UNIVERSITEIT TWENTE & MEDISCH SPECTRUM TWENTE

Developing a tool to address bottlenecks in the current practice of the TCT

Thorax Centre Twente

By
Nathalie Bekkering
s1371789

A thesis submitted to the Faculty of

Constuerende Technische Wetenschappen

for the
Bachelor's Degree
in

Industrial Design

UNIVERSITEIT TWENTE
Drienerlolaan 5
7522 NB Enschede
Netherlands

April 2015

Developing a tool to address bottlenecks
in the current practice of the TCT

By
Nathalie Bekkering

Supervisor MST: Prof. Dr. J.G. Grandjean
Supervisors UT: Dr. M. Rajabali Nejad
& MSc S.P. Haveman
Examinator: Dr. Ir. D. Lutters

UNIVERSITY OF TWENTE

Preface

Before I started studying Industrial Design three years ago, I thought about studying Medicine. After a long and careful consideration I decided to start studying Industrial Design in Enschede. Healthcare was still one of my main interests besides design, so as soon as I got the chance I chose health related courses. For my minor I followed courses of health sciences and health psychology.

I saw my bachelor assignment as another chance of getting more involved in the health sector. Via M. Rajabalinejad I met J. Grandjean, a thoracic surgeon at the MST. I had never been to the MST before but I was really motivated to learn about the hospital and its processes.

First of all I want to thank the employees of the MST for their cooperation. In addition, I want to thank M. Rajabalinejad and J. Grandjean for the assignment, their support and feedback. Furthermore I want to thank P. Siteur for his support, feedback, motivational input and for introducing me to the project “Niet noodzakelijk verbijf in het MST”. I want to thank E. Lutters and S. Haveman for their feedback provided in the final phase of my bachelor thesis.

Samenvatting

Achtergrond
Niet noodzakelijk verblijf is het verblijf van patiënten in een ziekenhuis dat niet medisch noodzakelijk is. Dit kan zowel wachten op een diagnose of interventie zijn als ook herstellen van een ingreep en wachten op thuiszorg of een plekje in een verpleeghuis. Door het niet noodzakelijk verblijf in het ziekenhuis te verminderen zal de bedbezetting dalen en kan de doorlooptijd van het proces dat een patient doorloopt verkort worden. Dit resulteert in een efficiënter en effectiever systeem.

Aangezien het Medisch Spectrum Twente, het ziekenhuis van Enschede, binnenkort gaat verhuizen en met de huidige manier van werken niet in de nieuwbouw past, is het nu van bijzonder belang dat de knelpunten binnen het proces in kaart worden gebracht. Daarnaast is het ook gewenst een verbetervoorstel te doen voor het verhelpen van deze knelpunten. Deze opdracht focust op het in kaart brengen en verhelpen van de knelpunten wat betreft de doorstroom van hart-chirurgie patienten binnen het Thorax Centrum Twente.

Aanpak
Dit individuele project begint met een uitgebreid onderzoek naar de processen die plaatsvinden binnen het Thorax Centrum Twente. De verschillende soorten patienten die te maken krijgen met dit specialisme, zoals bijvoorbeeld patienten van andere ziekenhuizen of spoedpatienten, worden in kaart gebracht en veel verschillende knelpunten binnen dit centrum worden verzameld.

Nadat duidelijk is welke afdelingen gerelateerd zijn aan het specialisme en welke rol deze afdelingen spelen in de huidige manier van werken, krijgen processen gerelateerd aan thorax chirurgische patienten de nadruk. Samen met verschillende stakeholders worden de onderliggende oorzaken voor de knelpunten naar boven gehaald en samengevat.

De gehanteerde aanpak resulteert in een ongeordende lijst van zowel gerelateerde als ongerelateerde bottlenecks, die verschillend zwaar wegen. Om hier meer structuur in aan te brengen, wordt er gebruik gemaakt van de opgestelde architectuur, verkregen uit een reverse architecting proces.

Resultaat
Aan de hand van de doorlopen stappen kan men de conclusie trekken dat het oplossen van één bottleneck niet resulteert in globale optimalisatie. Er is gekozen voor het ontwerpen van een tool om de ene na de andere bottleneck op te lossen. Om te beginnen wordt er gebruik gemaakt van een morfologisch schema om structuur aan te brengen in de knelpunten. Met behulp van clusteren wordt de meest belovende bottleneck geselecteerd. Door middel van een A3 Architecture Overview worden de interresesses van de key-stakeholders in kaart gebracht. Vervolgens wordt er een zelf ontworpen tool gebruikt om de mogelijke oplossingen te evalueren om zo naar een ideale oplossing toe te werken. Een case study wordt gebruikt om de bruikbaarheid van de tool te testen en te verbeteren. Daarnaast dient de case study als voorbeeld om de aanpak die het MST kan hanteren voor het oplossen van het ene na het andere knelpunt te verduidelijken.

Summary

Background
Inappropriate patient stay can be defined as an inefficient and ineffective overstay of patients that is not tailored to their needs. This can include waiting for a diagnosis or an intervention as well as recovering from the intervention or waiting for an available bed at a nursing home for further recovery. Through realising a decrease in the inappropriate patient stay of patients in the hospital, the bed availability will increase and the lead time of the process a patient goes through decrease. This results in a more efficient and more effective system.

Since the hospital of Enschede (Medisch Spectrum Twente) moves to a new building and does not fit into the new building with their current usage of beds, mapping the bottlenecks becomes very important.
In addition it is preferred to provide a solution for the bottlenecks to realize successful moving. This thesis focuses on mapping the bottlenecks in the current practice of the Thorax Centre Twente, to improve the continuous flow of cardiac surgery patients.

Approach
This individual assignment starts with a broad analysis of the current processes within the Thorax Centre Twente. Different categories of patients that are related to this medical specialty, as for example patients from other hospitals or emergency cases are identified and many different related and unrelated bottlenecks are discovered.

The related departments are mapped and their current practice is summarized. Hereafter, the scope of the assignment can be defined in more detail. The focus for further development will be on cardiac surgery patients. Together with the involved stakeholders the underlying causes of the bottlenecks are discovered.

The approach results in an unstructured list of related as well as unrelated bottlenecks, which vary in their importance. To realise more structure, an architecture of the system is used as a framework. This architecture is created by reverse architecting.

Results
After going through all the previously stated steps, it became clear that solving one single bottleneck does not result in global optimization of the process. Therefore, the decision was made to design a tool that provides support when solving one after the other bottleneck. To begin with, a morphological chart is used to structure the bottlenecks that were the outcome of the analysis. Hereafter, clustering is used to select the most promising bottleneck for continuing. For the next step, A3 Architecture overviews are used to map the interests of the key stakeholders. The usage of the A3 Architecture Overview resulted in the development of a new tool that supports the investigator and designer to evaluate possible solutions and modifying it until an ideal solution is evolved. A case study is used to verify and improve the usability of the developed tool. In addition it provides an example to clarify the adopted approach used to solve bottlenecks.

Table of contents

Preface
Samenvatting
Summary
Table of contents
Acronyms A-Z
1. Introduction 11
1.1 The hospital perspective 11
1.2 The patient's perspective 11
1.3 Scope 11
1.4 Outline 11
2. Literature and methods 12
2.1 Root cause analysis 12
2.1.1 Data collection 12
2.1.2 Causal factor charting 12
2.1.3 Root cause identification 12
2.1.4 Recommendation generation 13
3. Collecting, selecting and processing data 14
3.1 Stakeholders 14
3.1.1 Cardiology 14
3.1.2 Cardiac thoracic surgery 15
3.2 Chain of events 15
3.2.1 Scenarios 15
3.2.2 Entering the hospital via Policlinic 18 16
3.3.3 Entering the hospital via the Cardiac First Aid Unit (CFAU) 17
3.3 Patient centred support system 17
3.4 Scope 19
3.4.1 Pros and cons 19
4. Analysis and outcomes 20
4.1 Admission 20
4.1.1 How a patient gets scheduled for surgery 20
4.1.2 How the patient gets informed 20
4.2 Pre-operational process 21
4.3 Operational process 22
4.4 Post operational process 22
4.4.1 Intensive care 22
4.4.2 Nursing departments 23
4.5 Outcome of analysis 23
4.6 Extraction and abstraction 26
4.6.1 Addressing the problem at the appropriate level of aggregation 26
4.6.2 Reverse architecting 26
5. Solution design 27
5.1 Designing a tool 27
5.2 Morphological chart 27
5.2.1 Morphological chart in theory 27
5.2.2 Morphological chart in practice 28
5.3 Project selection 29
5.3.1 Clustering in theory 29
5.3.2 Role of the stakeholders 29

5.4 A3 Architecture Overview 30
5.4.1 A3 Architecture Overview in theory 30
5.4.2 A3 Architecture Overview in practice 30
5.5 Stakeholder table 32
6. Case Study 33
6.1 Redesign of the pre-operative day 33
6.1.1 Project selection 33
6.1.2 Define the project 34
6.1.3 Role of the stakeholders 34
6.1.4 Impact of the changes 35
6.1.5 Introducing additional poly-clinical screenings 38
6.1.6 Conclusion 38
6.1.7 Evaluation and recommendations 38
7. Discussion and recommendation 40
7.1 Design verification 40
7.1.1 Redesign of the consults at polyclinic 18 40
7.2 Further research 40
7.2.1 Allocation of facilities 40
7.2.2 Shorten processes 40
8. Conclusion 41
8.1 Conclusion 41
8.2 Evaluation 41
8.2.1 Pitfalls 41
9. References 42
9.1 Literature 42
9.2 Figures 43
Appendices

Acronyms A-Z

CABG	Coronary artery bypass graft
CAD	Coronary artery disease
CAG	Coronary angiography
CCL	Cardiac catheter laboratory
CCU	Cardiac care unit
CFAU	Cardiac first aid unit
ECG	Electrocardiogram
EuroSCORE	European system for cardiac operative risk evaluation
IC	Intensive Care
ICD	Implantable cardioverter defibrillators
IOM	Institute of Medicine
IPS	Inappropriate patient stay
LOS	Length of stay
MC	Medium Care
MST	Medisch Spectrum Twente
PCI	Percutaneous coronary intervention
PPOS	Poly-clinical pre operational screening
SE	Systems Engineering
TAVI	Trans-catheter aortic valve implantation
TCT	Thorax Centre Twente
TEE	Trans-oesophageal echocardiogram

1. Introduction

1.1 The hospital perspective

On the 7th of January 2016 the hospital of Enschede, called Medisch Spectrum Twente (MST) is going to be moved to a new building. At the moment this top clinical teaching hospital consists of two buildings connected by a 800 meter long bridge.

Since the new building contains fewer beds than the old building because of financial-cutbacks, the MST has to reduce the number of hospital beds needed to fit into the new building. In 2015 the number of beds has to be reduced by 50 in total. The number of hospital beds that needs to be reduced per department still needs to be defined. An option to cope with the reduction of hospital beds in the new building is to cut back on inappropriate patient stay (IPS). Panis, Gooskens, Verheggen, Pop, and Prins (2003) define IPS as an inefficient and ineffective overstay of patients that is not tailored to their needs. If the MST does not take action in this matter, it would mean that they could treat fewer patients at the hospital. This is of course not acceptable because it is a reduction of the MSTs standards.

Figure 1 - Medisch Spectrum Twente

1.2 The patient's perspective

Patients need to wait at several stages during their hospital stay. If patients perceive the time waiting as unnecessary or even dangerous, the quality perception of the received care decreases. In addition, IPS of hospitalized patients results in the unavailability of beds for other patients. This leads to longer waiting times for receiving first aid which results in a major decrease of patient safety.

1.3 Scope

The goal of this research is to find bottlenecks in the process that a patient goes through during a hospital stay. More specifically, this paper is going to focus on the bottlenecks within the Thorax Centre Twente, the cardiac centre of the MST.

The main research question is: "In what way are bottlenecks within the processes of the cardiac centre of the MST causing unnecessary delays?" This question can be divided into several sub-questions:

- What does the current system look like?
- What are the bottlenecks in the process?
- Do these bottlenecks lead to delays?
- Are there already solutions available?
- What are recommendations for possible improvements?

1.4 Outline

Chapter two starts with a methodology part. The root cause analysis is described in detail, since it provides support when analysing the underlying causes of the observed bottlenecks, which is necessary to solve the causes instead of the symptoms. The next chapter is about collecting, selecting and processing data. Based on the information gathered, it is possible to narrow the scope of the thesis down to cardiac surgery patients. Hereafter, in chapter 4 the analysis and outcomes of the data analysis are discussed. The outcomes of the analysis are two tables with bottlenecks. The total in-hospital process cardiac surgery patients undergo, is divided into smaller sub-processes that are summarised in an architecture-model. The resulting architecture-model provides support when structuring the related and unrelated bottlenecks gathered during the analysis. An adjustment of the goal of this thesis is described in the first part of chapter 5. Since working towards a solution for just one bottleneck seems not adequate for global optimization, it has been decided to design a tool to solve bottlenecks. The tool is described in the other parts of chapter 5. Initially, the tool is used to solve the most promising bottleneck, the pre-operative day. This case study is elaborated in chapter 6. Chapter 7 includes the design verification, conclusion and evaluation of the tool. Chapter 8 ends the thesis with a conclusion and evaluation of the thesis in general.

In a complex environment, focusing on a single problem, by addressing a cause that may be arbitrary is pointless. However, fully scrutinising all situations to obtain an elaborated and thorough overview is impossible in such a complex environment. Consequently, any solution direction needs to be singled out while the complex environment is not fully mapped.

To do this, a wide arsenal of analysis tools has been depicted in literature. For an industrial designer, no tool can ever meet all requirements; however, most tools can provide a backbone against which the solution direction can be determined. Given the time-frame available in a bachelor project, extensively selecting the most promising tool is impossible. Consequently, here, a straightforward tool selection has been made. Based on the characteristics of the problem and the environment, the so-called 'Root Cause Analysis' is used as a pragmatic starting point.

2.1 Root cause analysis

Bergman, Fundin, Gremyr, and Johansson (2002) explain that the root cause analysis is used in many different industries as a tool for problem solving. RCA is used to identify the true cause of a problem. Furthermore it can be used to define the actions necessary to eliminate these root causes. This thesis focuses on finding the most basic reasons for a problem to occur. The definition of RCA by Rooney and Heuvel (2004) is used.

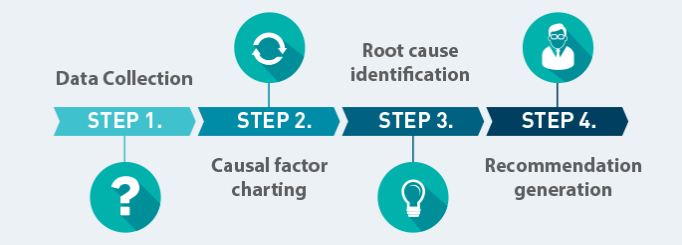


Figure 2 - Steps Root Cause Analysis

They define root cause as the following: 1) Root causes are specific underlying causes, 2) Root causes are those that can reasonably be identified, 3) Root causes are those management has control to fix and 4) Root causes are those for which effective recommendation for preventing recurrences can be generated. In addition, root causes can be related to events with safety, health, environmental, quality, reliability and production impacts and consists of four major steps, which are shown in the figure. 1) Data collection, 2) Causal factor charting, 3) Root cause identification and 4) Recommendation generation (and implementation).

2.1.1 Data collection

First of all, data needs to be collected. This includes understanding the chain of events or the process. Without understanding the process, the causal factors resulting in these events cannot be identified. During the data collection a causal factor chart can be useful to keep an overview.

After a preparation during which stakeholders of the system are analysed, further information can be collected. The RCA consists of several tools, for example flow charts and brainstorming. Furthermore collecting information can be done through interviews with stakeholders, observations and data set analyses.
According to Andersen and Fagerhaug (2006) RCA knows the following main tools for analysing: histograms, Pareto charts, scatter charts, problem concentration diagrams, relations diagrams and affinity diagrams. The affinity diagram, also known as the KJ chart is typically a creative technique that requires an open mind. It is used to group possible causes and can also include relationships between these groups.

2.1.2 Causal factor charting

The information can be displayed and summarised in a causal factor chart. Using the chart should be done as soon as the investigator starts collecting data. The chart is used to identify gaps in knowledge and to provide a clear overview of the data that still needs to be collected. As Rooney and Heuvel (2004) explain, causal factors are those contributors, human errors as well as component failures, where eliminating them would either have prevented the occurrence or reduced its severity.

2.1.3 Root cause identification

Root cause identification is the process step that takes place after the cause factors have been identified. According to Rooney and Heuvel (2004), a decision diagram called Root Cause Map (RCM) is used to identify the underlying reason(s) for each causal factor. The RCM helps the investigator to determine the reasons for an event that occurred, after which the circumstances of the occurrence can be listed.

Andersen and Fagerhaug (2006) present a selection of different tools that can be used for the identification process, which are the following: 1) Cause-and-effect

chart, 2) Matrix Diagram, 3) Five whys and 4) Fault tree analysis. The Five whys is also known as the root cause map which was described in short earlier.

Cause-and-Effect chart

The cause-and-effect chart, also known as an Ishikawa diagram, is a tool used for analysing the relationships between a problem and its causes. It is a powerful technique as it combines aspects of brainstorming and systematic analysis and helps the investigator to understand what causes a problem. Furthermore it helps to systematically evaluate the causes and determine which of them are most likely to be root causes, as it arranges the causes on different levels. When analysing a complex system, a fishbone diagram is constructed for each step of the process that is believed to present problems. After designing these separated charts as displayed below, a collective analysis is conducted to identify the most important cause(s).

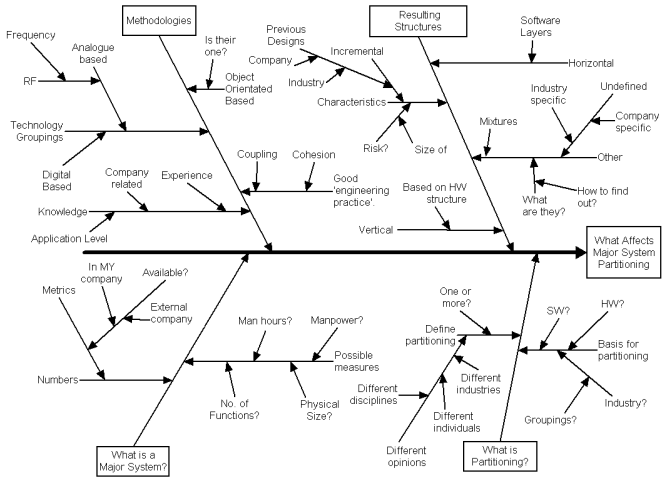


Figure 3- Example of Ishikawa diagram

Matrix Diagrams

Matrix Diagrams can be used to map the overall impact of different possible causes of one problem and highlights the most prominent cause. This is usually the root cause. There are several different types of matrixes that could be used for this step. The L-shaped matrix is the most common and displays the problem characteristics on one axis and the possible causes on the other. The impact of each cause will be displayed by using a symbol with a specific weight, which enables the investigator to identify likely root causes by selecting the causes with the highest weight.

Five Whys

As a starting point of the analysis either a problem or a cause has been identified by the investigator. After this the investigator should ask himself "Why?". When answering the why-questions underlying causes come up, which results in a cause hierarchy. Often it requires at least five times questioning to find a root cause.

Fault Tree Analysis

The fault tree analysis is a graphic model of pathways within a complex system that can lead to an undesirable loss event. It results in improved understanding of system characteristics and is very useful when striving for optimization. Probabilities can be added, but it can also be used to get qualitative insight without adding numbers.

2.1.4 Recommendation generation

The last of these four steps consists of the generation of recommendations, which prevent reoccurrence of the problems. Even though implementation will not be part of the thesis, it will be taken into account as a requirement to formulate adequate recommendations. To do this, the recommendations can be discussed with the stakeholders and evaluated afterwards.

It is essential to understand the existing system when designing an improved version of the system. (Churchman, 1968). Furthermore he states that it is necessary to understand the whole system to effectively evolve it. This is all the more true in recognizing the prevailing close relation between investigating the problem and solving it (Bonnema, D. i. G. M., Veenvliet, I. K. T., & Broenink, D. i. J. F. , 2012) (see also *Appendix 1*). Therefore the current practice of the TCT is analysed to start with. This is done by interviewing employees and patients, observing the system, analysing data from the hospital data management and doing literature research. I took several weeks for my orientation and visitation of different departments of the TCT to get an overview of the patient flow. The reason for this is not only that the TCT-context is new for me, but mainly that a thorough exploration of that context is considered to be significant to use any analysis approach adequately.

3.1 Stakeholders

The TCT performs a lot of cardiothoracic treatments. Regional as well as non-regional cardiologists refer to the MST. A lot of treatments taken place at the TCT are related to heart failure and heart dysfunction. The main processes that are executed are coronary angiography (CAG), percutaneous coronary intervention (PCI), implantable cardioverter defibrillators (ICD) and surgeries.

