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Input data management in health care simulation

Industrial methodology for discrete event simulation applied in a health care system

Master of Science Thesis in the Master Degree Programme, Systems, Control and Mechatronics

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Reproservice, Chalmers
Gothenburg, Sweden 2012

Abstract

In 2010 the Swedish government introduced a health care reform called Vårdvalet. This lead to a higher level of competition between different health care centres and their desire to be more effective increased. In industry, DES-simulation is often used to investigate how different changes affect a system, to get the best improvements to system performance for the lowest cost. This method for modelling flows is now becoming more common in the health care sector. Input data management is the most time consuming part of a DES-project, so if it can be reduced the total time and cost for DES-projects decrease. Due to this, an input data management methodology, originally developed for industrial use, will be evaluated in a health care context in a case study at Sörhaga health care centre in Alingsås. The evaluation will investigate how well the methodology works in DES-projects for health care systems and what modifications it might need to be more suitable for such projects.

Sörhaga health care centre experiences problems with their waiting room, which gets crowded during their emergency reception, also called triage reception. Another problem with the triage is that it usually does not end when planned, which puts a lot of pressure on the personnel who sometimes have to skip their lunch or work overtime to catch up.

From the simulation model of Sörhaga health care centre it was seen that the physicians and the district nurses working during the triage are alternating bottlenecks. Several concepts were then developed to try to cope with this problem. The concepts were analysed and four concepts, two including minor changes and two including more extensive changes, were recommended to the health care centre. The health care centre should chose one of the more extensive changes but both of the two minor changes should be implemented.

The evaluation of the input data management methodology showed that the methodology is suitable for DES project in health care systems. It is believed that by using this methodology can the total time consumption for DES project in health care be reduced and that this will lead to that simulation will become a greater option for optimising patient flows. This will in turn result in more effective health care systems with less waiting times and thus shorten the course of the diseases which in the long run will give a healthier population.

Foreword

This report is the result of our master thesis performed at the Department of Product and Production Development at Chalmers University of Technology during the spring of 2012. The project has been performed in cooperation with Sörhaga health care centre in Alingsås and ÅF AB.

We want to thank Catharina Persson along with all the other personnel at Sörhaga health care centre for helping us with such enthusiasm. We also want to thank our two supervisors Anders Skoogh at Chalmers and Nils Bengtsson at ÅF AB. Thanks also to those at ÅF who have helped us with DES modelling tips. Finally Floda health care centre deserves thanks for having us and showing us how they work.

Gothenburg, June 2012:

Sofia Holmblad and Malin Ivarsson

Table of Contents

1 Introduction

In 2009 the Swedish government decided to introduce the health care reform [Vårdvalet], which means that from 2010 is every person allowed to choose what district health care centre they want to be listed at (Sveriges riksdag, 2009). This puts more pressure on the health care centres to meet patients' expectations to be highly competitive as more patients yield more money from the county council (Socialstyrelsen, 2010). To stay competitive patients should be received and taken care of as quickly as possible, which means that queues and lead times have to be reduced. Even though some money is received for each patient are the health care centres' resources, such as personnel and premises, limited and still have to suffice for a possible increase in number of patients.

The health care centre in this study, Sörhaga health care centre in Alingsås, has attracted many patients due to its good reputation. As a result the health care centre now has to admit more patients than it was originally designed for. Due to this, there is now a major problem with the waiting room, which sometimes gets so crowded that patients are sitting on the floor. Also, there are many patients and little personnel during the emergency reception, which leads to long waiting times for the patients and the personnel sometimes have to skip lunch or work overtime to catch up. This leads to both unsatisfied patients and personnel, which in turn can lead to economic losses. There is a risk of an increased amount of patients as the health care situation might change in the region. Thus, the health care centre will not only have to be able to handle the patients who are already listed but also new patients and still meet the expectations of both patients and personnel.

To deal with this, the health care centre's director wants to try an approach normally used in industry called Discrete Event Simulation (DES), which is becoming more common within the health care sector (Centre for health care management – University of British Columbia, 2011). It can provide a decision basis to improve operations management but the result from a DES simulation depends heavily on the quality of input data. The data collection phase is also the most time consuming part of a DES project (Skoogh, 2008) and can be even more time consuming if data is not collected in an organised way. Therefore, this study will examine if an input data management methodology (Skoogh, 2008), originally developed for industrial use, can be applied in the medical sector.

1.1 Purpose

The purpose is to contribute to making DES-simulation a greater option for analysing patient flows in health care by evaluating the input data management methodology by Skoogh (Skoogh, 2008). A good methodology for input data management reduces time and cost for DES-projects. Skoogh's methodology is originally designed for industrial projects and might need some modification to fit for health care projects. This methodology will therefore be applied in a case study at Sörhaga health care centre to see what such modifications might be.

The high number of listed patients at Sörhaga health care centre is causing concern as it causes crowding in the waiting room. Another concern is the stress level for the health care personnel, who feel that the situation is unsustainable. The second purpose of this project is therefore to provide the health care centre director with a decision basis, of how to take best actions to meet the high demands.

1.2 Project aim

The aim is to apply and evaluate the input data management methodology in a case study to find out how well it works for DES-projects in health care systems. Modification suggestions shall also be given which can make the methodology more suitable for health care applications.

The aim of this project is also to provide Sörhaga health care centre with a solution suggestion to their problems regarding the high demands on the personnel and crowded waiting room caused by the high amount of listed patients. The aim is that the developed concepts will handle the current amount of patient and meet the health care centre's goals.

In short terms, the following will be done for the health care centre:

- Model and analyse the current situation at the health care centre.
- Develop solution concepts.
- Model the concepts.
- Analyse and optimise the most promising concepts.
- Present the best ones to the health care centre.

1.3 Problem formulation

The general question is: Is the Input Management Methodology for DES-projects usable for DES-projects in health care systems and how can it be modified to be more suitable for health care systems?

The combination of the input data management methodology and a DES-project is applied at Sörhaga health care centre. This combination will evaluate how the triage can be organised to meet the triage goals with the current number and type of triage patients. A major part of this question is to answer: Can the current staff manage the triage or will more personnel have to be scheduled for it?

1.4 Delimitations

These are the delimitations for the DES-project:

- The health care centre takes care of several different types of patients during a day but only triage patients, afternoon emergency patients, semi-emergency patients and revisiting patients will be modelled and analysed.
- Only activities at the health care centre itself will be taken into account.
- The counsellor will not be modelled or analysed.
- The district nurses will only be analysed during the triage.
- The medical secretaries will only be modelled while they are at the reception desk.
- The time for a patient to undress and dress is the same with a district nurse as with a physician.
- All revisiting patients are scheduled for 45 minutes if they are seeing a resident physician, i.e. if only 30 minutes are scheduled in the real system it is changed to 45 minutes in the model.
- There are always two district nurses scheduled for the triage, never only one as it is in the real schedule one day.
- No regard is given to the fact that there are usually more patients at the triage during Mondays.

- All triage patients see a district nurse first.
- No wild cards will be modelled, such as patients who should have been sent to a hospital emergency ward. This sort of patients craves more time and they are rare.
- Medical aspects will not be taken into consideration.

1.5 Short description of the health care centre

At the health care centre there are four main groups of personnel: physicians, district nurses, assistant nurses and medical secretaries. When a patient calls in the morning and needs to see a district nurse or physician the same day they are booked for the triage. The district nurses, who answer the calls, assess whether a patient needs to come to the health care centre or not. If so, the patient is told to come sometime within a 30-minute span. Each patient needs to call first and have to register at the reception desk when they arrive, where a medical secretary is stationed. The patient will then have to wait until it is their time to see a district nurse, who examines them. Then the patient has to wait again, unless it is sent home, until it is called for by a nurse assistant from lab or by a physician. Either a physician or a district nurse can call for the patient after a visit to lab. The physicians can also send patients to wait for lab tests but then the physician will call for them again. All waiting is done in the same waiting room, which often becomes crowded during the triage.

1.6 Report outline

Chapter 1 – Introduction: Here the purpose, aim, problem formulation and delimitations for the project are presented. There is also a short description of the health care centre at which the case study in this project is performed.

Chapter 2 – Theory: The theory used during the project is presented here. Some theory is usually used in industrial projects and some theory specific for health care projects presented.

Chapter 3 – Method: Several methods are used during the project and they are presented here. The chapter is divided into three parts where the first part describes the input data management methodology that is evaluated in this project. The second part describes how the evaluation of the input data management methodology will be made and the third part describes how the case study is performed.

Chapter 4 – Current system: A more extensive description of how the health care centre is organised today is provided in this chapter. Also the results and analysis from the simulation model of the current system are presented here.

Chapter 5 – Improvement concepts for the health care centre: All of the improvement concepts developed for the health care centre are presented here. There are eight concepts divided into three categories depending on their characteristics.

Chapter 6 – Results: The results from the evaluation of the input data management methodology and from the model runs of the different concepts are presented in this chapter. There are also some results from model runs with the current strategy but with more personnel presented here.

Chapter 7 – Analysis: In this chapter the results from the evaluation of the input data management methodology and from the model runs are analysed.

Chapter 8 – Discussion: The results and the analysis of the input data management methodology and of the different model runs are discussed and conclusions are drawn in this chapter. The methods used during this project are also discussed here.

Chapter 9 – Conclusion: The final conclusions of this project are presented in this chapter.

2 Theory

The theory used during the project is described in the following four sections. Theories from industrial systems that can be applied in health care systems are described, namely Lean and Theory of constraints, and what needs to be considered when applying these theories in health care systems. There are also some theories that are specific for health care systems, namely what needs to be considered while performing a simulation project in health care systems and an improvement strategy specific for health care systems called Genombrott.

2.1 Lean

When talking about Lean, the expression ”Lean thinking” is often used instead of just Lean. This is because Lean is not a method that is implemented once to optimise the system but it is a work philosophy that gives a long term effect in a system (USIL, 2007)(LERC, 2007). Lean is about using current resources in a better way, creating a flexible work environment, reduce lead times, increase quality and to focus on the costumers desires (Lean Concepts AB). To successfully use Lean it has to be implemented throughout the entire organisation, everyone must be on board and engaged in the change and remember that the most important resource when working with Lean is the co-workers. Lean requires good leaders that should work to create a culture that values candidness, consensual trust, teamwork, customer focus and education. The focus within the organization should not be on results but instead on the people and the work environment. If something does not work as intended one should not try to find a scapegoat but instead see it as an opportunity to learn and correct it so it does not happen again. The leaders in the organization should be visible to the co-workers, they should listen to the co-workers and act from it, it is important that the co-workers feel attended to. It is also important that the co-workers know that their improvement suggestions will benefit them and not lead to that someone losses their job (ibid).

There are several main principles in Lean that should be kept in mind at all times (ibid):

- Focus on the costumer
- Work in a standardised way to reach stability in the system
- Each step in the process should be done with high quality
- The demand should control the workflow
- Teamwork and commitment
- Continuous improvements

Another important principle of Lean is to minimise waste by dividing time into value adding time and non-value adding time and then try to remove as much non-value adding time as possible. To make this process easier there are five steps that can be followed (LERC, 2007):

1. Specify value from a costumer perspective
2. Identify all activities in the value stream and remove non-value adding activities when possible
3. Tighten the sequence of the value adding activities
4. Let the costumer pull value from the sequence
5. Repeat step 1-4 until perfection is reached

In a typical manufacturing system, research suggests that only about 5% of all activities add value to the product, 35% are necessary non-value adding activities and 60% do not add any value at all to the product. This suggests that there is much to gain by removing the non-value adding activities (ibid).

2.1.1 Lean Healthcare

There are two main principles for Lean Healthcare (SUS, 2009):

- Focus on patient flow.
- Change the work structure to allow different work teams to improve their own way of work on a continuous basis.

To achieve this, the managers in the health care sector will have to change how they work. Their most important task has to be to work for an organization with constantly improving quality, productivity and well-being for the personnel (SUS, 2009) (USIL, 2007). Most of today's health care managers' lack the knowledge needed to carry out this change and it is therefore important to provide education (USIL, 2007).

When it comes to the patient flow it should be improved by creating work teams that include all the competence needed to treat the patient so that the patient can be treated immediately. This has proven efficient; one example is that the time to assess a woman with a lump in her breast was reduced from 42 days to 2-3 hours (ibid).

The co-workers are, off course, still the most important resource and it is they who have to impel improvements in the organization. It can be seen as co-workers in health care today have two jobs: one is to provide care to the patient and the other is to improve their way of work with respect to the patient (SUS, 2009) (USIL, 2007).

2.2 Simulation in health care

It can be rather difficult to perform simulation studies in the health care sector for several reasons, some of them being (Hakes, 1994):

- Historically there has been low motivation to control costs in the health care sector.
- Health care managers' find their current methods for decision making sufficient.
- Simulation is unfamiliar and can sometimes be seen as dehumanising, which is deterring.
- Simulation requires a high technical knowledge and it can thus be hard to understand.

In spite of this the health care sector is starting to use simulation more and more due to higher demands on cost control. Simulation is a suitable decision making tool due to its ability to handle the highly stochastic nature of disease processes and the high complexity in and between different subsystems. Still, there are several tactical issues concerning simulation in health care that need to be considered when performing a simulation project for the health care sector, namely the degree of model complexity, definitions of input distribution, model validation and interpretation of findings (Lowery, 1996).

Since it takes quite a lot of time and effort to perform a simulation project it is desirable not to spend more time than necessary on building a model. Because of this the complexity of a model should be as low as possible but still high enough to give proper answers of how to address problems in the system. It is better to first build a simpler model and then later on, if proven necessary, add complexity to the model. This can in most cases be done without wasting any time by first building the simpler model. In a health care application one example can be the patient case-mix that can give a high complexity to the model if it is divided into an unnecessary number of categories. The key is not to divide the case-mix patient into more categories than what is needed with respect to the objectives of the model. If the objective is to investigate the effect of a change in the patient case-mix with respect to different departments such as surgery or medicine than the patients should only be divided into these categories and no more (ibid).

When building the model there are several areas that might be experienced as difficult by someone used to perform simulation projects in industry. The patients might need to be given care in another order than how they arrived and are instead given a priority. A patient with a life threatening condition will have to be given priority over patients with non-life threatening conditions even though the physician already has started to treat a patient with lower priority. A similar problem can occur if an emergency operation has to be performed on a patient. The recovery room might be full and a patient from the recovery room will have to be moved to a ward to make room for the emergency patient. It might also be difficult to model a reunion of e.g. lab samples with the right patient or when a patient is leaving a room and later should return to the same room. It can also be just as difficult to model random room reservations, i.e. when any patient can be examined in any room. The use of multiple resources at the same time can also be tricky to model or when several activities are performed for one patient at the same time. Last but not least, it is important to remember that patients are not the only persons in a waiting room. Many patients bring companions who might follow the patient or stay in the waiting room during the patients visit; this should be taken into account when creating a model (Nordgren, 2012).

A health care simulation model often need input data such as arrival time for patients and the service time for different resources (e.g. physicians, nurses, rooms, beds, equipment, etc.). This data can then be represented either as a theoretical or as an empirical input distribution in the model. The advantage of an empirical distribution is that it fits the data set but has the disadvantage that the entire distribution will have to be changed while testing different values of the input data. For a theoretical distribution only the distribution parameters will have to be changed, the shape of the distribution can be assumed to remain the same, but on the other hand it might not fit the data as good. It is important to weigh these factors to each other when deciding what type of distribution that should be used. It can also be seen in the model validation if the accuracy of the input data distributions are enough, if not it is better to use an empirical distribution (Lowery, 1996).

Many clinicians and administrators still doubt the capability to simulate the high complexity and randomness in a health care system even though this is way simulation was chosen. Due to this it is important to properly validate the model and demonstrate it. Validation of a model can be done by comparing a sample of model observations to a sample of real observations given that they have the same set of input conditions. This can however be rather difficult to accomplish in a health care system because of the many rapid changes in health care today. Even though the validation of a model fails, i.e. the simulation model does not accurately model the real system, the simulation model might still be useful. Such as, if the purpose for building the simulation model was to compare different alternatives to each other and not to give absolute answers of how the system will behave when implemented (ibid).

Once the model is validated different experiments can be performed to provide answers to the desired questions. There are however some common misunderstandings when clinicians and health care managers review the results from the model. First, they often want the model to provide a single answer of how to optimise the system, which a simulation model does not give. Instead it gives answers to “what if” questions, which require a lot of time and effort to review, and gives more information about how different input parameters affect each other. Secondly, they often think that the simulation model can predict the future, i.e. predict how the input parameters will change in the future, which is not possible to do with the model either. What is possible though is to do a sensitivity analysis of the input parameters to provide information about how much a change of a variable affects the system and this can be used while deciding what parameters that should be given extra attention. To avoid misunderstandings it is important to explain early in the simulation project what a simulation can and cannot do. A simulation project can also help the decision making process in other ways then just by the results from the model. It allows all the persons involved in the project to understand how the whole system works and therefore prevents disagreements over assumptions that do not correspond to how the system actually works. Due to this it is not always necessary to perform a full-scale simulation project but it can be enough to only do some steps (ibid).

