the data has been collected, and why. Third, measures taken by the authors are presented with regards to ethical considerations, quality criteria and sustainability issues.

3.1 Research Strategy

The strategy of the research project was of both quantitative and qualitative nature. This mixed methods strategy was necessary due to the quantitative aspects of measuring elements related to productivity in combination with qualitative data to provide further guidance and conclusions from the quantitative data (Bryman & Bell, 2018).

There are two main approaches to conducting research (Bryman & Bell, 2018); a deductive approach and an inductive approach. With a deductive approach, research is conducted based on hypotheses and ideas inferred from theory. An inductive approach means that theory is generated based on the research conducted. The inductive approach was chosen since it is preferable when data is first collected and then generalized. Additionally, the inductive approach makes it simpler to get an initial overview of the topic at hand and ultimately enhances the understanding of the topic. For this study, although the inductive approach was chosen as the principal approach, the study was similar to that of an iterative research approach. This means that the data collection and study of theory were conducted in parallel. Even though it is argued by research methodologists that quantitative studies mainly use a deductive approach, Bryman and Bell (2018) also state that quantitative studies are often a good deal more exploratory than what is typically assumed. Hence, one could also argue that this study is in large designed as an exploratory study with conclusions induced from quantitative data. Why this is the case is further described in section 3.2.

3.2 Research Design

In this section, the research design explains in which order the study has been conducted. Throughout the study, a literature study was conducted. This allowed the authors to build an understanding of the topic at hand and, ultimately, bring inspiration from previous research. Initial data collection consisted of a work sampling study to get a quantitative overview of the activities performed by the staff. Being physically present at the surgery unit also provided opportunities for observation of the environment. The overview of the current situation would provide mainly quantitative data that would act as a guide to where high impact improvements could be made. Once the area of issues had been established, historical numerical data related to the issue area was collected in order to further quantify the issue. During the the work sampling and collection of historical data, unstructured and spontaneous interviews were conducted with the staff related to the study. This provided qualitative information about processes and what improvements that could or could not be feasible. For visual reference of the research design, see figure 3.1.

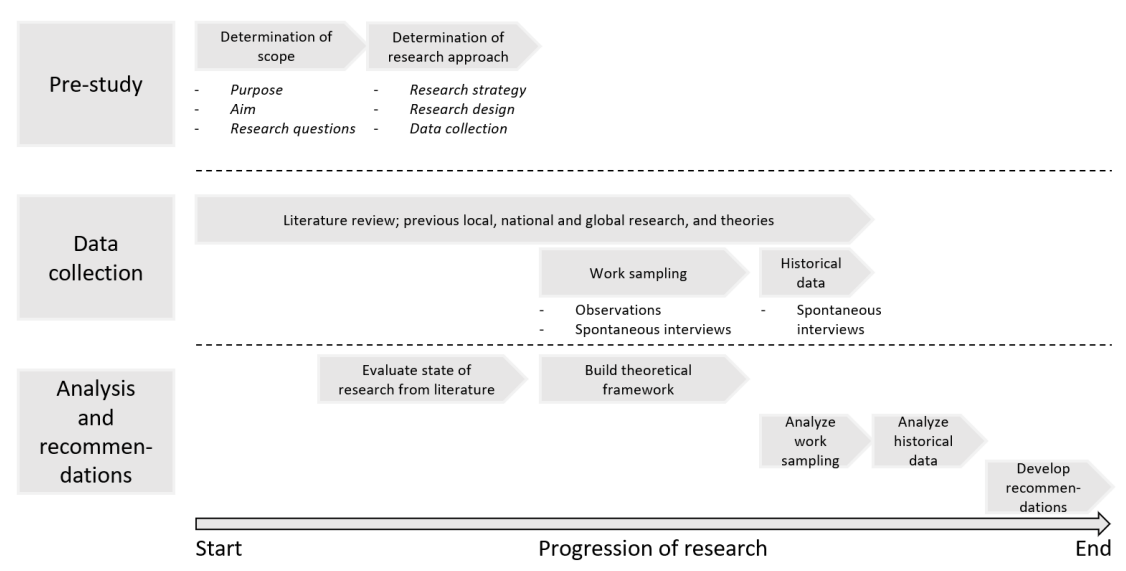

Figure 3.1: The figure illustrates the research design

3.3 Data Collection

This section aims to provide the reader of how the data collection has been carried out.

3.3.1 Literature Study

The literature study had two general purposes. First, to build an understanding of the healthcare industry. This included healthcare as a topic, previous research and work in healthcare - globally, in Sweden and at SU. Second, previous research and

work done at surgery units provided guidelines as to which methods have been used, which methods have worked and inspiration of what is feasible at SU.

For conducting the literature study, two principal databases were used; Chalmers' own digital library and Google Scholar. Both of these databases have a large amount of publications and provided easy accessibility for the authors, which is why they were chosen. Key words used when enabling initial understanding of the topic were words such as "healthcare capacity", "surgery unit capacity" and "healthcare work sampling". Later in the study, when scoping down on the key issues related to capacity, key words such as "surgery unit process improvements", "surgery changeover times" and "surgery preparation times" were used. The format of the literature collected online include articles and books. Other literature used consisted of previous internal work and research by SU itself and studies conducted by Chalmers in relation to capacity issues at SU.

3.3.2 Work Sampling

A work sampling study was conducted at the surgery unit Operation 1, Östra Sjukhuset. The work sampling was planned to continue for 40 hours with 2 hours per observation session, meaning 20 sessions. There was one session per day. The sessions aspired to be evenly distributed throughout the day and week, between 07:00-16:00, Monday through Friday. A schedule of the work sampling sessions can be found in A.2.

Each session would start with a conversation with the planning coordinator for the day. The planning coordinator guided the observers to which surgical teams that were eligible for observation that particular day. Some teams had pagers on themselves in order to respond to possible emergencies that might occur at Operation 1, but also in other parts of the hospital. Since this study mainly focuses on elective surgeries, the teams carrying pagers were excluded for observation. The observers chose a team at random with no regard to experience of the observed roles or previous observations.

All surgical teams consist of one or two nurse assistants, surgical nurses, one anaesthetist nurse, one anaesthetist and one or two surgeons. The roles that were observed were nurse assistants, surgical nurses and anaesthetist nurses. Every 30 seconds, one of the roles were sampled at random, e.g the activity for a random role was registered every 30 seconds. There were 32 different activities to be sampled. The list of activities has been developed in collaboration with SU and Chalmers in order further help standardize research at surgery units. The list of the 32 different activities are described in A.1

The equipment for work sampling consisted of a tablet with an installed software called MVV Frekvensstudie where the list of 32 activities were programmed in. The program was configured with the three roles to be observed, the observation interval of 30 seconds and which dates and times the sessions were planned. Every

30 seconds, the tablet notified the observers and the activity was registered. The program automatically consolidated the data which could be extracted into Excel for further analysis.

3.3.3 Observations

When conducting development in a production environment work, Toyota's lean principles come to mind. Among these 14 principles, one principle emphasizes the importance of being physically present at the location where activities are conducted in order better grasp the situation - also known as *genchi genbutsu* (Liker, 2006).

This study had two key observational periods. The first one was in the beginning of this study where the purpose was to get a better overview and to ultimately facilitate smooth data collection during the work sampling. Activities to be observed in the work sampling was clarified by the staff at Operation 1. The routines of different procedures were also noted down along with the physical layout of Operation 1. The second observational period was done during the work sampling. Observations were noted down and served as a basis to ask the staff of why certain procedures or activities were done in a certain way.

During the observations, the staff frequently passed by the location of the observers which ultimately led to opportunities for short informal interviews. The interviews were unstructured and relaxed. The data collected from these interviews first provided explanation of why certain procedures or activities were done in a certain way, and what opportunities or risks there could be when changing the procedure.

3.3.4 Historical data

Through the work sampling study and observations, it was observed that the first case setup times and changeover times were issue areas where change of procedures might have an impact. Operation 1 collects data on when the patient is ready for surgery, when the staff enter the theatre to prepare for the surgery, when the patient is retrieved for surgery, when the the anaesthetists begin with the anesthesia, when the surgery preparations are complete, and finally, when surgery begin. These times are recorded by the staff and are presented for each patient and surgery in a hospital-wide database called Orbit. Due to the professional secrecy of patient data, the data was collected manually by the authors in coordination with an nurse assistant.

3.4 Method of Analysis

The method of analysis in this study had the goal to integrate the explorative and iterative nature of this study, e.g. connecting the literature study, work sampling, observations and historical data together. As a first step in the analysis of this study, the state of the research was evaluated. This included research related to capacity in healthcare but also previous work done at SU. This facilitated the creation of the theoretical framework to be used when analyzing the current state, work sampling

and historical data.

An overview of the current state at Operation 1 was established through observations and spontaneous interviews. This entailed both the organizational situation and the surgery process. The data collected for this part of the analysis is principally qualitative. Hence, measuring the impact of the recommendations was not as natural as the quantitative data analyzed later on. The analysis was done with the help of the literature study and the measures presented for increasing capacity at a surgery unit.

By using the theoretical framework and work sampling study, capacity-related issue areas could be found and thereafter analyzed. The purpose of the work sampling study was to get a general overview of how the different activities was divided between the roles, and how much time was spent on them.

The acceptable relative error was set to 20% with a confidence level of 95%. If a certain activity was within the 20% error margin it was deemed significant to analyze. Naturally, the activities with the most observations were the ones taking up most of the working time, and they were also the ones with the lowest relative error margin. Together with the theoretical framework, the significant activities were analyzed. Recommendations, along with potential impact, was then provided for each of the significant activities. To fully make use of the data generated by the work sampling study, further grouping of activities could be made in order to decrease the relative error margin below 20% and make them significant to analyze.

Historical data was analyzed in order to further specify where improvements could be made and where they would have the most impact. First, the 20 most frequent surgery types were analyzed based on the total accumulated time spent on surgery preparations. Out of these 20, three of them were chosen based on the average length of the surgery, if they were most frequent during the day shift and if they were mainly elective or emergency surgeries. The reason for the chosen parameters are further explained in the analysis section. The historical data also served as basis for how much of an impact the recommendations could have on the capacity.

3.5 Ethical Considerations

Since this study is done within a hospital environment, ethical considerations are of utmost importance. Bryman and Bell (2018) present several considerations which are relevant for this study.

First, considerations need to be taken whether there is a risk of harm to participants of the study - physical harm, harm to development prospects of the individual, stress, self-esteem and future career prospects. For this study, the main harm identified was the increased stress levels that would increase due to observation. To mitigate this, observers presented themselves to the whole department and clarified why this study was being done, and that they were not observed on an individual level.