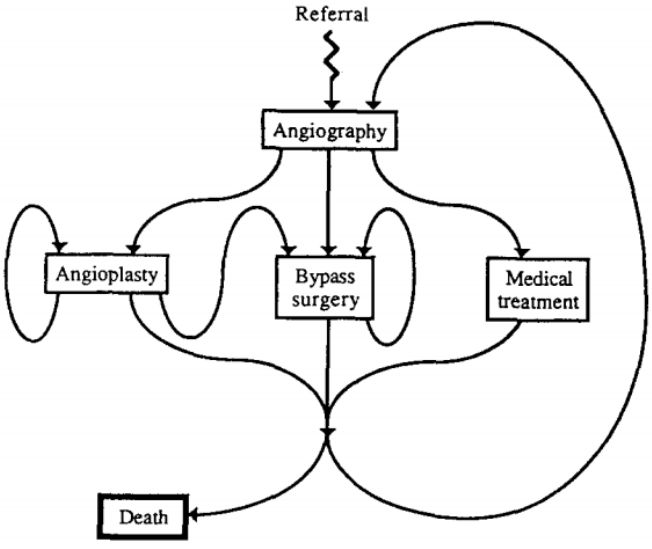


Figure 4 - Treatment CAD, long term system

Coronary artery disease can be treated in different ways, either by a cardiologist or by a cardiac surgeon or a combination of both. The different treatments could be long term drug therapy, angioplasty (stretching and unblocking arteries under X-ray) and heart surgery. As displayed in *Figure 4* follow up treatments are scheduled on regular basis at out-patient clinics (Davies, 1994).

3.1.1 Cardiology

Cardiology consists of different interventions. The two main interventions are coronary angiography and percutaneous coronary intervention. New upcoming surgeries are trans-catheter aortic valve implantation (TAVI) and MitraClip interventions.

Cardiac catheterization is one of the techniques performed to find out the causes of the medical complaints of the patient. It is used to visualize the narrowing but is also a procedure that takes place to cure narrowing of the arteries.

Coronary angiography (CAG)

An angiogram is performed in the Cardiac Catheter Laboratory (CCL). Via infusion the patient receives medication for relaxation. A catheter is brought into the major artery via the wrist or groin, the aorta up to the arteries around the heart under control of x-ray. The catheter is placed and dye (contrast solution) is used to visualise the coronary arteries. The heart still pumps and narrowing in the arteries can be displayed. On average the procedure takes about 20-40 minutes.

Percutaneous coronary intervention (PCI)

In some cases these narrowings needs to be stretched immediately. This can be done by stretching the arteries with a small balloon; Different types of balloons can be used for this procedure. This process is called Coronary Angioplasty or PCI. After this stretching procedure a stent can be inserted into the artery to help keep is open. Patients get well again because the blood flow improves. This procedure can take up to 2 hours depending on the blockage.

Until a few years ago these procedures looked a bit different. The catheter was inserted via the femoral artery in the groin, which required a bed for the patient to recover. Nowadays, if possible, the procedure is done by inserting the catheter through the radial artery in the wrist. The patient does not need to recover in a bed, but recovering while sitting in a chair is fine for about 30% of the patients. After a period of two hours of recovering the cardiologist will check the patient and then the patient is discharged.

3.1.2 Cardiac thoracic surgery

First of all a patient needs to get a diagnosis by a cardiologist. A coronary angiogram (CAG) is made to display the arteria around the heart. By echoscopy the function of the heart can be visualised. This can be done via the oesophagus or just from outside by placing the technology on the chest. The functionality of the heart valves can also be analysed by such an echoscopy procedure.

If the patient has more than one narrowing, the main artery is narrowed or there are other complaints detected (e.g. valve dysfunction), the patient needs to be discussed during a conference of a heart-team. This conference takes place every day from Monday to Friday at about 13:00. The further procedure is being discussed during this meeting. Thoracic surgeons together with cardiologists decide whether a patient needs to undergo a surgery or PCI, or which other following steps need to be taken (e.g. medication or consult). After a patient has been operated, the anatomy could be different from the original situation. This leads to more risks during a second surgery. To prevent these situations all coronary complains need to be diagnosed before a surgery takes place.

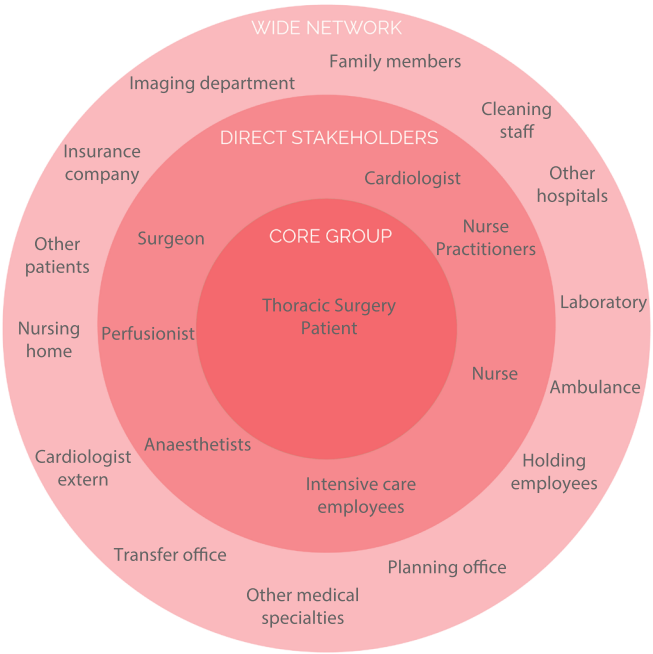


Figure 5 - Stakeholders diagram

When a patient is going to be operated, medication needs to be adapted. Because the patients' heart function is not optimal or the coronary arteries around the heart are full of plaque the patient often takes medication to make the blood thinner. A blood thinner. Thinner blood is also required when an angiogram is made. This is dangerous medication for a heart surgery. The patient needs to stop taking this medication if possible. This also needs to be discussed during the heart team conference.
Cardio thoracic surgery mainly consist of the following treatments: aorta surgery, heart valve replacements or repair (AVR, MVR), coronary artery bypass graft surgeries (CABG) and chest wall corrections.

Usually, a thoracic surgery patient arrives the evening before the surgery at the hospital and stays overnight. The next day a nurse brings the patient to the operation room.

3.2 Chain of events

To get an overview of the chain of events, patients were interviewed during their stay at the MST. This information has been translated to scenarios to better understand the process as an outsider. A qualitative questionnaire was used to collect the information necessary for writing these scenarios. The names are of course made up because of the privacy reasons.

Although the collected information is bound to the current location, there are many events that will not change after moving. The distances and along with that the time needed to travel between the departments will change. This does not change the overall process.

3.2.1 Scenarios

Case I

Mrs. Zonneveld was at her work when she began to feel ill. On her way home she passes the general practitioner (GP) and decides to go for a check. The GP measures her blood pressure and concludes that it is extremely high. An ambulance is called immediately. She enters the hospital via the Cardiac First Aid Unit (CFAU). One day later, on Friday, she is brought to the E2 department where the nurses keep an eye on her. Furthermore she wears a monitor that keeps track of her heartbeat. In the hospital this is called a telemetry patient. During the next few days no further research on the causes of the high blood pressure will be done. Monday is going to be Kingsday so Saturday, Sunday and Monday will probably go by without any further research.

On Saturday an emergency case comes in. The on-call team comes to the hospital to help this patient. After the emergency intervention action the cardiology team gets in contact with the E2 department. Mrs. Zonneveld can go for an unscheduled cardiac catheterization, as the on call operation team is already in the hospital.

Case II

Mr. Coes a 77-year old man from Oldenzaal who survived a brain haemorrhage without fatal consequences one year ago. Furthermore some of the arteries in the leg are narrowed. This can be cured by doing exercises which

enable the body to create natural bypasses. Therefore Mr. Coes goes to the physiotherapist once a week. The distance from his home to the physiotherapist is about 700 meter and usually Mr. Coes does not need to pause on his way. But on Monday the 20th of April he has to pause several times and feels very exhausted. Before he arrives at the physiotherapist he passes out. There are a lot of people around him and an ambulance is called immediately.

Because of a concussion no further action can be taken. Mr. Coes needs to recover before the heart catheterisation can take place because blood thinners could have fatal consequences when suffering from a concussion. His heart beat is observed 24 hours at the E2 department, the follow up department of the CFAU and CCU.
On Friday Mr. Coes goes for a bike test in the other building on the Haaksbergerstraat. Transporting a patient over this bridge can take up to 15 minutes. At 13:30 he is scheduled for the bike test. Because his heart beat has to be observed 24 hours, 3 people need to transport the patient over the bridge. One of them is just a transport person and the other two are nurses which could cardiopulmonary resuscitate.

One of the nurses picks up the patient and just before she leaves the department somebody reminds her that she needs to take a colleague with her. A few minutes later the team is ready to transport Mr. Coes to the other building.
Arrived at polyclinic 18 where the bike test takes place a woman is waiting for Mr. Coes. Patches are attached on the chest and the activity of the heart is measured with an ECG while the patient is riding a bike. Blood pressure is also measured.

After the test Mr. Coes is placed back in his bed where he has to wait for the results. The results need to be written on a form and the printed ECG needs to be attached. The summary of the test is written on the computer, so the results can be opened immediately by the doctor, but the ECG is placed in a folder which is placed in the bed of the patient. The nurses and the transport person have to wait until the folder is ready. The patient is brought back to the other building with the attached folder with the results. The bed is placed back in the double room where Mr. Coes can further recover. On Tuesday or Wednesday the heart catheterisation might take place.

3.2.2 Entering the hospital via Polyclinic 18

Before a surgery takes places patients go for a pre operational screening procedure. This can either take place at the nursing department the day before surgery or at the polyclinic 18. Patients see several specialists before the surgery takes place. As some of these specialists are not available on Sunday, patients who are going for surgery on a Monday arrive several days before their surgery at the polyclinic for poly-clinical pre operational screening (PPOS). To get an overview of what this process looks like two couples were interviewed and followed through a process.

The process consists of five different stages, with all the same goal: Informing and preparing the patient and family members for the upcoming surgery and the aftercare procedure. Furthermore it is the first time the surgeon sees the patient and it is an opportunity to check te patients health status. In this case the surgery was going to take place 5 days after the pre surgery procedure.
At every stage another specialist is involved. All patient start at different specialists and rotate during this procedure. The order of the talks is not important and after every conversation the patient has to return to the waiting room.

Pharmacy specialist

The conversation with the pharmacy specialist is about the medication taken at the moment and medication history. The specialist registers the medication the patient takes and tells the patient which medication should be taken and at which moment the medication should be paused related to the upcoming surgery.

Surgeon

The surgeon informs the patient about the upcoming surgery be telling him how the procedure will look like. Informing the patient about risks and the possible side effects is also part of this informative talk. This talk is also very emotional in some cases, depending on the patient and the involved risks. The surgeon provides information in a constructive way and motivates the patient.

Nurse

The nurse measures the length and weight of the patient. After that the patient needs to take place on a bed and an electrocardiogram (ECG) is made.

Nurse specialist

The patient tells the specialist about his complaints. The nurse informs the patient about the medication and surgery and checks if the patient takes the right medication and has stopped taking several medicines because of the upcoming surgery. Furthermore information about allergic reactions to previous medication is collected. The nurse asks the patient whether family members have had coronary diseases.
The specialist takes a look at the veins in the calves and arms because the patient is getting a bypass surgery where veins of different body parts could be needed.

Anaesthetist
The anaesthetist explains to the patient which types of pain could be experienced during and after the process. He explains what kind of feeling could come up after waking up at the intensive care (IC) and informs the patient about the risks of the procedure.

Waiting room of polyclinic 18
The waiting room is also part of the procedure. During my observations several couples began to talk to each other about their experiences and feelings involved in this process. The waiting room is also an important part because different patients and spouses or other family members could meet and talk about the phase they are going through. Knowing that others are going through the same or a comparable situation can support emotionally.

3.2.3 Entering the hospital via the Cardiac First Aid Unit (CFAU)

In emergency cases, when patients have chest pain or cannot breathe easily, they usually enter the hospital via the CFAU. The CFAU has its own ambulance entrance, so the patient can be brought directly to the right location. It is also possible that a patient walks in at the department.

At the moment the CFAU is next to the Cardiac Care Unit (CCU). Room numbers 110-116 belong to the CFAU and number 100-109 belong to the CCU. Of course a patient does not want to be moved many times but sometimes it happens that a patient is moved from room 110 to 109, just because there needs to be a free room at the first aid. The employees work all together and can help each other out if necessary. The departments are so interrelated that personnel from the CFAU do CCU tasks and vice versa. At the moment because of the interrelation it is also possible to have an extra first aid bed and one less CCU-bed.

First of all the hospital needs to be informed about the coming patient. The hospital can be called by the ambulance or by the GP. A room is prepared for the patient and the history is looked up while the patient is on his way to the hospital. As soon as he arrives, he is connected to a monitor and an infusion is placed. This enables the personnel to give medication whenever needed. The infusion might have been placed by the ambulance personnel already.
After that, blood pressure is measured and blood samples are taken. An ECG is made and medication is given. As soon as possible the team tries to find out whether the complaints are coronary or not. If the complaints are coronary the patient stays at the department, if not the patient needs to be picked up by a team member of another specialty. Sometimes this cannot be done immediately.

At the CFAU and CCU the patient is monitored 24 hours a day. This is called a telemetry patient. Usually as soon as the patient is more stable or is already about 24 hours on the CFAU the patient is transported to the CCU or leaves the hospital. From the CCU the patient can either leave or go to the follow up department, nursing department E2. At the E2 department there are telemetry patients and non-telemetry patients that are recovering or that are waiting for a diagnosis or intervention.

When the patient has got an infarct (MI), the patient can be brought directly to the cardiac catheterization laboratory. There the arteries can be widened or another intervention can take place to prevent the heart from further damage. After that the patient is brought back to the E1 department (CFAU&CCU).

3.3 Patient centred support system

Brainstorming about a patient centred support system resulted in a map displayed in *Appendix 3* which was used to collect relevant vocabulary for further research. The "IOM 6 Aims for Improving Health Care" came up, during research on the internet using the vocabulary form the brainstorm session. As displayed in *Figure 6*, improving health care can be done by focusing on different goals. These aims are: 1) Safety, 2) Effectiveness, 3) Patient-centred care, 4) Timeliness, 5) Efficiency and 6) Equitable care.

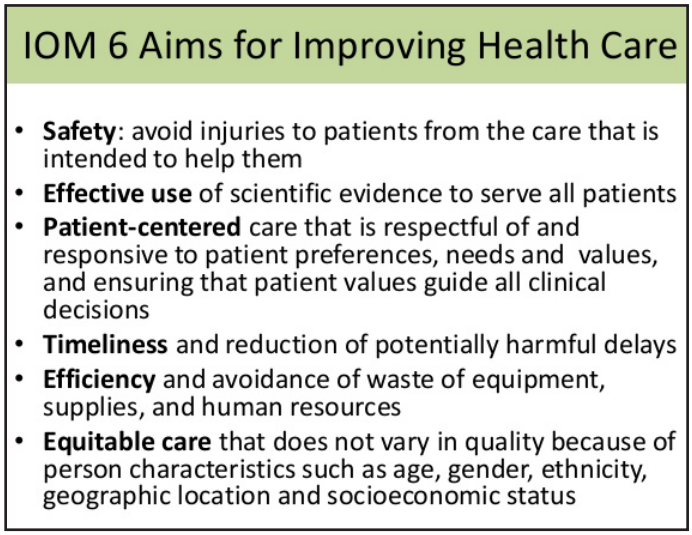


Figure 6 - IOM 6 Aims

The hospital wants to focus more on the patients than before and wants to improve the quality and logistics. (Medisch Spectrum Twente, 2013). Therefore this thesis will focus on patient-centred care and efficiency. It goes without saying that equilibrium needs to be found when improving both, since patient centred care and efficiency can be seen as two conflicting aims. The

Institute of Medicine (IOM) defines patient-centred care as: "Providing care that is respectful of and responsive to individual patient preferences, needs, and values, and ensuring that patient values guide all clinical decisions." whether efficiency includes avoidance of waste. The hospital and patients need to work together to produce the best outcomes possible.

According to Barry and Edgman-Levitan (2012), the Picker Institute, in partnership with patients and families, identified eight characteristics of care as the most important indicators of quality and safety from patient-perspective in the US: 1) respect for the patient's values, preferences, and expressed needs, 2) coordinated and integrated care, 3) clear, high-quality information and education for the patient and family, 4) physical comfort, including pain management, 5) emotional support and alleviation of fear and anxiety, 6) involvement of family members and friends, as appropriate, 7) continuity, including through care-site transitions and 8) access to care. These indicators can be compared to Dutch quality indicators from patient perspective. The indicators described by Barry and Edgman-Levitan (2012) are also relevant when investigating Dutch health care (Oosterhuis, 2010). The aspects that score very high when mapping the consumer quality indicators in the Netherlands are: 1) clear information about medication and treatment, provided in an appropriate level of detail 2) (quick) access to care and 3) assistance with self-management.

To map the processes at the Thorax Centre Twente patients and employees were interviewed. From the CCU and CFAU nurses were interviewed. At the E2 and A2 nursing-departments employees as well as patients were interviewed. In addition B. Aalbers Koning, team head of the cardiology department has been interviewed to get an overview of the process and points of improvement. Furthermore I spent one day with the cardiac catheterization team, one day at the holding of the CCL and joined an open heart surgery. The processes are comparable to the process displayed in *Figure 7*. This figure displays a flow chart from the Guy's Hospital of London (Davies, 1994).

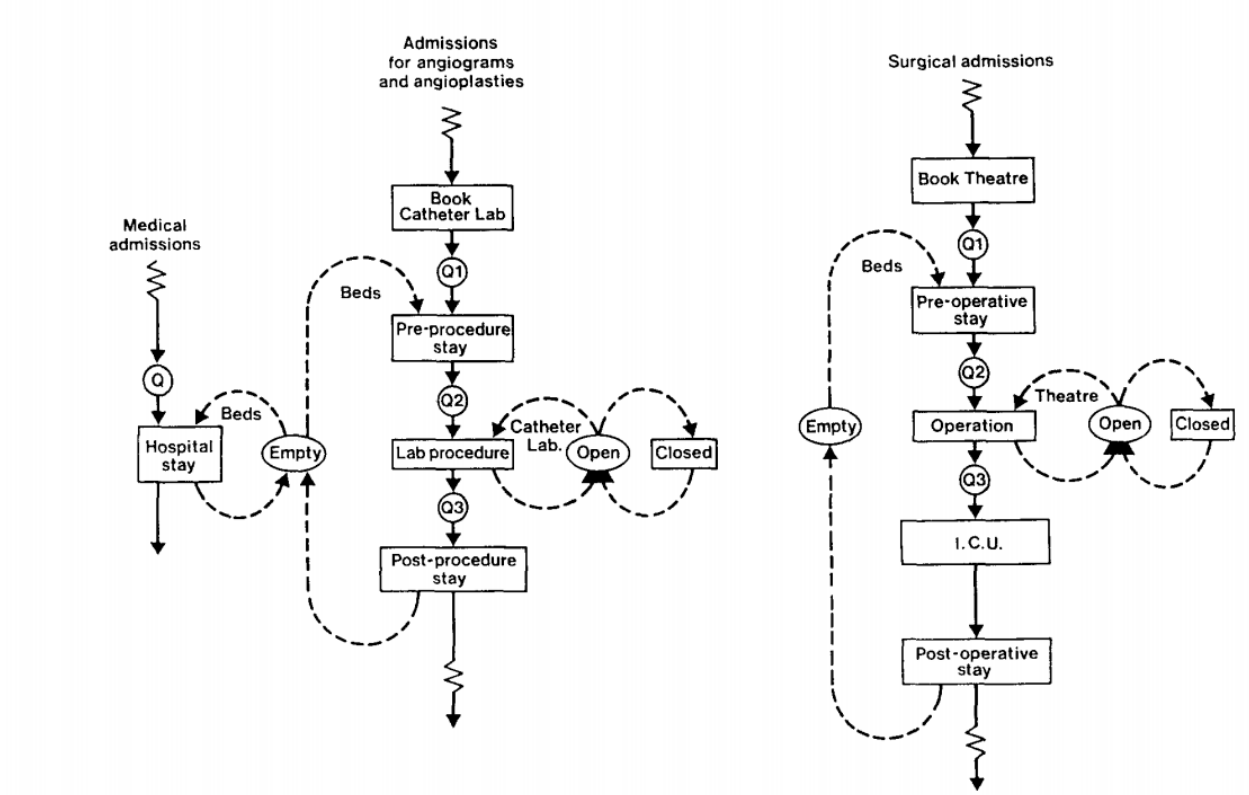


Figure 7 - In-patient system of Guy's Hospital, London

3.4 Scope

Since a certain level of detail is required and time is a limited resource, the project needs to be narrowed down. As a result of the broad analysis, a founded decision to abate the project scope can be made. The two following processes can be distinguished: cardiac surgery and cardiology. In addition both processes can be divided into elective and emergency cases.

3.4.1 Pros and cons

To make an educated decision about which of the two processes should be analysed, a short list of positive and negative elements of the two processes was made:

Cardiology

+	Long waiting lists
+	Many unnecessary delays
+	Not dependent on surgery
+	Patient interviews
+/-	Optimization in smaller details
+/-	Patients may require further medical or surgical intervention at a later date
+/-	Increasing demand for treatment
-	High turnover rate
-	Process input dependent on GP
-	Process spread over two buildings
-/-	Already a lot of plans for changes

Surgery

+	Clear boundary with respect to type of patient
+	Length of stay about five days
+	J. Grandjean as contact person
+	Plannable patients
+/-	Dependent on cardiology
-	Poor health status

Because the cardiology process will undergo major changes when moving to the new building, any suggestions for improvement may become outdated or infeasible quickly. Consequently, a focus on cardiac surgery is more appropriate. The main change in the procedure will be that about 30% of the patients leave after heart catheterization and no further hospital stay is required. Furthermore the boundaries of thoracic surgery were more present.