Factors commonly used to measure performance of a health care system are utility for different resources like personnel, rooms, equipment and machines (Brenner, 2010). Other measures are patients’ total time, also called throughput time, and number of waiting patients in queues (Thorwarth, 2009). Performance can in some cases be calculated into costs, where different events can increase or decrease money earned per patient (Swisher, 2002).

2.3 Theory of constraints

The purpose of the theory of constraints is to improve system performance through change (Dettmer, 1997). To accomplish this, three questions have to be answered:

- What to change? (What is constraining the system?)
- What to change to? (How should we change it?)
- How to cause the change? (How should it be implemented?)

When answering these questions several principles should be considered (ibid):

- Systems as Chains – A chain can never be stronger than its weakest link and nether can a system.
- Local Optima vs. System Optimum – The sum of all local optima is not the same as the whole system’s optimum. If all resources in a system are performing at its maximum capacity, the whole system is still not performing as good as possible.
- Cause and Effect – An event at one place in a system can cause effects in another place in the system.
- Undesirable Effects and Core Problems – Almost all issues seen in a system are not the real problems but merely the problems’ undesirable effects. It can seem like fixing an undesirable effect will solve the problem but unless the core problem is fixed there is a large risk that new undesirable effect will arise instead.
- Solution Deterioration – No matter how good a solution seems to be when implemented, it will still deteriorate over time. To maintain a good efficiency of a solution continuous

improvements are necessary. When improving a system it can have some inertia, even though a problem already has been solved once it does not mean it cannot come back.

- Physical Constraints vs. Policy Constraints – Physical constraints are often rather easy to identify and adjust but most constraints are policy constraints. Policy constraints are often complex and hard to both identify and adjust but when adjusted it generally improves the system to a much larger extent than a physical constraint.
- Ideas are not solutions – An idea cannot solve any problems unless it is implemented.

To make the process of continuous improvement easier and to get a positive effect in the system performance from every improvement five sequential steps have been developed (ibid):

1. **Identify the system constraint**
   Where is the weakest link in the system? Is it physical or is it policy?
2. **Decide how to exploit the constraint**
   How to get the most capacity out of the constraint without expensive changes?
3. **Subordinate everything else**
   Tune the rest of the system to allow the constraint to operate at its maximum capacity. Then check if the constraint still is constraining the system. If not, continue to step five otherwise go to step four.
4. **Elevate the constraint**
   Take whatever actions needed to break the constraint. This involves major changes to the system that can require large investments in money, time and energy.
5. **Go back to the first step, but watch out for inertia**
   The cycle never ends; the system always has a constraint. It can either be a completely new constraint or an already broken constraint that has reoccurred.

2.4 Improvement strategy for health care

There is a Swedish improvement strategy called Genombrott (Landstingsförbundet, 1998), which is built on a model called Breakthrough Series developed by The Institute of Health Care Improvement (IHI) in Boston, USA. The idea of this improvement model is that there is knowledge that is not administered enough within the health care today. The participants should learn what changes will lead to an improvement of the system by systematically testing small changes and document their effect on the system. There are four headstones to follow then using the Genombrott model. First is Tom Nolan's method for improvement, the Plan-Do-Study-Act cycle, see figure 2.1. Second is a structured working process, which structures both time and content of the project, that should be followed. Third is that there should be people and organizations with different experience working towards a common goal, allowing an exchange of knowledge, within the project group. The fourth and most important headstone is the pressure and will of change within the organization, which is something the manager of the organization will have to accomplish (ibid).

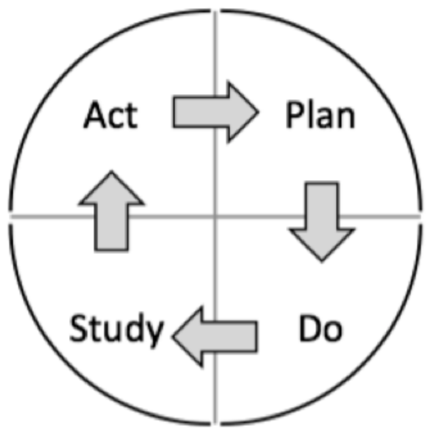

Figure 2.1: *The Plan - Do - Study - Act cycle developed by Tom Nolan which is used in the Genombrott model.*

The work towards improvement should start with establishing the goals. They should be challenging and clear to give pressure to change and to make it clear that it will not be possible to reach these goals with the current work method. By clear, it means that the goals should be numeric i.e. they should be measurable in numbers. To be able to know if a change leads to an improvement it is important to know the value of the goal variables before the change was implemented and the value after. It is also important to have some balancing measures from other parts of the organization to make sure that the change will not deteriorate something else, the problem should not be moved from one part of the organization to another. All changes that are to be tested should follow the PDSA-cycle (Plan-Do-Study-Act) they should thus first be implemented in a small scale and then be evaluated before it is decided whether they should be implemented in the whole organization or not. To get the process of change started there are several changing concepts to get ideas from. The concepts are divided into three strategies: “Match capacity to demand”, “Influence demand” and “Change the system”, and can be seen in table 2.1 (ibid).

Changing concept	Strategy		
	Match capacity to demand	**Influence demand**	**Change the system**
	Predict demand with higher accuracy	Confine material- and instrument selection	Do several work tasks in parallel
	Level off variations in demand	Watchful waiting may reduce demand	Elaborate and use care programs for common problems
	Adapt manning to predictable needs	Coordinate patient visits	Minimize the number of elements and involved persons in the process
	Identify and remove bottlenecks	Standardize, establish routines and care programs for common problems	Synchronize different instances
	Work up accumulated queue	Triage- correct evaluations and handling from the beginning	"Attract patients" instead of that previous link are "pushing patients away"
	Use existing resources flexibly	Practice knowledge based medicine	Reduce distance between different functions in the process to ease communication
	Keep alternative options of action prepared if the planning bursts	Move demand on a care service to another care instance	Automate when possible
		Preempt demand by fulfilling the need before it arises	Work up understanding for the system to make persons within the organization work towards the same goal
		Promote self-care and engage the patient more in its own care and treatment	Create more work stations, plan premises and equipment so they can be used flexibly
			Use persons with specialist knowledge to what they are good at
			Move tasks in the process that could be better executed somewhere else or by someone else

Table 2.1: *The changing concepts from Genombrott. They are divided into three different categories: Match capacity to demand, Influence demand and Change the system. The changing concepts are supposed to help to get the process of ideas of changes started.*

3 Method

There are several different approaches that could have been used to analyse the health care centre system. One such approach is queuing theory, which is fairly easy to use and can predict how well improvements will work out. However, it cannot forecast short term crowding. Another method is regression-based analysis, which major advantage is its ability to predict short term crowding and it is easy to use. A major drawback is though that it cannot be used to analyse improvements very well (Wiler, 2011). A health care centre is a complex system with many different paths for patients and every patient traveling through the system is unique. This makes it unsuitable to use a simple evaluation method such as linear analyse with an Excel spread sheet, which is more suitable for less complex systems with fewer paths. Instead agent based simulation (Siebers, 2010) can be an alternative which focuses on modelling the entities and their interactions in the system, i.e. the patients, personnel and rooms. This seems applicable since almost all entities in the system are unique but there are no textbooks, methodologies or frameworks available for this method (Siebers, 2010). Thus, it is hard to use for a novice and it was therefore not used in this project. Instead Discrete Event Simulation (DES) was used, which is a well-known method and there is a lot of available information. This simulation method focuses on modelling a system's dynamics and not so much its entities (Siebers, 2010). DES simulation is good at predicting how well improvements affect a system and can also predict short term crowding. The drawback with DES is that a lot of special knowledge is required to develop and use a model (Wiler, 2011).

A DES-project structure by Banks, from now on referred to as Banks' model (Banks, 2010), has served as the main structure of the DES-project. Banks' model has been a good support for the project as it reflects a natural way to perform a DES-project. There is another structure for DES-projects by Kelton, which is similar to Banks' model but it is not as detailed and there is no data collection step (Kelton, 2007). Banks' model does therefore give better support for this form of project. Figure 3.1 shows the relationship between Banks' model, the evaluation of the input data management methodology and the case study at the health care centre. While all steps but the last of Banks' model has been performed the focus of the case study has mainly been to model the current situation at the health care centre, analyse it, create concepts and evaluate the concepts to provide decision support for the health care centre director.

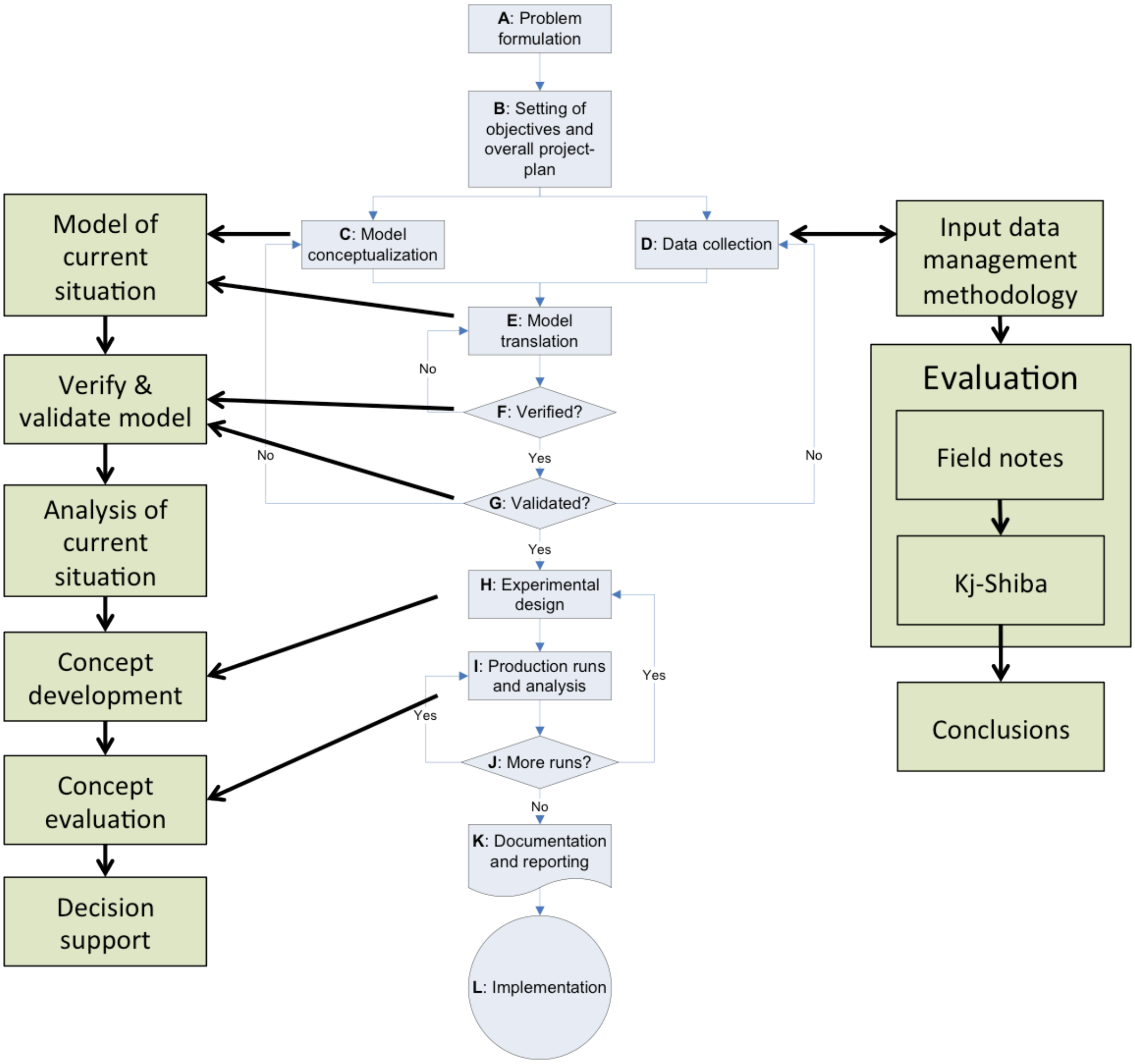

Figure 3.1: *Relationship between the different parts of the DES-project. The DES-project structure by Banks is shown in the middle in light grey boxes. To the left are the main steps of the case study and to the right is the evaluation of the input data management methodology.*

3.1 Input Data Management Methodology

The input data management is built on 13 steps and is created to assure that no important activities towards having sufficient and representative input data are forgotten. The methodology is believed to give great improvements to DES-projects, especially for project groups with little experience. This methodology is mainly aimed to DES-projects in industry and can be seen in figure 3.2, (Skoogh, 2008).

Identify and Define Relevant Parameters: In the first step the system needs to be examined in order to determine all parameters required in the model. An extensive understanding of the system is important because this task is not as simple as it might seem. The level of detail should not be greater than stated by the problem definition and what is required for the project. How parameters will be measured and used in the model also have to be defined to avoid confusion later.

Specify Accuracy Requirements: The second step includes defining how accurate the data parameters have to be. More data points gives better accuracy but to be efficient it is important to identify how important the different parameters are compared to each other. Parameters describing parts of a system that are constraining other parts are more important to focus on, as they have greater influence on the output.

Identify Available Data: Data collection is generally one of the most time consuming steps of a DES-project and a lot of time can be saved if there is previously gathered data which can be used. This step includes identification of such data, how and where it can be accessed. This should result in a list of available data and how it can be retrieved.

Choose Methods for Gathering of Not Available Data: Suitable gathering methods need to be chosen for data that is not already available. There are two types of data, the first can be collected and the second cannot be collected. The first type is the most time consuming to collect, as this type of data often requires a lot of manual work. Therefore the most common method is to manually clock the processes with a stopwatch. Some data like cycle times might be collectable from e.g. code for PLC or NC machines. This is though not possible if the system does not exist or if no data can be collected, instead estimates will have to suffice. Valid estimates can be created by discussions with system experts and machine vendors or by examining similar systems or historical data. Care should be taken when gathering data by clocking working humans due to several reasons. Workers can be influenced by knowing that someone is clocking them and cause the Hawthorne effect, i.e. they will work in another way than they usually do. Humans are also more unpredictable than a mechanised system but may still be described by statistical distributions.

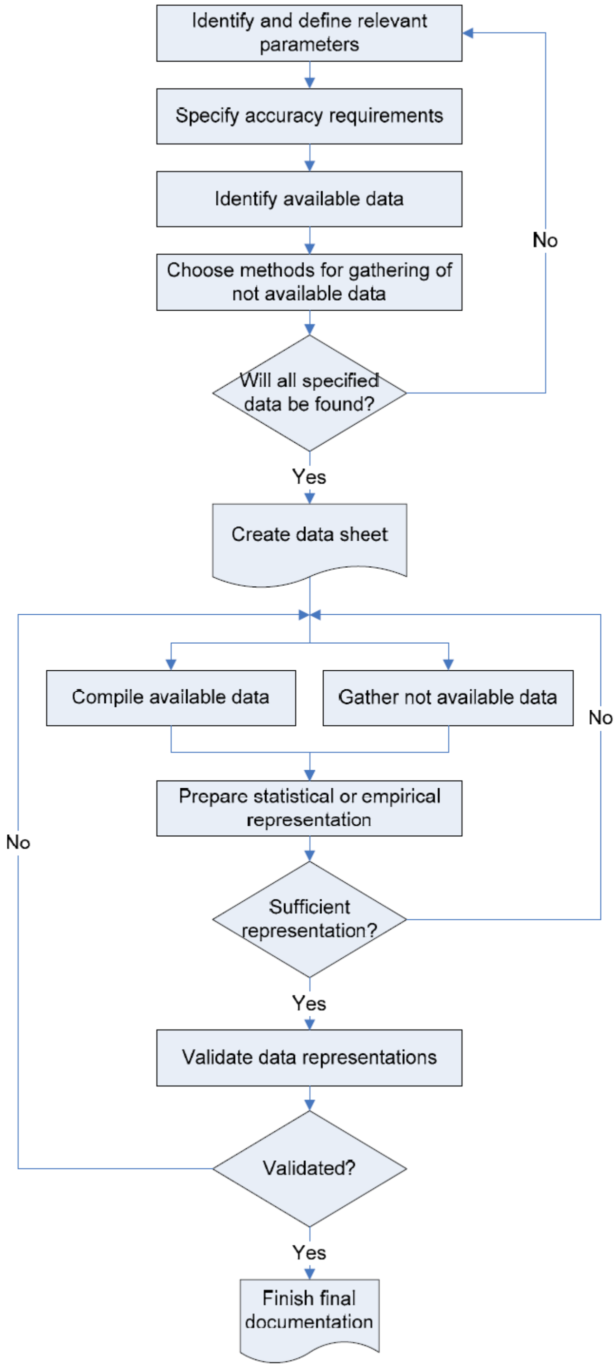

Figure 3.2: *Input data management methodology (Skoogh, 2008).*

Will All Specified Data Be Found?: If the previous steps result in that all required data can be found and at a sufficient accuracy, next step can be started. If not, the previous steps have to be re-evaluated. There is always a risk that accuracy requirements have to be re-evaluated if it later turns out that some data is not measureable after all.