Second, considerations need to be taken whether there is a lack of informed consent to participating in the study. Since this study was on an organizational level, the majority of the staff did not feel that they needed to consent to anything. All aspects regarding the data collection and study was transparent, and all individuals were invited to ask questions about the study and its purpose. Additionally, the study was approved by each of the roles' union representative.

Lastly, considerations need to be taken with regards to data management and invasion of privacy, both for the employees and the patients. Observations and spontaneous talks are aggregated. Hence, there is no way to distinguish which specific employee that corresponds to certain data. Additionally, the observers signed a confidentiality agreement with SU due to the sensitive information visible when collecting the historical data.

3.6 Quality critera

This section aims to provide the reader on how the quality criteria has been considered regarding validity, reliability and transferability.

3.6.1 Validity

Reige (2003) presents 4 approaches to establish validity in a report; *Using multiple sources of evidence*, *Triangulation*, *Notes during meetings and observation* and *review of report*. During the literature study, several relevant sources have been used and examined in order to create a clear structure for an analysis and to give a correct measurement of observations. A triangulation has been achieved by ensuring that ambiguities in retrieving historical data, literature, small conversation and the work sampling is correct. This through continuous communication with our supervisor and the staff at Operation 1. At every meeting with our supervisor and during the observations at Operation 1, at least one person has taken notes or measured on the content. Notes and the result from work sampling have later been processed and documented in a personal database to give validated results. Review of the report have been carried out continuously the last six months. An initial review of the planning report was carried out by an associate professor at Chalmers, who is also our supervisor, to give an approval for further study on the subject. Furthermore, the report has undergone a final examination by our supervisor as well as students from Chalmers. Organizational description and historical data have been reviewed by external project owner, to ensure that it is properly described.

3.6.2 Reliability

Since the theory selected for this report can be used in different forums within Operations Management, authors and articles related to hospitals have been reviewed.

The supervisor for this project has acted as a link between the hospital and the University. He has contributed with knowledge and support to this project through his role as a professor at the University as well as responsible for ongoing projects at Sahlgrenska University Hospital.

All meetings have contributed to discussions, which has enabled follow-up questions to be made in order to ensure that no important and essential information has been missed. The meeting respondents have been from different organizational levels to ensure that the right person answers the right question. When things have been perceived as uncertain, the right respondent has been contacted to clarify what has been said.

During the work sampling, all staff members were informed and got the work sampling method explained to them at the start of the observation session and they were told to behave just as usual. The observers kept a low profile to not disturb the staff which could affect the results. If it was not obvious what the staff were doing, the observers walked closer or asked questions just to make the results more reliable. The observation sessions were also good opportunities to get a deeper understanding of what the staff were doing and a more detailed understanding of the hospital processes.

3.6.3 Transferability

Transferability in this report refers to how problem identification and further recommendations can be applied in other hospitals. The recommendations are based on the three most frequent surgery types with a high impact on the current capacity and are supposed to be applicable in similar departments or clinics. The solutions cannot guarantee similar improvement for all kind of surgeries due to the differentiation of surgical process in other departments or hospitals. In addition, it is possible to use the recommendations as a base for clinics with elective surgeries. Operations that performs emergency surgeries have a different preparation process because of difficulties in assessing the high variation.

4
Results

In this chapter, results from the short informal interviews and observations were used to create an overview of the current state at O1. Further, results from the work sampling and collection of historical surgery data is presented.

4.1 Current State

The current state at Operation 1 is divided into two categories. The first one covers the organizational aspects at Operation 1 such as, role definitions at the surgery unit, required roles in the surgical theatre, planning and control, and what tools are used by the staff to organize the surgery unit. The second covers the entire surgery process, where certain sub-processes have received additional attention due to the focus of report, such as not focusing on the actual surgery.

4.1.1 Organization

Key roles which are related to capacity utilization and planning are nurse assistants, surgical nurses, anaesthetist nurse, anaesthetists and surgeons. Operation 1 is manned 24 hours a day, 7 days a week. The 24 hours a day are separated into three different shifts. Although this study has its main focus on the day shift, it is important to mention the other shifts since the activities performed during the end of the night shift have proven to be resourceful for the start of the day shift.

The working times for the day shift are bestowed to 07:15-16:00, with 07:15 being the starting time of the daily morning meeting. Some nurses start 06:45 due to staffing needs or personal needs. Due to the nature and severity of surgery, nurses and anaesthetists time their unpaid lunch time of 45 minutes together with a planning coordinator, who finds a temporary replacement.

The surgery unit has 10 surgical theatres out of which, only 5 can be utilized simultaneously when fully manned with the current staff. At minimum, one nurse assistant, one surgical nurse, one anaesthetist nurse, one anaesthetists and one surgeon were required per surgery. Depending on the type of surgery, an additional surgical nurse or nurse assistant can be added. The planning coordinators are the ones planning and controlling the utilization of surgical theatres and personnel. There is at least one present at all times during the day shift. They hold the daily morning meeting in order to make sure that everyone knows what they are supposed to do, and

in which surgical theatre. They are also responsible for the planning and flow of patients during the week, and during the day. Additionally, they make sure that everyone gets their planned breaks. The job requires a large amount of know-how, and it is why the nurses with most experience, related to Operation 1, are the ones handling the planning and controlling.

With regards to efforts in continuous improvements at SU, they frequently bring new ideas to the table. One of these is that the night shift helps prepare the instrument tables in the surgical theatres in order to reduce the preparation time for the first surgery of the day. Another study that has been done in parallel with this one is the having a coordinator in the theatre. This role acts as the spider in the web controlling timing and resources for the specific surgery. By having this role, it was concluded that it significantly reduced surgery procedure times and that it is a solution that could be further explored.

4.1.2 Surgery Process

The elective surgery process entails two different preparatory procedures. First, making sure the patient is ready. Second, making sure the surgical theatre and team is ready for the patient. Figure 4.1 below visualizes the flow of both preparatory procedures. The figure is mostly for illustrative purposes and does not depict the exact timeline or order of processes.

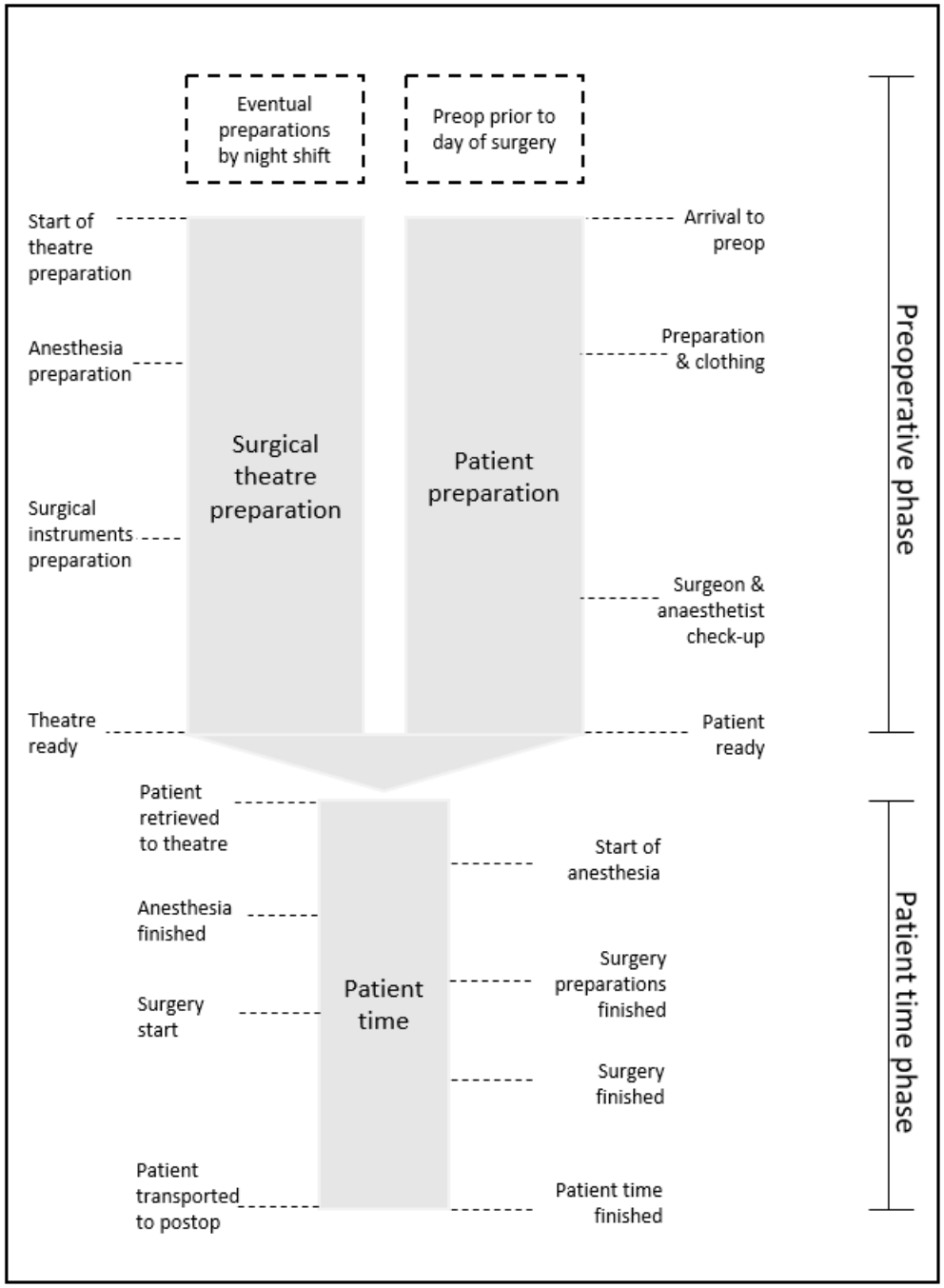

Figure 4.1: The surgery process

Preoperative patient preparations

The preoperative patient process usually start prior to the day of surgery. The patient's health condition is evaluated by the anaesthetists. Factors included in the evaluation range from age to complexity of the surgery. Based on this evaluation the anaesthetists supervise the patient's condition up until day of surgery and tries to choose the anesthesia most suitable for the patient. The supervision of the patient's condition by the anaesthetists continue throughout the day of surgery. If, at one point, patient safety is at risk, the anaesthetists can cancel the planned surgery and

re-evaluate the situation.