For this thesis the focus will be on elective patients as these are more common and more predictable. In addition optimization within this category will result in more profit.
Thoracic surgery can be divided into different phases: admission, pre-operative, operative and post-operative phase. *Figure 8* displays this process for the MST from the moment the patient gets scheduled for surgery.

4. 1 Admission

4.1.1 How a patient gets scheduled for surgery

Surgery patients enter the process via the general practitioner. He refers to the cardiologist after which the patient is scheduled for consult at the polyclinic. This results in long waiting lists, since all patients have to get an appointment there first. After that, usually a CAG is used as an imaging tool to display the arteries around the heart. Surgeons are not involved until the cardiologists decides to or until they come together with surgeons during the daily heart-team conference. During this heart-team conference at least one surgeon, one cardiologist and one member of the planning office are present. They discuss the diagnosis of the patients from the internal cardiologists as well as the dossiers of patients from external cardiologists. The requirements before discussing a patient are that a recent CAG and ECG are available. After that, the conference results in different lists of patients that need to be scheduled for different follow up processes. The different conclusions drawn during the conference are: 1) patient needs surgery 2) patient needs PCI 3) patient has to come for consult 4) patient's risks are too high to undergo an intervention or 5) patient needs to be discussed again during next conference. From the interview with J. Grandjean the conclusion can be drawn that about 1/3 of the patients receive surgery, 1/3 a PCI and about 1/3 medication.

When making the decision to perform cardiac surgery, the European System for Cardiac Operative Risk Evaluation (EuroSCORE) is used. The EuroSCORE identifies a number of risk factors which help to predict mortality from cardiac surgery (Nashef et al., 1999). When the heart team decides that the patient needs to undergo surgery the employee of the planning office makes sure the patient gets scheduled for all necessary screening processes and for the surgery. The cardiologist will be contacted to inform the patient. Furthermore the MST informs the patient about the day of surgery by letter. As you can imagine, it is possible that the patient receives the letter first and then gets informed by the cardiologist.

Critical process steps

- According to the interviews that took place in January 2015 organized by Irma Wolters-Strootman (Team head of planning office cardiac centre) cardiac surgery patients complained about the delay caused by the GP and the long waiting list for the consult with the cardiologist. W. Alblas, the team head of the polyclinic 18 confirms this.
- The patient receives a letter about the appointment. According to the information received during an interview with W. Alblas, the team head of the polyclinic 18 the communication system with the patient needs to be improved. The letters do not include information about the location of the appointment, which results in confusion since patients could have several medical complaints and more than one appointment scheduled. Furthermore the letters do not always reach the patient.
- The surgeon is not involved until the cardiologist decides to. This results in a lot of tasks for the cardiologists as well as an input flow for the surgeon which is dependent on the availability of the cardiologist.

4.1.2 How the patient gets informed

Providing information about the upcoming surgery plays an important role when it comes to how elderly experience the procedure. This information can be provided through patient brochures, informative meetings or pre-operative consults with specialists and reduces the fear and pain experienced during their hospital stay (Blommers, Klimek, Klein, & Noordzij, 2008).

At the MST, the patient arrives at the A2 department at least one day before surgery. Based on the day of surgery and the previous departments the patient visited, the further procedure needs to be defined. There are three different types of patients: 1) Poly-clinical patient 2) clinical patient and 3) emergency patient. Every type of patient received different amounts of information.

About 40% of the elective patients are poly-clinical patients. Before these patients come for their intake procedure they already received a document that contains information about the preparation for the upcoming surgery, the surgery and post-surgery processes. This is also true for the other patient categories.

Every Thursday a PPOS takes place, during which eight patients are already screened. This is why this patient category is called poly-clinical patients. These patients can visit the hospital before their intake procedure to be seen by several specialists and receive information. Three out of these eight patients have their surgery on Monday and need an extra step during the procedure, since their intake will take place on a Sunday. On Sunday the anaesthetist and surgeon are not available which results in a poly-clinical procedure during which these specialists are already involved.

- Poly-clinical patients who have had the complete PPOS arrive the day before surgery at 19:00. These patients have seen al specialists and received all necessary information. During the intake procedure there is the possibility to ask questions if needed.
- Poly-clinical patients who have had the normal PPOS arrive the day before surgery at 14:00. At 16:00 a surgeon, a nurse specialist, an anaesthetist and a perfusionist come together to discuss the status of the patients that undergo surgery the next day. They make sure all necessary tests and screenings are completed and the health of the patient meets the requirements.
- Clinical patients are transported by ambulance to the hospital. The time of arrival depends on the working hours of the ambulance. Patients who have their surgery on Monday cannot be brought to the hospital by ambulance on a Sunday, since the ambulance is out of service. These patients frequently arrive on Friday. During normal weekdays the patient arrives at about 11:00 o'clock.

Critical process steps

- During the PPOS on Thursdays eight patients are scheduled. During one week approximately 28 surgeries take place.

  *2 surgeries * 3 operation rooms * 4 days +*
  *2 surgeries * 2 operation rooms * 1 day*
  = 28 surgeries per week

  According to the information received from I. Wolters-Strootman and J. Grandjean 40% are poly-clinical.

  *0.4 * 28 = 11.2*
  11 poly-clinical patients per week

  Assuming that 40 % of the patients are poly-clinical, the conclusion can be drawn that the capacity of poly-clinical screening should increase. At the moment only eight poly-clinical screenings are provided, since the number of complete screenings that can be provided is limited by the availability of the anaesthetist and the time available at one day. It should be reconsidered if one day of PPOS is enough, or that more patients should be screened completely before the intake procedure. Consequences of screening more patients in advance are that another day should be scheduled for PPOS and specialists need to be available at one more day for poly-clinical screening. An advantage is that patients can arrive the evening before the surgery and the workload of nursing staff decreases.
- Patients are all informed on different levels. Clear communication with external hospitals is important as their cardiologists already provide information about the surgery. Furthermore the information level needs to be documented clearly to prevent disparity.

4. 2 Pre-operational process

As described previously, patients arrive at the hospital at different times, dependent on the information provided and tests performed. On the day of intake some final tests are scheduled and final information is provided by specialists. Furthermore the patient is visited by the anaesthetist and surgeon. Every day (Monday-Thursday) at 16:00 a meeting is scheduled. Surgeons, anaesthetists and nurse practitioners come together to discuss the status of the patients, who are scheduled for surgery the next day. Furthermore the procedure is discussed. The meeting can result in necessary steps that still need to be taken or in rare cases cancelling the surgery.

After the meeting the patients get informed and prepared for the surgery the next day. Showering with a special scrub is required when undergoing a CABG procedure. Furthermore a specific nose salve needs to be applied several times until the surgery. Before going to bed the patient receives sleep medication. From that moment the patient is no longer allowed to leave the bed unattended. Nurses need to be available during night to help the patient when needed with going to the bathroom for example.

Critical process steps

- At 16:00 the meeting starts, during which the health status of the patient is evaluated. Patients need to arrive several hours before, so that the specialist like the nurse practitioner and surgeon can visit the patients. It enables these specialists to make the right decisions during their meeting and makes sure the patient is available and prepared for the next day. Usually the specialists have never seen the patient before. Even though it seems ideal to refresh the information on the patient just before the surgery, this procedure results in cancelled surgeries which could be avoided in an earlier phase. When deciding

to cancel the surgery the patient is already taken in and placed in a bed.
- The patient needs to arrive the day before surgery, which results in an input-problem. On Sunday the ambulance is out of service. The effect is that patients arrive on Friday or Saturday for their surgery on Monday. This could be avoided by only scheduling patients from the region on Monday.

4.3 Operational process

The TCT has four operation rooms of which three are used; the fourth is shared with "regular" operations. The first surgeries of the day start at 7:40, 7:45 and 8:15. One of the surgeries starts significantly later than the others because there are two anaesthetists for three operation room. This is possible, since the anaesthetist is only needed at the beginning and at the end of the procedure. If a patient is scheduled for the first time slot in the morning, he needs to get up at about 6:30 o'clock. Of course he is not allowed to eat or drink anything. The patient gets picked up by a nurse and is brought to the holding of the operation room. The surgery teams are already present and prepare the operation rooms. The patient is brought into the operation room and the anaesthetist brings the patient to a deep sleep after a time out procedure. During this time out the team checks if the right patient is put onto the table.

The MST shortly introduced an additional procedure, which is called trans-oesophageal echocardiogram (TEE). TEE is a test that uses waves to create moving images of the heart and its blood vessels, which are of higher quality than the images created previously. Since the procedure includes bringing a flexible tube down your throat it takes place just before the surgery when the patient is already under narcosis. The created images result in new information that either assist or change the operative procedure (Sheikh et al., 1990). In rare cases the surgery needs to be cancelled.

On average a surgery takes about 3 to 4 hours, after which the patient is brought to the IC. The second surgery of the day has no fixed start. The start of the second surgery is planned as soon as the first surgery is finished. The time between surgeries is dependent on the availability of the surgery-team and on an external company that cleans the OR after each use.

Critical process steps

- During the TEE procedure the conclusion can be drawn that the procedure gets more complex than expected. Relevant forecasts about the expected LOS can no longer be provided before the procedure because of uncertainty.
- When working with two instead of three anaesthetists the schedule of the ORs are dependent on each other.
- Starting time of the surgery is dependent on the availability of the patient and several employees.
- Patients need to be available the day before surgery in order to minimize the change that a surgery has to be cancelled and the OR is left unused.
- Emergencies come through and change the schedule. Surgeons have to make a moral decision which patient needs to wait several hours longer. This includes additional four hours of fasting.

4.4 Post operational process

4.4.1 Intensive care

The first step after surgery is recovering at the intensive care (IC). The intensive care is at the same floor as the operation room and usually the patient spends only one night at the IC. The number of beds at the IC depends on the day of the week. The IC has 12 beds, but only ten of them are used. Patients that do not need the special care provided at the IC are brought to the A2 or D2 (MC) department. On Saturday morning the IC goes back from 10 beds to 8 beds because of personnel reduction during the weekend. If there are no beds available at the nursing departments the healthiest patients at the nursing department receive a discharge letter.

Unfortunately the reason of the increased stay is not documented. Increased LOS at the IC could be the effect of medical reasons or logistic reasons. These logistic reasons are interesting when it comes to analysing the bottlenecks in the flow of patients.

Critical process steps

- In April 2015 the flow of patients from the intensive care to the nursing department has been observed. Increased LOS because of logistic reasons was observed during this period. This was caused by the poor patient flow from the nursing department to nursing homes or homes. No beds were available at the nursing department and patients had to stay longer than necessary at the IC.
- According to P. Siteur, patients stay at least one night at the TIC. The next day the patients are brought to the nursing department, which leads to inappropriate patient stay (IPS) at the TIC, since about 90% of the patients are already recovered enough to leave the TIC in the evening.
- At the moment the planning office of thoracic surgeries uses the EuroSCORE to schedule patients. Patients with high EuroSCORE's should be helped as soon as possible. As reported by Ettema et al. (2010), the EuroSCORE can also be used to identify patients

with a high probability of prolonged IC stay. This prediction of LOS is not used for scheduling at the moment, despite the fact that this could improve the patient flow.

4.4.2 Nursing department (A2/D2)

As soon as the patient is allowed to further recover at the nursing department, nurses pick up the patient at the IC. The nursing departments A2 and D2 are specialised on cardiac surgery patients and have 21 beds available for recovering of cardiac surgery patients. On the nursing department A2 cardiac surgery patients as well as cardiology patients are recovering. At the nursing department D2 only cardiac surgery patients are recovering. The D2 consists of two parts; one part is called the medium care (MC) and the other part is just the ordinary nursing department. Dependent on the health of the patient, the patient is either brought to the MC or to one of the other rooms at the D2. At the MC patients receive less intensive care than at the IC, but more than at the nursing department. The heart rhythm is monitored continuously and tests are taken frequently. Patients that receive additional attention and care recover at the MC until they are stable enough to be brought to another room at the D2. Physiotherapists visit the patients every day from Monday to Friday and help patients with exercising. After an average of four days patients are ready to leave the department. Patients from external hospitals are transported by ambulance to their own hospital. Patients that receive care by their family members can leave as soon as their discharge letter is ready and the family members arrive to pick them up. The third category of patients needs to recover at a nursing home or at home with special caregivers. This aftercare is often organised during the hospital stay of the patient by hospital employees.

Critical process steps:

- For employees there is a difference between weekends and weekdays, which results in different care provided. Physiotherapists are not available during the weekend and hand these tasks over to the available nurses.
- Ambulances do not transfer patients as frequently as during weekdays. On Sunday no ambulance transfer can take place. Telemetry patient cannot be transported back to their own hospitals during weekends, since ambulances do not take this type of patients.
- Aftercare is not always organised during hospital stay. This results in patients waiting at the nursing department for an available bed at a nursing home.
- A discharge letter is required before discharging a patient. Organisation of the document results in delays especially during the weekend.
- Dependency on laboratory, imaging department and pharmacy

4.5 Outcome of analysis

The analysis of the current system resulted in a list of bottlenecks that are displayed in tables and separated in more cardiology-related bottlenecks and more surgery-related bottlenecks. Even though a distinction between cardiology and cardiac surgery was made, several bottlenecks were found that are more related to cardiology than to cardiac surgery. The input of patients for cardiac surgery is dependent on cardiology and the patient needs to visit the cardiologist for follow up consults. Therefore the two processes can never be seen as totally separated.

By using the Ishikawa diagram, a tool explained earlier in *Chapter 2 - Literature and methods*, the bottlenecks could be divided in causes and effects. The first column contains a short description of the bottleneck. The cause and effect are displayed in column two and tree. The Ishikawa diagrams used to create the tables can be found in *Appendix 7*.

Bottleneck	Cause	Effect
A2 & D2: Nursing departments		
The patient flow from A2/D2/MC back home, to nursing homes or to other hospitals is not efficient.	Patients cannot leave the hospital because follow up care is not organised. other hospitals are not able to take patient, ambulance is out of service.	IPS, bed blocking, OR capacity decreases
Employees at nursing department are not working discharge-focussed enough.	Information collected about patient during intake or pre operational screening is not used to forecast length of stay (LOS).	Patients cannot leave the hospital because no transportation or care at follow up department is organised.
Patients have to wait for tests (MRI-scan, CT-scan etc.)	A lot of different patients need to go for these tests	Higher costs, more health complications, bed blocking, decreased OR capacity
Patients stay over the weekend and cannot be discharged	Discharge personnel is not available, patients cannot be send home without medication for a few days and internal pharmacy specialist are not available	Increased costs, bed blocking, nurses spent less time on patients that need attention
The pre-operative intake takes place at least one day before surgery.	Surgeries start early, patients need to take sleep medication, surgeons do not want to wait for delayed patients, fasting guidelines	Inappropriate hospital stay, bed blocking, decreased surgery capacity, decrease of time spend on other patients that need care
Combination of automated and non-automated procedures, difference in procedures and documentation	Different programs used by different departments intern and extern (other hospitals), different types of documentation, no clear guidelines, no standardisation	A lot of time spent on copying information from one system into another, increased risk of making errors, decreased efficiency working hours nurses.
Limited control and overview	Variation in procedure and process chain, complexity, poor communication and documentation, no access to documents	Errors, wasting time on calling and finding out which steps have already been taken.
Thoracic intensive care (TIC)		
The patient flow from the intensive care (IC) to nursing departments is not efficient.	No beds available at the nursing department.	Increased duration of stay at IC, higher risk of infections, less physical activity because employees are less focussed on regaining mobility, less sleep during night because of noisy environment, higher costs, bed blocking at IC, decreased capacity of OR
Planning office thoracic surgery		
No forecast of length of stay (LOS) is used to schedule patients.	Planning office plans patients with highest EuroSCORE as soon as possible, poly-clinical patients are not scheduled by using an indication for LOS because employees are not used to doing so.	Patients with high EuroSCORE need to recover longer. If these patients go for a surgery on Monday they might be recovered by Friday but stay over the weekend because they cannot be discharged.
Flexibility of surgery planning, emergency cases can be helped within hours or the next day, other patients receive their surgery later but are poorly informed about this	Poor communication between planning office and patients that are already in the hospital, communication via surgeon, nurse and secretary of nursing department, no direct communication, no explanations	Secretary of department does not know which patients are helped and which might be helped that day, patients do not know when surgery will start, cannot eat, cannot drink, receive sleep medication.
Operation room		
Fluctuating workload operation room, employees not scheduled efficient.	During the afternoon workload decreases and number of employees increases	Unnecessary costs, stressful work experience.
New procedure trans-oesophageal echo (TEE) results in cancelled surgeries.	A TEE can highlight medical complications that where not known previously. This procedure takes place when the patient is under anaesthesia before the surgery begins.	The surgery can change or can get more complicated which results in increased duration. Surgeries can also be cancelled and need to be rescheduled.
No fixed starting time for the second surgery results in patients waiting	Duration of first surgery is unknown	Patients all need to be available at the same time, patients are waiting and do not know when their surgery will start.
Two anaesthetists available for 3 OR's	Decreased costs	Surgeries are dependent on each other.
Patient receives different information from different specialists	Cardiologists from other smaller hospitals refer to the MST	Patient receives information about the upcoming surgery from the cardiologist of the external hospital

Table 1 - Bottlenecks thoracic surgery

Bottleneck	Cause	Effect
Polyclinic 18		
Combination of automated and non automated procedures.	Different programs used by different depatments intern as well as extern (other hospitals).	A lot of time spent on copying information from one system into another, increased risk of making errors
Results of bike test are printed and need to be placed in the dossier of the patient (placed in the bed of the patient).	No available digital system for bike test results.	Patients have to wait (including nurse if telemetry patient), less employees at nursing department.
Patients do not come to their poly-clinical appointment and specialists are scheduled unnecessary.	Patients receive a letter with the appointment; these letters get lost intern	Wait of time and expensive recourse, inefficient use of expensive resource, no new input of patients for surgery.
Limited number of poly-clinical consults are planned, planned consults are cancelled frequently.	Specialists prefer not to be scheduled for consult, consult is least important when it comes to replacing ill or unavailable employees.	Limited number of poly-clinical consults are planned, no new input for the system, long waiting lists for check-up and follow up consults.
Cover distance with patient from A2 to polyclinic 18 takes about 8 minutes, cover distance with patient from E1/E2 to polyclinic 18 takes about 20 minutes.	Two separated buildings and location of polyclinic 18.	Nurses spend a lot of time traveling, decreased patient safety as limited equipment available when traveling, decreased patient safety when employees are not available because of traveling.
Discrepancy between patients and the received information	Patients from other hospitals cannot come to the polyclinical pre-operative screening at the MST, no equal information provided	Limited overview of information level, discrepancy between patients, high risk of patients being not well informed
E1: Cardiac First Aid Unit (CFAU) & Cardiac Care Unit (CCU)		
The patient/general practitioner (GP) does not know the consequence of contacting the hospital.	GP does not know what happens inside the hospital if he calls to announce a patient, bad communication.	Hospital (CFAU) reserves a room for expected patient, patient arrives hours later than expected.
Few employees during night and weekends. Leaving the department causes dangerous situations. At the moment this can partly be solved because of the collaboration between the CFAU and the CCU.	Personnel reduction during late shifts and weekends, no secretary available.	At least one of the employees should be able to leave the department if necessary. This is not possible because too few employees are left to manage the incoming calls and take a look at the patients.
Patients need to be moved frequently which causes time consuming tasks for the employees.	The CFAU always needs to have available beds for incoming emergencies. Therefore patients are moved to the CCU after a maximum of 24 hours if possible. After that patient can either leave the hospital or be transported to the E2 nursing department.	Patients are moved from one room to another eventhough the distance between these departments is just a few meters. This leads to additional time consuming tasks for the employees. Employees spend less time on providing care.
Patients are lying at the E1 department but do not belong at this department. They wait to be transported to the right department.	Patients come to the CFAU by ambulance with symptoms like chest pain. This is not always an indication for heart failure or heart disease. Specialists from other medical specialties need to pick up these patients but this task has low priority.	Patients bock beds for cardiology patients and get care provided by specialists and nurses from that department. Spending time at this department could result in no progression of health status of these patients.
A2 & E2: Nursing department cardiology		
Reduced bed availability and increased workload for employees.	Patients are waiting for test results, a diagnosis, an intervention like cardiac catheterization or for transportation.	Patients do not leave the department as fast as expected and block beds for others
Cardiac Catheterization Laboratory (CCL)		
Patients are waiting in the holding of the CCL where equipment and availability of employees is scarce.	Location of the heart catheterization room and status of holding of CCL number 4.	Employees need to be called 30 minutes before start of CC to transport patient to the CCL. This means that a patient needs to be called before the previous CC begins.
If cardiac catheterization is used a a diagnosis the duration of the CC is unknown when they start the procedure.	During the CC the diagnosis can lead to an intervention. The team would prefer doing the intervention immediately if possible.	The diagnosis procedure takes about 15-30 minutes. The intervention can take up to 120 minutes. The employees have a fixed amount of patients on one day, the employees work until they are finished even if this results in working after 16:30.

Table 2 - Bottlenecks cardiology

4.6 Extraction and abstraction

4.6.1 Addressing the problem at the appropriate level of aggregation

Although the devil is in the detail, solving a single detail is not necessarily contributively to solving the problem. In other words: local optimisation does not necessarily lead to global optimisation. Therefore, all critical process steps that are observed are interrelated and are related to the architecture that underlies the overall process. As a convenient architecture is not available, a reverse architecting approach is used.

4.6.2 Reverse architecting

In their paper about evolving systems, Borches and Bonnema (2010) state that in most companies, complex systems are poorly documented. To improve the current system a system architect reconstructs the existing system architecture representation, which is called reverse architecting. Since experts find it much easier and less time consuming to modify wrong representations than creating new ones, process flows were created right from the beginning. Experts (employees of the hospital as well as patients) were asked frequently to provide feedback. The process flow has been optimized several times. (*Appendix 6*) The result did not provide an optimal overview, since it contained too many small process steps.