Create Data Sheet: All data, both raw and analysed, should be stored in a spread sheet or database, common to all project members. No data should be stored in model interfaces or temporary data sheets. Data risk to be deleted and a lot of data analysing risk having to be redone if not stored in a specific location.

Compile Available Data: Already available data should be collected here. Some data may already be ready for validation while the rest needs to be filtered and analysed before it can be validated. If everything is in order the required amount of data points specified earlier can be extracted. Collectable data does often need to be calculated to a desired value, e.g. calculating processing times from timestamps, and filtered from faulty or non-representable data points. When this step is completed the result should be a list of data points ready for calculating a suitable representation.

Gather Not Available Data: This step aims to convert not available data into available data ready for calculating data representations. Collectable data should be collected as decided earlier in "Choose Methods for Gathering of Not Available Data" and non-collectable data should be estimated. There is a high risk that this step is the most time consuming step, especially if many parameters are not of the available data category and/or if cycle times are long as more than 200 data points are preferable.

Prepare Statistical or Empirical Representation: In this step non-constant data need to be represented in some way. There are basically four different options: statistical distributions, empirical distributions, traces or bootstrapping. While the last three can be calculated fairly easily, the first is more difficult to calculate. There are however tools like ExpertFit or Stat::Fit which can calculate and analyse statistical distributions.

Sufficient Representations?: This is a difficult step where the representations from the previous step have to be confirmed to be good enough. A goodness-of-fit test at the 0.05-level can be applied but it is hard for a representation to pass. Therefore the level can be set differently, reflecting the accuracy requirements. A graphical test can be performed between the original data and the representation to see how well the representations correspond to the data. If the representation is not sufficient the data collection and analyse will have to be complemented. If there is no way to reach the requirements, the requirements may have to be re-evaluated.

Validate Data Representations: This step is difficult and consists of validating that collection, calculations, analyses and filtering of raw data have been done correctly. This is due to that the same data is used for validation. Data can however be validated by production follow-ups, ensuring face validity and following good routines during the whole input data management. Even though this step is difficult a good data validation will minimise the risk for later iterations of previous steps. Naturally this step is more important for parameters with high accuracy requirements.

Validated?: If all data representations pass the validation checks they are now ready to use in the model. It is important to remember that data can still be the problem if a model validation fails, due to the difficulty of the previous step. Results from previous steps need to be re-examined if this step shows that some representations do not fulfil the requirements. However, this is often a result from errors in the preparation and analysis of raw data.

Finish Final Documentation: Besides from the data sheet there are other things that do not fit in a data sheet that have to be documented. These things include everything from assumptions during data collection, definitions of data, how data was validated and results from validation steps. The data sheet should be as good as complete by now as documentation should be written during all steps of the methodology. This step therefore results in a complete data sheet and a data report that should end up in the simulation project documentation.

3.2 Evaluation of input data management methodology

The input data management methodology by Anders Skoogh has been applied for all input data for a simulation model of the health care centre. Field notes have been used during the implementation to capture different aspects of the methodology. Field notes can, according to Mulhall, be used to record all sorts of impressions during a field study. Notes can range from how people behave, activities, processes and dialogues to special events, building layouts and personal reflections (Mulhall, 2003). Field notes have in this study been used to capture thoughts and aspects that have arisen during the implementation. Some thoughts have arisen during the implementation while others have arisen afterwards when the bigger picture is more distinguishable. Using field notes makes it easier to capture brief passing thoughts. Another method that could have been used is memoing. However, a memo is usually more extensive than a field note and it is harder to find time to write them. Originally, some unstructured interviews were planned but capturing dialogues with field notes resulted in sufficient information such that no unstructured interviews were needed. This also worked well for capturing information about the health care centre organisation.

In order to analyse the field notes has inspiration been taken from a method called KJ-Shiba (Ulrich, 2003). It is a method designed to analyse and understand problems and consists of several steps, how many varies with each version of the method. With the KJ-Shiba method, facts about a problem are written on self-sticking notes. All notes are grouped, those groups are then in turn named with headers, which are grouped and voted on so that the most important headers stand out. Major conclusions can then be drawn from the important headers. For this study, step four to seven, marked with green in figure 3.3, have been used. The field notes have served as input to step four instead of facts about a problem from step three. This method is far less ceremonious than performing a grounded analysis which would be all too time consuming. Due to previous knowledge of the methodology it would also not be possible to perform a correct analysis with grounded theory

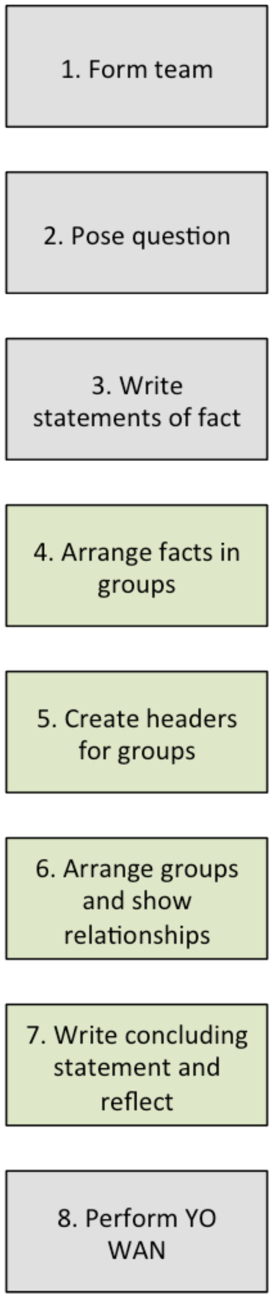

Figure 3.3: *The eight steps from the used version of the KJ-Shiba method.*

(Gelling, 2011). The KJ-Shiba method has the drawback however that important details might get lost in the process as it generalises a lot. At the same can this be an advantage; it reduces the risk of being drowned with details.

3.3 Improvement of the health care central

The health care centre was simulated with a discrete event simulation model and almost all data for it was gathered manually by clocking. The resulting model was verified and validated graphically, with output data and by health care centre personnel. Simulated concepts were then compared to the model of the current situation and to each other.

3.3.1 Discrete Event Simulation

It is most common to simulate industry processes with DES-simulation. One way to model systems with this method is to model products as loads. Logic code is written to build the model and a row is executed when a load reaches it. That is, each load runs through the code and depending on what load type and attributes carried by the load, each load will run different paths in the code. A load can be told to wait for other events or move into queues. Machines and other resources, like personnel, are modelled as so called resources. A load can use resources and make them unavailable to other loads, which then have to wait. Patients can be modelled as loads while personnel, rooms and equipment can be modelled as resources in a model of a health care application. Some problems arise when a health care system is going to be modelled in this way that seldom arises in an industrial case.

The software that has been used to create the simulation model is called Automod and it was chosen due to the fact that it is ”load driven” simulation software. This was suitable in this specific application since the patients can be modelled as loads. Also, two of Automod's strengths are detailed models and operational decision support which both are important in this application.

3.3.2 Input data management

All input data regarding times have been collected manually with stopwatches by following staff members while they were working during three weeks. Times have been clocked from the physicians, the district nurses, in the lab from assistant nurses and from the reception desk. Statistics of how many patients that need to undress etc. have been deduced from the time measurement data, while statistics of paths patients follow through the system have been taken from patient journals. The schedule planner could provide personnel schedules but the number of patients in the waiting room had to be counted manually each 15 minutes. Note that all data were not meant as input to the model but as validation data in order to validate the model. Table 3.1 and 3.2 show how different input data were collected along with their definitions and number of collected data points. The number of desired data points is calculated with respect to the available time for data collection, how many that can be gathered per day, how important the parameter is and how large the variation of the parameter is. In an ideal case this number would be higher. The input data were then calculated with ExpertFit into statistical distributions. Quality of the distributions was checked with ExpertFit's assessments of the distributions and by comparing original data with the distributions graphically.

Collected input data							
Data	**Gathered from**	**Gathered by**	**Definition (starts)**	**Definition (stops)**	**Patient type**	**Nr of data points**	**Desired nr of data points**
Preparation time	Physicians	Clocking	Physician chooses a patient	Physician leaves its room	Triage	43	20-30
To waiting room	Physicians/district nurses	Clocking	Physician leaves room	Physican will call patient's name	All	127	40-50
Back to physician's room	Physicians/district nurses	Clocking	Physician calls patient's name	Patient walks into the room	All	147	40-50
Patient takes off outerwear	Physicians/district nurses	Clocking	Patient enters room	Patient sits down	All	147	40-50
Patient time	Physicians	Clocking	Patient sits down	Patient rises to leave	Triage	47	40-50
Patient time	Physicians	Clocking	Patient sits down	Patient rises to leave	Afternoon emergency	20	40-50
Patient time	Physicians	Clocking	Patient sits down	Patient rises to leave	Semi-emergency	23	40-50
Patient time	Physicians	Clocking	Patient sits down	Patient rises to leave	Revisiting	21	40-50
Patient undresses	Physicians/district nurses	Clocking	Patient is asked to undress	Physician starts to examine	Triage/afternoon emergency	18	40-50
Patient undresses	Physicians/district nurses	Clocking	Patient is asked to undress	Physician starts to examine	Semi-emergency/revisiting	20	40-50
Patient dresses	Physicians/district nurses	Clocking	Patient reaches for clothes	Patient sits down or heads for outerwear	Triage/afternoon emergency	13	40-50
Patient dresses	Physicians/district nurses	Clocking	Patient reaches for clothes	Patient sits down or heads for outerwear	Semi-emergency/revisiting	17	40-50
Patient takes on outerwear	Physicians/district nurses	Clocking	Patient rises and heads for outerwear	Patient leaves room	All	155	40-50
Administration time	Physicians	Clocking	Patient leaves room	Physician starts doing things not connected to the last patient	Triage	46	20-30
Administration time	Physicians	Clocking	Patient leaves room	Physician starts doing things not connected to the last patient	Afternoon emergency	20	20-30
Administration time	Physicians	Clocking	Patient leaves room	Physician starts doing things not connected to the last patient	Semi-emergency	23	20-30
Administration time	Physicians	Clocking	Patient leaves room	Physician starts doing things not connected to the last patient	Revisiting	20	20-30
Preparation time	District nurses	Clocking	District nurse chooses a patient	District nurse leaves its room	Triage	53	20-30
Patient time	District nurses	Clocking	Patient sits down	Patient rises to leave	Triage	55	40-50
Administration time	District nurses	Clocking	Patient leaves room	District nurse starts doing things not connected to the last patient	Triage	50	20-30

Table 3.1: *Data sheet over gathered data, where the gathered data comes from, how it is gathered, its definition and from what patient type. The number of desired data is calculated with respect to the available time for data collection. Important data has a desired number of data points of 40-50, less crucial data only requires 20-30.*

Collected input data, continued							
Data	**Gathered from**	**Gathered by**	**Definition (starts)**	**Definition (stops)**	**Patient type**	**Nr of data points**	**Desired nr of data points**
Preparation time	Lab (assistant nurses)	Clocking	Assistant nurse chooses a patient	District nurse leaves leaves the lab	All	36	20-30
Fetching patient	Lab (assistant nurses)	Clocking	Assistant nurse leaves the lab	Patient enters the lab	All	35	20-30
Testing time	Lab (assistant nurses)	Clocking	Patient enters the lab	Patient leaves the lab	All	38	40-50
Administration time	Lab (assistant nurses)	Clocking	Patient leaves the lab	Assistant nurse starts doing things not connected to the last patient	All	37	20-30
Attending time	Reception (medical secretary)	Clocking	A patient takes a queuing ticket to the reception desk	Secretary calls for next queuing number	All	53	20-30
Response time	Reception (medical secretary)	Clocking	Secretary calls for next queuing number	Patient arrives at the reception desk	All	135	20-30
Registration time	Reception (medical secretary)	Clocking	Patient arrives at the reception desk	Patient leaves the receptiondesk	All	77	20-30
Registration and paying time	Reception (medical secretary)	Clocking	Patient arrives at the reception desk	Patient leaves the receptiondesk	All	33	20-30
Paying time	Reception (medical secretary)	Clocking	Patient arrives at the reception desk	Patient leaves the receptiondesk	Triage	17	20-30
Administration time	Reception (medical secretary)	Clocking	Patient leaves the reception desk	Secretary starts doing something not connected with the last patient	All	41	20-30
Number of patients in waiting room	Waiting room	Available data	-	-	All	6 days	Every 15 min 10 days
Patient paths	Patient journals	Available data	-	-	Triage	50	40-50
Patient paths	Patient journals	Available data	-	-	Afternoon emergency	20	20-30
Patient paths	Patient journals	Available data	-	-	Semi-emergency	20	20-30
Patient paths	Patient journals	Available data	-	-	Revisiting	21	20-30
Chance for d. Nurse to ask for advice	District nurses	District nurse	District nurse asks for advice from a physician	-	Triage	65	20-30
Chance for patient to be sent home	District nurses	Available data	District nurse is adviced to send the patient home	-	Triage	10	20-30
Number of patients at the triage	Journal system	Available data	Number of patients at the triage each day	-	Triage	20	20-30
Number of afternoon emergency patients	Journal system	Available data	Number of afternoon emergency patients each day	-	Afternoon emergency	20	20-30
Share of paying patients	Journal system	Available data	The percentage of patients who have to pay	For each of the four patient types	All	20	20-30
Patient arrival times	Reception	Observing	A patient has arrived when it takes a queuing ticket to lab		All (triage separately)	44	40-50

Table 3.2: *Data sheet over gathered data, continued, where the gathered data comes from, how it is gathered, its definition and from what patient type. The number of desired data is calculated with respect to the available time for data collection. Important data has a desired number of data points of 40-50, less crucial data only requires 20-30.*

3.3.3 Verification and validation of models

The model of the health care centre has been verified by analysing output data. When an output data point has been unreasonably far away from other data, the source of this data has been tracked down and corrected. The model has also been verified graphically. The validation has been conducted by comparing output data with data from the real system. The health care centre's director has also been introduced to the model and agreed to that it works as intended and that the output data are reasonable.

3.3.4 Triage goals and evaluation of concepts

The health care centre has four goals for the triage, which should be reached all average days, i.e. when no special event occurs. Such a special event could be the arrival of a patient who requires a lot more effort and maybe ought to have been sent to a hospital emergency ward instead.

- The triage should end at 12:30, i.e. the last triage patient should not leave later than 12:30.
- There should be no need for a triage back-up.
- Ideally there should be no more than 10 patients in the waiting room at the same time, but the absolute maximum is 15 patients in the waiting room at the same time.
- The triage should be handled with the same manning as today, i.e. two physicians and two district nurses.

The goals have been given different priorities with respect to the health care centre's needs and preferences. The highest prioritised goals are that the triage should end at 12:30, together with the no need for triage back-up goal. After these two is the number of patients in the waiting room goal. The lowest prioritised goal is that the other goals should be reached with the same manning as today.

Along with these goals, the throughput time for patients and utility of physicians and district nurses have been analysed, i.e. the following parameters have been analysed:

- When the last triage patient leaves.
- How many triage patients the triage back-up physician handles.
- How many patients there are in the waiting room.
- Utility for physicians and district nurses.
- Patient throughput time.

The concept evaluation has been inspired by systematic construction (Olsson, 1976) and three different methods have been used. First a method called rating criteria method (ibid) was used to evaluate how well the concepts fulfil the triage goals. The fulfilment of each goal have been marked with yes, no or almost for all concepts and the priorities of the goals have been taken into account. To complement this analysis, two methods based on comments have been used. First out was a motivation method (ibid) where arguments are given to why a concept have been or have not been chosen. Here the throughput time and the utility have been taken into account. Secondly, an advantage/disadvantage method (ibid) has been used to take other aspects, such as social aspects, into account.

4 Current system

Here is a description of how the health care centre is organised today with schedule, personnel, building layout and patients. There are also simulation results and analysis of the current situation here together with comments and opinions from the personnel.

4.1 Description

The current organisation at the health care centre, only parts included in the model are described thoroughly.