On the day of surgery, the patient first arrives to the preoperative unit. Here, the patient is prepared and clothed, and the patient's health condition is evaluated by the anaesthetists and surgeon. If the surgery is the first case of the day, the anaesthetists and surgeon are required to have spoken with the patient and evaluated the patient before 07:45. After this, the patient is deemed ready to be retrieved when the preoperative theatre preparations are finished.

Preoperative theatre preparations
Independent of the preoperative patient process, the surgical team commence the preoperative preparations for the surgical theatre. If the surgery is the first case of the day, the preparations start after the daily morning meeting at 07:15. The morning meeting takes about 10 minutes. All team members of the surgical team read up on the patient journal related to the surgery. All team members then participate in a team meeting in the surgical theatre clarifying roles and what needs to be done and prepared. If it is the first surgery of the day, the night shift staff might have cleaned and prepared the surgical theatres as much as their time has allowed and as much as possible. For example, the night staff had recently tried preparing the surgical theatre with the surgical instruments needed for the first surgery of the day shift, at the end of the night shift. This resulted in a significantly faster theatre preparation.

The surgical nurse begin setting up the instrument table with help from the nurse assistant. The instrument preparations are done inside the surgical theatre so that the instruments does not get contaminated by moving them from room to room, through corridors. The instrument preparations are required by procedure to be done in a room with certain ventilation and the surgical theatre is one such room. The sterilized instruments are retrieved to the surgical theatre by the surgical nurse from the storage room. The instruments are mainly packed in sealed plastic or textile containers. When retrieved, the surgical nurse dress up in sterilized clothes with help from the nurse assistant. The surgical nurse then cover the instrument table with a sterilized sheet. The nurse assistant supports the surgical nurse by opening the containers and keeping them open, which are now contaminated due to movements from room to room. The sterilized surgical nurse picks up the instruments from the container and sets them up on the table. The surgical nurse then controls that all instruments are present and that they are clean. If assembly of instruments are needed, the surgical nurse does this too. The nurse assistant then supports the surgical nurse by entering the instrument data into the system for additional traceability, in case an instrument goes missing during the surgery or if a certain instrument has caused any infection to the patient. As a last step, the surgical nurse covers the instruments with sheets in order to keep the instruments sterilized as much as possible. During this whole process, it is recommended that no other staff enter the surgical theatre until the instruments are covered. The movement and opening of doors increase the risk of instrument contamination and risk of rework since new instruments must be retrieved.

The anaesthetist nurse retrieve necessary medication and equipment from a medicine storage room outside the surgical theatre and prepares it inside the surgical theatre. The anaesthetists has to provide the anaesthetist nurse with detailed information about the preoperative process that has taken place but also which medicine is required. If changes are made to the anaesthesia procedure by the anaesthetists before or during the surgery, the anaesthetist nurse has to retrieve the medicine required and redo the preparations.

When the patient is ready and prepared for surgery and the surgical theatre and team preparations are complete, the anaesthetist nurse retrieves the patient from the preoperative unit for transportation to the surgical theatre. As soon as the anaesthetist nurse connects with the patient, the patient time starts.

Patient time
Patient time start when the anaesthetist nurse retrieve the patient from the preoperative unit and transports it to the surgical theatre. When the patient enters the theatre, it is transferred from its hospital bed to the surgery bed. The team then runs through the first part of the WHO surgical safety checklist. The team then helps the patient to position itself correctly for surgery. The time for positioning the patient depend on the patient's health condition and the type of surgery. Also, some surgeons have preferences regarding positioning that are not always communicated until the surgeon enters the surgical theatre. After positioning, the patient is connected to diagnostic equipment and relevant anaesthetic equipment. Anaesthesia is commenced once this is done. Once the patient is anesthetized other preparations may start and the area of surgery on the patient's body is sterilized and the patient is draped. The patient is then deemed ready for surgery and the surgeon is called upon, if not already present. When the surgeon is present, the second part of the WHO surgical safety checklist is ran through. The full surgical team is then ready for the first incision, and the surgery may start. The patient time ends when surgery is complete and the patient is transferred to the postoperative unit for recovery. During the transfer, the preoperative preparations for the surgical theatre are started in order to prepare for the next patient, and the process repeats.

4.2 Work Sampling

This section summarizes the data collected through the work sampling method. Usually, a work sampling starts with a pre-study to determine the least amount of required observations. However, the aim of work sampling in this study was to get a quantitative overview of situation to find where areas where improvements could be made, and where focus could be directed. Therefore, the study continued with a predetermined observation period instead of basing it on a pre-study. This was decided together with the supervisor of this study.

In total, 4415 observations were made during approximately 38 hours. 360 observations were eliminated from the data set, due to the observed object gone missing,

having lunch or any other unpaid breaks. Therefore, only 4055 observations were used as data for analysis. The original period of observation was 40 hours. However, it was revealed during the study that the day shift usually end 14:00 on Fridays and not 16:00 like every other weekday. Hence, one planned observation session was removed from the observation period. The accepted relative error was approximately 20%. Since the relative error is over 20% for certain activities, these are not as significant to analyze as those with under the error threshold.

First, a general overview is presented of all activities observed. Last, a categorization is done to give a rough overview of how the time is spent.The categorization was done with guidance from the supervisor of this study.

4.2.1 General Overview

Table 4.2 below show how the different roles use their time for the activities observed. Hence, as a first presentation of results, only those with relative error under 20% are presented.

Table 4.1: Results from the work sampling

Activity	AN	SN	AsN	Total	Relative error
PPPO	53,5%	66,1%	55,8%	58,6%	**3%**
Document and read information about patient	9,4%	5,3%	7,9%	7,5%	**11%**
Prepare surgical theatre	4,7%	6,9%	6,2%	5,9%	**12%**
Paid break	5,9%	4,6%	3,8%	4,8%	**14%**
Manage other staff issues	6,0%	4,1%	3,7%	4,6%	**14%**
Retrieve or drop off materials, samples and equipment for specific patient	2,8%	5,0%	5,3%	4,4%	**14%**
Cleaning work	0,8%	1,6%	5,2%	2,6%	**19%**
Conversation with patient	3,5%	1,5%	0,1%	1,7%	24%
Communicate about a patient	2,6%	0,7%	1,5%	1,6%	24%
Pick up and refill materials	0,2%	0,1%	3,1%	1,1%	29%
Manage other interference or waiting	0,5%	1,3%	1,4%	1,1%	29%
Handle other materials	0,2%	0,7%	2,1%	1,0%	30%
Supervise students	1,9%	0,1%	0,8%	0,9%	32%
Retrieve planned patient	2,6%	0,1%	0,1%	0,9%	33%
Transport the patient outside the unit	2,3%	0,4%	0,0%	0,9%	33%
Wait for information	0,5%	0,7%	0,8%	0,6%	38%
Prepare pharmaceuticals	0,5%	0,1%	0,6%	0,4%	46%
Manage non-specific patient information	0,8%	0,3%	0,2%	0,4%	47%
Wait for surgeon	0,4%	0,1%	0,7%	0,4%	47%
Wait for anaesthetist	0,3%	0,4%	0,1%	0,2%	62%
Check stock and order new supplies to storage	0,3%	0,0%	0,4%	0,2%	65%
Perform other assistance to patient	0,2%	0,0%	0,1%	0,1%	98%
Perform other pharmaceutical work	0,1%	0,0%	0,0%	0,0%	196%
Total	100,0%	100,0%	100,0%	**100,0%**	

For example, it can be observed from the table that PPPO constitutes 58.6% of the total working time. PPPO is the actual surgery time and represents working time related to the patient. This is equals 281 minutes for an 8-hour working day. Surgical nurses spend 66.1% of their time on patient time. A reason for this could be that the surgical nurses are required to stay in the surgical theatre at all times during surgery due to sterilization requirements and due to being the primary assistant to the surgeon.

Documenting and reading information about a patient constitutes 7.5% of the total working time. The differences between vocations are explained by the anaesthetist nurse required to monitor and document the anesthesia and the medication given. The nurse assistant assists the surgical nurse with documentation and reading about the patient during the actual patient time and during preparation of surgical instruments. Hence, the allocated time for this activity is higher for the nurse assistant.

Preparing the surgical theatre constitutes 5.9% of the total working time. The majority of this time consist of setting up the table of surgical instruments, done by the surgical nurse and the nurse assistant. Other sub-activities include checking that medicine for anesthesia is in place, and other material or equipment required to performing the surgery.

Taking a paid break constituted 4.8% of the total working time. Even though this adds no value to the patient, it should be noted that this number is low in comparison to other hospitals in Sweden, according to the management team at SU.

Managing other staff issues constitute 4.6% of total working time. The majority of this time can be attributed to the 2-hour morning meetings on Wednesdays where the whole staff participates.

Retrieving or dropping of material, samples and equipment for a specific patient constitutes 4.4% of the total working time. The anaesthetist nurse and the anaesthetists usually decide prior to the surgery which anaesthesia medicine and equipment to use for the anaesthesia, and medicine is usually put in a safe cupboard in the surgical theatre. Therefore, the anaesthetist nurse's time is low. If additional surgical instruments are needed during the surgery, the nurse assistant retrieves the instruments, and other materials if need be. Hence the nurse assistant's time spent on this is higher.

Cleaning constitutes 2.6% of the total working time. It should be noted that cleaning could take place during the preparation of the surgical theatre but also simpler cleaning during the surgery in order to make the changeover process between surgeries faster. In addition, the cleaning could also be done by called in cleaners from a cleaning firm, and the cleaning firm personnel is not included in the observations.

4.2.2 Weekly and daily overview

This section presents a weekly and daily overview of how much of the working time is spent doing patient surgery-related work (PPPO). This is done in order to better pinpoint where potential for improvements may exist.

In the figure below, the weekly and daily split is presented, see figure 4.2 and 4.3.