To obtain a manageable set of information, the next phase consisted of grouping and filtering the extracted information. During this abstraction phase all detailed, unnecessary information has been eliminated. The process chain needed to be approached from different stakeholders' perspectives to determine which information is relevant for all involved. It can be assumed that detailed medical information can be left out, since the patient is also one of the stakeholders involved. The patient's perspective was experienced as one of the most useful perspectives, since this stakeholder is involved in a lot of process steps at a lot of different departments. The final process chain is displayed in *Figure 8*.

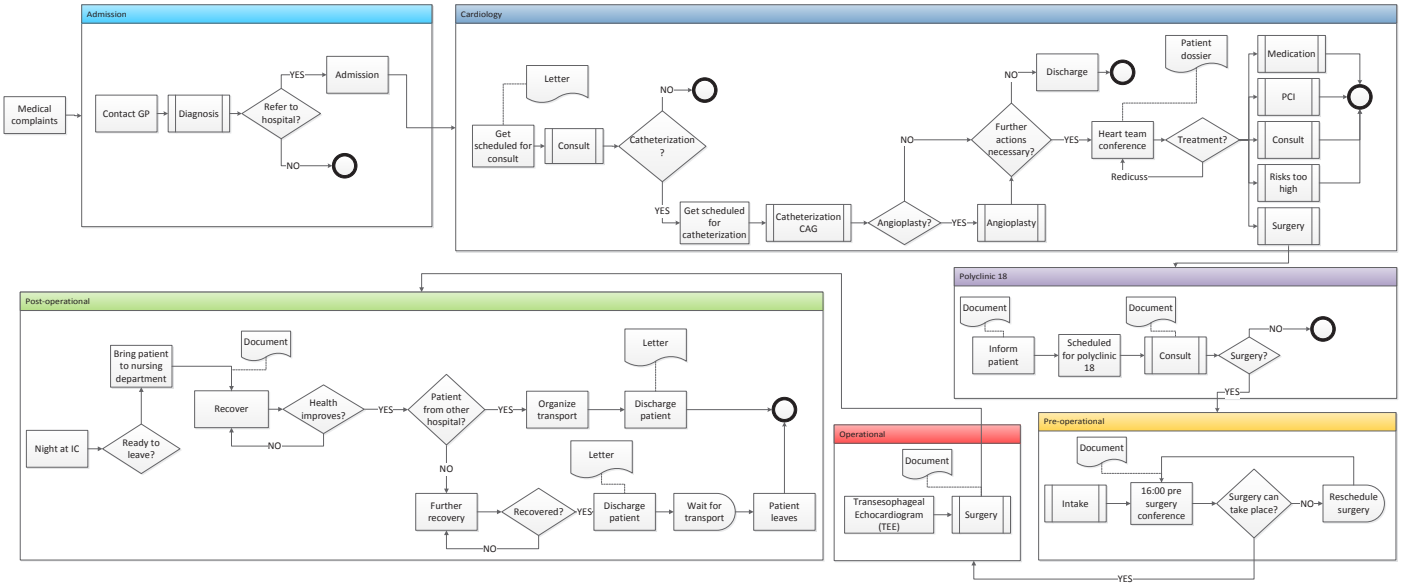


Figure 8- Architecture TCT

As addressed several times already, the MST is going to move to a new building and has to reduce the number of beds, which results in the necessity to work more efficient (resources need to be used optimally) and more effective (successful in serving clinical purpose). After an orientation of several weeks it became clear that the current system contains a considerable amount of bottlenecks. Solving only one of the bottlenecks would not result in a significantly more effective and efficient system. In this chapter a method to solve bottleneck after bottleneck, starting with the most promising ones, is elaborated. This chapter covers translating the bottlenecks to possible solutions, selecting the most promising solution, evaluating and the impact of the solution and tailoring the solution.

5.1 Designing a tool

To realise a significant improvement, the current system needed to be analysed. This was done in the previous chapters. The next step is to evaluate and categorise the bottlenecks to work towards a solution. Evaluating the system can either be done by 1) focusing on medical improvement (e.g. enhanced technologies for treatment) or 2) focussing on logistics and process optimization. The logistic approach was chosen for this thesis, because the provided recommendations should not result in increased costs or high implementation risks. Furthermore, as an industrial designer it is much more adequate to analyse the problem from a strategic, non-medical perspective. A creative approach will be used to map the different requirements of the solution. This needs to be done from several perspectives, since the interests of related stakeholders (e.g. patients and surgeons) differ.

The solution provided should not increase uncertainty and should contribute to the realisation of moving to the new building. Since the new building is already nearly finished, recommendations with respect to changes in architecture and distances between departments are not relevant. In addition the main focus will not be on improving OR capacity and OR scheduling, since there are already many papers on this subject. (Cardoen, Demeulemeester, & Beliën, 2010; Fei, Meskens, & Chu, 2010; Guinet & Chaabane, 2003; Lamiri, Xie, Dolgui, & Grimaud, 2008)

A tool to solve existing bottlenecks needs to be provided, which enables hospital employees to solve further bottlenecks, in a way explained and shown in this paper.

The two previously shown tables contained a lot of different bottlenecks. At this moment the only relevant bottlenecks for further analysis are the bottlenecks that are related to an increased usage of beds. Eliminating unnecessary tasks and process steps is an important aspect when working on reducing the time patients spend in the hospital. But what other solution approaches are there? And what are unnecessary tasks or process steps when there are a lot of different stakeholders involved, with different opinions?

5.2 Morphological chart

Now a clear overview of the process chain is available, the unstructured bottlenecks from the previous tables can be organised according to this architecture, to work towards a general solution. The first step is made by organising the bottlenecks by solution approach. A morphological chart has been used as a tool to extract the most useful aspects from the previous tables. Even though the morphological tool provides support as a framework, it is not ideal. Therefore, the tool was used to start with and has been modified until it fitted the situation.

5.2.1 Morphological chart in theory

A morphological chart is a method to generate ideas in an analytical and systematic way. Usually, functions of a product are displayed in the vertical direction and the solutions that fulfil that specific function are displayed in horizontal direction. From every row one solution is selected. If a solution is selected for every row a functional product will be the outcome. By choosing different paths from the top to the bottom different concepts for products can be generated.

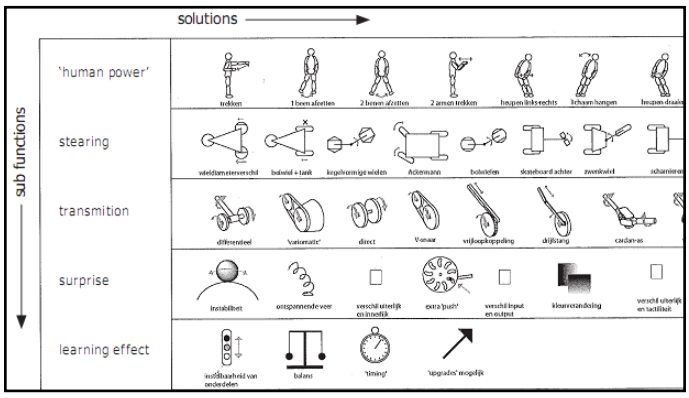


Figure 9- Example morphological chart

5.2.2. Morphological chart in practice

To work with the discovered bottlenecks, the number of individual, detailed bottlenecks needed to be reduced. It can be stated that the focus of the hospital at this moment is working on bed reduction. Therefore, the bottlenecks relevant to bed reduction were selected from the table. Solutions to realise bed reduction were added to the table. These were derived from the underlying causes that were uncovered during the analysis. Solutions which were raised during several interviews with patients and employees of the TCT were also included. Hereafter the solutions were sorted by approach. Assumptions and relations were discussed and confirmation about the importance of aspects has been collected.

The outcome of this process is a matrix that contains several solution approaches in vertical direction and the corresponding solutions in horizontal direction. A timeline derived from the process chain was added to the horizontal axis of the diagram. From the left side of the matrix to the right the different stages of the process chain can be found. The same colours as in the architecture were used. This step was executed, since it enables the investigator to identify whether the bottleneck hinders the input, continuous stream or output.

BED REDUCTION	Admission	Cardiology	Polyclinic 18	Pre-operational	Operational	Post-operational
Improve availability resources	Improve availability laboratory	Improve availability imaging department	Increased number of specialists for consults	MitraClip not on Monday reduces tasks on Sunday	Decrease number of employees OR during day	Improve availability of ambulance
	Improve availability pharmacy	Sort patient by town (Transport after discharge)	Increase number of employees on Sunday	Reduce dependency on ambulance	Ambulance also telemetry patients	Reduce dependency on nursing homes
Schedule tasks parallel (e.g. recovery parallel)	Surgeons involved during cardiology consults	Patients from Enschede surgery in the morning	Sort patients by EuroSCORE (expected LOS)	Time to inform family members about discharge	Time to organize transport before discharge	Prepare discharge letter during stay
Change order of tasks		Meet patient before scheduled for specific day				
Improve communication	Inform patients about delays and explain causes	Inform GP about consequences when contacting MST	Inform patients about surgery by phone and letter	Prepare family members for discharge	Use pre operational screening to forecast LOS	Monitor why patient is at the hospital
	Collect information from patients about discharge	Feedback about appointment surgery	Make clear which problems are going to be solved	Inform patient about expected discharge date	Provide consistent information intern as well as extern	
Allocation		Poly-clinical pre-operative screening	Prepare for scheduled surgery (Drink, Salve...)	Wait for scheduled surgery	Recover from surgery	Recover from unhealed wounds
Reduce buffers		Less patients waiting (in a bed) for surgery	Max two surgeries scheduled per day per OR	Close 1 OR instead of Tuesday on Friday	Last Friday of the month	No more "closed" or reserved beds
Reduce number of tasks	Less steps necessary to get appointment scheduled	Recalculate the average LOS to improve forecast			Move patient and belongings less often	
Improve documentation	Documentation accessible by everyone necessary	Reduce number of documentation systems used		Agreements on documentation between hospitals	Consistent documenting intern	Overview of available nursing homes
...						

Table 3 - Morphological chart

5.3 Project selection

The morphological chart as it is used for this thesis can be seen as a matrix that contains a lot of suggested projects. From every row different solutions can be selected and not all columns need to be covered by a selection. Even just selecting one solution can result in a project. From the results presented in the morphological chart it can be concluded that the interviewed key stakeholders from inside the organisation (hospital management, nurses and surgeons) as well as the customer (patients) identified the need for project activity.

One of the projects from the morphological charts needs to be selected to start with. Project selection can be based on different aspects. One of these aspects is selecting the project that results in benefits for the highest possible number of stakeholders. Implementation of the new or changed procedure will be much easier and has a higher success rate if the stakeholders are involved, informed and recognize the positive and negative effects of the change.

5.3.1 Clustering in theory

Establishing the project with the highest possible number of stakeholders can be done by clustering. Every stakeholder has his own collection of possible projects that he is interested in to be carried out. The clusters overlap and there where all clusters come together the most promising aspects for further development can be found. *Figure 10* displays an example of clustering.

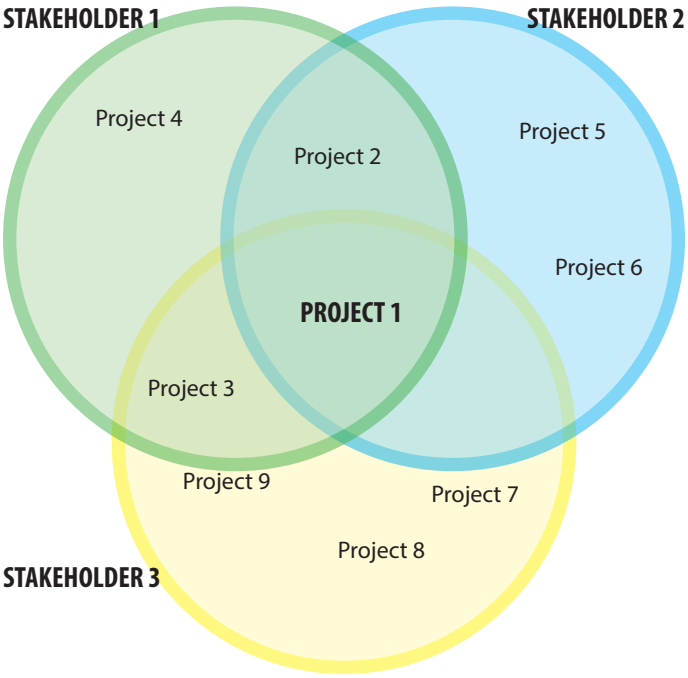


Figure 10 - Example stakeholder cluster

Hereafter, the values of the different suggested projects need to be compared against each other. Here the values of the hospital management play a role. Project selection has the benefit of resulting in a priority order for the projects, based on indicators like time, budget, relevance or received support. The different indicators can get the following values: 3, 6 or 9. Selecting the next project will be supported by a transparent documentation of the project selection method. The project with the highest total value will be the first to carry out.

	Project 1	Project 2	Project 3
Relevance			
Support			
Acceptance			
Time			
Costs			
...			
Total			

Table 4- Example project selection

5.3.2 Role of the stakeholders

It is crucial to have individuals from the affected areas involved in the project. The key stakeholders (including hospital management) are the driving force through all stages of the project, from development to implementation. Forgetting an important stakeholder and his requirements to the solution can result in high costs towards the end and taking the project longer than expected. The project team should be aware of the fact that the stakeholders involved are able to change during the project.

Identifying the customer's demands and interests of involved stakeholders is a primary task after the project has been selected, since they can provide answers and feedback on how things should go. First of all the key stakeholders must be able to clearly explain the necessity for the project. Requirements can be provided by the stakeholders internal as well as external.

Involving the key stakeholders needs to be done by using a tool that can be understood by all parties. Therefore, the A3 Architecture Overview seemed a suitable tool.

5.4 A3 Architecture Overview

Based on the characteristics of the situation, the A3 Architecture Overview was chosen as a tool for further development. Even if the tool does not fit the hospital environment perfectly, working with a tool and adjust it to ones needs is much easier than working without a tool. The main goal of the A3AO approach is to make architecture information easily available to a wide range of stakeholders, while also supporting the evolution of the system.

5.4.1 A3 Architecture Overview in theory

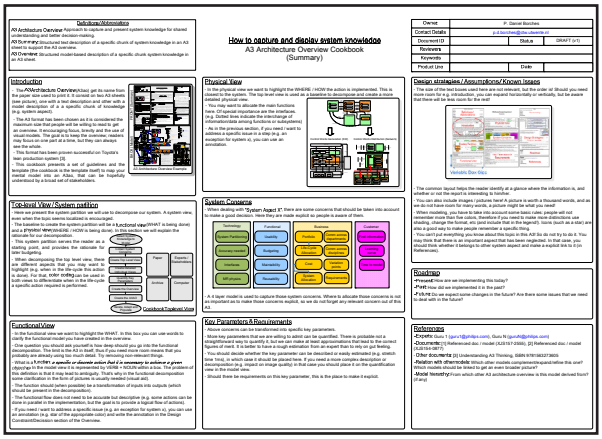


Figure 11 - Example of A3 Architecture Overview

Creating A3 Architecture Overviews (A3AOs) is a method to capture architectural knowledge and provides an effective framework to support decision making when evolving and improving complex systems (Borches & Bonnema, 2010). The knowledge needed to architect a new variation of the system is usually not clearly structured nor captured in an effective way. Various stakeholders are involved, with each their own viewpoint, interests and vocabulary. The large amount of information, implicit (captured in the mind of the experts) as well as explicit (captured in form of documents) needs to be collected and summarised. This was done in the previous phases.

With the collected information a support system for solving bottlenecks one after the other can be created. An important requirement is that several stakeholders need to get involved in the solving procedure, since knowledge sharing is one of the main barriers. Sharing knowledge is difficult and a tool that can be understood and accepted by all stakeholders is required. A3AOs enable stakeholders to address the effects of system changes, which is essential when improving the system.

As stated by Borches and Bonnema (2010) the main evolution barriers when dealing with new developments are: 1) managing system complexity, 2) communication across disciplines and departments, 3) knowledge sharing and 4) finding the necessary system information. This is also applicable to the situation in the MST. The research done in the past couple of weeks confirms these barriers. Using an architecture description helps to manage with complexity, by providing an structured overview and improves communication between disciplines and knowledge sharing. The A3AO provides an overview on an A3 paper, which forces the designer of the communication tool to find and summarize the essential system information.

5.4.2 A3 Architecture Overview in practice

Two A3 overviews have been created to communicate with stakeholders about selected bottlenecks and possible solutions. It can be assumed that surgeons, nurses and patients are not used to the tool, therefore the A3AO were significantly less technical than the A3AO used to communicate between different technical specialties when designing. The A3AO was chosen, since it summarises the most important data. Furthermore the requirements from several stakeholders for the new system could be gathered and discussed.

Although the tool helped summarizing the gathered information, it was not a success for improving the current system. The A3AO was more a barrier itself than a support for improved communication and knowledge sharing. Usually, all drawings are subject to agreed rules, codes and conventions. Learning how to make and how to read those drawings is a crucial requirement when using the tool (Borches & Bonnema, 2010). For this application the tool needed to be self-explaining and understandable without any foreknowledge.

With a printed A3AO that looked more like a poster the planning office and several thoracic surgery patients were approached. (*Appendix 8*)

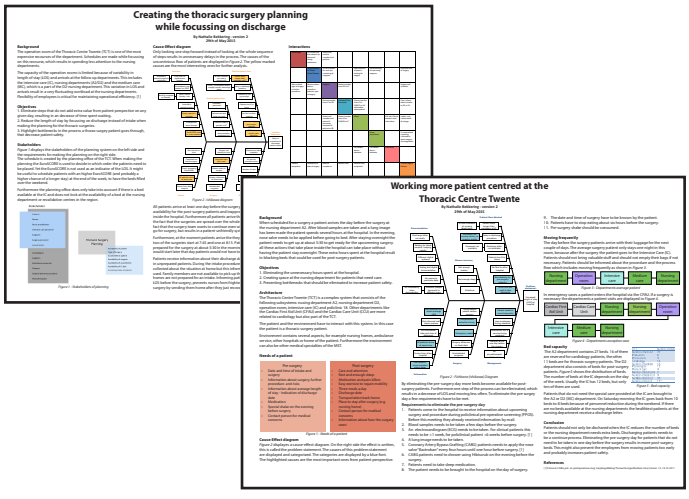


Figure 12 - A3 Architecture Overview

The approached stakeholders expected an explanation along with the poster, since they were used to the fact that posters are adopted to underline aspects and provide a guideline for presentation. In addition, employees experienced reading and looking at the tool as more time consuming than evaluating while discussing. One of the causes could be that the A3 contained a lot of information.

Patients experienced a description of scenarios in combination with a presentation as much more comfortable and less tiresome. For communicating with employees the poster had some additional value, while patients experienced the poster as not useful and/ or helpful. The A3AO was developed further and used more as a poster to communicate with the planning office. Regardless the effort that was put into further development of the A3, poor feedback on the A3 has been received. The tool was put aside.

Nevertheless this experiment led to new input for further development. Conclusion about the format of a new tool could be drawn from the gathered information. Requirements that need to be met by the new system were collected and the information was confirmed and modified where necessary one again.

The A3AO is…

- ...not useful when communicating with patients, since they prefer a less active role in the beginning. After they are informed well, they want to play a more active role.
- ...not ideal when communicating with the management employees, since they experience reading the A3 as too time consuming.
- ...useful when information needs to be gathered.
- ...helpful when it comes to verifying the collected information.

The new tool should…

- ...support active communication between investigator and stakeholder.
- ...support personalization of the communication and provided information.
- ...support providing the feeling that the stakeholder can actually change something.
- ...help reaching a clear goal. The investigator should inform the participants about this goal.
- ...be useful when asking stakeholders to confirm gathered information.
- ...require only limited time from the approached stakeholders.
- ...be qualitative instead of quantitative.

5.5 Stakeholder table

Since the A3AO only offers limited support, a new tool needs to be developed. The new tool should contain the positive aspects of the A3AO like providing a fundament when it comes to gathering information and verifying the collected information. In addition it should require only limited time from the approached stakeholders. The A3AO was experienced as time consuming since it contained a lot of information, including information that was not relevant at that specific moment in time. The tool should not be used as a medium to explain the architecture but as a tool that offers support when mapping the positive and negative outcomes of a concept of a solution. By evaluating the concept new information is gathered that can be used to optimize the solution, so that it fits the needs of the affected stakeholders as good as possible.

As stated previously, it is important that the tool personalizes information. The A3AO provides different views of the architecture on one sheet. Every stakeholder recognizes at least one familiar view on the sheet. This aspect did not work out for the A3AO in practice since two posters were generated, one for each key stakeholder. The A3AO therefore contained too much information. It can be concluded that several views should be included and clearly separated to keep overview. Reading only one part of the sheet should be possible without the necessity to look at all parts of the tool. Different starting points for reading should be available.

Since ill patients are one of the key stakeholders and reading can easily be experienced as tiresome, an oral explanation should go along with the tool. A written tool as a guideline is preferred in order to provide equal information to all participants. In addition, information and arguments from others can be verified or used as a basis for supplementary arguments.