4.1.1 Schedule

Every day there is a triage reception, which is a way to categorise patients depending on how crucial their injuries or illnesses are. At Sörhaga, a simplified form of triage is implemented by having district nurses assess whether a patient has to see a physician or not. The triage begins at 9:45 and was originally planned to always end at 12:00. Nowadays it is unofficially accepted that it should end at 12:30. That is, the last patient should leave at 12:30. Two district nurses starts the triage at 9:45 and two physicians (three on Mondays) starts working at the triage at 10:00. There is a triage back-up scheduled from 12:30 – 13:00 but this physician often has to stay longer than 13:00 as there are still triage patients who have not seen a physician yet. This happens even as the two ordinary triage physicians helps the back-up by continuing past 12:30 if there are too many patients left. The afternoon emergency visits are taken care of between 15:00 and 16:00 and each visit are planned to take either 15 or 30 minutes. All other types of visits to physicians can be booked anytime during office hours depending on each physician's personal schedule. The lab has booked appointments during the day except between 10:00 to 12:00. Those visits are booked in the sense that the lab knows they will come but the patients still has to pick a queue ticket for lab when they have been registered. All district nurses take phone calls until 9:30 every day but after this they can have patient visits any time during office hours, unless they are scheduled for the triage, depending on each district nurse's schedule. There is always at least one district nurse scheduled to take phone calls during the day. A medical secretary always keeps the reception desk open from 7:45 to 16:45.

4.1.2 Personnel

The health care centre has in total ten employed physicians, six of them are general practitioners while the rest are resident physicians. There are also eight district nurses, four assistant nurses and four medical secretaries. The physicians have five main activities: administration, triage, semi-emergency visits, return visits and afternoon emergency visits. There are also other activities like geriatric care located elsewhere etc. The administration activity includes everything that is not related to a patient coming soon or that has just left, like calling patients, managing prescriptions, approving dictate transcriptions and more. District nurses' tasks include among other tasks; answering phone calls, especially in the mornings, triage, bandaging and measuring blood pressure. Assistant nurses are responsible for the lab, all tests and analyses. They should also refill materiel in all rooms once a week and help physicians and district nurses when they need assistance. The medical secretaries are responsible for transcribing dictates from physicians, the reception desk, scanning mail, billing patients and more. The secretary responsible for the reception desk transcribes dictates when there is no patient at the reception desk.

4.1.3 Building layout

The health care centre building is a part of a larger building and is connected to a hospital. There are in total 16 examination/administration rooms, physicians occupy ten, district nurses occupy six

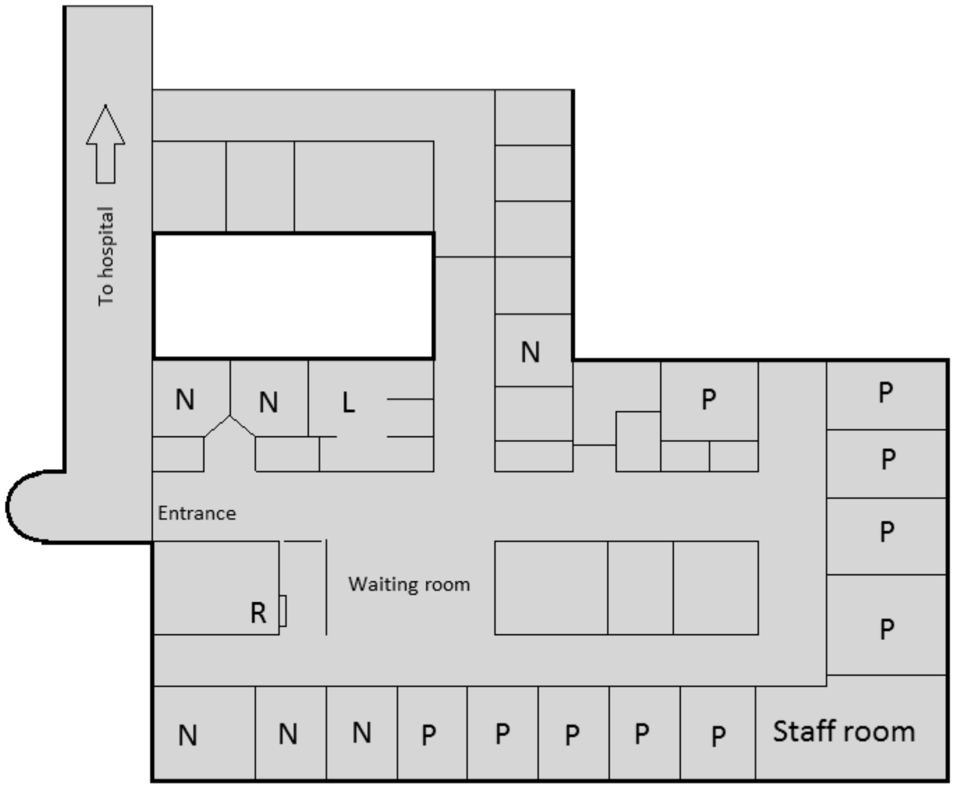

Figure 4.1: *Layout of the health care centre. P marks physicians' rooms, N are district nurses' rooms, R is the reception desk and L marks the lab.*

rooms. Each physician does therefore have a room of their own room, as do most of the district nurses. The lab room can manage three patients at the same time. Figure 4.1 shows a simplified layout of the health care centre, physicians' rooms are marked with a P, district nurses' rooms with an N, the lab with L and the reception is marked with an R.

The waiting room originally had seats for nine patients but as the waiting room gets crowded during the triage a number of chairs have been placed there. Today there are about 13-15 extra seats with the additional chairs, resulting in a total of around 25 seats. All of those seats are not used however, the original nine seats are three three-person sofas but there are mostly only two persons sitting in each sofa. The highest number of patients in the waiting room has been counted to 25 and since many patients bring relatives everyone will not get a seat. However, this has only been counted during one week. It has been estimated afterwards that at least 30-40 % of the patients have a relative or a friend with them. During the worst crowding some patients sit on the floor, as there are no seats for them.

4.1.4 Patients

There are several different types of patients coming to the health care centre. The district nurses have their own clinics and these patients can be sent to lab after the visit. The triage is meant to handle at most 28 patients, but it is not uncommon to have 30. There can even be up to 33 patients a day at the triage. Physicians have appointments with triage patients, revisiting patients, semi-emergency patients, and afternoon emergency patients:

Triage patients have called to the health care centre in the morning the same day. They are told to come within a 30-minute time span but are not given a time booked visit. When they arrive at the health care centre they are placed in a queue for each examination they are sent to during the visit at the health care centre. This means there is a risk that they will have to wait for a long time if many patients arrive at the same time. There are several different paths a patient can take through the system:

1: Register – District nurse – Pay
2: Register – District nurse – Lab – District nurse – Pay
3: Register – District nurse – Lab – District nurse – Physician – Pay
4: Register – District nurse – Lab – Physician – Pay
5: Register – District nurse – Lab – Physician – Lab – Pay
6: Register – District nurse – Lab – Physician – Lab – Physician – Pay
7: Register – District nurse – Physician – Pay
8: Register – District nurse – Physician – Lab – Pay
9: Register – District nurse – Physician – Lab – Physician – Pay

If the patient has to pay she has to do it afterwards, as the personnel cannot say beforehand if a patient will see a physician or not. There are patients who forget to pay but they get a bill sent home instead. The paths above can be visualised as in figure 4.2 but the data collection showed that no patient follows path 6. Triage patients are booked for lab by the district nurse or physician when they are sent there: Except what type of samples they want they also have to put them on a waiting list to lab, special to the triage patients. Thus, the triage patients do not need to pick a queue ticket like all other patients.

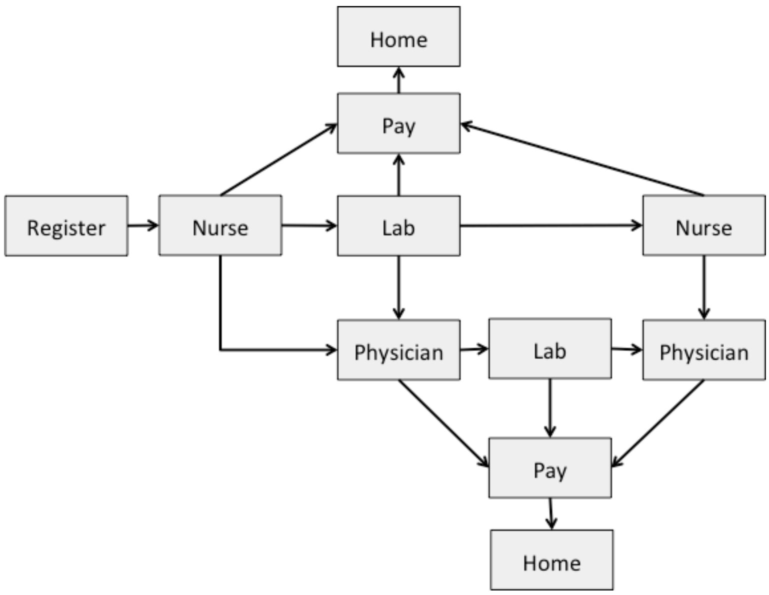

Figure 4.2: *Possible paths through the system for a patient at a visit at the triage.*

Afternoon emergency patients have called to the health care centre the same day, just as the triage patients have, but may require more than 15 minutes. It can also be inadvisable to have them in the waiting room at the same time as all the other triage patients due to risk of infection. These patients do not need to see a district nurse before they are sent to a physician and can follow a path as in figure 4.3.

Revisiting patients often got some form of illness that requires at least one visit a year with a physician and also follows a path as in figure 4.3. The patient registers at the reception and then waits to be fetched by the physician. The patient can sometimes be sent to lab after visit, which is planned to take 30 minutes in total for the physician. This planned time always includes preparation time before and administration time after the visit.

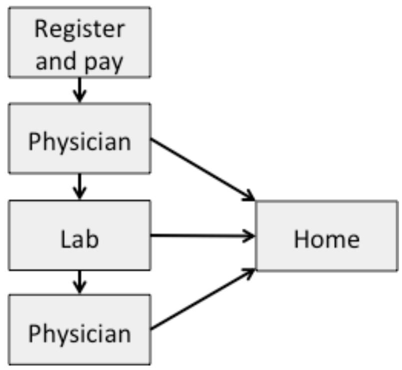

Figure 4.3: *Possible paths through the system for a patient at another visit than triage to a physician.*

Semi-emergency patients do not need to see a physician immediately but can wait up to a week. They can be booked up to five work days before a visit. The procedure at the health care centre is the same as for the revisiting patients.

4.2 Results from model of current system

The model of the current system was analysed by running the model ten times with different random numbers every run. The 2.5th and 97.5th percentiles were calculated for the average number and the maximum number of patients in the waiting room. The average number of patients was also calculated and the simulated maximum number of patients in the waiting room can be seen in diagram 4.1. The grey vertical lines represent the 95th percentile range, i.e. in 95 % of all cases will the value be within this interval, and the continuous line represents the average maximum number of patients.

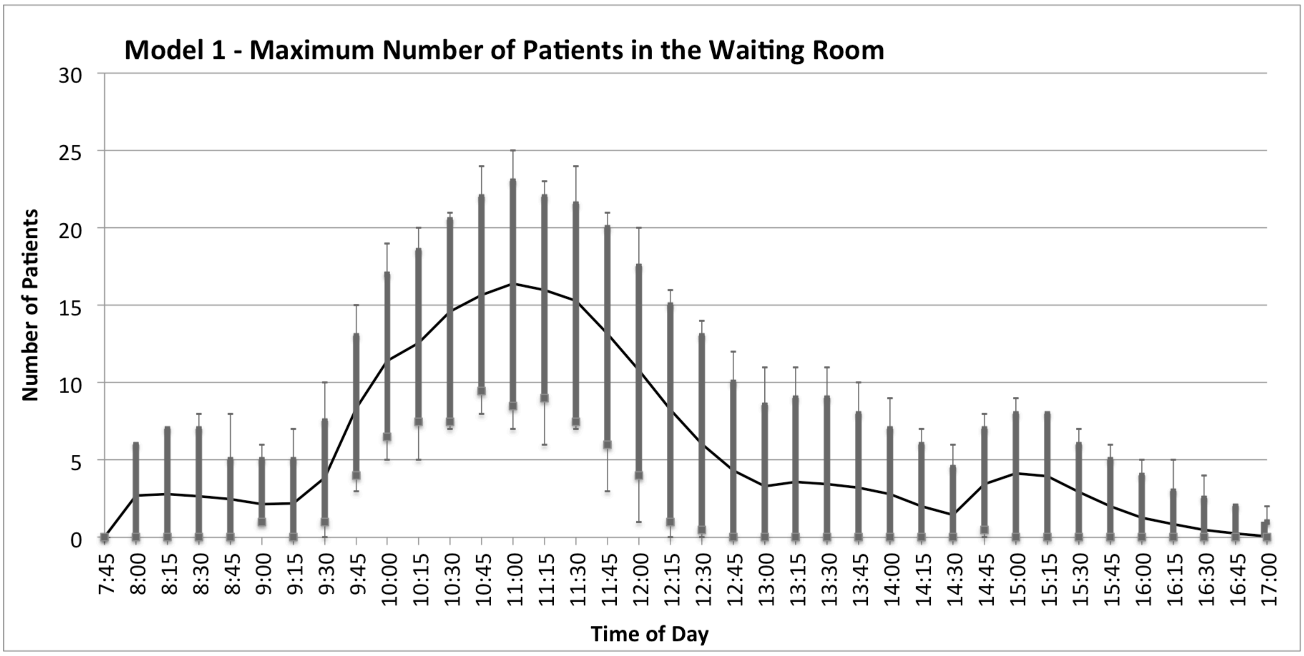

Diagram 4.1: *Simulated maximum number of patients in the waiting room every 15 minutes. The thin vertical lines represent the full range of simulated results. The thick vertical lines represent the 95th percentile range of output data points. The continuous line is the average of the maximum number of patients.*

Other results can be seen in table 4.1. For each parameter are the average and the 97.5th percentile value shown. The 97.5th percentile is chosen instead of the maximum value to remove extreme values that do not represent normal system performance.

Current system			
		Average	97.50%
Throughput time	h:mm	01:15	02:28
Number of patients to triage backup	#	3.21	7.00
Time of last patient leaving the triage	Time	13:15	14:00
Number of patients in the waiting room	#	12.7	23
Utility for physicians	Value	0.919	-
Utility for district nurses	Value	0.991	-

Table 4.1: *Simulation results from the current system.*

4.3 Analysis of the current system

The average time a physician spends on a triage patient is 14.7 minutes and the average number of patients at the triage is around 28-30 per day. The physicians should not spend more than 15 minutes per patient during the triage, including preparation and administration time. On average do 2/3 of the patients see a physician. With two hours and two physicians this gives 16 patients that can be handled before 12:00. Add 30 minutes and an additional four patients can be handled, which then sums up to 20, equal 2/3 of 30. Thus it should be possible for the physicians to handle the patients sent to them until 12:30. However, this does not take into account that some patients see a physician more than once and it is only on an average day. A day when more patients need to see a physician or the visits with the physicians take more than 15 minutes, the triage back-up will be needed. This does also not consider disturbances for the physicians, like when district nurses come to ask for advice or if a really ill patient arrives. However, one physician does say that 15 minutes per patient during the triage is reasonable without much stress.

There is another problem among the health care centre personnel, an underlying “us against them” attitude. The atmosphere is generally good among the staff but when trouble arises some personnel hesitate to tell what they think and about their ideas, while others feel they are not listened to. Also, physicians and district nurses feel they do unnecessary tasks during a day, like booking triage patients to lab. The physicians have a lot to do and state that there is no problem finding other things to do if they get a few minutes of free time during the triage.

From the simulation results it can be seen that the district nurses and the physicians are alternating bottlenecks of the system. It can also be seen that neither of the triage goals can be fulfilled on a daily basis as expected from observations at the triage.

5 Improvement concepts for the health care centre

Three different kinds of concepts have been developed; general concepts, triage team concepts and other concepts. There is also a category called current strategy where the current work strategy is tested with more personnel scheduled for the triage. The general concepts are not developed to reach the triage goals on their own but can instead be implemented together with another concept, see figure 5.1.

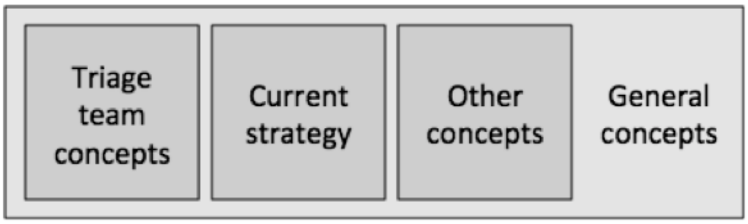

Figure 5.1: *The different concepts. General concepts can be implemented at the same time as another concept.*

5.1 General concepts

The general concepts are developed from ideas that arose from observations at the health care centre. There are three general concepts; the first two of them deal with booking to lab, while the third deals with scheduling. The second lab concept can only be implemented together with the first lab concept. All these concepts can be implemented at the same time as another concept.