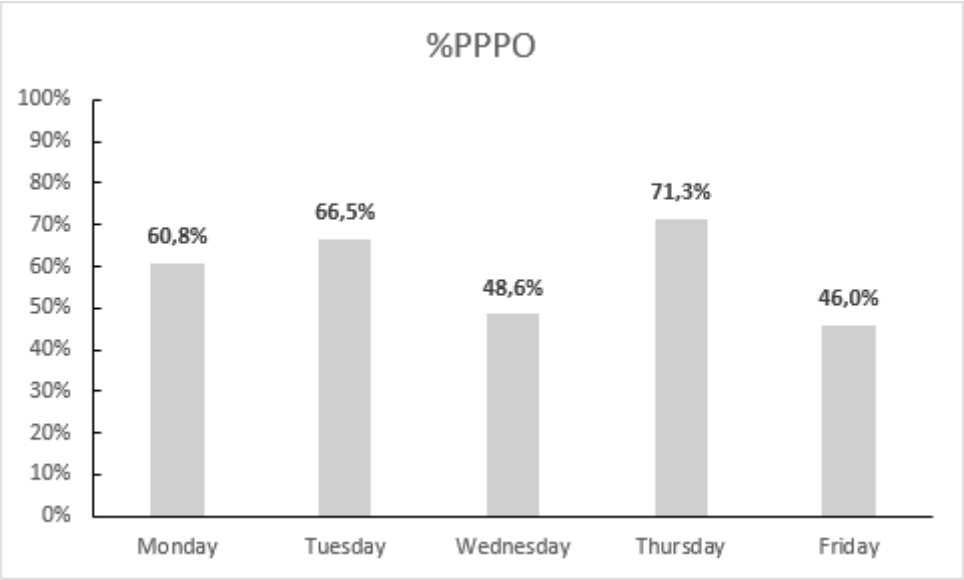

Figure 4.2: %PPPO, weekly split

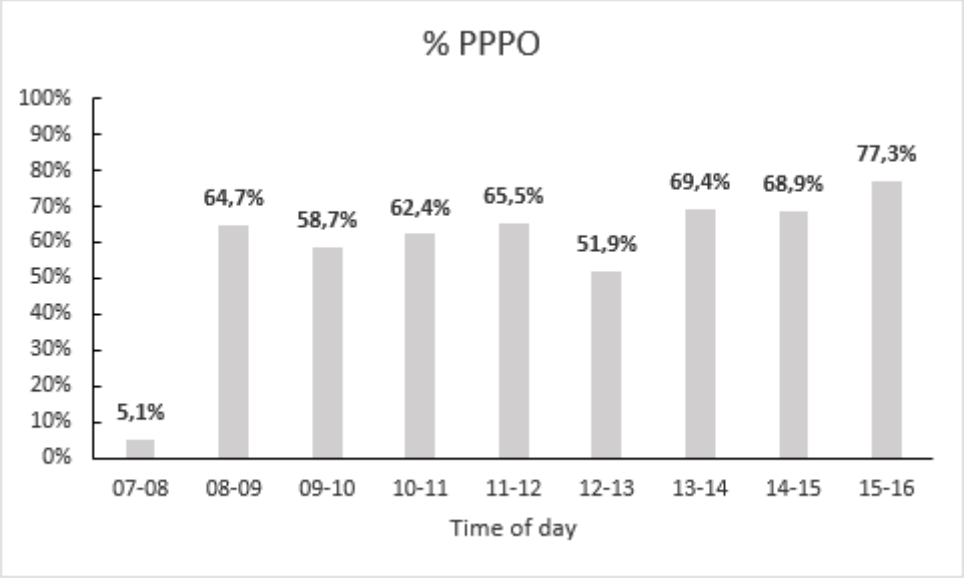

Figure 4.3: %PPPO, daily split

From the total percentage of PPPO presented in section 4.2.1, e.g 58.6%, it is possible to draw some general conclusions about the weekday differences and daily time

differences.

For example, Wednesdays and Fridays have low PPPO activity meaning that there could be other activities that might take time. Wednesdays, the staff has a morning meeting of two hours, which is why PPPO is lower in this case. Fridays have standardized procedure for colorectal surgeries, meaning that surgeries are quicker and more frequent along with faster preparation times. The higher number of surgeries mean that more total time is spent cleaning the surgical theatre, communicating with the patients, and retrieving materials for the surgeries. Hence, this might a reason why PPPO activity is low.

Obvious discrepancies from the mean PPPO-percentage are during the first hour of the day. This is mainly due to the Wednesday morning meeting, the daily morning meeting and surgical theatre preparations preparations.

4.2.3 Categorization

As mentioned previously in 3.4, grouping some data posts will decrease the relative error and hence make it significant to analyze. This categorization was done for two reasons. First, to make use of all data and decrease the relative error. Second, to get a better overview of the split between roles. *Direct patient work* is composed of all the work done in direct proximity to the patient. This includes work in the surgical theatre while the patient is present. *Indirect patient work* is composed of all the other planned work related to the patient, but while the patient is not present. *Service work* is composed of all other non-patient work. *Other* is composed of all non-value adding activities, such as handling interferences, paid breaks and waiting time. See figure 4.4 for a breakdown, and table 4.2 for the results.

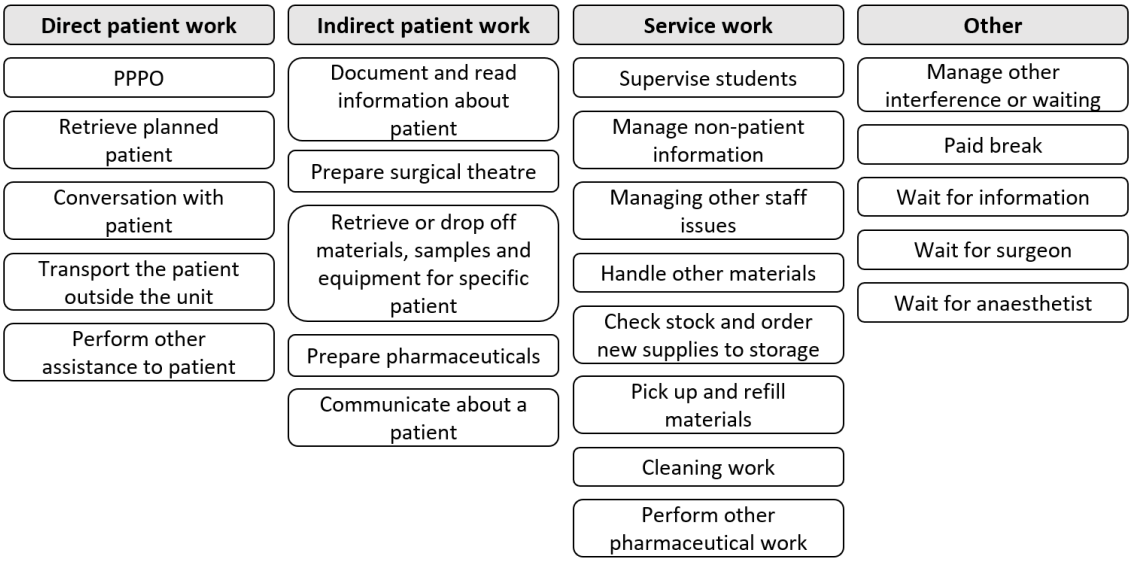

Figure 4.4: Activities included in categorization

Table 4.2: Categorization

Activity	AN	SN	AsN	Total	Relative error
Direct patient work	62,2%	68,0%	56,2%	62,1%	**2%**
Indirect patient work	20,0%	18,0%	21,6%	19,9%	**6%**
Service work	10,3%	6,8%	15,4%	10,9%	**9%**
Other	7,5%	7,1%	6,8%	7,2%	**11%**
Total	100,0%	100,0%	100,0%	100,0%	

4.3 Historical Data

This section presents historical data collected from the software system, Orbit, at Operation 1. First, general data on surgeries is presented. Second, the most common types of surgeries performed at Operation 1 are presented, which will be the basis for which specific types of surgeries to focus on. Additionally, times related to affectable processes are presented - processes not related to direct patient work. As mentioned 3.3.4, the historical data was collected with the help of an experienced nurse at Operation 1. It was collected manually from their internal software Orbit. From Orbit, it is possible to find, among other things, each surgery that has taken place and planned surgeries. For each specific surgery it is possible to extract data on surgery type, time of day, when the patient preoperative phase is done, when the team start theatre preparations, when patient time starts, when anesthesia starts, when the surgery preparation is done and when the surgery begins. Description of the data collected is further described below:

- **Preop done** - When the patient is prepared and ready at the preoperative unit
- **Theatre start** - When the team is in the theatre and preparations for the surgery begins
- **Patient time start** - When the team is locked to a patient e.g. retrieving the patient from the preoperative unit
- **Anaesthesia start** - When anesthesia induction is started inside the surgical theatre
- **Surgery preparation finish** - When the patient is washed, dressed and ready for surgery, and the equipment is on site.
- **Surgery start** - When first knife incision is recorded.

4.3.1 General Data

In this section, general data is presented. This includes the average start time of the first case of the day, the average surgery time for elective operations, how many elective surgeries that was performed during the period, how much total time was spent performing elective surgery. Also, two histograms of surgery times and changeover times are presented, see figure 4.5.
From the figure it is apparent that most surgeries take between 61-120 minutes to perform, while most changeovers take 61-90 minutes to perform. Additionally, the

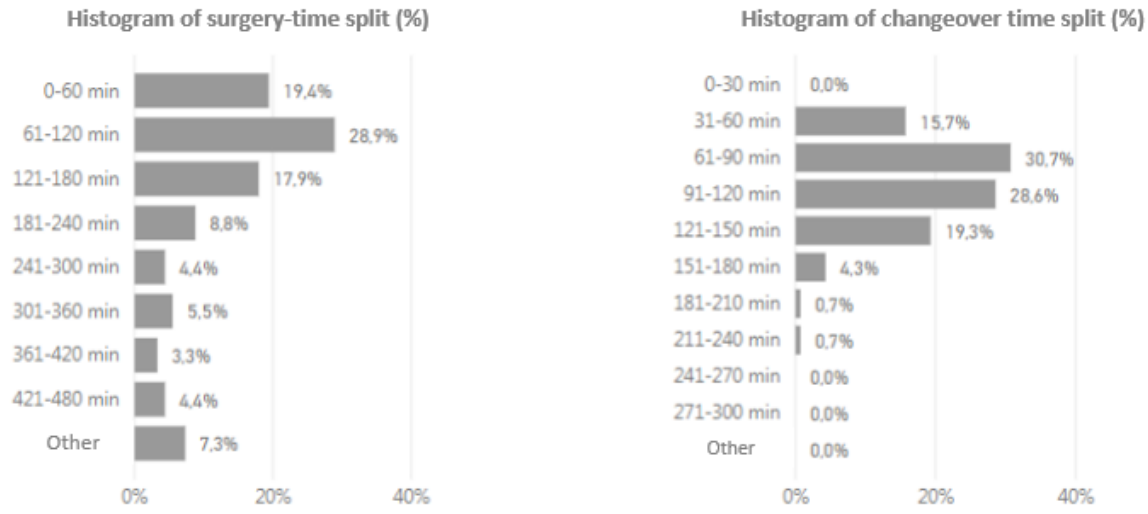

Figure 4.5: Split of average surgery times and changeover times from February to April

average first case setup time was 09:18, e.g. 123 minutes after the daily morning meeting has ended. The average elective surgery time is 129 minutes. The number of elective surgeries performed during the period of February to April was 502. 64555 minutes was spent doing elective surgery during the period. These numbers equate to 167 surgeries per month and 8 surgeries per working day, spread across the available surgical theatres, e.g. 4 or 5 theatres. This means an average of 2 surgeries per day and theatre. From the work sampling study, it was concluded that 281 minutes was spent on elective surgery time, %PPPO, which equates approximately 140 minutes per surgery.