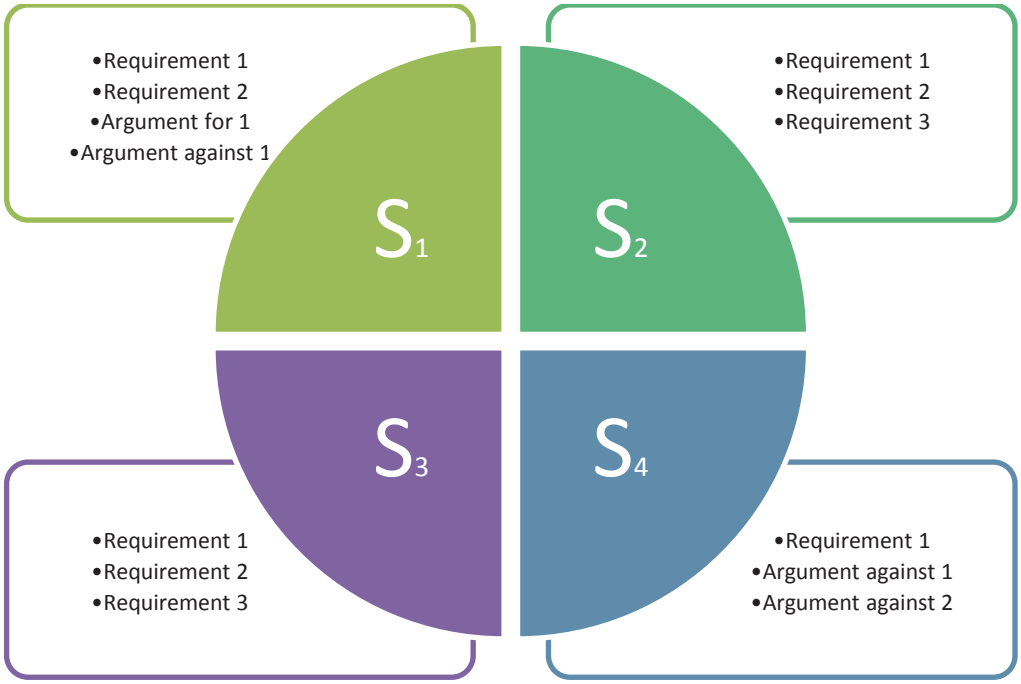


Figure 13 - Stakeholder table

Managing all expectations is difficult since expectations can conflict. Evaluating the positive and negative effects of the project solution is necessary when striving for a durable solution.

The developed tool is composed of a table divided into parts. The number of parts is equivalent to the number of key stakeholders involved. Next to the parts a window containing the different requirements of the stakeholders is added. The investigator should start with including several assumed requirements. The next step is to verify the assumptions and completing the list of requirements. This is done by approaching the key stakeholders with the diagram. Stakeholders can be approached individualy but the tool can also be used during sessions including all relevant stakeholders.
Inspiration about aspects can be gathered by looking at the requirements addressed by other stakeholders. Therefore it is important to include a stakeholder specific part, while not excluding information from other stakeholders. Hereafter the arguments for and against the solution can be added. Reading the arguments of others can result in new requirements and new arguments.

To demonstrate how the previously shown method can be used in the MST to develop a suitable solution, a case study will be executed. The example should function as a guideline for further problem solving by the MST.

6.1 Redesign of the pre-operative day

6.1.1 Project selection

First of all the selected project should suit the goal and requirements of the organization. It can be assumed that the TCT will focus on bed reduction for at least the next couple of months. Therefore, the bottlenecks relevant to bed reduction were clustered and sorted by stakeholder. This could only be done because of the broad analysis of the current situation and use of morphological charts and A3AO to map the interests of the different key stakeholders. Performing the RCA led to a clear distinction between causes and effect, which is necessary to tackle the causes and not only some effects.

Since the hospital management is a major decision maker that transcends sheer stakeholder interest, they are not included in the cluster diagram. The decision made by the hospital management can be influenced by several factors like goals and requirements of the organization (relevance), budget (costs), time or acceptance by stakeholders.

In this case, however, the focus will be on stakeholder acceptance. The project is selected by looking at the coherent needs and interests of the stakeholders, as described in the previous section (5.3 Project selection). The requirements of the hospital management could not be left out completely and are therefore used to decide between the projects with the highest number of stakeholders.

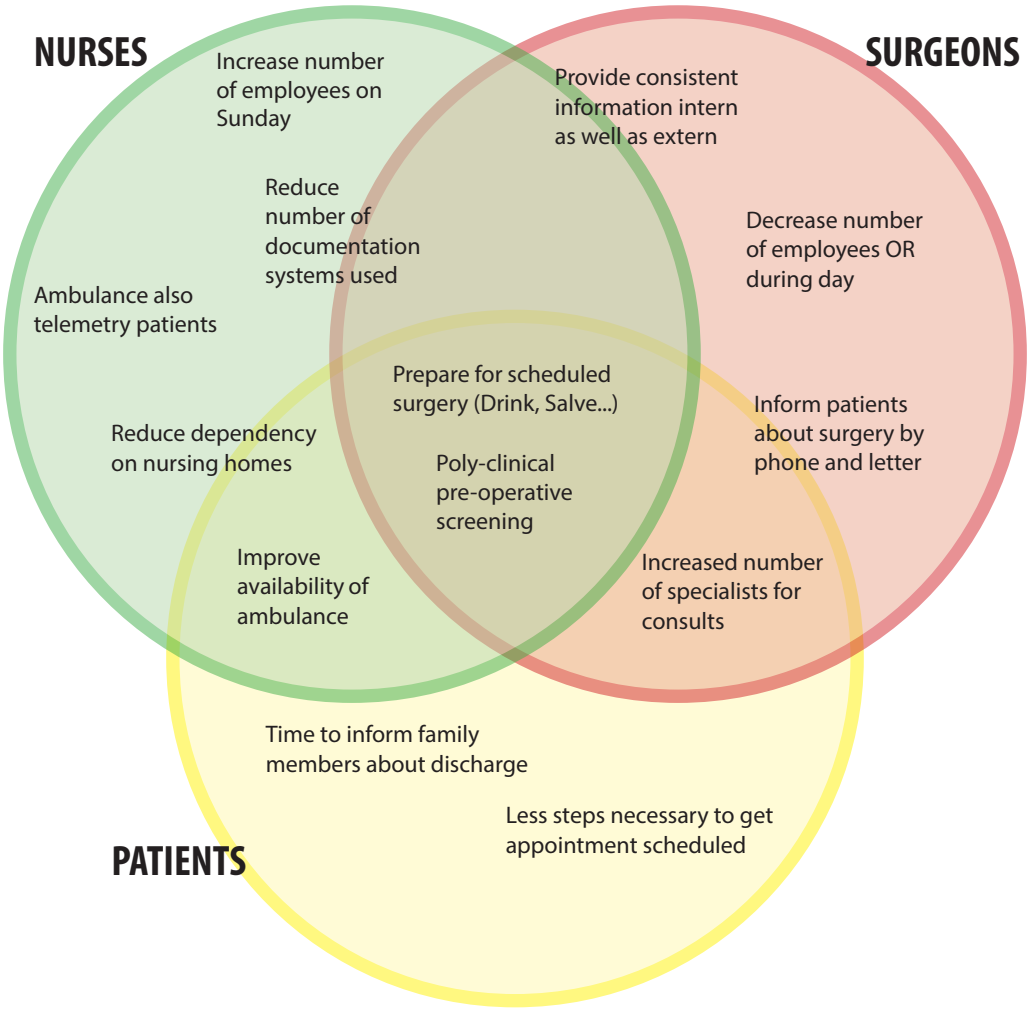


Figure 14 - Stakeholder cluster

The bottlenecks that involved most stakeholders possible were listed and different values were added to the main problems that could be approached. In vertical direction the criteria were displayed. In horizontal direction the main issues that could be elaborated in more detail can be found. Scores (3, 6 or 9) were added to the table.

	Ambulance & Nursing homes	Pre-operative procedure	Consults at polyclinic 18
Relevance	3	6	6
Support	0	3	3
Acceptance	9	6	6
Time	3	6	3
Total	**15**	**21**	**18**

Table 5 - Project selection

When comparing the different project against each other a change in the pre-operative procedure received the highest score. Changing the pre-operative day has high relevance when striving for bed reduction and it involves the highest possible number of stakeholders. Advice in order to start the case study has been received from an expert of the hospital management. On the 5th of June she stated: "At the moment eliminating the pre-surgery day would result in the biggest profit. Research needs to be done about the costumer and firm value of this process step"

6.1.2 Define the project

Before starting to work on the project, the project needs to be defined in more detail by using the core information from the performed analysis at the TCT of the MST.

A few months ago the pre-operative screening has been re-designed. Instead of having several appointments at one day at fixed times all patient come to the hospital on Thursday morning at the same time. According to the employees of the MST this change is a big improvement. Patients have to wait less and it is no longer possible to miss an appointment because the previous is not finished yet.

On average eight patients are scheduled on Thursday for a polyclinic pre-operative screening procedure. Five of the patients are screened partial and do not visit the surgeon and nurse practitioner. Three of them, those are the patients who have their surgery on Monday, are screened completely and can therefore arrive much later at the hospital for their intake. When looking for possibilities to reduce the length of stay this pre-operative day is one of the aspects hospital managers want to eliminate. This case study is about defining the barriers different stakeholders experience when discussing about eliminating the pre-operative day. If these barriers can be avoided or minimalized the solution would result in increased satisfaction and more successful implementation.

6.1.3 Role of the stakeholders

Hospital management

First of all, the staff members that coordinate moving to the new building are involved. These employees benefit from changes that realize a bed reduction, since they are responsible for moving to, and fitting into the new building. Floor managers are responsible for the individual departments and are involved when it comes to specific department changes. Employee and patient planning offices are involved, since a change in the process may results in a shift in workload and tasks. In addition, there will be stakeholders that prove if the solution meets the requirements on safety, quality, privacy, security and serviceability. These stakeholders are taken together and will be called the hospital management.

Patients

The category of patients that is interesting for this case is the group that is going to undergo or underwent a cardiac surgery. The patient should not be from another hospital, because they cannot go to the poly-clinical pre-operative screening at the MST.

Only a limited number of patients will go to the poly-clinical screening more than once in a lifetime. Therefore, patients are not able to compare the old situation to the new situation. The advantage that goes along with that is that they do not have to struggle with getting used to the changed procedure.

Surgeons

Thoracic surgeons are stakeholders of the change since they perform a part of the screening procedure. Patients indicated that meeting their own surgeon before the surgery would be of increased value to the provided care and received information. Changing the pre-operative day would have impact on the schedule of the surgeon.

Nurses (including nurse practitioners)

Nurses and nurse practitioners also perform a part of the pre-operative screening procedure. Screening the patient at the policlinic instead of partially on the department after intake would result in a shift of the workload. Furthermore screening the patients in an out-patient clinic reduces the pressure on the beds and changes the work experience.

Other stakeholders of this case are for example anaesthetists, pharmaceutical employees, family

members and many more. These were not taken into account since they play a significantly smaller role. It needs to be mentioned that the key stakeholders of the case can change through the project.

6.1.4 Impact of the changes

After the stakeholders were identified, participants for the case study were approached. Two surgeons, three employees of the hospital management, three nurses and three patients were asked to give their opinion about a process chain without a pre-surgery day. The outcome of this analysis is displayed on the following pages. The key stakeholders were interviewed separately.

PATIENTS

...prefer knowing as early as possible when a surgery cannot take place.
...require low number of cancelled surgeries.
...require flexibility.
...require a high OR capacity.
...prefer patients that recover fast.
...require no decrease of quality.
...prefer a reduced LOS of patients.
...require a low re-operation rate.

- Eliminating the pre-surgery day decreases flexibility
- At 16:00 a meeting takes place, this meeting needs to take place later if patient arrive later. This results in a shift of the workload.

-/+ Patients are no longer seen by the surgeon the day before the surgery but several days before the surgery.

-/+ The patient has to be seen

-/+ More scheduled poly-clinical screenings, at the moment three patients per week are seen at the PPOS

-/+ does not have a big impact on the travel time, since partial screening is already at the hospital. Screening should not be spread over two days.

SURGEONS

...prefer knowing as early as possible when a surgery cannot take place.
...require low number of cancelled surgeries.
...require flexibility.
...require a high OR capacity.
...prefer patients that recover fast.
...require no decrease of quality.
...prefer a reduced LOS of patients.

- Eliminating the pre-surgery day decreases flexibility
- At 16:00 a meeting takes place, this meeting needs to take place later if patient arrive later. This results in a shift of the workload.

-/+ Patients are no longer seen by the surgeon the day before the surgery but several days before the surgery.

-/+ The patient has to be seen

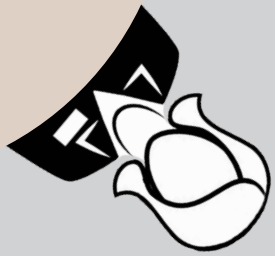
-/+ More scheduled poly-clinical screenings, at the moment three patients per week are seen at the PPOS

NURSES

...require no increased workload.
...require a more constant workload.
...require reduced number of tasks during employee reduction periods.
...prefer increased well-being of patients.
...prefer increased amount of interaction with surgeons and patients.
...require reduction of pressure on bed especially on Friday.
...require a solution that does not increase the amount of documenting tasks.

+ Reduced number of tasks.
+ Patients can arrive later at the hospital, maybe not the morning before surgery but at 19:00.
+ More patients that are informed on the same level.
+ Less pressure on the beds.
+ Salve and scrub can be applied at home.
- Increased number of tasks during employee reduction (late shift) if intake takes place at 19:00.
- Patients arrive nearly always much earlier than scheduled for their meeting.

HOSPITAL MANAGEMENT



...require that quality must not decrease.
...require that length of stay reduces.
...want IPS to be mapped including reasons why.
...require that number of surgeries should not decrease.
...require increased patient well-being.
...require reduced pressure on nursing beds.
...prefer no increase of uncertainty
...require appropriate forecasting should be possible.

+ Less surgeries are cancelled last minute.
+ Less pressure on the post-operative beds.
+ Patients are already seen by the surgeon at the polyclinic, therefore the 16:00 does not have to take place for these patients. Patients from other hospitals still need to be discussed during the 16:00 conference.
-/+ Increased number of tasks during late shift is no problem, we could change the working hours and schedule more employees during the late shift.
- Laboratory and imaging employees are not available; no further actions can be taken if necessary.

6.1.5 Introducing additional poly-clinical screenings

Assume that we are going to eliminate the pre-operative day completely, the schedule of the surgeon would undergo major changes. The surgeon needs to visit the patient at another moment, since meeting and checking the patient is required. The decision whether the surgery should take place or not should not be decided from a look at the patient dossier. Additional consult hours need to be scheduled at Thursday. It might be necessary to introduce another day to plan more screenings.

6.1.6 Conclusion

The general outcome of the discussion sessions with the interviewees is that arriving the evening before surgery is of additional value. Eldery, the main category of patients that undergoes cardiac surgery, generaly prefers arriving the afternoon before surgery. Handing over resonsibility is one of the main aspects that patients mention when asked to give a reason why they prefer a system with a pre-operative day. Modifying the solution to fit the requirements and preferences of the key stakeholders can results in a more suitable solution. Therefore the critical aspects were summarised in *Table* 6.

6.1.7 Evaluation and recommendations

Evaluation of outcome

The pre-operative day is of additional value for the patient. It needs to be considered if this is reason enough to keep the pre-operative day. Altered solutions that could also be advisable to consider are: 1) Patients that have a surgery in the afternoon arrive on the day of surgery; Patients that are scheduled for the first surgery arrive the previous day. 2) To provide the required flexibility, patients arrive the day of surgery, all at the same time, but are not placed in a bed. A process change that goes with patients arriving the day of the surgery is that surgeon already have seen the patient at the polyclinic for a screening. This minimizes the risk of surgeries being cancelled shortly before the surgery is scheduled.

Even though the solution direction in the case study in itself did not yield direct results, it is striking to see that assessing the proposed solution yields additional leads/associations for various other solutions. This implies that the used approach indeed interconnect the bottlenecks and the different solutions. Here, even an unsuccessful attempt may lead to other, more successful approaches.

Evaluation of approach

Since the customer value needed to be analyzed, patients were asked to give their opinion about the pre-surgery day. This was done during or after their pre-operative day, but not in advance. Patients should be asked about their expectations before their intake and after their intake to compare the expectations to the actual process.

Stakeholder	Role	Level of interest	Level of influence	Suggestion on managing relationship
Patient	Patients arrives the day before surgery at the hospital for intake and final screening	Low	Low	• Patients can decide whether they want to come the day before • Patients get clear instructions about how to prepare for surgery
Surgeon	The surgeon meets the patient at the polyclinic or after intake	Low	Medium	• Provide same flexibility but without pre-operative day • Limit the number of schedule changes • Limit the number of surgeries being cancelled
Nurse	The nurse performs some final tests during intake and is responsible for preparing the patient for surgery	Medium	Low-Medium	• More patients arriving the day before surgery is only manageable if the number of employees during the late shift increases
Hospital management	Hospital management employees add several requirements to the solution and strive for realisation of bed reduction	High	High	• Realising bed reduction without reducing safety or quality of care

Table 6 - Summary case 1

Further research

During the period of my bachelor thesis no meeting with all stakeholders at the same time took place. A scheduled session where managers, surgeons, nurses and patients come together would really benefit a further detailed analysis, which is necessary before implementing changes. Stakeholders can directly comment on their ideas and more information about the requirements can be gathered. The communication can be supported by using posters. Big sheets on which requirements and arguments are written down, help focusing on the essential aspects. Furthermore it would be of additional value to compare the costs of a poly-clinical screening to the in-patient screening procedure. Surgeons need to be scheduled for consults and can no longer visit the patient after their last surgery. Changing the pre-operative day would result in more poly-clinical screenings of the same style as the screenings of patients that undergo surgery on Monday. Therefore it would be interesting to compare the number of cancelled surgeries on Monday to the number of cancelled surgeries on Tuesday-Friday.

7. Discussion and recommendation

7.1 Design verification

To confirm that the design output meets the requirements and provides support in the hospital environment a case study was carried out. This case study turned out to be indispensable to develop and evaluate the usability of the tools. For example without a case study it would not have been discovered that the A3AO does not suit the environment and which changes were needed to make the tool applicable in the hospital environment.

7.1.1 Redesign of the consults at polyclinic 18

Since only working on one case still does not prove that the tool is useful in all situations, another case needs to be elaborated. The case will not be executed in this paper because of limited time available during a bachelor thesis. After eliminating the bottleneck regarding the pre-operative day it would be advantageous to redesign the consults at polyclinic 18. As described in Chapter 4.8 - Outcome of analysis, the consults at polyclinic 18 form a bottleneck, since cardiology patients as well as cardiac surgery patients need to see the cardiologist regularly. This results in long waiting lists and along with that, unadvisable waiting times.

7.2 Further research

During my time working with the MST a lot of different bottlenecks came up. The bottlenecks were dividend in categories using a morphological chart. I want to highlight one of these categories. In addition I want to address one more promising aspect that has not been elaborated in this paper.

7.2.1 Allocation of facilities

As displayed in the morphological chart, research needs to be done on which process steps could be allocated. The morphological chart contains some aspects as for example recovering from surgery or recovering from unhealed wounds. It should be examined whether it is worthwhile to establish a own nursing home to increase independency and enhance a continuous flow.

7.2.2 Shorten processes

The second aspect I want to highlight is shortening the tasks. For this thesis the process steps where approached as individual blocks with a fixed duration. The proposed solutions suggested either scheduling the tasks parallel or eliminating specific blocks completely.

8.1 Conclusion

The goal of the assignment was to provide an analysis of the current system and its bottlenecks. As an industrial designer this could be done without being biased by medical knowledge or experience with the current practice and long-established process steps. The process was analysed from a whole different perspective than previously done, enabling the investigator to address undetected bottlenecks. In addition, bottlenecks that were already detected by employees were placed in a different light, since design-tools (as for example morphological charts and A3AO's) were used.

The cardiac centre of the MST is a large and complex system, therefore the investigator narrowed down the scope by focusing on the cardiac surgery patients. The result of this bachelor thesis is a tool that provides support when solving the bottlenecks of the current practice of the TCT.

First of all the current practice of the TCT was observed. It took several weeks to understand the relations between the processes and discover the related departments. The outcome of the analysis are several related and unrelated bottlenecks, summarized in two tables. Reverse architecting was used to order the processes in time, which enabled the investigator to locate the bottlenecks. A morphological chart was used to structure the bottlenecks, bases on the architecture, and indicate a solution approach.

Hereafter the goal of the assignment was reformulated. Solving one bottleneck does not necessarily contribute to global optimization of the system. Therefore a tool was designed to rank, analyse and solve the bottlenecks. Clustering was used to identify the most promising project. After that, A3 Architecture Overviews were used to map the interests of the key stakeholders. The usage of the A3AO was evaluated and a new tool was designed to evaluate solutions. The tool was proved as useful during a case study.

8.2. Evaluation

Doing research inside a hospital without a medical background was very exciting and challenging. The knowledge from the previous three years of Industrial Design could be used in a whole different situation, which really added value to my development of becoming an industrial designer.

First of all, during my bachelor I learned analysing and mapping the requirements of a product or system. This can be done by observing the system and interviewing different stakeholders. Both of these methods were performed during this assignment. The chain of processes a patient goes through can be seen as a production process. This production process knows a lot of limiting variables, which is also true for the patient flow (e.g. recovering time of the patient, availability of resources).