5.1.1 Drop-in to lab during triage

Triage patients have to be booked to the lab today. Many physicians and district nurses state that this is an unnecessary activity that only takes time. According to Lean and Genombrott non-value adding activities should be removed and the number of elements in a process should be minimised. This concept will probably synergy well with the new schedule concept as there will be fewer patients queuing to the lab during the triage. It will also lighten the workload for the bottlenecks. This concept is based on that triage patients should be sent as drop-in to lab to pick a queue ticket like all other patients.

5.1.2 Special booking to lab

This concept builds on the previous concept. To reduce the patients in the waiting room can those triage patients who will be sent home right after a lab visit be prioritised to lab. They will simply be booked to lab as all triage patients are today.

5.1.3 New schedule

The number of patients in the waiting room varies a lot as it is today and the highest levels occur during the triage. Genombrott theory includes levelling out variations in demand to decrease strain in a system. Today there are other patients than triage patients visiting district nurses or physicians during the time of the triage. The health care culture is to see patients between 10:00 – 12:00, which is the same time as the triage. Scheduling other patients' visits to any other time than between 10:00 – 12:00 can even out the demand on the waiting room. Genombrott theory states that patient visits should be coordinated as far as possible, so that a patient does not need to come back different days instead of handling all examinations during one day. This can also be turned to the opposite; coordinate so that all patients do not come at the same time. That is, schedule them to come during any other time than during the triage.

5.2 Triage team concepts

The triage team concepts have been developed together with the health care centre with inspiration from the current work method at Floda health care centre, where they work in teams. The main idea of the Triage team concepts is to introduce work teams during the triage, like suggested in Lean Healthcare. The team will consist of both physicians and district nurses and the purpose with introducing a team is to get a more flexible system, minimise the number of activities, reduce the distance between physicians and district nurses to ease communication, create a common goal and to reduce the feeling that the district nurses are "pushing patients" to the physicians. All of these are involved in the changing concepts of Genombrott.

Special triage rooms will be used in both concepts; there will be several examination rooms and one room for administration. This will minimise the distance between the rooms and the waiting room and thus shorten the time used for transportation. It is also believed that the patient time i.e. the time from when the patients sits down in the examination room until the patient rises to leave the room, will be reduced due to that the patient will understand that it is an emergency reception and that there is no time to discuss other concerns. This should apply even though it might be their usual district nurse or physician since they are not in their usual examination room. The patient will stay in the examination room between district nurse visits and physician visits, also to minimise the transportation needed but also to minimise the actions of undressing and dressing i.e. the patient will only need to undress and dress outerwear once and the same goes for clothes that has to be undressed and dressed during the examination. In both concepts district nurses will bring patients to the examination rooms to reduce possible confusion regarding usage of the rooms i.e. if the room is available or not.

5.2.1 First concept

Each district nurse will have their own examination room so in this concept there is no risk for confusion about if a room is available or not. The district nurse will bring a patient to her examination room and examine the patient. She then has three options of how the patient's treatment should continue; send the patient home, to the lab or to get a physician to look at the patient. If the patient is sent home the district nurse will do some administration in her examination room and then proceed to the next patient. If the patient instead is sent to the lab the district nurse will continue with another patient until the patient is finished in the lab, but if she chooses to get a physician she will leave the patient in the examination room and go to the administration room and wait until a physician is available. When a physician is available she will update the physician about the patient's condition and then bring the physician to the examination room where she will wait until the physician is finished with her examination. When the physician is finished she will leave and the district nurse will take care of showing the patient out of the room. In the mean time the physician will go back to the administration room and do the required administration for the patient. In this way the district nurse will only need to administrate when the physician does not see the patient, thus an activity can be removed for the district nurse. Also, the medical records will get shorter if only one person administrates which in the long run can lead to shorter preparation times for the district nurses and physicians since they do not have to read as much.

By working in this way the district nurses get direct feedback of their decisions about how to treat the patient. This will in the long run lead to that the district nurses make better decisions regarding if the patient needs to see a physician or not, which is desirable according to Genombrott. This will most likely lead to that fewer patients are sent to the physicians mostly because the district nurses will trust their own ability to make the right decision when they have more knowledge.

5.2.2 Second concept

All district nurses will share all examination rooms and all their administration will be done in the administration room. This will allow the examination room to be used only for the activities that has to be performed in the examination room, which can be motivated from Genombrott. The drawback with this is thus that some confusion may arise about which examinations rooms are available and not.

First the district nurse will prepare for the patient in the administration room, then she brings the patient to an available examination room and examines the patient. She will then decide if the patient should go home, to the lab or see a physician, just like in the first concept. If the patient is sent home the district nurse will go to the administration room to administrate for the patient and to prepare for the next patient. If the patient instead is sent to the lab she will continue with another patient until the patient is finished in the lab. Her final choice is to let the patient see a physician and if this is the case she will go to the administration room and administrate for the patient and add the patient to the physicians' queue together with the room number of the room that the patient is in. In this way the physician will know where to find the patient while the district nurse continues with the next patient.

The physicians will do administrative tasks in the administration room until the district nurse puts a patient in the physicians' queue. When there is a patient in the queue a physician will prepare for the visit and then go to the examination room where the patient is to examine the patient. When the examination is finished the physician will have to take care of showing the patient out of the room before she can go to the administration room and administrate for the patient. In this concept both the district nurse and the physician will administrate for all patients they examine.

In this concept the district nurses' will be used more efficiently since they do not have to wait while a physician examines a patient and they do not always take care of showing the patient out of the room. According to Theory of constraints this is the way to go since the district nurses' are the systems main bottleneck, even though the physicians closely follow them.

5.3 Other concepts

The other concepts group consists of three different concepts; advices, back-up starts early and extended triage. The advice concepts and the back-up starts early concepts have been developed from ideas that arouse during observations at the health care centre. The extended triage concept, on the other hand, has been developed with inspiration from the current work method at Floda health care centre where they work similarly to this concept.

5.3.1 Advices

Removing non-value adding tasks is a part of Lean philosophy. It is a non-value adding activity by the district nurse to send a patient to a physician if the patient does not need to. The physician will only send the patient home anyway and this infringes the Lean principle to do something correctly the first time to avoid rework. This concept is to schedule administration time for a physician during the triage. District nurses can then ask this physician for advice if she is uncertain whether a patient can be sent home or not. This will also facilitate for continuous improvement from Lean theory as the district nurses get direct feedback and can learn until next time. The district nurses may only ask for advice about patients who are sent to physicians and then home, that is, patients following path three and seven.

5.3.2 Back-up starts early

Today there is a triage back-up who starts at 12:30 but the amount of patients in the waiting room is highest around 11:00. By having the triage back-up starting at 11:00 instead is the manning more adapted to predictable needs, as mentioned in Genombrott theory. The triage back-up should not start earlier as the physicians sometimes have little to do in the beginning of the triage.

5.3.3 Extended triage

Another idea to see how the number of patients in the waiting room depends on the triage is to spread out the triage over the day. This should level out the demand on the waiting room over the day as Genombrott theory mentions as an improvement strategy. One district nurse starts the triage at 9:45 and continues to 12:15, the next district nurse handles the triage from 12:15 to 14:45. A physician starts at 10:00 and works with the triage to 12:30, the next physician works from 12:30 to 15:00 and a triage back-up is scheduled from 15:00 to 15:30 but works until all patients are taken care of. The last physician before the back-up continues after 15:00 if there are too many patients left for the back-up.

6 Results

First the result from the evaluation of the input data management methodology will be presented and then the results from the different concepts. To get valid results from the model runs each model has been run ten times with different random numbers. The following parameters have been used to evaluate the models:

- Patient throughput time.
- Number of patients to the triage back-up.
- Time when the last patient leaves the triage.
- Number of patients in the waiting room.
- Utility for physicians, district nurses and examination rooms when needed.

These parameters have been chosen with respect to the goals of the triage given by the health care centre, see table 6.1, but also with respect to theory from section 2.2. For each parameter the average value has been evaluated but also the 97.5th percentile. The 97.5th percentile has been chosen instead of the maximum value to remove extreme values that do not represent normal system performance. The results for each parameter have also been compared with the result for the same parameter from the model of the current situation, which can be seen in table 6.2. This is to make it easier to evaluate the effects of the concepts and it is shown as a percentage for each parameter in the results.

Triage Goals		
Number of patients to triage backup	#	0
Time of last patient leaving the triage	Time	12:30
Number of patients in the waiting room	#	15

Table 6.1: *The three first triage goals can be seen in the table, the fourth goal is that the three first goals should be met with the same manning of the triage as today.*

Due to the amount of time needed to perform a single model run the number of runs has been minimised. Therefore, data for all experiment parameters are not available for all runs of each concept.

Current system			
		Average	97.50%
Throughput time	h:mm	01:15	02:28
Number of patients to triage backup	#	3.21	7.00
Time of last patient leaving the triage	Time	13:15	14:00
Number of patients in the waiting room	#	12.7	23
Utility for physicians	Value	0.919	-
Utility for district nurses	Value	0.991	-

Table 6.2: *Simulation results from the current system.*

6.1 Input data management methodology

The first five steps of the KJ-Shiba method resulted in nine groups and 21 sub-groups, which are presented in table 6.3. Voting results are indicated by dots and show how important different sub-groups were valued. The result from the sixth step, i.e. the links between the different groups, is presented in figure 6.1.

Results from KJ-Shiba method				
Group header	**Sub-group header**			
The method is suitable for simulation in health care, especially for those without previous experience	The method is suitable for simulation in health care, especially for those without previous experience •••			
Lack of experience	Lack of experience of the input data management method •	Lack of experience of simulation in health care •		
Hard to estimate the time needed for data management	Data management takes a lot of time •	Hard to estimate how long the data management will take		
Hard to define what parameters that are necessary	It is hard to define what parameters that will be needed for simulation	Harder to define what input data that is needed than in industry		
Several steps can be performed in parallel	Step 7-9 can be performed in parallel	Step 9-11 can be performed in parallel	Step 1-4 can be performed in parallel unconsciously	
Input data is affected by social aspects, the human factor and nature of the system	The clocked times are affected because the personnel enjoy to talk with the person who clocks them •••	The clocked times are affected because of the information that need to be given to the patients ••	The input data is affected by the systems nature	The input data is affected by how long the data collection have come
Little available data and it is hard to get	There is a very limited amount of available data in the health care sector	Some data cannot be extracted since the personnel do not write it down	Some data is hard to extract due to difficulties to access the computer system	
Personnel and patients are interested	Personnel and patients are curious of what is measured •	Some of the personnel have expectations of change that do not fit inside the project	Those who are clocked find it fun ••	
Some find the idea of getting clocked disturbing	Some find the idea of getting clocked disturbing			

Table 6.3: *Result from step 4-6 from the KJ-Shiba method based on the field notes. Each group is divided into several sub-groups which contains the field notes. The sub-groups have been given priorities based on what is considered to be the most important results. The dots in the sub-groups mark their priority where three dots mark the highest priority and no dots the lowest.*

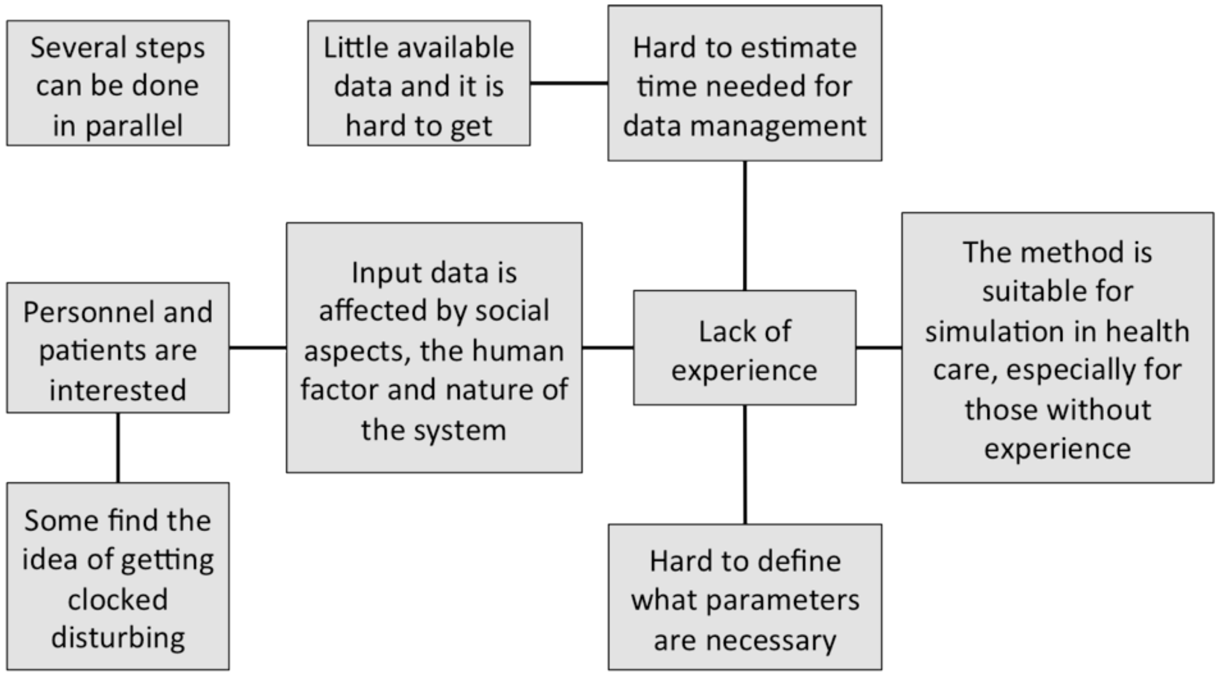

Figure 6.1: *The resulting connections between the groups from step 7 in the KJ-Shiba method.*

6.2 General concepts

Results from the three general concepts are presented in table 6.4 – 6.6. For the "New schedule" concept, only the number of patient in the waiting room is affected, which is why only this parameter is presented. The shape of curve of the waiting room level was affected by this change and can therefore be seen in diagram 6.1.

Drop-in to lab during triage			
		Average	97.50%
Throughput time	h:mm	01:11	02:26
	%	-5.14%	-1.01%
Number of patients to triage backup	#	2.82	6.52
	%	-12.15%	-6.79%
Time of last patient leaving the triage	Time	13:12	14:12
	%	-1.52%	4.73%
Number of patients in the waiting room	#	12.93	23
	%	1.65%	0.00%

Table 6.4: *The results from the Drop-in to lab concept. It shows that most values are improved slightly.*

Special booking to lab			
		Average	97.50%
Throughput time	h:mm	01:14	02:24
	%	-2.16%	-2.70%
Number of patients to triage backup	#	2.80	6.00
	%	-12.77%	-14.29%
Time of last patient leaving the triage	Time	13:11	14:00
	%	-2.01%	0.23%
Number of patients in the waiting room	#	12.71	24.53
	%	-0.08%	6.65%

Table 6.5: *The results from the Special booking to lab concept. It shows similar results as the Drop-in to lab concept.*

New schedule			
		Average	97.50%
Number of patients	#	11.8	21
in the waiting room	%	-7.09%	-8.70%

Table 6.6: *The results from the New schedule concept. It shows improvement of the number of patients in the waiting room. The 97.5% has decreased with 2 persons and the average with about 1 person.*

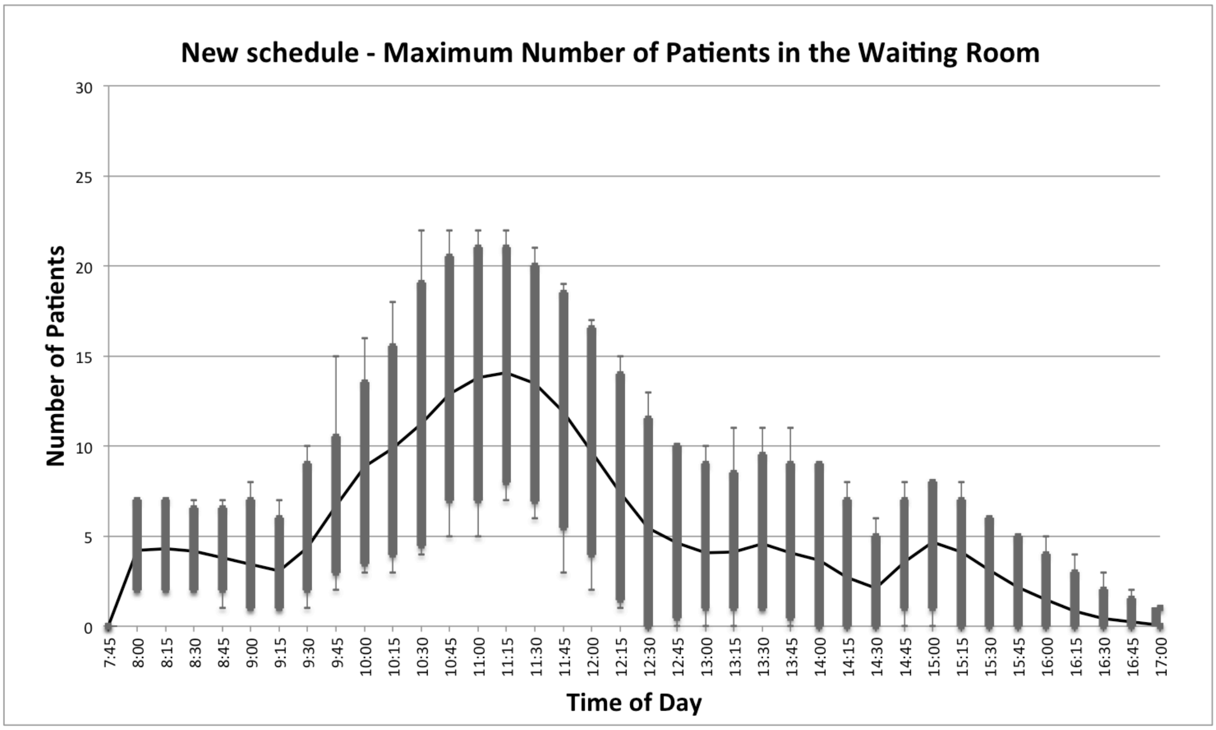

Diagram 6.1: *Simulated maximum number of patients in the waiting room every 15 minutes with the new schedule concept. The thin vertical lines represent the full range of simulated results. The thick vertical lines represent the 95th percentile range of output data points. The continuous line is the average of the maximum number of patients.*

6.3 Triage team concepts

Here are the results presented which are needed to evaluate the two triage team concepts. The results are sorted by the percentage of patient time used in the specific model run. Patient time is defined as the time the physician or district nurse spends with the patient, starting when the patient sits down and ending when the patient rises to leave.