Operation 1 have previously implemented a Fast-Track programme for colorectal surgeries, which are all performed during Fridays. This was done due to the speed of which changeovers can take place at a much faster pace than other surgeries, allowing for more surgeries to be performed during the same day. Colorectal surgeries, due to their nature, require less sterilization measures to take place. It is therefore interesting to see the same type of histograms as presented above, but filtered by Fridays, during the same period of time. See figure 4.6.

From the figure, it is apparent that most surgeries take between 0-60 minutes to perform, while most changeovers take 61-90 minutes to perform. Additionally, the average first case setup time was 08:42, e.g. 87 minutes after the daily morning meeting has ended. The average elective surgery time is 30 minutes. The number of elective surgeries performed during the period of February to April was 116. As can be seen from the work sampling study in figure 4.2, Fridays have a lower %PPPO (surgery time), than other weekdays. This is mainly because changeover times are almost double the average surgery time, even though a greater number of surgeries can be performed.

The comparison of weekdays versus Fridays, which have standardized colorectal

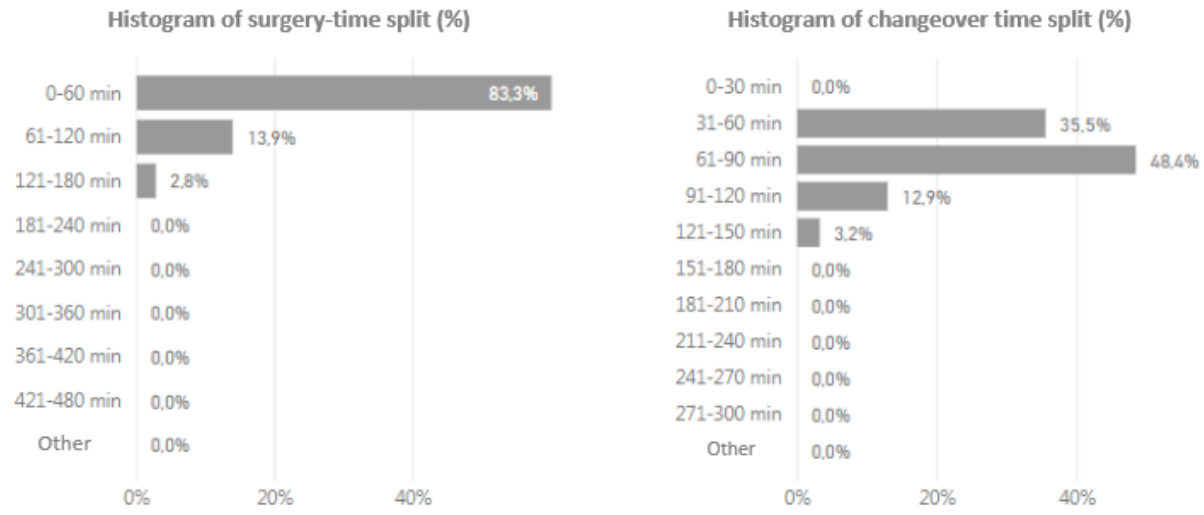

Figure 4.6: Split of average surgery times and changeover times from February to April, Fridays

surgeries, show that high volume surgery-types can allow for more surgeries to take place if changeover times are low in combination with low average surgery times. These findings are further analyzed in chapter 5.

4.3.2 Specific Data

To bring the highest impact, it was decided that the surgery types with the highest accumulated preparation times would be a way to start the filtering. Some data extraction difficulties existed related to Orbit and no rigid data for the frequency or number of surgeries was readily available - for specific surgery types. Hence, the accumulated preparation time was deemed sufficient to serve as a proxy for establishing the most common surgery types. Data on the 20 most common surgery types was collected, see table 4.3. The accumulation period was between January and April, 2019. It should also be mentioned that these times include *all* surgeries, meaning that no regard is taken to whether they are elective or emergency surgeries, or if they were done during the the day, evening or night shift.

To enable a more focused analysis, only three surgery types were chosen: JAH00, JKA21 and JAH01. Filtering was done together with an experienced nurse assistant. Filtering was based on surgery types with mainly day shift procedures, shorter length of surgery, mainly elective surgeries, mainly multiple surgeries of the same surgery type during the same day, in combination with the highest accumulated preparation times.

Day shift procedures were chosen since it is within the scope of this study. Surgery types with shorter surgery times were chosen because this means that more changeovers take place during a single day, and the total impact of reducing changeover times would be greater. Elective surgeries were chosen because is is within the scope of

Table 4.3: Top 20 surgery procedures sorted by highest accumulated preparation times

Type of operation	Accumulated preparation time (min)	Type of operation	Accumulated preparation time (min)
JEA01	9404	JDF11	1580
JAH00	7070	JAP01	1461
JKA21	6142	JAB30	1455
JAH01	3850	JFB00	1425
JFB30	3190	JFF13	1386
JFF10	3071	JFB46	1294
JHA00	2624	JFF27	1213
JHD30	2564	JDF97	1103
JGB01	1740	JFB47	1086
JFG00	1713	JFB31	1076

the study. Surgery types that are done several times during one single day are chosen because they are easier to standardize, like the case with colorectal surgeries on Fridays. For example, JAH00, JKA21 and JAH01 are mainly done during Tuesdays and Thursdays.

Table 4.4 shows the total number of surgeries between February and April. The total number of surgeries for these types were 76, or approximately 15% of total number of surgeries during the period of February to April. This period was chosen since surgery activity was low during January and it could possibly skew the data. Mean theatre preparation time is the time it takes from *Theatre start* to *Surgery preparation finish*. The preparation time calculated does not differentiate between first case setup or changeover times, since the procedures are more or less the same.

Table 4.4: Calculations of historical data

	JAH00	JAH01	JKA21
Number of surgeries	22	14	40
Mean theatre preparation time (min)	103	85	75
Accumulated preparation time (min)	2266	1190	3000
Mean time between finished preparations and surgery start (min)	5	8	5
Mean time between preop finished to patient time (min)	26	30	30
Mean time between patient time to anaesthesia start (min)	21	22	21
Mean time between patient time to theatre start (min)	37	25	25

The time intervals presented at the end of the table are the main data that was available to extract from Orbit, for specific surgery types. To further illustrate the intervals, see the example of JAH00 in figure 4.7.

The purpose of the illustration is to show how much time is spent between the different processes and to circle back to the theory presented earlier in this study when analyzing the surgeries. For the case of JAH00, eliminating the delay after the surgery preparations are complete would result in 5 minutes saved per surgery. Moreover, the patient time starts when the anaesthetist nurse retrieves the patient

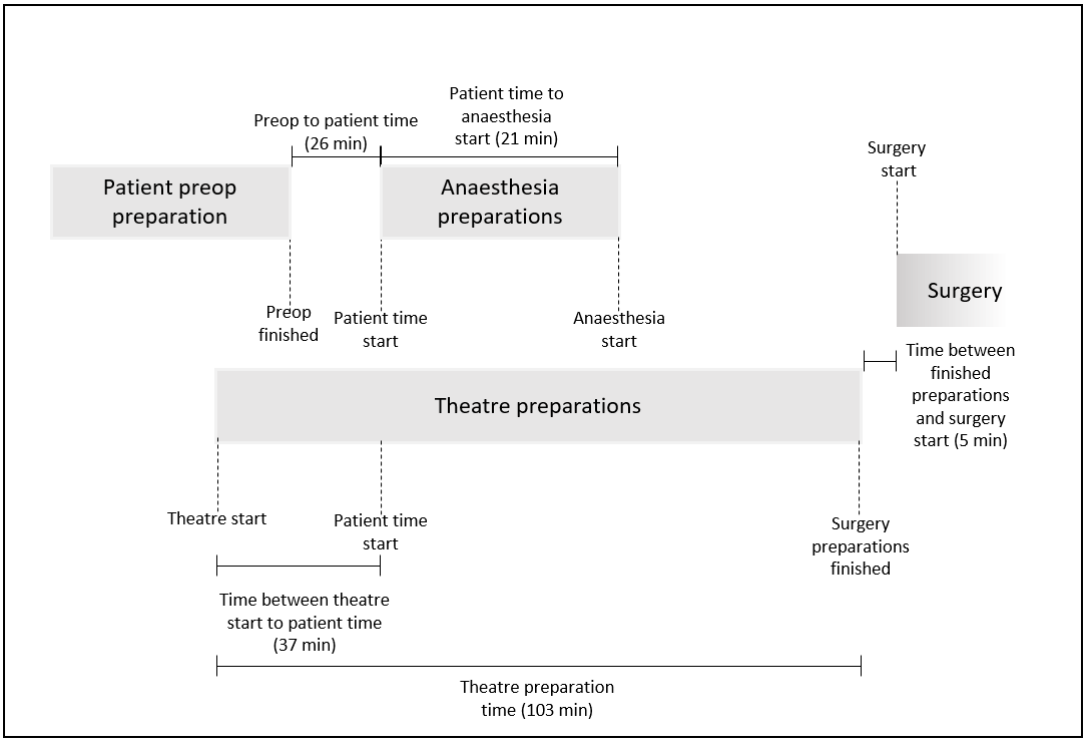

Figure 4.7: Time between different processes for surgery type JAH00

from the the preoperative unit. For JAH00, the time between retrieving the patient to start of anaesthesia is 21 minutes. Improving this process by even 5 minutes would mean that at least 10 additional minutes could be saved. Ultimately, the goal is to reduce the number of minutes across all intervals so that the number of minutes saved equals an additional surgery during the same day. This is further analyzed in chapter 5.

5

Analysis and Recommendations

In this chapter, the data collected through observations, work sampling and from Orbit is analyzed with the theoretical framework as basis. The data is analyzed with the main goal of increasing capacity at the surgery unit. From the literature study, it became apparent that two general areas have received the most focus in operations management of surgery units. Hence, results will mainly be analyzed through the lens of changeover time and variation. Recommendations to increase capacity at Operation 1 will be presented with regards to these two areas. Furthermore, recommendations for continuous improvements is provided in order keep improving on recommendations provided earlier.