8.2.1 Pitfalls

The MST can be seen as a big company. Even though they are a teaching hospital, there are limited or supporting facilities for an industrial designer. Other students are advised and guided, but the hospital employees are not used to working with industrial designers. No work space was organised which resulted in working at home, in the library or in the public waiting room for patients and family members. In addition, clear data availability seemed obvious to me. It turned out that data is hidden, and not always accessible. Meetings needed to be scheduled to receive information. Nearly always the initiative to schedule meetings or receive information needs to be taken by the investigator. Meeting the right employees to receive the necessary information takes many questions and being send from pillar to post is not unusual. The approach and outcome of this bachelor thesis was influenced by the received support of particular departments.

When working on my bachelor thesis I realised that I was much more limited than during projects with others. During project it is possible to focus on your strength and others can help you or compensate for your weaknesses. During the bachelor thesis your strength and weaknesses are a parameter that defines your path.

Adding numbers to the process chain that indicate the amounts of patients that go through the different steps would have been interesting. However, when looking for answers rough data sets were received. Analysing and using the rough data sets turned out to be much more difficult and did not result in a useful outcome.

The last aspect I want to highlight that made the bachelor thesis challenging is planning and scheduling. Managing with the great amount of uncertainties made it very hard to plan. Every time I found out something new, plans changed and the actual plan became irrelevant.

9. References

9.1 Literature

Andersen, B., & Fagerhaug, T. (2006). Root Cause Analysis: Simplified Tools and Techniques: ASQ Quality Press.

Barry, M. J., & Edgman-Levitan, S. (2012). Shared decision making—the pinnacle of patient-centered care. New England Journal of Medicine, 366(9), 780-781.

Bergman, B. L. S., Fundin, A. P., Gremyr, I. C., & Johansson, P. M. (2002, 2002). Beyond root-cause analysis [product development process improvement]. Paper presented at the Reliability and Maintainability Symposium, 2002. Proceedings. Annual.

Blommers, E., Klimek, M., Klein, J., & Noordzij, P. (2008). Perioperatieve zorg voor de oudere patiënt. Nederlands tijdschrift voor geneeskunde, 152(27), 1513-1517.

Bonnema, D. i. G. M., Veenvliet, I. K. T., & Broenink, D. i. J. F. (2012). System design and engineering - lubricating multidisciplinary development projects. Enschede, the Netherlands: University of Twente.

Borches, P. D., & Bonnema, G. M. (2010). A3 architecture overviews: focusing architectural knowledge to support evolution of complex systems.

Cardoen, B., Demeulemeester, E., & Beliën, J. (2010). Operating room planning and scheduling: A literature review. European Journal of Operational Research, 201(3), 921-932. doi: http://dx.doi.org/10.1016/j.ejor.2009.04.011

Churchman, C. W. (1968). Challenge to reason: McGraw-Hill New York.

Davies, R. (1994). Simulation for planning services for patients with coronary artery disease. European Journal of Operational Research, 72(2), 323-332.

Ettema, R. G., Peelen, L. M., Schuurmans, M. J., Nierich, A. P., Kalkman, C. J., & Moons, K. G. (2010). Prediction Models for Prolonged Intensive Care Unit Stay After Cardiac Surgery Systematic Review and Validation Study. Circulation, 122(7), 682-689.

Fei, H., Meskens, N., & Chu, C. (2010). A planning and scheduling problem for an operating theatre using an open scheduling strategy. Computers & Industrial Engineering, 58(2), 221-230.

Guinet, A., & Chaabane, S. (2003). Operating theatre planning. International Journal of Production Economics, 85(1), 69-81.

Lamiri, M., Xie, X., Dolgui, A., & Grimaud, F. (2008). A stochastic model for operating room planning with elective and emergency demand for surgery. European Journal of Operational Research, 185(3), 1026-1037.

Medisch Spectrum Twente. (2013). Bestuursverslag 2013. Enschede.

Nashef, S. A., Roques, F., Michel, P., Gauducheau, E., Lemeshow, S., Salamon, R., & Group, E. S. (1999). European system for cardiac operative risk evaluation (EuroSCORE). European Journal of Cardio-Thoracic Surgery, 16(1), 9-13.

Oosterhuis, T., Trimstra, M., Rademakers, J. (2010). CQ-index Hartfalen: meetinstrumentontwikkeling. NIVEL.

Panis, L. J., Gooskens, M., Verheggen, F. W., POP, P., & PRINS, M. H. (2003). Predictors of inappropriate hospital stay: a clinical case study. International Journal for Quality in Health Care, 15(1), 57-066.

Rooney, J. J., & Heuvel, L. N. V. (2004). Root cause analysis for beginners. Quality progress, 37(7), 45-56.

9.2 Figures

Retreived: 30th of June 2015

Cover http://t3.gstatic.com/images?q=tbn:ANd9GcTyGPBWx8H7dMsJ5tPxo_9dyIwNAt3nGBgKy3ZmX6bK2Y349MCGLg

Figure 1 http://oornon.umcg.nl/nl/zkh/PublishingImages/entree_MST_webformaat.jpg

Figure 2 http://cdn2.hubspot.net/hub/228582/file-2659016059-png/ApolloFourSteps.png?t=1435692784007&width=619

Figure 3 http://www.sharpy.dircon.co.uk/index_files/image4064.gif

Figure 4 Davies, R. (1994). Simulation for planning services for patients with coronary artery disease. European Journal of Operational Research, 72(2), 323-332.

Figure 6 http://image.slidesharecdn.com/rushuniversityipe-140214111806-phpapp02/95/rush-university-ipe-11-638.jpg?cb=1392376975

Figure 7 Davies, R. (1994). Simulation for planning services for patients with coronary artery disease. European Journal of Operational Research, 72(2), 323-332.

Figure 9 http://www.wikid.eu/images/thumb/8/80/DDG-2-32.png/700px-DDG-2-32.png

Figure 11 *http://www.esi.nl/dotAsset/2f65480a-7add-4c82-86dd-d2695880aa2f.pdf*

Appendices

Appendix 1 V-model
Appendix 2 Data MST
Appendix 3 Brainstorming
Appendix 4 Questionnaire
Appendix 5 IPS data collection
Appendix 6 Flow chart
Appendix 7 Root Cause Analysis
Appendix 8 A3 Architecture Overview

Appendix 1 - V-model

Engineers need to be continuously aware whether they are thinking in problem domain or in solution domain. Switching between the two during the process is required, as displayed in the process loop below.

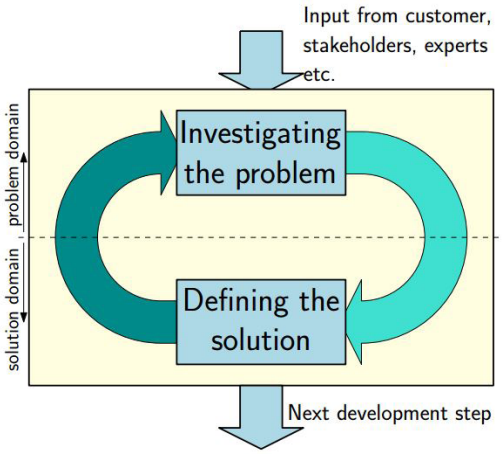


Figure I - Process loop decomposition

At the right hand side of the loop the arrow represents the design of a solution. The arrow on the left hand side depicts the verification: Does the solution solve the issue without having too many negative effects?

The first part of the process focuses on decomposition of the system. The customer wishes are mapped and the system is divided into smaller sub-systems. These sub-systems consist of different assemblies, which can also be broken down to several components.

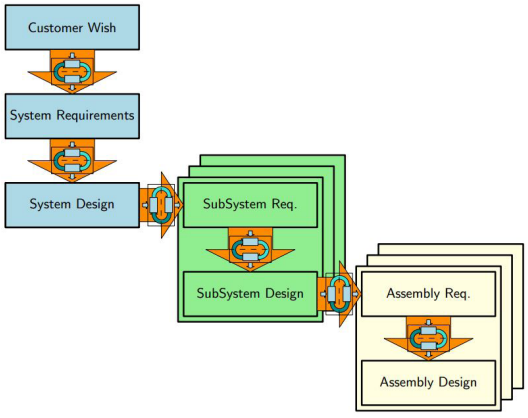


Figure II - Decomposition

When the bottom of the V-model has been reached, the subsequent building up of the system starts. The goal is to deliver a solution that solves the problem and generates value by fulfilling the customer needs.

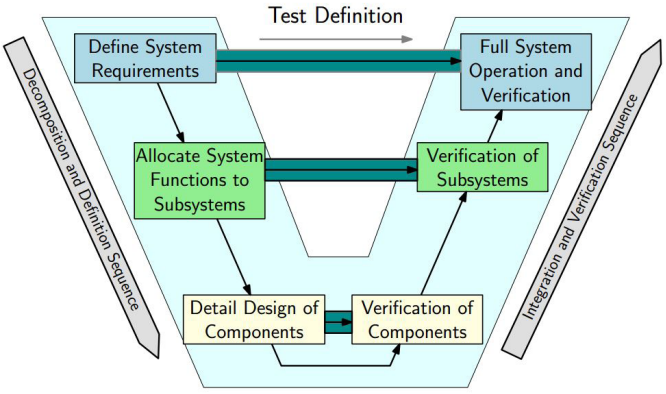


Figure III - V-model

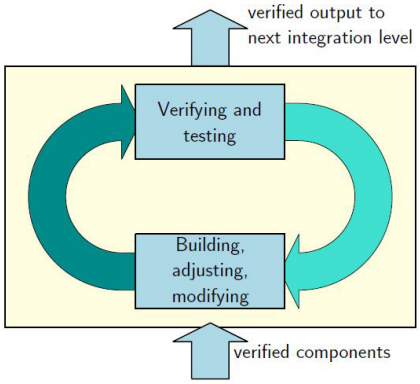


Figure IV - Process loop integration

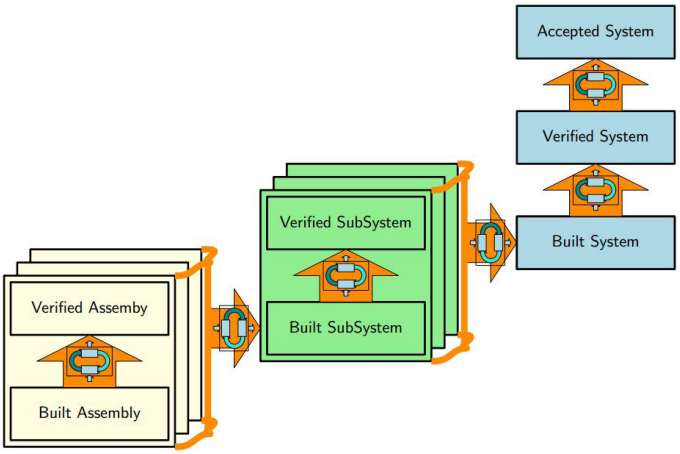


Figure V - Integration and verification

Bonnema, D. i. G. M., Veenvliet, I. K. T., & Broenink, D. i. J. F. (2012). System design and engineering - lubricating multidisciplinary development projects. Enschede, the Netherlands: University of Twente.

Appendix 2 - Data MST

2.1 Operational process

According to Huijskes, Rosseel, and Tijssen (2003) cardiac artery bypass grafting (CABG) and artery valve replacement (AVR) are the most commonly performed cardiac operations. Of the total of 14.500 cardiac operations performed in the year 2001 in the Netherlands, about 80% is a CABG, a heart valve operation or a combined procedure. For the MST this is also true. In 2014 in total 549 CABG surgeries, 142 AVR surgeries and 90 combination surgeries took place. Bellow the number of surgeries is displayed.

These numbers were displayed in a histogram. *Figure VI* displays the number of surgeries performed per month and *Figure VII* displays the same data sorted by day of the week.

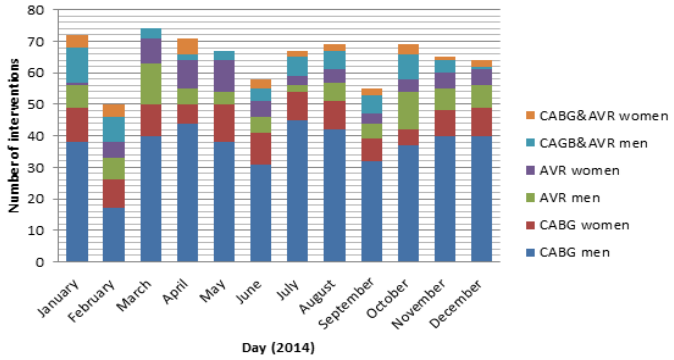


Figure VI - Surgeries performed 2014 per month

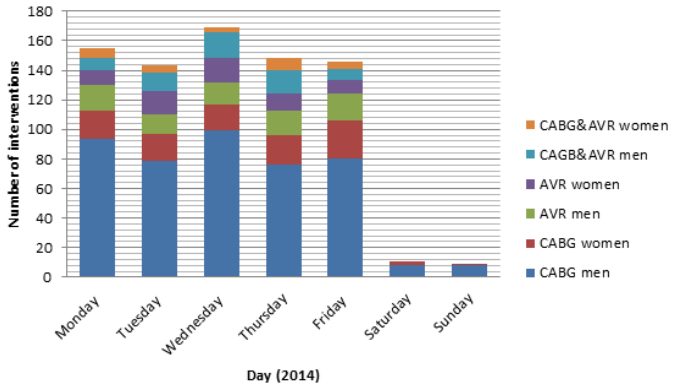


Figure VII - Surgeries performed 2014 per day

2.2 Post-operational process

The Scatter chart shows the LOS at the IC in March 2014. The red diamonds represent the LOS from patients who had a surgery during the weekend. This chart was used to visualise the number of patient per month that stay significantly longer than one night. A scatter chart was used as displaying the avarage would result in a distorted picture.

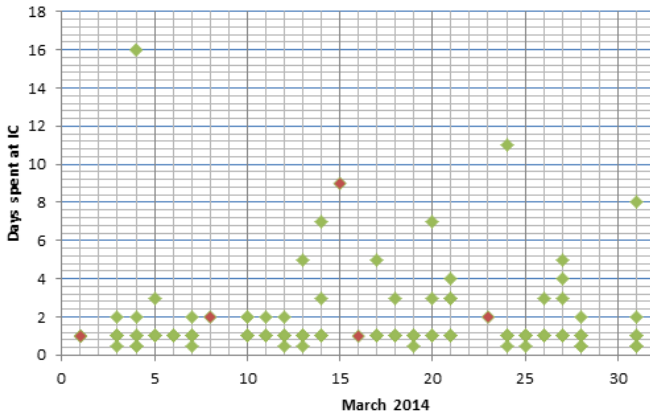


Figure VIII - Length of stay at intensive care

2.3 Bed capacity TCT

Department	Number of beds
Number of beds A2	27
Pre-surgery	6
Post-surgery	5
Cardiology	16
Number of beds D2	16
Post-surgery	12
Medium Care	4
Number of beds EHH	7
Number of beds CCU	9
Number of beds E2	33
Number of beds IC	12*

Figure IX - Bed capacity TCT

Huijskes, R. V., Rosseel, P. M., & Tijssen, J. G. (2003). Outcome prediction in coronary artery bypass grafting and valve surgery in the Netherlands: development of the Amphiascore and its comparison with the Euroscore. European Journal of Cardio-Thoracic Surgery, 24(5), 741-749.

Appendix 3 - Brainstorming

Brainstorming about a patient centred support system resulted in a map displayed in *Figure X,* which was used to collect relevant vocabulary for further research.

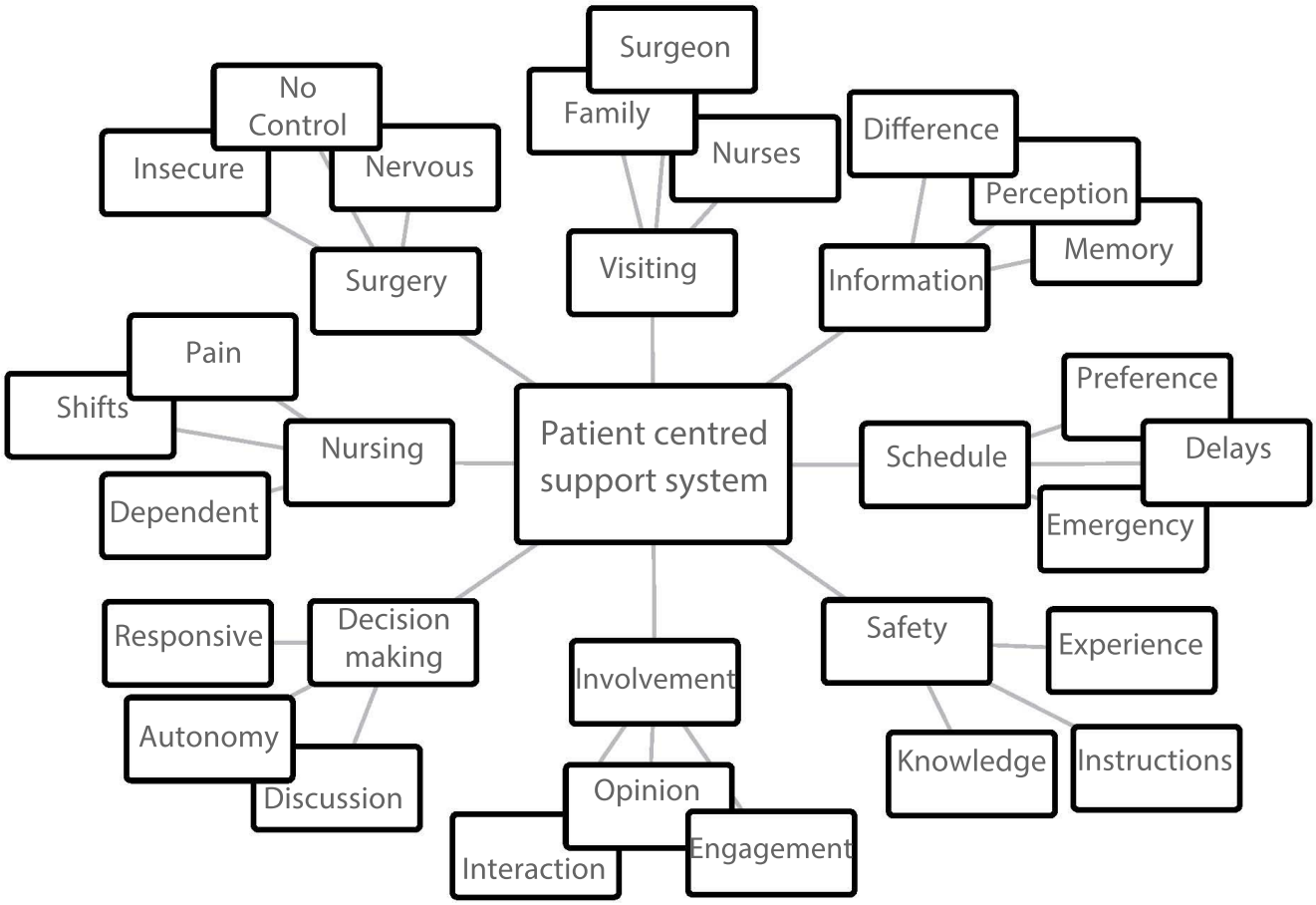


Figure X - Brainstorming

http://blog.biguniverse.com/wp-content/uploads/2013/01/map.jpg

Appendix 4 - Questionnaire

4.1 Questionnaire

4.1.1 Pre-operational interview

General information
Name:
Gender:
Date:
Age:
Location of interview:

Part I: Getting first help; Pre-Surgery Consultation

1) What are the symptoms that brought you here?
2) When did the symptoms start?
3) When did your symptoms become serious enough for you to seek medical care?
4) When did you actually call 112 or go to the hospital?
5) How long did it take before you first see a health care provider?
6) How does the further procedure look like?

Part II: Information provided

1) Did you go to the pre-operational screening?
    a. Yes
    b. No
2) On a scale from 0-10, did the anaesthetist explain things in a way that it was easy to understand?
3) On a scale from 0-10, did the surgeon explain things in a way that was easy to understand?
4) Did the anaesthetist and surgeon listen carefully to you?
    a. Yes, definitely
    b. Yes, somewhat
    c. No
5) Do the nurses spend enough time with you?
    a. Yes, definitely
    b. Yes, somewhat
    c. No
6) Which medical tests have you done?
7) Did someone follow up to give you the results?
8) What is the next step and when is this going to be?

Part III: Health and stay at MST

1) On a scale from 0-10, how would you rate your overall health?
2) On a scale from 0-10, how would you rate your overall mental or emotional health?
3) For how long are you in the hospital now?
4) Does this time spent in the hospital feel unnecessary to you?

4.1.2 Post-operational interview

General information
Name:
Gender:
Age:
Date:
Location of interview:

Part I: Surgery

1) What type of surgery did you went through?
2) Did you have to wait before the surgery could take place?
3) Where did you have to wait?
4) Were you informed why you had to wait?
5) How long did you have to wait before the surgery took place?
6) Was the operation as successful as expected?
7) What effect has the operation had on your condition?

Part II: Information provided

1) Did the surgeon visit you after the surgery?
2) Did the surgeon tell you how the surgery went?
3) On a scale from 0-10, did the surgeon explain things in a way that was easy to understand?
4) Did the anaesthetist and surgeon listen carefully to you?
    a. Yes, definitely
    b. Yes, somewhat
    c. No
5) Do the nurses spend enough time with you?
    a. Yes, definitely
    b. Yes, somewhat
    c. No
6) What is the next step and when is this going to be?

Part III: Health and stay at MST

1) On a scale from 0-10, how would you rate your overall health?
2) On a scale from 0-10, how would you rate your overall mental or emotional health?
3) For how long are you in the hospital now?
4) Does this time spent in the hospital feel unnecessary to you?
5) How long do you think it will take to recover to feel well enough to leave the MST?
6) Are there any reasons why you would not leave the hospital when you feel better?
7) Did you see the physiotherapist yet?
8) Did you already go for a small walk? If not, why not?