6.3.1 First concept

The first concept was run with two physicians and two district nurses, two physicians and three district nurses, two physicians and four district nurses and finally with three physicians and four district nurses. The results are presented in tables 6.7-6.10.

Triage team - first concept with 2 physicians and 2 district nurses					
	Patient time	80%		60%	
		Average	97.50%	Average	97.50%
Throughput time	h:mm	01:39	03:02	01:31	02:53
	%	31.58%	22.97%	21.21%	16.89%
Number of patients to triage backup	#	4.07	6.00	3.58	7.00
	%	26.79%	-14.29%	11.53%	0.00%
Time of last patient leaving the triage	Time	13:57	14:45	13:36	14:30
	%	19.85%	17.67%	10.22%	11.97%
Number of patients in the waiting room	#	15.14	22	14.73	22.53
	%	19.03%	-4.35%	15.80%	-2.04%
Utility for physicians	Value	0.513	-	0.494	-
	%	-44.15%	-	-46.29%	-
Utility for district nurses	Value	0.609	-	0.662	-
	%	-38.51%	-	-33.19%	-

Table 6.7: *The results from the First triage team concept with two physicians and two district nurses for 80% and 60% patient time. No matter what the patient time is, the concept show deterioration of the system performance for almost all values. The only value that is slightly improved is the number of patients in the waiting room.*

Triage team - first concept with 2 physicians and 3 district nurses									
Patient time		95%		90%		85%		80%	
		Average	97.50%	Average	97.50%	Average	97.50%	Average	97.50%
Throughput time	h:mm	01:16	02:20	01:13	02:10	01:10	02:07	01:08	02:05
	%	0.78%	-5.41%	-3.52%	-12.16%	-6.44%	-14.19%	-9.71%	-15.54%
Number of patients	#	2.75	6.00	2.32	5.00	2.2	5.00	1.75	5.00
to triage backup	%	-14.33%	-14.29%	-27.73%	-28.57%	-31.46%	-28.57%	-45.48%	-28.57%
Time of last patient	Time	13:11	13:59	13:03	13:54	12:59	13:46	12:52	13:42
leaving the triage	%	-2.00%	-0.15%	-5.48%	-2.31%	-7.58%	-5.26%	-11.03%	-7.02%
Number of patients	#	12.11	20.53	11.9	19	11.4	19	11.14	20
in the waiting room	%	-4.80%	-10.74%	-6.45%	-17.39%	-10.38%	-17.39%	-12.42%	-13.04%
Utility for	Value	0.781	-	0.770	-	0.776	-	0.756	-
physicians	%	-15.08%	-	-16.21%	-	-15.64%	-	-17.75%	-
Utility for	Value	0.524	-	0.543	-	0.543	-	0.570	-
district nurses	%	-47.08%	-	-45.16%	-	-45.19%	-	-42.45%	-

Table 6.8: *The results from the First triage team concept with two physicians and three district nurses for 95% to 80% patient time. A lower patient time show greater improvements to the system performance. The utility for the physicians decreases with the patient time while the utility for the district nurses increases.*

Triage team - first concept with 2 physicians and 4 district nurses											
Patient time		95%		90%		85%		80%		60%	
		Average	97.50%	Average	97.50%	Average	97.50%	Average	97.50%	Average	97.50%
Throughput time	h:mm	01:03	02:03	00:59	01:55	00:58	01:53	00:54	01:43	00:44	01:21
	%	-15.62%	-16.89%	-21.58%	-22.30%	-23.32%	-23.65%	-28.04%	-30.41%	-41.57%	-45.27%
Number of patients	#	1.41	5.00	1.08	5.00	1.04	5.00	0.66	5.00	0.07	1.00
to triage backup	%	-56.07%	-28.57%	-66.36%	-28.57%	-67.60%	-28.57%	-79.44%	-28.57%	-97.82%	-85.71%
Time of last patient	Time	12:42	13:37	12:33	13:34	12:34	13:32	12:25	13:24	12:05	12:44
leaving the triage	%	-15.41%	-8.81%	-19.74%	-10.16%	-19.53%	-10.77%	-23.66%	-13.98%	-33.16%	-29.54%
Number of patients	#	9.87	19	9.08	19.5	8.97	18.28	8.44	17.5	6.83	15.5
in the waiting room	%	-22.41%	-17.39%	-28.62%	-15.22%	-29.48%	-20.52%	-33.65%	-23.91%	-46.31%	-32.61%
Utility for	Value	0.917	-	0.911	-	0.897	-	0.889	-	0.837	-
physicians	%	-0.27%	-	-0.94%	-	-2.43%	-	-3.27%	-	-9.00%	-
Utility for	Value	0.473	-	0.478	-	0.496	-	0.508	-	0.559	-
district nurses	%	-52.26%	-	-51.79%	-	-49.94%	-	-48.71%	-	-43.58%	-

Table 6.9: *The results from the First triage team concept with two physicians and four district nurses for 95% to 80% and for 60% patient time. A lower patient time show greater improvements to the system performance. With a patient time of 60% the concept gets quite close to fulfilling the triage goals. The utility for the physicians decreases with the patient time while the utility for the district nurses increases.*

Triage team - first concept with 3 physicians and 4 district nurses											
Patient time		95%		90%		85%		80%		60%	
		Average	97.50%	Average	97.50%	Average	97.50%	Average	97.50%	Average	97.50%
Throughput time	h:mm	00:49	01:33	00:47	01:28	00:45	01:19	00:44	01:18	00:37	01:08
	%	-34.93%	-37.16%	-36.68%	-40.54%	-40.25%	-46.62%	-41.20%	-47.30%	-49.90%	-54.05%
Number of patients	#	0.16	2.57	0.04	0.00	0.01	0.00	0	0.00	0	0.00
to triage backup	%	-95.02%	-63.21%	-98.75%	-100.00%	-99.69%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%
Time of last patient	Time	12:15	13:08	12:09	12:45	12:06	12:39	12:05	12:39	11:53	12:15
leaving the triage	%	-28.26%	-20.10%	-31.15%	-29.21%	-32.88%	-31.76%	-33.11%	-31.56%	-38.78%	-40.97%
Number of patients	#	7.78	17.53	7.44	17	6.65	16.53	6.79	16	5.84	15.58
in the waiting room	%	-38.84%	-23.78%	-41.51%	-26.09%	-47.72%	-28.13%	-46.62%	-30.43%	-54.09%	-32.26%
Utility for	Value	0.749	-	0.746	-	0.736	-	0.717	-	0.661	-
physicians	%	-18.54%	-	-18.85%	-	-19.99%	-	-22.04%	-	-28.11%	-
Utility for	Value	0.529	-	0.542	-	0.543	-	0.561	-	0.582	-
district nurses	%	-46.63%	-	-45.32%	-	-45.22%	-	-43.39%	-	-41.25%	-

Table 6.10: *The results from the First triage team concept with three physicians and four district nurses for 95% to 80% and for 60% patient time. A lower patient time show greater improvements to the system performance. At 85% patient time the concept almost reaches the triage goals and with 60% patient time the goals are met with a margin. The utility for the physicians decreases with the patient time while the utility for the district nurses increases.*

6.3.2 Second concept

The second concept was run with two physicians and two district nurses, three physicians and four district nurses and finally with three physicians and three district nurses and the results are presented in tables 6.11-6.13.

Triage team - second concept with 2 physicians and 2 district nurses					
Patient time		100%		95%	
		Average	97.50%	Average	97.50%
Throughput time	h:mm	01:14	02:22	01:11	02:16
	%	-1.95%	-4.05%	-5.74%	-8.11%
Number of patients	#	2.76	6.52	2.29	6.00
to triage backup	%	-14.02%	-6.79%	-28.66%	-14.29%
Time of last patient	Time	13:11	14:03	13:01	14:00
leaving the triage	%	-2.00%	1.38%	-6.68%	0.00%
Number of patients	#	11.07	19.525	10.73	19
in the waiting room	%	-12.83%	-15.11%	-15.51%	-17.39%
Utility for	Value	0.832	-	0.839	-
physicians	%	-9.49%	-	-8.80%	-
Utility for	Value	0.850	-	0.861	-
district nurses	%	-14.20%	-	-13.06%	-
Utility for	Value	0.795	-	0.791	-
examination rooms	%	-	-	-	-

Table 6.11: *The results from the Second triage team concept with two physicians and two district nurses for 100% and 95% patient time. The concept show improvements to the system performance regardless of the patient time but a lower patient time show greater improvements to the system performance.*

Triage team - second concept with 3 physicians and 3 district nurses					
	Patient time	100%		95%	
		Average	97.50%	Average	97.50%
Throughput time	h:mm	00:46	01:26	00:43	01:20
	%	-38.40%	-41.37%	-42.87%	-45.95%
Number of patients to triage backup	#	0.09	1.00	0.01	0.00
	%	-97.20%	-85.71%	-99.69%	-100.00%
Time of last patient leaving the triage	Time	12:09	12:55	12:04	12:31
	%	-31.45%	-25.47%	-33.84%	-34.70%
Number of patients in the waiting room	#	6.23	17	5.79	15.05
	%	-50.94%	-26.09%	-54.41%	-34.57%
Utility for physicians	Value	0.846	-	0.825	-
	%	-8.02%	-	-10.31%	-
Utility for district nurses	Value	0.749	-	0.746	-
	%	-24.38%	-	-24.72%	-
Utility for examination rooms	Value	0.842	-	0.827	-
	%	-	-	-	-

Table 6.12: *The results from the Second triage team concept with three physicians and three district nurses for 100% and 95% patient time. The concept show great improvements to the system performance regardless of the patient time but a lower patient time show greater improvements to the system performance and at 95% patient time the triage goals are met.*

Triage team - second concept with 3 physicians and 4 district nurses					
	Patient time	100%		95%	
		Average	97.50%	Average	97.50%
Throughput time	h:mm	00:42	01:22	00:39	01:19
	%	-43.40%	-44.38%	-47.64%	-46.62%
Number of patients to triage backup	#	0.02	0.00	0	0.00
	%	-99.38%	-100.00%	-100.00%	-100.00%
Time of last patient leaving the triage	Time	12:03	12:39	11:59	12:36
	%	-34.03%	-31.75%	-36.10%	-32.92%
Number of patients in the waiting room	#	5.24	14	4.6	15
	%	-58.74%	-39.13%	-63.78%	-34.78%
Utility for physicians	Value	0.880	-	0.847	-
	%	-4.34%	-	-7.87%	-
Utility for district nurses	Value	0.558	-	0.569	-
	%	-43.67%	-	-42.54%	-
Utility for examination rooms	Value	0.896	-	0.877	-
	%	-	-	-	-

Table 6.13: *The results from the Second triage team concept with three physicians and four district nurses for 100% and 95% patient time. The concept show great improvements to the system performance regardless of the patient time but a lower patient time show greater improvements to the system performance and the triage goals are as good as met already with 100% patient time.*

6.4 Other concepts

Results from the three other concepts are presented in the following sections.

6.4.1 Advices

The tables presenting the results from the advice concept are sorted with respect to the chance that the district nurse will ask a physician for advice, provided that the patient is one of the two patient types that the district nurse can need advice for. The chance that the patient is one of these two types is 38% so if the chance to ask for advice is 28% for the right patient type, the chance that the district nurse will ask for advice for all patients would be 10.64%. Each table are also sorted with respect to the chance that the patient should be sent home after the district nurse has asked for advice from a physician. The results from the model runs are presneted in tables 6.15-6.17.

Advice - 28% chance to ask for advice							
Chance to be sent home		41%		51%		61%	
		Average	97.50%	Average	97.50%	Average	97.50%
Throughput time	h:mm	01:10	02:14	01:10	02:14	01:10	02:12
	%	-6.63%	-9.46%	-6.69%	-9.46%	-7.62%	-10.81%
Number of patients to triage backup	#	2.15	6.00	1.96	6.00	2.14	5.00
	%	-33.02%	-14.29%	-38.94%	-14.29%	-33.33%	-28.57%
Time of last patient leaving the triage	Time	13:04	13:57	13:02	13:56	13:01	13:51
	%	-5.10%	-1.16%	-6.18%	-1.34%	-6.46%	-3.49%
Number of patients in the waiting room	#	11.40	19	11.67	20	11.65	20.53
	%	-10.25%	-17.39%	-8.25%	-13.04%	-8.27%	-6.39%

Table 6.15: *The results from the Advice concept with a 28% chance for the district nurse to ask for advice provided that it is the right type of patient. After the district nurse have asked for advice there are either 41%, 51% or 61% that the patient is sent home. The system performance is slightly more improved when the chance to send the patient home increases. The system performance is not increased as much as with a 28% chance to ask for advice.*

Advice - 18% chance to ask for advice							
Chance to be sent home		41%		51%		61%	
		Average	97.50%	Average	97.50%	Average	97.50%
Throughput time	h:mm	01:11	02:17	01:09	02:12	01:10	02:16
	%	-5.57%	-6.89%	-7.75%	-10.81%	-6.72%	-8.11%
Number of patients	#	2.59	7.00	2.24	5.52	2.35	6.00
to triage backup	%	-19.31%	0.00%	-30.22%	-21.07%	-26.79%	-14.29%
Time of last patient	Time	13:10	14:05	13:05	13:56	13:07	13:58
leaving the triage	%	-2.36%	2.17%	-4.70%	-1.36%	-3.92%	-0.56%
Number of patients	#	11.75	20	11.62	20	11.87	22
in the waiting room	%	-7.47%	-13.04%	-8.65%	-13.04%	-6.54%	-4.35%

Table 6.16: *The results from the Advice concept with a 18% chance for the district nurse to ask for advice provided that it is the right type of patient. After the district nurse have asked for advice there are either 41%, 51% or 61% that the patient is sent home. The system performance is slightly more improved when the chance to send the patient home increases. The system performance is not increased as much as with a 28% chance to ask for advice.*

Advice - 38% chance to ask for advice							
Chance to be sent home		41%		51%		61%	
		Average	97.50%	Average	97.50%	Average	97.50%
Throughput time	h:mm	01:09	02:13	01:11	02:14	01:12	02:17
	%	-7.98%	-10.14%	-5.95%	-9.46%	-4.44%	-7.43%
Number of patients	#	2.11	5.52	2.35	6.00	2.30	6.00
to triage backup	%	-34.27%	-21.07%	-26.79%	-14.29%	-28.35%	-14.29%
Time of last patient	Time	13:02	13:59	13:07	14:00	13:04	13:58
leaving the triage	%	-6.32%	-0.11%	-3.75%	0.21%	-5.06%	-0.58%
Number of patients	#	11.29	20	11.8	20	11.92	20
in the waiting room	%	-11.09%	-13.04%	-7.09%	-8.70%	-6.12%	-13.04%

Table 6.17: *The results from the Advice concept with a 38% chance for the district nurse to ask for advice provided that it is the right type of patient. After the district nurse have asked for advice there are either 41%, 51% or 61% that the patient is sent home. The system performance is slightly more improved when the chance to send the patient home increases. The system performance is about the same as with a 28% chance to ask for advice.*

6.4.2 Back-up starts early

The back-up starts early concept only needed one model run and the results can be seen in table 6.18.