5.1 Changeover and preparation times

The main goal of increasing capacity at a surgery unit is to be able to perform more surgeries in the same amount of time. While this can be done with adding extra labor, this is not an option for Operation 1. Hence, the capacity increase must come from making the processes more efficient. Sandberg et al. (2005) defined two types of periods for a surgery process: non-surgery time and surgery-related time. It is the reduction of non-surgery time that will provide the possibility of increasing capacity for the surgery unit. Non-surgery time is the time between two surgeries, and changeover time is a part of this time - the time when there is no patient in the surgical theatre (Peltokorpi et al., 2009). In this study, the time for preoperative theatre preparations, as described in 4.1.2 is the changeover time for the process.

From the specific historical data in 4.3.2, the changeover time can be calculated approximately as the time between *theatre start* and *anaesthesia start*. For JAH00, the changeover time is 58 minutes. JAH01, 47 minutes. JKA21, 46 minutes. These times are below the mean of changeover time, as presented in figure 4.5, but have high total preparation times. Note that the mean preparation times are higher than the changeover time. This is because the preparation times include the induction of anaesthesia and positioning of the patient. Because the instrument preparations take place before the theatre patient preparations, such as the anaesthesia, the surgical nurse and nurse assistant can have moments where they are idle and have to wait for the anaesthesia to be finished. Hence, there are two interrelated aspects to look at. First, how do we reduce the changeover time? Second, how do we reduce what makes the total preparation time so long, e.g. the anaesthesia process?

Meredith et al. (2011) provided five factors which determine if changeovers are efficient. They are presented below in figure 5.1.

	Faster	Slower
Process archetype	Patient preparation and instrument preparation concurrently	Patient preparation and instrument preparation in series
First case setup timing	Long first case setup	Short first case setup
Prepare surgical instruments	Two stage preparation, start of day and during changeover	Complete preparation during changeover
Surgeon availability	Surgeon in theatre during changeover	Surgeon arrives after patient is ready for operation
Theatre layout	Set up room adjacent to theatre for patient preparation	No set up room - all processes occur in theatre

Figure 5.1: Summary of activities which make faster or slower changeovers (Meredith et al., 2011)

The *process archetype* at Operation 1 is of the slower type - patient preparation and instrument preparation are done in series, see figure 2.5. This is done for all types of surgeries except for colorectal surgeries on Fridays, which explains the much lower changeover time of 30 minutes. Because colorectal surgeries does not require the same amount of sterilization, the instrument preparation process can be done at the same time as the patient preparation process in the surgical theatre. This is called concurrent processing, and provides the most significant impact on changeover time, see figure 2.6.

Furthermore, Meredith et al. (2011) found that the presence of the surgeon during the changeover boosted team morale, sped up the instrument preparation process, reduced misunderstanding that could lead to late changes and obviously be on time for the surgery. At Operation 1, the surgeon availability varied depending on individual surgeons. It is not a requirement from the surgeon to fully help in the changeover process. However, the surgeon should be on time for when the patient is ready. For example, one of the main causes of the waiting time between finished preparations and surgery start is the late arrival of surgeons - in JAH00, this is on average 5 minutes per surgery.

Additionally, Meredith et al. (2011) escalates the need for a setup room adjacent to the theatre for patient preparation so that the patient preparation does not interrupt the theatre preparations. At Operation 1, the patient preparation is done in the theatre. For other surgeries than colorectal ones, the sterilization requirement still applies. As such, it is not possible to prepare instruments at the same time of patient preparation - which is why the patient preparation has to be done somewhere else in order to achieve a concurrent design.

Therefore, this study will make an effort for a process redesign in order to reduce the total preparation time through parallelization of instrument preparation and patient

preparation processes. Smith et al. (2008) and Harders et al. (2006) have done the same procedure and achieved close to 50% reduction in non-surgery time. Hence, methods and systems are derived from their research. Furthermore, the reason for specific surgery types (JAH00, JAH01 and JKA21) is because Dexter and Macario (1999) found that surgeries with less than two hours surgery time have the largest potential of adding an extra surgery to the daily schedule. Even if it does not, the additional time saved will be used for supporting activities (Wong et al. 2010). In an 8-hour workday there are 480 minutes. Assuming that the average surgery takes two hours, the total JAH00-procedure takes 223 minutes. In a day, this equates to 446 minutes if not working overtime. A reduction of 50% in non-surgery time would yield an additional 103 minutes during a day. With the remaining 34 minutes from the 480 minutes, and the 103 minutes saved, one could achieve 137 minutes extra to perform a shorter surgery. It should be further noted that it is not the aim of this study to detail the specifics of the three surgery types, but rather showcase the impact that standardization and parallelization can have on high volume surgeries.

5.1.1 Process Redesign

Operation 1 currently has no concurrent processing. With proven results from parallelization (Meredith et al. 2011; Harders et al., 2006; Smith et al., 2008), this is the recommendation to Operation 1. One particular object is needed for this to work; namely the anaesthesia induction room, which allows the patient to be prepared for surgery while the instrument preparation process can keep running. At Operation 1, they have idle surgical theatres in proximity to each other. It is therefore recommended that at least one of these are used an anaesthesia induction room. While no map of the surgical unit layout is available, it is estimated that the transport time from such a room to any of the surgical theatres at Operation 1 is less than one minute. Additional benefits of having a anaesthesia induction room is the centralization of where anaesthesia is induced, meaning that a larger pharmaceutical inventory can be moved into the room and reduce the need for running back and forth between the surgical theatre and the medicine room.

It is also possible to have a room with the same ventilation as the surgical theatre for preparing the instruments. This would allow the anaesthesia to take place as usual in the surgical theatre while the instruments would be brought in, in time for the surgery. However, from interviews with the staff, the risk for contamination of instruments during the transport to the surgical theatre would be greater. It was therefore decided that this might not be a trade-off that they would be willing to risk, since patient safety is of utmost importance. If such a solution was possible, it would be approximately interchangeable, in impact measured, with the anaesthesia induction room. Hence, an instrument preparation room where instruments are transported to the surgery room is not an option for Operation 1.

For an anaesthesia induction room to work smoothly, a mobile surgical bed is needed. Operation 1 transports the patient from the preoperative ward to the surgical room on the preop bed and then has to, sometimes, lift the patient onto the surgical table

which is fixed. The mobile surgical bed will allow for transports without the need for lifting patients. Further, if the patient is able to have the correct positioning during the time in the anaesthesia induction room, this will save additional time. While in the anaesthesia induction room, monitoring leads can be placed on the patient so that the connecting of monitoring equipment is done quickly when the patient arrives into the surgical theatre. Harders et al. (2006) estimated that they saved on average 7-8 minutes of non-surgery time, per surgery, by using a mobile surgery bed.

5.1.2 Process Redesign Impact

For JAH00, the changeover time is 58 minutes. JAH01, 47 minutes. JKA21, 46 minutes. The mean theatre preparation time (non-surgery time), is 103, 85 and 75 minutes respectively. This means that the theatre patient preparation part part is 55, 38 and 29 minutes respectively.

Without making any changes to the theatre preparation processes (changeovers), moving the patient preparation for JAH00 eliminates a maximum of 55 minutes from the mean theatre preparation time, since the instrument preparation can continue during the patient preparation. JAH00 has a planned surgery time of 140 minutes accompanied by 103 minutes of preparation. This makes it possible to fit two of these into one day for 486 minutes. With an anaesthesia induction room, 110 minutes can be saved. Not enough for an additional average surgery but a significant save. For JAH00 to be able to add an extra surgery to the day, an addition of 133 minutes is needed.

Without making any changes to the theatre preparation processes (changeovers), moving the patient preparation for JAH01 eliminates a maximum of 38 minutes from the mean theatre preparation time. JAH01 has a planned surgery time of 78 minutes accompanied by 85 minutes of preparation. On a regular work day of 480 minutes, it is possible to squeeze in three JAH01 procedures for a total of 489 minutes. With an anaesthesia induction room, 114 minutes can be saved. Not enough for an additional average surgery but a significant save. For JAH00 to be able to add an extra surgery to the day, an addition of 49 minutes is needed.

Without making any changes to the theatre preparation processes (changeovers), moving the patient preparation for JKA21 eliminates a maximum of 29 minutes from the mean theatre preparation time. JKA21 has a planned surgery time of 84 minutes accompanied by 75 minutes of preparation. On a regular work day of 480 minutes, it is possible to squeeze in three JKA21 procedures for a total of 477 minutes. With an anaesthesia induction room, 87 minutes can be saved. Not enough for an additional average surgery but a significant save. For JKA21 to be able to add an extra surgery to the day, an addition of 72 minutes is needed.

As can be seen from the analysis, all three surgery types require additional minutes in order to perform an additional surgery of the same type, under the assumption that

each surgery type is performed after each other. However, adding an anaesthesia induction room is not the whole part of the solution. It decreases the non-surgery time significantly by eliminating time equal to the patient preparation process. As a result, the non-surgery time is equal to the changeover time, since the patient preparation time was lower than the changeover time. As a next step, reducing the changeover time through reduction in variation is of priority as well as standardizing these type of surgeries.

5.2 Variation

As stated by Holweg et al. (2018), variation is inherent in all process inputs, tasks and outputs. Also, variation can occur in quality, quantity and timing. Operation 1 is no different. From observations and work sampling, it could be observed where variation in processes caused delays, from variation in organizational issues to variations in the surgery process.

Variation in operations management can, according to Holweg et al. (2018), be distinguished into two different types, common causes and assignable causes. Variation created by common causes is random and difficult to predict, such as a malfunctioning IT-system, late patient arrival, late arrival of external cleaning services or that the patient may refuse surgery on day of surgery (Harders et al., 2006). The scheduling software might crash which could cause heavy delays and paralyze the whole surgery unit. A late patient arrival might postpone other surgeries for the day, causing idle time for the surgical team, or in worst case, the patient gets sent home. Late cleaning services results in a longer changeover time. The patient, anaesthetists or surgeon might cancel the surgery due to no consent or deteriorated health condition. Non of these are easy to control from the perspective of the surgery unit.

Variation caused by assignable causes are, on the other hand, easier to predict and remedy (Holweg et al., 2018). From table 2.2 by Harders et al. (2006), several assignable causes for delay can be identified at Operation 1. Difficult IV or intubation, instruments or supplies unavailable, anaesthetist delayed and surgeon delayed - among others. These are further elaborated upon below.