4.2 Scenarios

From the gathered information different scenarios could be derived Some of the scenarios were included in *Chapter 3*. The scenario below was not included, since it did not contain relevant information for the selected process. However, the scenario below includes an interesting aspect when analysing the poly-clinical follow up consults. Relevant information can be sent to the MST, which results in appropriate scheduling and prepared employees.

4.2.1 Exception case

Three months ago Mr. Koenen, a 62-year old man, got a heart surgery. The thorax needed to be cut open to reach the heart. After the surgery the bones are stitched up again by a metal wire. The metal wire caused an infection and very unpleasant pain. Mr. Koenen contacted the hospital and sent them a picture by mail of the wound. An appointment was made for him as soon as possible. Still he needed to wait because the bones needed to grow together before the wire could be removed. Three months after the surgery the wire could be removed.

The day before the surgery Mr. Koenen arrives in a hotel near the hospital where he stays the night. The next day he travels to the hospital where he arrives at 9:00. He is placed in a bed where he has to wait until 15:00, to get the metal wire removed that was used during the heart surgery three months ago.

The metal wire was removed on Wednesday but Mr. Koenen could not leave the hospital because the wound kept bleeding. He did not spoke to the surgeon after the operation. The nurses told him that he could leave on Friday, after seeing the surgeon.

Appendix 5 - IPS data collection

During May, April and June a project has been executed to measure the inappropriate patient stay inside the MST. Employees from different departments joined this project. Employees from the A2, D2 (MC), CFAU, CCU and the IC represented the TCT. During this period, employees filled out questionnaires about the unnecessary stay of patients and the reasons for their stay. Data has not yet been collected for the A2 department, the department where surgery patients spend the pre-operative day.

5.1 Measuring

At the moment IPS is measured by employees of the department. During the weekends regular measurements are neglected, because of employee reduction. When measuring it is important to measure always and not only during the week. Not measuring in the weekends because of a reduction of employees results in missing relevant information.

Furthermore at the moment the unnecessary stay at the hospital is divided into different categories. The necessary stay is not divided into different aspect, since this would result in a much more time consuming questionnaire. This results in an outcome that makes it impossible to track the reason of stay of the patient. Since the definition of IPS is not equal at all departments, this results in a distorted picture.

5.2 Reasons inappropriate patient stay April/May 2015 MST

WACHT OP BEHANDELING/VERZORGING IN VERPLEEG-/VERZORGINGSTEHUIS	367	39%
ONNODIG VERBLIJF TEN GEVOLGE VAN VERTRAGING IN ONTSLAGPROCEDURE	148	16%
VERTRAGING/WACHTEN M.B.T. VERRICHTINGEN NODIG VOOR VERDERE BEHANDELING	129	14%
WACHT OP BEHANDELING IN INSTELLING (EXTERN)	79	8%
PROBLEMEN MET BETREKKING TOT THUISSITUATIE/MANTELZORG	77	8%
WACHT OP BEHANDELING ANDERE AFDELING (INTERN)	38	4%
leeg	30	3%
WACHT OP BEHANDELING IN ANDER ZIEKENHUIS	24	3%
OP VERZOEK VAN PATIËNT	14	2%
VERTRAGING DOOR NIET TIJDIG ONTVANGEN VAN UITSLAGEN	12	1%
PRE-OPERATIEVE OPNAMEDAG	7	1%
WACHT OP BEHANDELING IN REVALIDATIECENTRUM	3	0%
BEHANDELING WAARBIJ KLINISCHE CONTROLE/OBSERVATIE VEREIST IS	2	0%
CONTROLES/MONITORING	1	0%
	931	

Table I - IPS MST April/May 2015

According to the e-mail from M. Nieuwland (project manager IPS), 1st of June 2015

5.2 Measurements inappropriate patient stay April/May 2015 department D2

Datum	Afdeling	Bedden	Patienten	NV	NNV	
30-4-2015	D2-H	11	14	11	0	0,00%
6-5-2015	D2-H	8	14	7	1	12,50%
7-5-2015	D2-H	7	14	7	0	0,00%
9-5-2015	D2-H	6	12	6	0	0,00%
10-5-2015	D2-H	6	14	6	0	0,00%
11-5-2015	D2-H	9	14	9	0	0,00%
12-5-2015	D2-H	6	14	6	0	0,00%
15-5-2015	D2-H	8	14	6	2	25,00%
15-5-2015	D2-H	6	14	6	0	0,00%
19-5-2015	D2-H	11	14	11	0	0,00%
19-5-2015	D2-H	11	14	10	0	0,00%
20-5-2015	D2-H	8	14	7	1	12,50%
21-5-2015	D2-H	10	14	8	2	20,00%
22-5-2015	D2-H	11	14	10	1	9,09%
23-5-2015	D2-H	12	14	10	2	16,67%
24-5-2015	D2-H	12	14	7	2	22,22%
25-5-2015	D2-H	12	14	8	4	33,33%
				135	15	10,00%

Table II - IPS D2 April/May 2015

5.3 Reasons inappropriate patient stay April/May 2015 department D2

Redenen NNV		
WACHT OP BEHANDELING IN ANDER ZIEKENHUIS	7	47%
WACHT OP BEHANDELING/ VERZORGING IN VERPLEEG-/ VERZORGINGSTEHUIS	5	33%
ONNODIG VERBLIJF TEN GEVOLGE VAN VERTRAGING IN ONTSLAGPROCEDURE	2	13%
VERTRAGING/WACHTEN M.B.T. VERRICHTINGEN NODIG VOOR VERDERE BEHANDELING	1	7%
	15	

Table III - Reasons IPS D2 April/May 2015

Appendix 6 - Flow chart

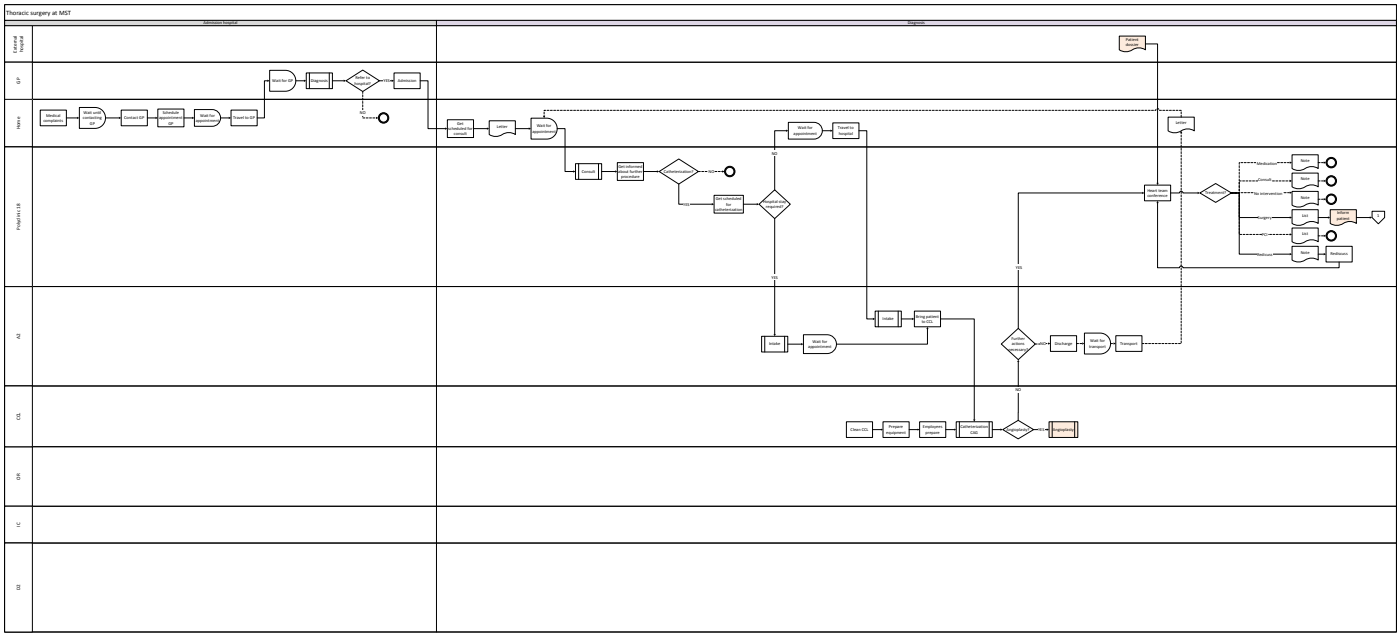


Figure XI - Total chain, detail part 1

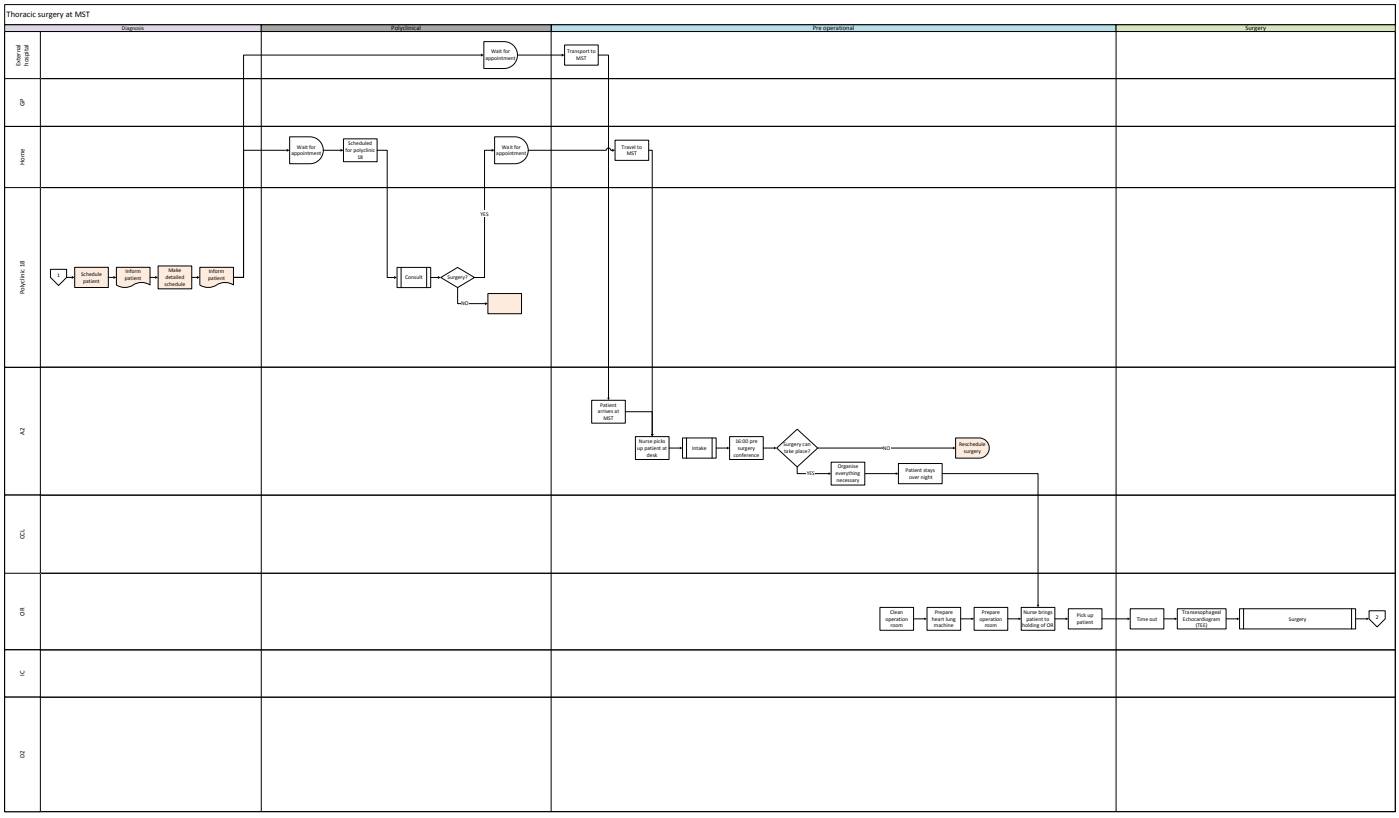


Figure XII - Total chain, detail part 2

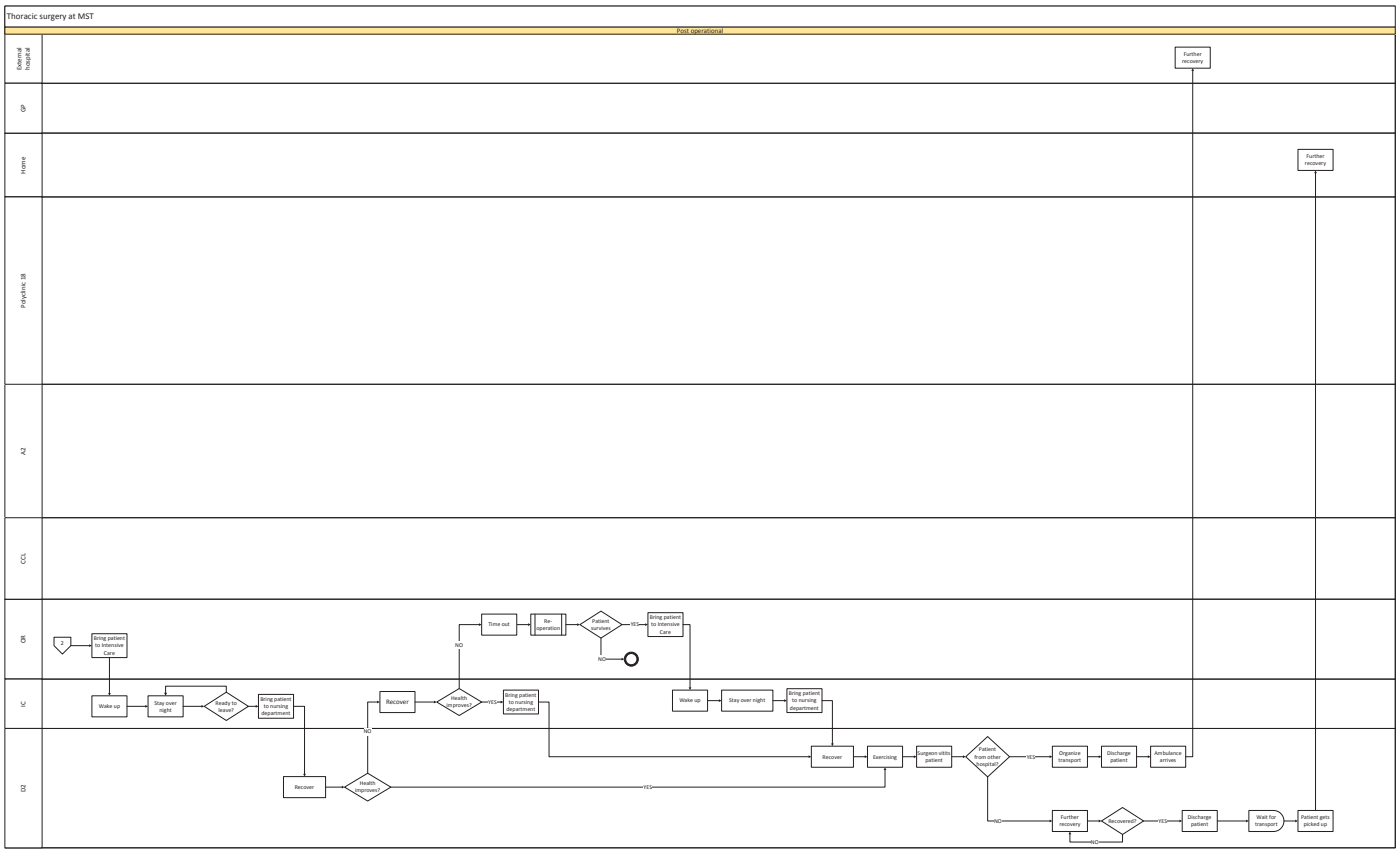


Figure XIII - Total chain, detail part 3

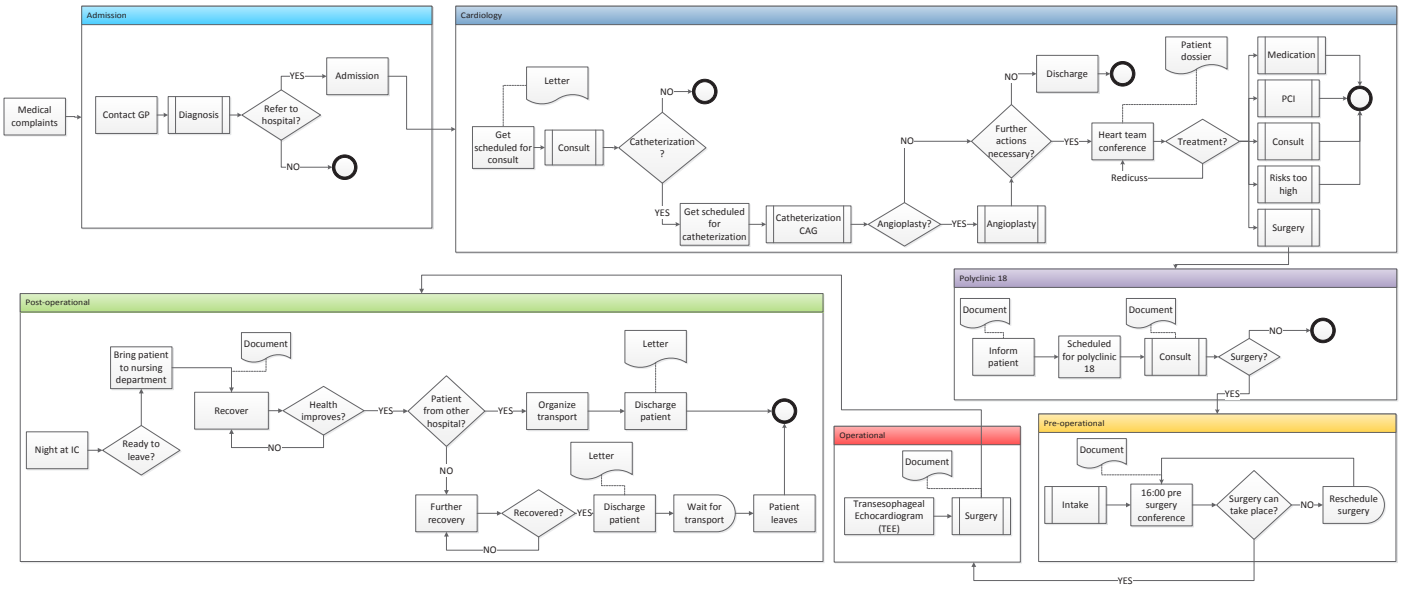


Figure XIV - Total chain, compact version

Appendix 7 - Root Cause Analysis

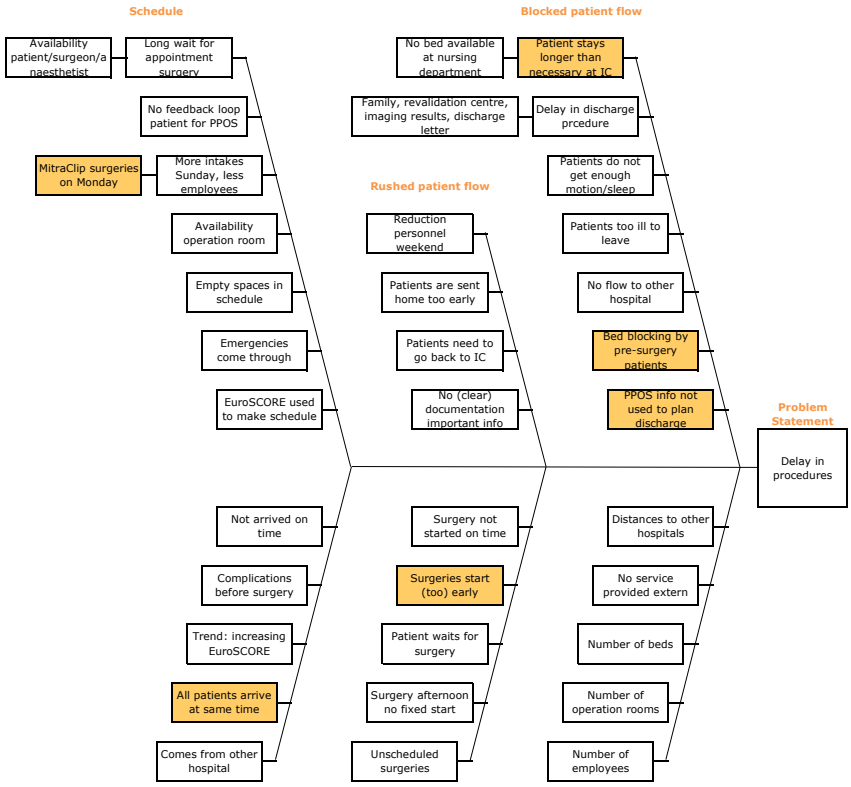


Figure XV - Ishikawa diagram scheduling office

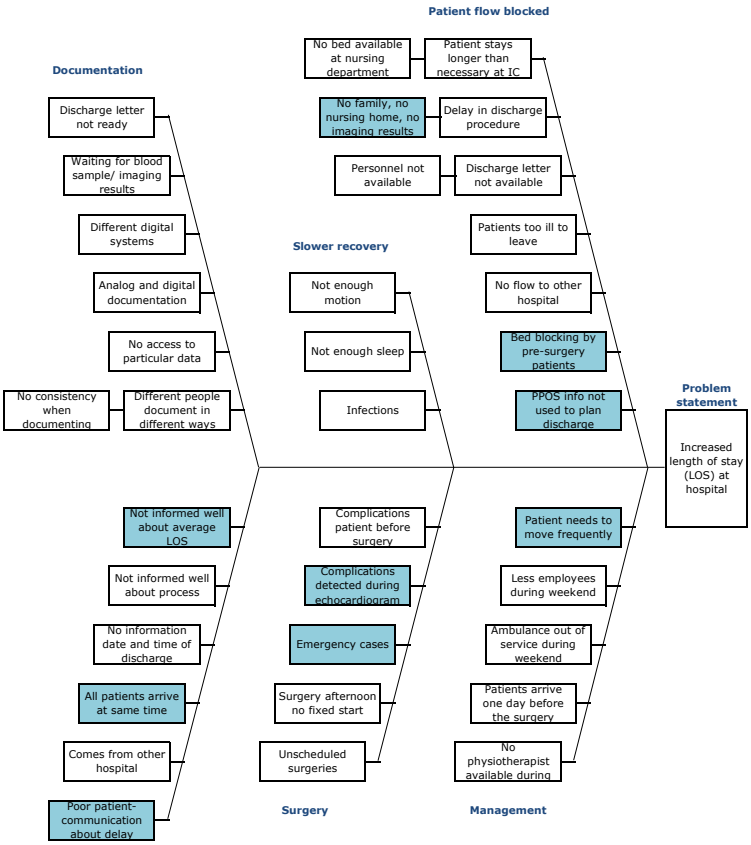


Figure XVI - Ishikawa diagram nursing department

8.1 A3 Architecture Overviews

Creating the thoracic surgery planning while focussing on discharge

By Nathalie Bekkering - version 2
29th of May 2015

Background

The operation room of the Thoracic Centre Twente (TCT) is one of the most expensive recourses of the department. Schedules are made while focusing on this recourse, which results in spending less attention to the nursing departments.