Back-up starts early			
		Average	97.50%
Throughput time	h:mm	01:02	01:47
	%	-17.56%	-27.70%
Number of patients to triage backup	#	0.47	3.00
	%	-85.36%	-57.14%
Time of last patient leaving the triage	Time	12:37	13:22
	%	-18.04%	-14.68%
Number of patients in the waiting room	#	10.61	18.53
	%	-16.46%	-19.43%

Table 6.18: *The results from the Back-up starts early concept. It gets about half way there to reaching the triage* goals.

6.4.3 Extended triage

The extended triage concept only needed one model run, just like the back-up starts early concepts, and the results are presented in table 6.19. The shape of the curve of the waiting room level changed when this concept was implemented which can be seen in diagram 6.2.

Extended triage			
		Average	97.50%
Throughput time	h:mm	01:25	02:42
	%	12.70%	9.46%
Number of patients to triage backup	#	3.14	6.00
	%	-2.18%	-14.29%
Time of last patient leaving the triage	Time	15:49	16:44
	%	1.86%	5.72%
Number of patients in the waiting room	#	9.49	19.53
	%	-25.28%	-15.09%

Table 6.19: *The results from the Extended triage concept. The concept shows deterioration of system performance for the throughput time and for the time when the last patient leaves the triage. The percentage for when the last patient leaves the triage has been adjusted and takes the new end time i.e. 15:00 into consideration. The number of patient to the triage back-up and the number of patients in the waiting room on the other hand show improvements of the system performance.*

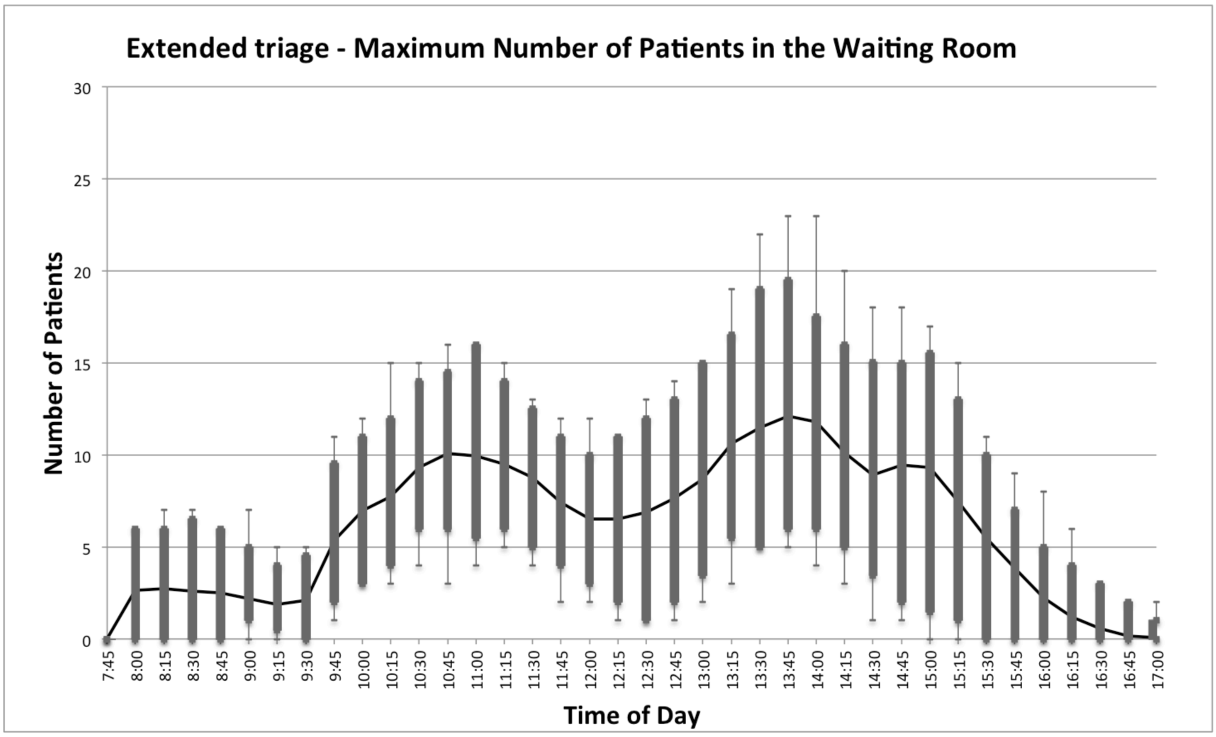

Diagram 6.2: *Simulated maximum number of patients in the waiting room every 15 minutes with the extended triage concept. The thin vertical lines represent the full range of simulated results. The thick vertical lines represent the 95th percentile range of output data points. The continuous line is the average of the maximum number of patients.*

6.5 Current strategy

The current work strategy was also evaluated and therefore two model runs with different manning was performed. First a run with three physicians and four district nurses, see table 6.20, and then a run with three physicians and thee district nurses, see table 6.21.

Current strategy with 3 physicians and 3 district nurses			
		Average	97.50%
Throughput time	h:mm	00:43	01:29
	%	-42.29%	-39.86%
Number of patients to triage backup	#	0.05	0.00
	%	-98.44%	-100.00%
Time of last patient leaving the triage	Time	12:06	12:41
	%	-32.74%	-30.98%
Number of patients in the waiting room	#	6.17	16.53
	%	-51.49%	-28.13%
Utility for physicians	Value	0.910	-
	%	-1.08%	-
Utility for district nurses	Value	0.784	-
	%	-20.89%	-

Table 6.20: *The results from the Current strategy with three physicians and three district nurses. The concept shows great improvments of the system performance and the triage goals are almost met.*

Current strategy with 3 physicians and 4 district nurses			
		Average	97.50%
Throughput time	h:mm	00:41	01:36
	%	-45.68%	-35.14%
Number of patients to triage backup	#	0.06	0.00
	%	-98.13%	-100.00%
Time of last patient leaving the triage	Time	12:02	12:45
	%	-34.41%	-29.27%
Number of patients in the waiting room	#	5.22	14
	%	-58.96%	-39.13%
Utility for physicians	Value	0.934	-
	%	1.54%	-
Utility for district nurses	Value	0.578	-
	%	-41.71%	-

Table 6.21: *The results from the Current strategy with three physicians and four district nurses. The concept shows great improvments of the system performance and the triage goals are almost met.*

7 Analysis

The results from the KJ-Shiba method is analysed for the input data management methodology and the results from the model runs are analysed for all concepts in this section.

7.1 Input data management methodology

The input data management methodology is suitable to use in simulation projects in health care. It is though important to remember some things when collecting data within health care namely:

- The data is easily affected by social aspects such as giving information to patient or when personnel explains what they are doing from a medical perspective.
- The data management takes a lot of time, often more than expected.

The personnel and patients had a very positive attitude overall to the project but it is important to give information about what is clocked and also how it will be used.

It should though be noticed that the lack of experience from the input data management methodology and simulation in health care could influence the results of the evaluation.

7.2 General concepts

The results from the three general concepts are analysed to see if their effect on the system performance is beneficial or not.

7.2.1 Drop-in to lab

There is a slight positive effect on the number of patients to the back-up and the throughput time. The number of patients in the waiting room and the end of the triage has more or less not been affected. This change has no negative influence on the system performance in the simulation.

7.2.2 Special booking to lab

Some parameters are marginally lower than in the drop-in to lab change, while others are a little higher. There is no improvement to speak of with this change.

7.2.3 New schedule

This change only affects the number of patients in the waiting room, as it does nothing to change the organisation of the triage. There is a positive effect on the number of patients in the waiting room, especially on the average number with -14.2%. This alone is however not enough to reach the goal for the number of patients in the waiting room.

7.3 Triage team concepts

The results from the triage team concepts are analysed to see how well they fulfil the triage goals given by the health care central.

7.3.1 First concept

When this concept is implemented with the current manning, i.e. two physicians and two district nurses, the system performance is deteriorated with as much as 31% with 80% patient time and 21% with 60% patient time. The utility for the personnel is also decreased to an unnecessarily low level, especially for the physicians. If one district nurse is added, the system performance is improved regardless of the patient time but a shorter patient time show greater improvement. The utility for the physicians are on an acceptable level but the utility for the district nurses is low. With four district nurses the system performance is greatly improved and with 60% patient time the goals of the triage are almost met. The utility for the district nurses gets even lower and the utility for the physicians gets a bit too high for the longer patient times. If three physicians and four district nurses are used then the utility for the physicians reaches acceptable levels, at least for the longer patient times. For the district nurses the utility is still low but is increasing with the decreasing patient time. The system performance almost reaches the triage goals already at 90% patient time with zero patients to the triage back-up in 97.5% of the time. With a patient time of 80% the goals can be considered fulfilled and with 60% patient time the goals are fulfilled by far. There is no point to try three physicians and three district nurses for this concept due to the great difference in system performance for two physicians and three district nurses vs. two physicians and four district nurses.

7.3.2 Second concept

The second concept shows system improvements already with the same manning as the current system, i.e. two physicians and two district nurses, although the improvements are not so large. The utility for the physician and for district nurses are almost the same and in a good level. With a manning of three physicians and three district nurses the system performance increases greatly and the triage goals are fulfilled if the patient time is decreased to 95%. The utility for the physicians remain about the same but decreases for the district nurses. If the number of district nurses is increased to four the system performance increases a bit more, fulfilling the triage goals regardless of the patient time. The district nurses' utility on the other hand decreases to a too low level while the utility for the physicians increases a bit which results in a level that is a bit too high.

7.4 Other concepts

The results from the three other concepts are analysed to see how they affect the system performance. In some cases the system performance is increased quite a lot but in most cases the system performance is slightly increased or even decreased.

7.4.1 Advice

The result ought to be better the higher the second parameter (chance that patient can be sent home after advice) is, if the first parameter (chance that a district nurse asks for advice) is constant. Results from this model are not very accurate with only ten runs, as the 0.38 | 0.41 parameters in some cases are better than 0.28 | 0.61. This comes from that 0.38 * 0.41 = 0.156, which is less than 0.28 * 0.61 = 0.171, which is the chance that a patient will be sent home. More patients are sent home with 0.28 | 0.61 and the district nurses spend less time on asking for advice, which should make the 0.28 | 0.61 give better results than 0.38 | 0.41. It is therefore risky to perform a sensitivity analysis on this data. With the parameters measured at the health care centre, 0.28 | 0.51, does the triage end at 13:00 on average. The triage back-up will have to take care of almost two patients on average and the waiting room will have less than or equal to 20 patients 97.5% of the time. While this is an improvement compared to the current situation it does not reach any of the triage goals.

7.4.2 Back-up starts early

There are great improvements with this concept together with the lab drop-in and special booking concepts. The triage back-up will only have one patient every other day after 12:30 and the throughput time is greatly reduced, especially the 97.5th percentile and maximum. So is also the number of patients in the waiting room. The triage goals are though not met.

7.4.3 Extended triage

The extended triage does level out the number of patients in the waiting room over the day. There are now two larger peaks during a day with the greatest peak during the afternoon but the triage goal for the number of patients in the waiting room is still not met. The number of patients to the triage back-up is slightly decreased but the 97.5th percentile of throughput time has increased and so has the time of when the last patient leaves the triage.

7.5 Current strategy

If the current work strategy is used but with increased manning, i.e. three physicians and three district nurses, the system performance is greatly increased and the triage goals are almost meet. The utility for the district nurses is acceptable but the utility for the physicians is still too high. When another district nurse is used the system performance increases slightly but the utility for the district nurses gets too low to motivate the slight increase in performance.

7.6 All concepts

No concept can reach all four goals but if the lowest prioritised goal, current manning, is disregarded both "Triage team concepts" and the "Current strategy" can meet the goals or at least get very close to the goals if more personnel are used. It is though clear that neither of the "Other concepts" or "General concepts" can meet the triage goals. The absolute best improvement can be seen for the first triage team concept with 60% patient time, three physicians and four district nurses. Second best improvement is seen in the second concept with three physicians and four district nurses followed by the current strategy with three physicians and four district nurses. If also the utility and the required personnel are taken into account the best option is considered to be the second concept with three physicians and three district nurses closely followed by the current strategy with three physicians and three district nurses. The second concept is considered better than the current strategy mainly because it seems to be more stable. A comparison of all concepts of how well they fulfil the triage goals can be seen in table 7.1.

Concept Comparison					
		Triage goal			
		Triage back-up	Triage end 12:30	Waiting room	Current manning
Concept	**General**				
	Drop-in to lab	No	No	No	Yes
	Special booking to lab	No	No	No	Yes
	New schedule	No	No	No	Yes
	Other				
	Advice	No	No	No	No
	Early triage back-up	No	No	No	No
	Extended triage	No	No	No	Yes
	First triage team				
	2 Phys. and 2 D. Nurse	No	No	No	Yes
	3 Phys. and 4 D. Nurse	Yes	Almost	Almost	No
	Second triage team				
	2 Phys. and 2 D. Nurse	No	No	No	Yes
	3 Phys. and 3 D. Nurse	Yes	Yes	Yes	No
	Current strategy				
	2 Phys. and 2 D. Nurse	No	No	No	Yes
	3 Phys. and 3 D. Nurse	Yes	Almost	Almost	No

Table 7.1: *The table show how well each concept fulfils the triage goals. It can be seen that neither of the concepts with the current manning can fulfil the triage goals and neither of the general or other concepts can fulfil them either. The only concept that does fulfil the goals completely is the second triage team concept with more manning.*

8 Discussion

The result from the evaluation of the input data management methodology and the results from the improvement concepts of the case study at health care centre will be discussed. Some advantages and disadvantages for the concepts and the methods used, both for the evaluation of the input data management methodology and for the case study, will also be discussed. This will give the line of argument that forms the final conclusions.

8.1 Input data management methodology

The input data management methodology is considered to be suitable for simulation projects in health care. It offers a structured way for collecting and managing data, which is extra useful when the experience of similar projects is limited. The methodology is though a bit stiff and should not be followed to the letter, it should more be considered as a guideline. This is though most likely the case in industrial projects as well. The difference of using this input data management methodology in health care compared to other projects could have been better evaluated if a greater knowledge about how it is to use the methodology in other projects would have been possessed. Also, it would have been good to have had more practical experience of input data management in health care without using this input data management methodology to better evaluate its effects.

During the project some things have been noticed about data management in health care. First of all is that the data can be affected by social aspects. When accompanying a patient at their visit to a physician it is for example necessary with a presentation and a short explanation to why their visit needs to be observed. It might also be necessary to let the physician explain what they are doing from a medical perspective if it makes them relax, it then feels like they have a medical student with them. Due to this it might be good to add a step in the methodology where it is thoroughly explained to the personnel how the data management works and what is needed from them to get as good data as possible. Secondly, it is hard to define what parameters to collect, especially for someone without experience from simulation in health care, and to estimate how long time the data management will take. It can be harder than expected to extract available data or some data might only be possible to collect at certain times, which might occur completely random. There might also be less data available than first believed since the amount of available data is limited in health care systems.

In this project both the personnel and patients had a positive attitude to the data collection. It is believed that this is because they wanted a change and saw this project as an opportunity but also due to good information about the project. The information could probably have been even better though, mainly about what should be measured and how it should be used. In this way it might have been possible to avoid the sceptical attitude that some persons still had, even though it probably would not have been possible to avoid it completely as some people will always disapprove.

The evaluation has been built mainly on field notes were thoughts and parts of dialogues have been noted when they arose. The drawback of this could be that not all thoughts are recorded, only those considered to be important, which might have led to a unconsciously prejudiced judgment due to that only certain types of thought might have been noted. If interviews in some form had been performed instead, everything that was said would have been noted and taken into account. On the other hand it would only be what was said during the interviews that would have been taken into account with the risk that something had been forgotten. It is thus believed that field notes were the best option due its ability to capture passing thoughts that is not possible in other methods such as interviews or memos.

To make it easier to evaluate the field notes the KJ-Shiba method was used. This method proved to be better than first expected with its ability to show the bigger picture. The drawback was that some of the details were lost during the process but in this project the bigger picture was considered to be more important than details and thus the method was considered suitable.

The simulation model can also be used to evaluate the input data management methodology. If the methodology were completely unsuitable, the validation of the simulation model would not have passed. Since the validation did pass in this project, it implies that the methodology at least is not unsuitable to use in health care projects.