Variation in preoperative patient preparations
Prior to each surgery, the anaesthetists and the surgeon are tasked with visiting the patient for a final check of the patient's health condition. As previously mentioned, if the anaesthetists or the surgeon considers the patient to not be in the right health condition for surgery, they can cancel it which ultimately leaves an opening in the schedule with underutilized time. Further, if the surgeon or anaesthetists has not checked up on the patient prior to the surgery, the surgery might be delayed further. At Operation 1, this was often the case and the surgeon instead did the check-up when arriving after all surgery preparations finished. When preoperative preparations are finished for the patient, it usually has to wait for the theatre to be fully prepared. For example, a patient undergoing a surgery of type JAH00 waits an average of 26 minutes for the theatre to be ready. This can result in anxiety and

in worst cases a deterioration of the patient's health condition. This variation in timing is possible to reduce (May et al., 2011).

Variation in preoperative theatre preparations
There are two main processes that can be affected by variation in the preoperative theatre preparations: the instrument preparation process and the anaesthesia preparation process. Prior to a surgery, the surgery type is communicated to the sterilization unit and the correct instruments are sterilized and packaged so that the instruments are available. However, in extreme cases, instruments for specific surgeries can be inaccessible or not ready for use. This can cause heavy delays or even cancellation of a surgery. According to Holweg et al. (2018), it is important that an organization has planned for availability of resources such as equipment and materials in order to achieve a high production level. Furthermore, in 4.2.1 it was shown that 4.4% of the total working time was spent on retrieving or dropping materials, samples and equipment for a specific patient, which happens when preparing for a surgery but also if rework of the instruments preparation needs to be done. Reasons for this is contamination of instruments, breakage of instruments, forgetful staff or that the surgeon has not communicated a change in the surgical procedure which require new instruments. Out of the 4.4% it is estimated that at least half is related to variations instrument preparations. A reduction of these variations would result in 10 minutes saved.

Variations in the anaesthesia process occur when the anaesthetists changes the anaesthesia plan in the last minute which means that the anaesthetist nurse has to redo all preparations of pharmaceuticals. As with the instrument preparation process, if the anaesthetist nurse forgets pharmaceuticals for the anaesthesia, he or she has to go the medicine storage to retrieve the required medication.

Variation during patient time
During patient time variation can occur due to the positioning, surgeon or anaesthesia. When the patient first enters the surgical theatre, he or she is transferred from the preoperative bed to the surgery bed. If the patient's health condition is critical, this can take additional time. The patient is then positioned for surgery, which may or may not take longer time than expected depending on the type of surgery and the condition of the patient. Also, the surgeon might have his or her own preferences regarding positioning, which could cause extra delay if the surgeon is late to the surgery. Variation is also prevalent when inducing anaesthesia. From small interviews with the staff at Operation 1, it became apparent that scheduling gets significantly harder because of the uncertainty of duration of anaesthesia induction. This is because every patient is different, reacts differently to medication and has different anaesthesia methods. In addition to this, SU is an university hospital and the anaesthetists doing the anaesthesia are sometimes supervised students which prolong the anaesthesia phase.

Variation during cleaning process
An underlying reason for the occurrence of waiting time between surgeries is mainly

because the preparation of surgeries is serial (Meredith et al., 2011). Between the surgeries, the surgical team need to wait for external cleaners, who are tasked to clean the surgery theatre. From the 4.2.1 it showed that 2.6% of the working time, around 12 minutes of a working day, consisted of cleaning the surgical theatres. In the department there are only two cleaners with responsibility to clean up to five surgical theatres between the surgeries. A recurring problem for the cleaning staff is when they need to clean several surgical theatres at the same time. In some cases, the surgical teams need to wait for the cleaning staff to complete their duties on another theatre or even clean the surgical theatre themselves. The reason is mainly due to the fact that resources for cleaning are limited and nurses may carry out tasks that are not related to their actual work. During the observations, it was clear that when surgeries were completed at the same time, there was difficulty in maintaining a planning for cleaning. The cleaners did not seem to have a schedule to follow and were called by the surgical team when cleaning assistance was needed. Furthermore, the cleaners worked in pairs and staff pointed out that it would be more efficient for them to clean one theatre each. Since a external firm is hired to clean the theatres, it is a waste to not fully utilized this resource. This would save up to 12 minutes per day if cleaning could be fully eliminated.

5.2.1 Reducing variation

There are easy wins to be had when reducing variation at Operation 1. First, make sure surgeons and anaesthetists are on time for the check-up prior to the surgery, and on time for the surgery. From 4.2 it can be observed that waiting time accounts for 2.4% of total work time, which is close to 12 minutes per day. Additionally, making sure the instrument process proceeds according to routine without contamination, forgetful staff and thorough communication from surgeons will potentially save an additional 12 minutes. A solution for the surgeons is to produce a list for specific surgery types with their preferences, so that no late changes due to lack of communication occur. The same goes for the relationship between the anaesthetists and the anaesthetist nurse. Moreover, if an anaesthesia induction room is added, with a centralized medicine storage in the same room, the effects of forgetting medicine or redoing the preparation process are reduced. The variation during patient time can be handled by the anaesthesia induction room. If somewhat predicted, the patient time can start earlier in the anaesthesia room. Of course, communication between the anaesthesia team and the surgical theatre team is required in order to time the both processes. Additionally, Harders et al. (2006) estimated 8 minutes of saved time when using a mobile surgery bed during the bed transfer and positioning phase. Last, paid breaks can be reduced but not eliminated. With reference to 4.2.1 paid breaks constitute 24 minutes. Hence, reducing this could further increase time available for performing additional surgeries. However, it should be noted that this number is relatively low in comparison to other hospitals in Sweden, and it might not be feasible to reduce this time any further.

5.2.2 Variation Reduction Impact

By eliminating waiting time, 12 minutes is saved. By eliminating mistakes in the instrument preparation phase, 12 minutes is saved. With a mobile surgery bed, 8 minutes is saved. Eliminating the cleaning for the staff and fully outsourcing it to the external firm would save 12 minutes. Reducing paid breaks could potentially save 24 minutes. In total, 68 minutes can be saved per day. Of course, these are optimal numbers. However, the 68 minutes are suddenly enough to perform an additional JKA21 or JAH01 per day and theatre, assuming only one surgery type is running in a single theatre and that an anaesthesia induction room is implemented.

5.3 Standardization and Continuous Improvement

With reference to Liker (2006), standardization of processes is important since they serve as a basis for continuous improvements. If they are not standardized, the risk is greater for improving the wrong process in a wrong way. Holweg et al. (2018) further argues that continuous improvements should made until breakthrough improvements are needed, see section 2.9. The high variety and high specialization nature of surgeries makes it hard to standardize processes.

The aim of the report was to increase capacity in any way possible, and optimally in such way that an additional surgery can take place during the same day and theatre. Hence, the main recommendation for continuous improvement is to have specific surgery types during certain days of the week or certain days during the month to enable standardization. As with the example of colorectal surgeries that take place only on Fridays, it is optimal to try and achieve the same standardization for other type of surgeries. For example, JAH00, JAH01 and JKA21 are most frequently done during Tuesdays and Thursdays. The suggestion would then be to have all JKA21 surgeries on Thursdays. This would increase the predictability of surgeries and ultimately allow for an additional surgery to take place in the same day and theatre. Apart from eliminating wastes and parallelizing processes, this would add value through making JKA21-surgeries more efficient.

To allow other organizational improvements in planning and visualization, it is suggested that the registering of disturbances is made easier, since not all disturbances are registered due to difficult software interface. Also related to software, using statistical methodologies and big data methodologies on extractable data from Orbit and other patient-databases could increase predictability of patient health conditions prior to day of surgeries. Additionally, visual management is an effective methodology used for continuous improvements. It is therefore suggested that average changeover and preparation times are visualized for the top 20 most frequent surgery types, alternatively start slow with only three surgery types.

5.4 Summary of Recommendations

The recommendation is threefold. First, an implementation of an anaesthesia induction room is recommended, along with a mobile surgery bed. Second, reduction of variation and wastes caused by it is recommended, especially easy wins through paid breaks, instrument preparation process and waiting times. Third, standardization of surgery types during specific days of the week or month, which will allow specialization and means for continuous improvements. With these recommendations, it is possible an extra surgery could be done same day.

6
Discussion

In this chapter, a discussion is presented regarding the execution of this study, where the use of methodology, recommendations and quality criteria will be in focus. The methodology is discussed with respect to how literature have been used in order to provide the hospital with useful suggestion on increasing the capacity, but also the advantages and disadvantages with using the method when collecting data. Further, a discussion of recommendations is made. Finally, the quality criteria on validity and transferability is discussed to give readers an overview of how reliable and useful this report could be for further studies in healthcare.

6.1 Method Discussion

The method has been based on three different starting points for data collection, using the literature study as a basis. The literature study provided an understanding of Process theory and Work sampling and has been the basis for producing recommendation to increase the capacity at Operation 1. During the work on compiling the analysis, it was discovered that the foundation was somewhat thin for some of the recommendations, which was then supplemented. If the theory had been complete earlier during the study, the performance of the observations could have been deeper, and an understanding of the outcome might have been better. The strength of the approach, however, is that the staff have not been guided to work in a certain way. The observations have been made in a thorough approach and focus has not been on any particular resource or something that has been considered more important than anything else. Instead, the results from the observations have been linked to useful literature available on similar studies.

6.1.1 Work sampling

The work sampling has provided support in the study by creating insight into the department's way of working. Through an identification of activities that occupy most time, an evaluation and reflection on actual data has been possible. The observations have laid the foundation for further investigation on interesting aspects and helped to create an understanding of how different activities are connected and affected to each other.

Work sampling was a good method for collecting information and data on current state. During the collection there was also the opportunity to ask questions to the staff as far as gaining knowledge of the processes. In an early stage of the work sampling, it could be understood from the personnel's' mind that we would chase the staff for increased performance and increase the pace in the workplace. This reinforced the importance of having ethical considerations such as harm to patient, lack of informed consent and privacy. This was clarified by continuously explaining the purpose of the study and what it should propose in the future. In addition, the staff were encouraged to ask questions to avoid misunderstandings and disturbances at the workplace. An email with information regarding our study was also sent out to all staff members before the start, with in-depth descriptions of the purpose of the study. Each staff member was randomly chosen during the observations based on their role and not their personal performance. The main purpose was not to increase the capacity at an individual level but at an organizational level, which meant that no names of the staff were needed in mind. Before the study began, a confidentiality agreement was also written to prevent patient information from being disseminated.

6.1.2 Historical data

Collecting historical data has helped to deepen the image created during the work sampling and observations. It created an understanding of how much time is spent on the preparation time and the surgery time. Getting all the data from their internal systems with the help of an experienced nurse made it easier to ask questions and to get an overall picture. The disadvantages of retrieving the historical data after the work sampling were that it seemed to be possible to adjust certain aspects during the observations to get more data, but the positive was that the historical data supplemented the problems identified from work sampling.