The capacity of the operation rooms is limited because of variability in length of stay (LOS) and arrivals at the follow up departments. This includes the intensive care (IC), nursing departments (A2/D2) and the medium care (MC), which is a part of the D2-nursing department. This variation in LOS and arrivals result in a very fluctuating workload at the nursing departments. Flexibility of employees is critical for maintaining operational efficiency. [1]

Objectives

1. Eliminate steps that do not add extra value from patient perspective on any given day, resulting in an decrease of time spent waiting.
2. Reduce the length of stay by focusing on discharge instead of intake when making the planning for the thoracic surgeries.
3. Highlight bottlenecks in the process a thorax surgery patient goes through, that decrease patient safety.

Stakeholders

Figure 1 displays the stakeholders of the planning system on the left side and the requirements for making the planning on the right side.
The schedule is created by the planning office of the TCT. When making the planning the EuroSCORE is used to decide in which order the patients need to be placed. Yet the EuroSCORE is not used as an indicator of the LOS. It might be useful to schedule patients with an higher EuroSCORE (and probably a higher chance of a longer stay) at the end of the week, to have the beds filled over the weekend.

Furthermore the planning office does only take into account if there is a bed available at the IC and does not look at the availability of a bed at the nursing department or revalidation centres in the region.

Figure 1 - Stakeholders of planning

Cause-Effect diagram

Only looking one step forward instead of looking at the whole sequence of steps, results in unnecessary delays in the process. The causes of the uncontinuous flow of patients are displayed in *Figure 2*. The yellow marked causes are the most interesting ones for further analysis.

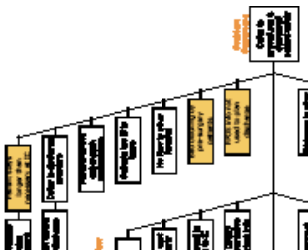


Figure 2 - Ishikawa diagram

All patients arrive at least one day before the surgery. This results in less bed availability for the post-surgery patients and inappropriate patient stay (IPS) inside the hospital. Furthermore all patients arrive the day before, neglecting the fact that the surgeries are spread over the whole day. This is caused by the fact that the surgery team wants to continue even when one patient cannot go for surgery, but results in a patient-unfriendly system.

Furthermore, at the moment patients arrive the they before surgery because two of the surgeries start at 7:45 and one at 8:15. Patients need to get prepared for the surgery at about 5:30 in the morning. If these surgeries would start later that day patients would not have to stay overnight.

Patients receive information about their discharge date late which results in unprepared patients. During the intake procedure information has been collected about the situation at home but this information seems not to be used. Family members are not available to pick up the patient and/or nursing homes are not prepared for an intake. Informing patients about the average LOS before the surgery, prevents nurses from frightening patients after their surgery by sending them home after they just recovered a bit.

Interactions

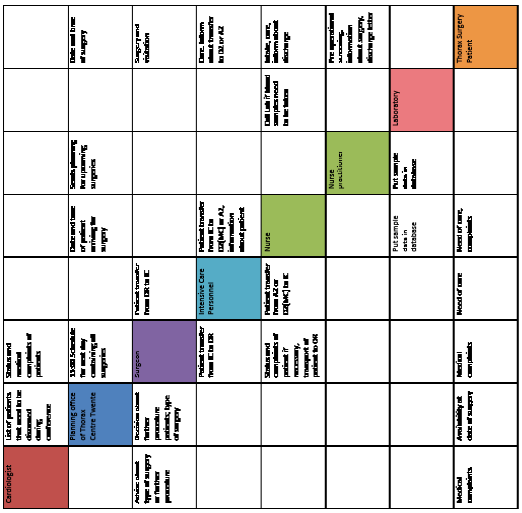


Figure 3 - N² diagram displaying interactions

In *Figure 3* the interactions between stakeholders are displayed. Down, in vertical direction the input is displayed and to the left, in horizontal direction the output is displayed. The input of the planning office for surgeons, nurses and nurse practitioners is a schedule containing all surgeries performed on the upcoming day. This schedule is published at 15:00 the day before. The input for the patient is the date of surgery. The output of the surgeons towards the planning office is the decision about the further procedure.

Conclusion

Surgeries should be planned while working more discharge-focussed.[2] Not only looking at the beginning of the chain but involving the LOS at the nursing departments when planning results in a more patient-centred support system. Furthermore the IPS rate could be reduced. By reducing the IPS more patients could be treated.

References

[1] Bruin A.M. de, Koole G.M., Visser M.C., "Bottleneck analysis of emergency cardiac in-patient flow in a university setting: an application of queueing theory" 2005

[2] Panis L.I.G.G., Gooskens M, Verheggen F.W.S.M. Pop P., Prins M.H., "Predictors of inappropriate hospital stay: a clinical case study", International Journal for Quality in Health Care 2003, 57-65

Figure XVII - A3AO to communicate with planning office

Working more patient centred at the Thoracic Centre Twente

By Nathalie Bekkering - version 2
29th of May 2015

Background

When scheduled for a surgery a patient arrives the day before the surgery at the nursing department A2. After blood samples are taken and a lung image has been made the patient spends several hours at the hospital. In the evening, nose salve needs to be applied before going to bed. After staying overnight the patient needs to get up at about 5:30 to get ready for the upcoming surgery. all these actions that take place inside the hospital can take place without having the patient stay overnight. These extra hours spent at the hospital result in blocking beds that could be used for post-surgery patients.

Objectives

1. Eliminating the unnecessary hours spent at the hospital.
2. Creating space at the nursing department for patients that need care.
3. Presenting bottlenecks that should be eliminated to increase patient safety.

Architecture

The Thoracic Centre Twente (TCT) is a complex system that consists of the following subsystems: nursing department A2, nursing department D2, operation room, intensive care (IC) and policlinic 18. Other departments like the Cardiac First Aid Unit (CFAU) and the Cardiac Care Unit (CCU) are more related to cardiology but also part of the TCT.

The patient and the environment have to interact with this system. In this case the patient is a thoracic surgery patient.

Environment contains several aspects, for example nursing homes, ambulance service, other hospitals or home of the patient. Furthermore the environment can also be other medical specialties of the MST.

Needs of a patient

Pre surgery	Post surgery
• Date and time of intake and surgery • Information about surgery, further procedure and risks • Information about average length of stay - Indication of discharge date • Medication • Special shake on the evening before surgery • Contact person for medical concerns	• Care and attention • Rest and enough sleep • Medication and pain killers • Easy exersice to regain mobility • Three meals a day • Discharge date • Transportation back home • Place to stay after surgery (e.g. nursing home) • Contact person for medical concerns • Information about how the surgery went

Figure 1 - Needs of a patient

Cause-Effect diagram

Figure 2 displays a cause-effect diagram. On the right side the effect is written, this is called the problem statement. The causes of this problem statement are displayed and categorized. The categories are displayed by a blue font. The highlighted causes are the most important ones from patient perspective.

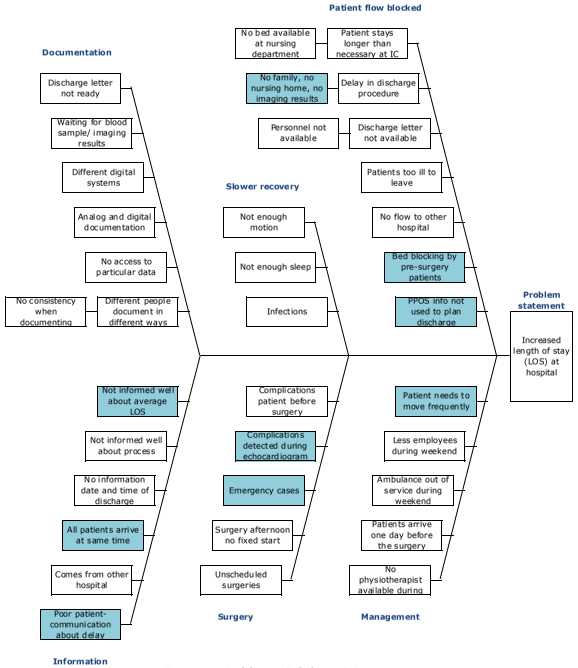


Figure 2 - Fishbone (Ishikawa) Diagram

By eliminating the pre-surgery day more beds become available for post-surgery patients. Furthermore one step of the process can be eliminated, which results in a decrease of LOS and moving less often. To eliminate the pre-surgery day a few requirements have to be met.

Requirements to eliminate the pre-surgery day

1. Patients come to the hospital to receive information about upcoming surgery and procedure during poly-clinical pre-operative screening (PPOS). Before this meeting they already received information by mail.
2. Blood samples needs to be taken a few days before the surgery.
3. An electrocardiogram (ECG) needs to be taken. For clinical patients this needs to be <1 week, for poly-clinical patient <6 weeks before surgery. [1]
4. A lung image needs to be taken.
5. Coronary Artery Bypass Grafting (CABG) patients need to apply the nose salve "Bactroban" every four hours until one hour before surgery. [1]
6. CABG patients need to shower using Hibiscrub on the evening before the surgery.
7. Patients need to take sleep medication.
8. The patient needs to be brought to the hospital on the day of surgery.
9. The date and time of surgery have to be known by the patient.
10. Patients have to stop eating about six hours before the surgery.
11. Pre-surgery shake should be consumed.

Moving frequently

The day before the surgery patients arrive with their luggage for the next couple of days. The average surgery patient only stays one night in this room, because after the surgery the patient goes to the Intensive Care (IC). Patients should not bring valuable stuff and should not empty their bags if not necessary. Patients should be informed about the procedure and the process flow which includes moving frequently as shown in *Figure 3*.

Figure 3 - Departments average patient

In emergency cases a patient enters the hospital via the CFAU. If a surgery is necessary the departments a patient visits are displayed in *Figure 4*.

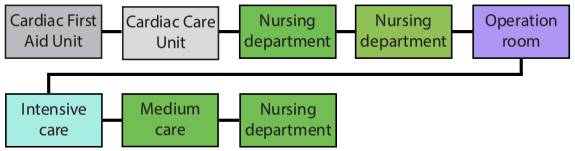


Figure 4 - Departments exception case

Bed capacity

The A2 department contains 27 beds. 16 of them are reserved for cardiology patients, the other 11 beds are for thoracic surgery patients. The D2 department also consists of beds for post-surgery patients. *Figure 5* shows the distribution of beds. The number of beds at the IC depends on the day of the week. Usually the IC has 12 beds, but only ten of them are used.

Department	Number of beds
Number of beds A2	27
Pre-surgery	6
Post-surgery	5
Cardiology	16
Number of beds D2	16
Post-surgery	12
Medium Care	4
Number of beds EHH	7
Number of beds CCU	9
Number of beds E2	33
Number of beds IC	12*

Figure 5 - Bed capacity

Patients that do not need the special care provided at the IC are brought to the A2 or D2 (MC) department. On Saturday morning the IC goes back from 10 beds to 8 beds because of personnel reduction during the weekend. If there are no beds available at the nursing departments the healthiest patients at the nursing department receive a discharge letter.

Conclusion

Patients should not only be discharged when the IC reduces the number of beds or the nursing department needs extra beds. Discharging patients needs to be a continue process. Eliminating the pre-surgery day for patients that do not need to be taken in one day before the surgery, results in more post-surgery beds. This might also prevent the employees from moving patients too early and probably increases patient safety.

References

[1] Protocol, CABG, pré- en postoperatieve zorg, Verpleegafdeling Thoraxchirurgie/Medium Care, Version 1.0, 18-10-2011

Improved communication with thoracic surgery patients

By Nathalie Bekkering - version 1
1st of June 2015

Background
Some thoracic surgery patients enter the hospital via the Cardiac First Aid Unit (CFAU), others are scheduled for a poly-clinical screening before they get diagnosed with something that needs to be treated by surgery. The information these patients receive depends on the way they enter the hospital.

Patients who are scheduled for the surgery and come to the hospital from their home receive information by mail. Patients who are sent to the hospital by another hospital receive next to the letter information from their cardiologist. Patients who are scheduled for surgery on a Monday receive additional information during a poly-clinical consult. This results in patients that all received and provided information differently. However, all patients need to be at the hospital at least one day before their surgery.

1. Improve the communication between hospital and patient
2. Eliminate the unnecessary hours spent at the hospital
2. Create space at the nursing department for patients that need care

The system
The Thoracic Centre Twente (TCT) is a complex system that consists of the following subsystems: nursing department A2, nursing department D2, operation room (OR), intensive care (IC) and polyclinic 18. Other departments like the Cardiac First Aid Unit (CFAU), the Cardiac Care Unit (CCU) and their follow up nursing department E2, are more related to cardiology but also part of the TCT.

The patient and the environment have to interact with this system. In this case the patient is a thoracic surgery patient. The environment contains several aspects, for example nursing homes, ambulance service, other hospitals or home of the patient. Furthermore the environment can also be another medical specialty of the hospital.

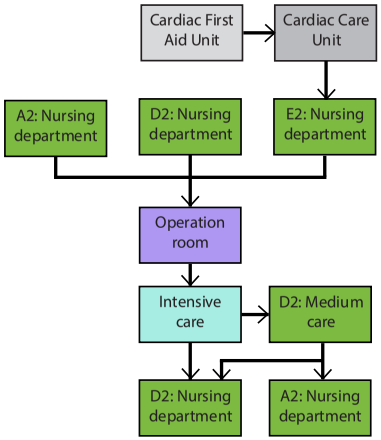


Figure 1 - Possible trajects through departments

Being transported frequently
The day before the surgery, the patient usually arrives with his luggage for the next couple of days at the nursing department. The average surgery patient only stays one night in this room, because after the surgery the patient goes to the Intensive Care (IC). Therefore you should not bring valuable stuff and should not empty your bags if not necessary. Patients should be informed about the procedure and the process flow which includes being transported frequently as shown in *Figure 1*.

Bed capacity
The A2 department contains 27 beds. 16 of them are reserved for cardiology patients, the other 11 beds are for thoracic surgery patients. The D2 department also consists of beds for post-surgery patients. *Figure 2* shows the distribution of beds.

Department	Number of beds
Number of beds A2	27
Pre-surgery	6
Post-surgery	5
Cardiology	16
Number of beds D2	16
Post-surgery	12
Medium Care	4
Number of beds EHH	7
Number of beds CCU	9
Number of beds E2	33
Number of beds IC	12*

Figure 2 - Bed capacity

The number of beds at the IC depends on the day of the week. The IC has 12 beds, but only ten of them are used. Patients that do not need the special care provided at the IC are brought to the A2 or D2 (MC) department. On Saturday morning the IC goes back from 10 beds to 8 beds because of personnel reduction during the weekend. If there are no beds available at the nursing departments the healthiest patients at the nursing department receive a discharge letter. Eliminating the pre-surgery day where possible would probably reduce the pressure on these nursing beds.

Needs of a patient
For the surgery-team to work as efficient as possible no gaps in the schedule should occur. If a surgery has to be cancelled the next patient should be available to fill this gap. The surgeons prefer office hours and therefore the first surgery starts at 7:45. The patient scheduled for the first surgery has to be in the hospital the day before but the patients scheduled for the second surgery could arrive in the morning, several hours before the surgery.

By eliminating the pre-surgery day more beds become available for post-surgery patients. Furthermore one step of the process can be eliminated, which results in a decrease of length of stay and being transported less often. To eliminate the pre surgey day a few requirements have to be met. If one or more of these requirements cannot be met, the patient should arrive the day before surgery.

Requirements to eliminate the pre-surgery day
1. Patients come to the hospital to receive information about upcoming surgery and procedure during poly-clinical pre-operative screening (PPOS). Before this meeting they already received information by mail.
2. Blood samples needs to be taken a few days before the surgery.
3. An electrocardiogram (ECG) needs to be taken. For clinical patients this needs to be <1 week before surgery, for poly-clinical patients <6 weeks before surgery. [1]
4. A lung image needs to be taken.
5. Coronary Artery Bypass Grafting (CABG) patients need to apply the nose salve "Bactroban" every four hours until one hour before surgery. [1]
6. CABG patients need to shower using Hibiscrub on the evening before the surgery.
7. Patients need to take sleep medication.
8. The patient needs to be brought to the hospital on the day of surgery.
9. The date and time of surgery have to be known by the patient.
10. Patients have to stop eating about six hours before the surgery.
11. Pre-surgery shake should be consumed.

Procedure in general
1. Cardiac surgery procedures last from three to six hours on average. Your family members will be informed during and/or after the surgery.
2. The average length of stay at the hospital after heart surgery is four to five days. The first night after surgery will be at the IC. Usually you are transported to one of the nursing departments A2 or D2 the next day.
3. You will need a lot of help for at least 10 days after surgery. The first days you will be inside the hospital but after discharge you need someone to help you at home. Inform the hospital about the care that could be provided at home by family members or caregivers and what you will probably need when you get back home. The hospital might be able to organise this for you during your stay.
4. You need help for about four to six weeks after surgery with tasks like lifting, driving and house holding.

During the intake procedure the information about care and assistance needed at home has been collected. It is important to receive information about your discharge date as early as possible so that you are prepared for leaving. Family members should be informed to be able to pick you up and/or nursing homes should be prepared for an intake procedure. Transportation has to be organised if needed.

Conclusion
Informing patients about the average length of stay before the surgery and collecting and information about the assistance needed at home improves the patient flow. It is important that the hospital uses the collected information and takes action if necessary.

Patients should not only be discharged when the IC reduces the number of beds or the nursing department needs extra beds. Discharging patients needs to be a continue process. Eliminating the pre-surgery day for patients that do not need to be taken in one day before the surgery, results in more post-surgery beds. This might also prevent the employees from moving patients too early and probably increases patient safety. Furthermore communication between patient and hospital needs to be optimal. Communication between nurses and the teams who organise discharge and transport has to be improved.

References
[1] Protocol, CABG, pré- en postoperatieve zorg, Verpleegafdeling Thoraxchirurgie/Medium Care, Version 1.0, 18-10-2011

8.2 Scenario

Since the A3AO did not work as a tool when asking patient for their opinion, a description of the following scenario was used:

Mr. van Beek has heart complaints and goes to the GP. Further action needs to be taken so an appointment with the cardiologist is made. The cardiologist of the hospital in Winterswijk decides that a heart catheterization needs to be done to see what causes the complaints. It turns out that the arteries of Mr. van Beek are narrowed at many locations and at the beginning of important arteries. The cardiologist concludes that a surgery is necessary. This heart surgery cannot be done in the small hospital in Winterswijk but Mr. van Beek needs to go to the hospital in Enschede. During a heart team conference a team of cardiologists and surgeons of the MST discuss if Mr. van Beek will be scheduled for surgery. After a few days the cardiologist of Winterswijk contacts the patient and informs him about the upcoming surgery. A few days later Mr. van Beek receives a letter. The surgery and a screening are scheduled.

On Thursday Mr. van Beek and his wife arrive at the MST. At policlinic 18 the upcoming by-pass surgery is discussed with several parties. To begin with, all patients watch a movie about the process. After that the patient has several short talks. During the day he has a talk with the pharmacy specialist, nurse, nurse practitioner, anaesthetist and surgeon he is informed well about the procedure. After that blood samples are taken and a lung image is made.

On Sunday evening Mr. van Beek arrives at the hospital. The nurse picks up the patient at the front desk and guides the patient to his room. With his wife on his side they go through the intake procedure. The nurse asks questions and blood pressure is measured. The surgery will start at 7:45 the next morning.

After the intake procedure Mrs. Van Beek leaves. Mr. van Beek is placed in a room with three other patients that are scheduled for surgery the next day. Two of them are from another hospital. They are already at the hospital for several hours. Mr. Klemm (53) experienced the past hours as unnecessary, while Mrs. Jansen (67) experienced the past hours as comforting.