What can be said to be negative in the choice of method is that the broad data collection has created more width than in depth. In a first stage, the work sampling was considered a correct method for looking at how resources are used and then analyzing the problems identified. Based on the fact that the time for implementation of this project is 5 months, a collection of historical data in a first stage would probably have generated more depth than width. The historical data provided a summary of how much time and resources have been spent during the past year, and which surgery types have the highest impact on the resources. By first analyzing the historical data and the specific surgery types, a work sampling could then have been carried out. This would have resulted in observations only been carried out on the most common surgeries. Furthermore, the results from the work sampling showed that the preparation phase constitutes a large part of the daily work. This could have been reduced with the help of the historical data, as the results from the work sampling includes Fridays which is a day for solely fast-track surgeries. During a fast-track day, more surgeries are performed than other days, which automatically generates more time for preparation. In addition, the export of historical data was limited to 3 months in order to link it to the work sampling. However, the width

of this work could also be considered as a strength, especially since the in-depth understanding of the resources in the department was very small.

6.2 Discussion of recommendations

In our recommendations for a reduction of non-surgical time, we have used literature and previous studies in the same field. The literature described how great a possible effect of reduction could be, and the expected result of improvements in this report is based on authors´perception and estimates. However, the estimates were in line with the improvement opportunities considered to occur from the collected data.

One thing that may have given the recommendations a chance to be completed in the hospital is the great impact it seems to have on the most frequent surgeries. By base the recommendations on the most frequent surgery types, it highlights an opportunity to easily implement it to several surgeries in the department. There is also a good chance for the recommendations to be fully possible to completed and have the impact presented in the report, based on the staffs' openness to change. During the observations, there appeared to be a desire to achieve more direct patient work among the staff. This has contributed to a continuous collaboration with the staff during the observation period. Majority of the staff members have provided the study with ideas and solutions that simplifies a implementation of the recommendations.

However, something that can be considered a disadvantage is the collection of data on the most frequent surgeries. There was no optimal function in Orbit that facilitated a complete export of data, which required a manual export. This may have led to the study covers incorrect entry of data. In addition, the calculations in the analysis have not taken the execution of planning for surgeries and the staff's paid break into account. It would have been good to study these aspects more to understand how and why the planning works as it does, and to see what effect it has on a future application of the recommendations.

6.3 Validity

The collected data from work sampling is statistically reliable based on the theory described in section 2.5. However, since the study was conducted over a relatively short period of time, due to time constraints on thesis work, the outcome is only representative of the prevailing circumstances during the selected time period. In order to achieve a more reliable study, the study should be carried out over a longer period of time with greater amount of observations. It would probably have resulted in less systematic errors when the observers became more used to handling the equipment and the activity list.

The activity list represents the activities performed in the workplace and is developed and approved by the staff at the unit. Since the activity list was standardized, it was easier to link and compare the result from work sampling with other studies performed in hospitals. The disadvantage of getting a finished list has been in the observer's lack of medical competence. Since the list has been specific in what steps are performed, it has sometimes been difficult to discern which activity is correct. In some cases, during surgery, it has been difficult to distinguish an activity when certain activities were relatively similar. If the observers grouped the activities into groups that were more clearly linked to what was actually done, the number of systematic errors could have been reduced.

Another problem concerning the execution of work sampling is the switch between nurses during the observations. On occasions when a nurse in the surgery theatre took a break and switched with another nurse, it could take a while before the observers knew what was happening. Most often, the observers understood that a switch of nurses had been made after asking for the nurse. This resulted in a disturbance when entering data and certain activities that have been performed have not been well represented.

For this work, the pre-study is considered to be too short in order to create a correct theoretical framework. A pre-study would have gained more concretization on which theories are considered to give most impact for increasing the capacity. The current theoretical framework is considered to be far too broad to give concrete solutions. This has actually led to the hospital having received recommendations for improvements but no concrete steps for an implementation.

It has been an advantage to take active notes during the observations, as it has given a higher reliability to observations and the informal conversations that have taken place. The work sampling resulted in a relative error of 20% for the smallest activity, which is acceptable for highlighting problem areas and providing the hospital with recommendations.

6.4 Transferability

The work in healthcare can differ both at a national and international level. This means that the requirements and resources that have proved to be sufficient or lacking in Operation 1, may not necessarily be perceived as general problems in healthcare. However, problem areas identified in the study are represented in other literature and studies carried out. It shows that the problems are not only department-specific, and they are important aspects to keep in mind when you want to increase the capacity of existing resources. However, similar studies need to be done on more healthcare departments to ensure that the result is generally for healthcare.

The activity list for work sampling was developed by the MOA-group, which is a group that works to modernize the work at Sahlgrenska by reducing the queuing

time for patients and increasing the capacity of existing resources. The list has been validated by all members of the group. This means that the activity list can be used by other departments within the organization for carrying out similar studies and allowing other departments to absorb the recommendations. The result from work sampling can also be used to compare results between different departments or other hospitals within the VGR, with some adjustment of department-specific activities.

However, the historical data is directly linked to Operation 1, but during the gathering of data it was also possible to export data from other surgical departments at Sahlgrenska. Based on the analysis of the historical data, the unit managers can compare the historical data of different departments in a similar manner to link to this study.

7
Conclusion

This chapter concludes this report. The aim of the study was to increase capacity at a surgery unit using the same resources. Three large areas was identified that affected capacity at a surgery unit. These were the processes affecting the non-surgery time, the variation in processes, and the planning and scheduling.

Through parallelization, it is possible to reduce the non-surgery time by as much as 55 minutes for one of the surgery types studied. This is done through setting up an anaesthesia induction room adjacent to the surgical theatres. Additionally, a mobile surgery bed is required to be able to move the anesthetized patient. Although simply implementing these features does not allow for an additional surgery to take place during the same day in the same theatre, the potential time saved is significant.

From the work sampling, activities performed during a regular work day could be analyzed. With the help of the current state and the work sampling, it was possible to find easy wins in terms of waste, which require no significant investment. The potential time that could be saved was 68 minutes per day.

By standardizing the specific surgery procedures and allocating them to certain days of the week, a basis for continuous improvement can be achieved. This enables specialization in the most frequent surgeries, which will have the highest impact on capacity, if continuously improved.

It is concluded that, yes, it is possible to increase the capacity with the same resource. If optimally successful, the possibility for performing an additional surgery in the same day and theatre can be achieved.

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A

Appendix

A.1 List of activities for surgery unit 1

List of Activities for Surgery Unit 1	
PPPO patient work	Clean work
Preparing operating room	Manage non-specific patient information
Retrieve the planned patient	Supervise students
Transporting the patient outside the Unit	Teaching a new employee
Execute external assignments	Managing other staff issues
Conversation with patient	Manage and develop the business
Report	Break
Communicate about a patient	Handle faults on equipment and premises
Document and read information about the patient	Manage IT interference
Prepare pharmaceuticals	Searching
Perform other pharmaceutical work	Wait for surgeon
Perform other patient assistance	Wait for anesthetist
Pick up and drop materials, samples and equipment for specific patient	Wait for information
Inventory and order material for storage	Handle other interference and waiting
Pick up and refill material	Objects missing
Handle other materials	Lunch or other breaks that are not paid

Figure A.1: List of activities used in work sampling

A.2 The ten process principles and subprinciples

Foundation

Principle #1: All operations are composed of processes.

Principle #2: Variation is inherent in all process inputs, tasks, and outputs.
(a) Variation can occur in quality, quantity, and timing.

(b) Variation in a process can be buffered by a combination of any of the following three means: time, inventory, and capacity.

Design

Principle #3: Work-in-process is determined by throughput rate and throughput time.

(a) The throughput time of a process is stochastic, not deterministic.

(b) Bottlenecks govern the throughput of a system.

Principle #4: Complexity in process design amplifies managerial challenges.

(a) Complexity is a function of the number of static elements (structure) in a process, their heterogeneity, and their dynamic interactions.

(b) A comparable, yes simpler solution will always outperform a more complex one in the long term.

Principle #5: Process choice requires fit between the task and the external requirements.

(a) The higher the volume/lower the variety of the process, the more dedicated the assets it uses will be.

Measure

Principle #6: No single measure can capture the performance of a process.

(a) Performance metrics are not necessarily independent of each other.

(b) Absolute measures are preferred to relative ones because of their greater explanatory power.

Principle #7: Process metrics can drive unintended behavior.

(a) You cannot manage what you do not measure.

(b) What you get is what you measure.

Improve

Principle #8: Processes are improved by reductions in throughput time or in undesired variation.

(a) Unmanaged processes will deteriorate over time.

(b) The total cost associated with an operational problem is inversely proportional to the speed of rectifying its root cause.

Principle #9: The rate of process improvement is subject to diminishing returns.

(a) There exists a trade-off between any two aspects of process performance.

(b) Trade-off can never be broken, but they can be shifted by altering process practice.

Principle #10: Processes do not operate in isolation.

(a) A set of suboptimal solutions can never produce a global optimum.

(b) Structure drives behavior.

A.3 Time schedule for performing work sampling

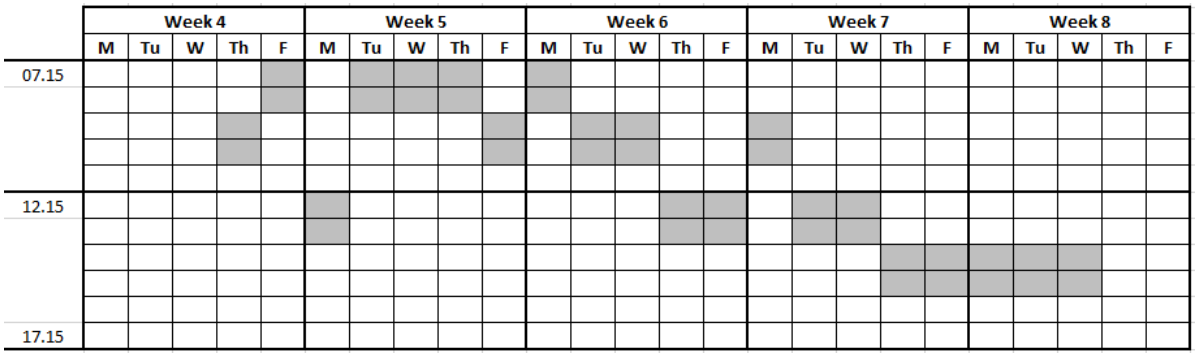

Figure A.2: Time for performing work sampling