The result from the evaluation of the input data management methodology is that the methodology is considered to be suitable for health care projects. Since it is believed that this methodology reduces the time consumption for input data management in industrial projects (Skoogh, 2008), especially for inexperienced users, it is believed to reduce the time consumption in health care projects as well. This will reduce the time and cost spent on a simulation project and might thus make simulation a greater option when analysing patient flows in health care.

8.2 DES-project

The input data management has taken a lot of time during this project but so has the model construction. Modelling a health care centre proved to be quite different from modelling an industrial production system, just as suggested by Nordgren (2012). One major weakness with the model is that it does not simulate patient's relatives, which is recommended by Nordgren (2012). This is due to that the recommendation was not written until after the data collection had finished and there were no time for additional data collection. It would though have been an asset to simulate this as the number of persons in the waiting room is higher than the number of patients. However, DES-simulation has proven capable to capture the high complexity of the health care centre and can show all of the systems dynamics, as suggested by Lowery (1996). The major drawback has been that the chosen software is mostly used to simulate industrial systems and that model construction took a lot of time, which also coincides with the findings made by Lowery (1996). This is probably why DES-simulation is not more widely spread in the health care sector today.

During this project, Banks' model has been used as a support to make sure that nothing is forgotten. It has proven to be a good support but has not been followed to the letter but rather to make sure that all but the last steps were performed. The last step was not performed as it is not within the frames of this project.

Clocking has been the main method to collect not available data during the input data collection in this project, which also is the most commonly used method according to Skoogh (2008). It was rather time consuming due to the long cycle time of most data and because of this it was not possible to collect as many data points as desired for all parameters. This was even though the desired number of data points was rather low compared to how many data points that is suggested to be collected according to Skoogh (2008). An option to clocking could have been to let the personnel collect data by writing down times while they are working. This would not have worked for several reasons in this project though. First of all the personnel is so heavily burdened that they would not have had the time and secondly the data would most likely not have been measured in exactly the same way by all persons, that Skoogh (2008) says to watch out for, which would have resulted in inaccurate data. Another alternative could have been filming but this would probably have been even more time consuming and it would not have been allowed due to patient privacy.

While evaluating the different concepts, systematic construction was followed briefly. It could have been followed more precisely, which perhaps would have given a different result or a smother way to reach the results but this is considered unlikely. The method served as a good support but is more extensive than necessary for this project and thus it would probably not have given anything to follow it more precisely and it would probably have taken more time to come to a result if it would have been.

8.3 Current system

It was surprising to find that the district nurses are at least as much of a bottleneck as the physicians. The health care centre has been stressing the fact that the physicians work long and hard at the triage and that one more physician might be required. They do not seem to have considered that the district nurses might be understaffed. It is easy to see why according to theory of constraints (Dettmer, 1997); the physicians are placed after the district nurses in the system, no matter if a problem arises for the district nurses or the physicians, the physicians have to work longer. These two resources form an alternating bottleneck and if the district nurses have a tough day the physicians will have to wait and catch up during their lunch instead. The physicians will naturally be delayed if they have a tough day but the district nurses will not be affected. The district nurses will have to be done at 12:15 to ensure that the physicians can have their lunch as scheduled at 12:30.

Today, some triage patients take more than 15 minutes and should have been scheduled for a semi-emergency or afternoon emergency visit instead. This is probably due to that these visits are too few and thus are these patients booked for triage instead as they have to be received. The health care centre would benefit from a deeper study into this matter to investigate how many semi-emergency and afternoon emergency visits they actually need.

8.4 General concepts

The results from the general concepts are discussed in the following three sections. The results for the drop-in to lab concept and for the new schedule concept turned out to be very promising and therefore these concepts have been included in both the triage team concepts and in all other concepts. Except from in the extended triage concept where only the drop in to lab is included. It might have been good to evaluate the concepts without these two concepts first and include them after and make another evaluation to better evaluate the effects of each concept. Due to the time restrictions this was though not possible and thus this seemed to be the best option.

8.4.1 Drop-in to lab

This change has a small positive impact on the modelled system. The impact is so small, so it cannot be guaranteed that it is not just due to the randomness of the model, but it can be stated that this change has no negative impact on the system in the model. There can be some other patients visiting the lab in the real system but they should be few as there are no booked patients to lab during the triage. The only patients that could have to go to lab would come from the district nurses but they are few compared to the number of triage patients, semi-emergency patients and revisiting patients sent to lab. It should therefore be safe to send triage patients to the lab via the drop-in queue. An explanation to the small improvement of the systems performance for this concept could be that the physicians and district nurses get rid of a non-value adding task and therefore saves some time, as suggested in Lean (LERC, 2007). Another benefit is that the physicians and the district nurses find the task of boking triage patients to the lab annoying and unnecessary so if this is removed it could lead to more pleased personnel. If this concept does not work after all they could have two drop-in queues where triage patients would have to pick another queue ticket than non-triage patients.

8.4.2 Special booking to lab

The results for the special booking to lab concept are about the same as the drop-in to lab concept, a small improvement for most values but not enough to use as a decision basis. Especially not since the value that should have shown the most improvement show deterioration instead. That is the 97.5th percentile of the number of patients in the waiting room should have decreased but instead it has increased with 6.7%. This implies that the results from both this concept but also for the drop-in to lab concept are uncertain. This is probably within the margin of error though, due to the sample size of only ten runs. Since the values are uncertain and if they are correct the improvements are still very small and also since it adds an extra task for the physicians and district nurses this concept is not to be recommended.

8.4.3 New schedule

The effect on the number of patients in the waiting room is positive. The improvement can be even greater in the real system as there are types of patients who are not simulated, whose visits also can be moved. However, the improvement could also be smaller in the real system as the ideal case has been modelled were all other visits have been moved away from 10:00 – 12:00, which probably is not possible in the real system. This improvement will put some demands on the schedule planner but can in return do improvements to the maximum and average number of patients in the waiting room. It is thus recommended that this improvement is implemented as far as possible at the health care centre.

8.5 Triage team concepts

Different aspects of the two triage team concepts are discussed in the following two sections. Both the triage team concepts turned out to give good improvements to the system performance and were thus considered as promising concepts.

8.5.1 First concept

Even though the utility for the district nurses is rather low the district nurses are still considered to be a bottleneck. This is because the district nurses spend a lot of time waiting in the examination room while the physician examines the patient, if this time was included in the district nurses' utility it would be much higher. With help from theory of constraints (Dettmer, 1997), this explains why the system performance shows such great improvements when the number of district nurses is increased.

It is believed that the patient time will be decreased to about 80% with this work method, if the same types of patients are sent to the triage as today. If the types change so that there is less semi-emergency and revisiting patients, that should not be booked to the triage, coming to the triage then the patient time might decrease to 60% and even lower. If it would decrease this much then this work method should be considered but as it is today there are too few appointments for semi-emergency and revisiting patient forcing them to come to the triage instead. This makes it unlikely that the patient time would decrease to 60%. As it is today it is most likely that the patient time will decrease to about 80%, which gives a good improvement to the system performance. Though, it is not as much as with the second triage team concept or the current strategy and it uses more personnel, therefore one of the other concepts is preferred.

A great advantage for this concept is though that the personnel most likely will feel like a team, which is preferred according to Lean Healthcare (SUS, 2009). Thus, the "us and them" mentality between the physicians and district nurses will be eliminated. Also the fact that the district nurses will get direct feedback at their decisions and thus learn more, i.e. gain more knowledge and be able to practice knowledge based medicine as suggested by Geonombrott (Landstingsförbundet, 1998), is considered to be a great advantage for this work method.

One disadvantage is though that it can be considered as a waste of time for the district nurses to do nothing while the physicians examines the patient, which can take up to 24 minutes with a patient time of 80%. According to the Lean philosophy this is considered as non-value adding time and should thus be removed to reach efficiency in the system (LERC, 2007). Another disadvantage is the computer system, it is slow which makes it impossible to sign in and out between patients. It is also not possible to be signed in at two computers at the same time and this prevents the district nurses from using a computer when they wait for a physician to come with them to see the patient. This in turn prevents the district nurse from doing anything while she waits since she needs a computer for all her work tasks, also resulting in non-value adding time (LERC, 2007).

8.5.2 Second concept

The second triage team concept shows system improvements already with the same manning as today, implying that this is a good work method. It also turns out to give the best and most stable system improvements when the manning is increased, making it the most promising concept. It is believed that the patient time will decrease slightly when this work method is used, mainly because the physicians and district nurses are not in their usual rooms. The concept is simulated with 100% and 95% patient time where 95% is considered to be the most likely option but it might decrease even more and then the system improvements would be even greater. Just as in the first triage concept it is also believed that the "us and them" mentality will be eliminated and the physicians and district nurses will start to work as a team, as recommended in Lean Healthcare (SUS, 2009).

There are though some disadvantages with this work method. First, it can be hard for the health care centre to find room for six persons to administrate. It will have to be six different computers due to the poor computer system otherwise it might have been enough with four. Secondly, it might be hard for the district nurses to keep track of which examination room that is available and not in reality, which does not show in the simulation. This can lead to delays that will decrease the system performance, which might result in that this work method is not the best after all. There might also be a problem with idleness when the district nurses have to wait for examination rooms or when the physicians have to wait for patients, which is not to be recommended according to Lean (LERC, 2007). This is though not considered to be a big problem in this concept since all personnel will have an available computer and thus can work with other work tasks e.g. phone calls or signing lab answers.

8.6 Other concepts

The results from the three other concepts are discussed in the following three sections. Neither of the other concepts turned out to give good improvements to the system performance and all of them were thus discarded.

8.6.1 Advice

This strategy could have been discarded without simulation when the statistical data of the two parameters was given by the health care centre. The problem is that too few patients will be sent home. There is a 38% chance for the district nurse to receive a patient she can be uncertain about and has to ask for advice for. With the 0.28 | 0.51 parameters and 30 patients the number of patients sent home each day will be about: 30 * 0.38 * 0.28 * 0.51 = 1.6. The district nurses will ask for advice about three patients but only 51% of them can be sent home, which is too few patients to make it all the way. This could have been good if the health care centre would have handled more patients each day, so that the number of patients sent home would have matched the number of patients one physician handles during the triage. If so, it would have given the same results as scheduling one extra physician to the triage. Another reason to why this concept does not work is that it puts even more pressure on the district nurses, who already are a bottleneck in the system, and thus the improvement effort will not give any effect, according to Theory of Constraints (Dettmer, 1997).

8.6.2 Back-up starts early

Despite all the improvements with this concept is it still not enough to reach the triage goals. The physician bottleneck is improved but the district nurse bottleneck is not and thus the system improvements are limited as suggested in Theory of constraints (Dettmer, 1997). It is unfortunate that utility for district nurses and physicians were not recorded here as it might show that this concept would have been better with an additional district nurse at the triage. It can be compared with the result from the current strategy with three physicians and three district nurses; the only difference would be that one physician starts at 11:00 instead of 10:00.

8.6.3 Extended triage

This concept does nothing else than reducing the amount of personnel working at the same time to half and doubling the time of the triage. With this concept it is a greater risk that patients will have to wait longer as there is no other district nurse or physician to cover up if the first one has a demanding patient. If there are many patients left for the triage back-up, both of the ordinary triage physicians will help the triage back-up by continuing before lunch in the current system. In this concept the first physician will go for lunch as planned with no regard to how many patients there are left. This leaves the triage back-up with only the afternoon physician to help out if there are many patients left, which also results in that the throughput time increases. This concept should not be used, even though it works at another health care centre, as it does not deal with anything but the time when the triage is planned.

8.7 Current strategy

The current strategy shows surprisingly good results if the manning is increased, with a system performance improvement almost equal to the second triage team concept. The utility is though still quite high for the physicians resulting in a less stable system performance. Other disadvantages are that the patients might experience all the moving around disturbing, especially for patients who finds it hard to walk. This could be one reason to why Genombrott recommend the distances between different functions to be as low as possible (Landstingsförbundet, 1998). The feeling of "us and them" will remain as it is today where the physicians' experience that the district nurses "throws" patients at them. There are though also some advantages with this work method. First of all it is a well-established work method and the personnel know what to do, how to do it and when to do it and secondly it does not require special rooms for the triage, which will make the scheduling of rooms a lot easier.

8.8 Comparing all concepts

The general concepts are considered to be beneficial to the health care centre. The drop-in to lab concept is highly recommended, not so much because it improves the system performance but because it removes one activity for the physicians and district nurses that they find annoying. The new schedule concept is also highly recommended since it does not require much effort and shows great improvement of the number of patients in the waiting room.

It can be seen that the current number and type of patients cannot be handled by only two physicians and two district nurses. Out of all tested concepts the second triage team concept, which includes the drop-in to lab and new schedule concepts, is considered to be the best option, both with the current manning but also with more manning to fulfil the triage goals. However, it requires quite big changes for the health care centre regarding the premises. If it is not possible to implement this change at this time, it is recommended to continue work according to the current strategy but add one extra district nurse and one extra physician to fulfil the triage goals. Adding more personnel to the triage can increase the amount of overtime for the district nurses and physicians as the other tasks remains the same. This can be an indication that the health care centre is understaffed, at least regarding physicians.

8.9 Summary

The simulation model turned out to simulate the health care centre in the case study accurately and it was discovered that not only the physicians were a system bottleneck but also the district nurses. It was then possible to try different improvement concepts in the model. No concept could fulfil all four triage goals, but disregarding the current manning goal, four concepts were considered promising enough to be recommended to the health care centre namely; the drop-in to lab concept, the new schedule concept, the second triage team concept and the current strategy but with an extra district nurse and an extra physician. The drop-in to lab and the new schedule are recommended no matter what other changes are considered but one of the second triage team concept and the current strategy with more manning should be chosen. It is though recommended to use the second triage team concept. In this way the health care centre will meet the triage goals and the personnel will be allowed to go for lunch in time and thus reduce their stress level. This will in turn result in a more sustainable work environment where the personnel will not risk being worn-out. If an investigation of the number of required semi-emergency and afternoon emergency visits is performed, the number of patients at the triage could be reduced. This would lead to that the health care centre also should be able to accommodate more listed patients in the future.

If the input data to the simulation model had not been valid, the model would not have been valid. Thus it is important that the input data management is done properly. This has proven to be the case if the input data management methodology by Skoogh (2008) is used. The methodology offers a structured way to manage input data and to make sure that the data is valid. Even though the methodology is developed for industrial projects it turned out to work well for health care projects as well. It is a bit stiff and more iterations can be needed than given in the methodology but what is most important is that no steps are forgotten if the methodology is followed. The total time of input data management is also reduced when following this methodology and this will in turn reduce the total time spent in a simulation project Skoogh (2008). One of the main reasons to why simulation is not more widely spread in the health care sector today is the extensive amount of time needed (Lowery, 1996). Since the input data management methodology can reduce the time needed it might lead to that simulation will become a greater option for the health care sector while optimising patient flow. Simulation turned out to be a good evaluation tool in the case study performed in this project and this has also been the case in many other simulation studies in the health care sector. If simulation is used more extensively it could lead to better health care systems with less waiting time and thus the shorten the course of diseases. In the long run this could lead to a healthier population with fewer persons affected by ill health and thus resulting in a more sustainable society.

9 Conclusion

The input data management methodology (Skoogh, 2008) is a good tool for structuring the input data management in DES-projects for health care systems. It has worked well in the DES-project at Sörhaga health care centre where the conclusion that the triage is understaffed regarding both physicians and district nurses can be drawn. This is due to that they are alternating bottlenecks in the system. To meet the triage goals more personnel need to be used at the triage. This leads to that the health care centre is generally understaffed regarding both physicians and district nurses as their workload outside the triage will remain on the same level even though more resources are spent on the triage.

All four goals cannot be met at the same time, therefore the concepts fulfilling the most important goals have been chosen. Thus, two minor changes and two more extensive changes are suggested, were one of the more extensive changes should be chosen. First a minor change where the health care centre ought to make sure to book as few other patients as possible during the hours of the triage. This will lower the number of patients in the waiting room and accommodate for the second minor change. This second minor change is that triage patients can go as drop-in patients to the lab since there are no other patients, thus physicians and district nurses will not have to spend time on booking them to the lab. The minor changes should be implemented regardless of which of the more extensive changes that is implemented.

The primary major change is the second triage team concept in which special triage rooms are used. One extra physician and one extra district nurse should be scheduled for the triage, this means in total three of each every day. This concept will require in total five examination rooms and at least one room to serve as administration room where each triage staff member will need a computer. A patient will be examined by a district nurse who then can decide to tell a physician to see the patient for examination, send the patient to lab or send the patient home. For a complete description of this concept see section 5.2.2. If the primary major change cannot be implemented, the second major change is to keep working according to the current strategy at the triage but with three physicians and three district nurses assigned to it.

The primary major change fulfils the triage goals and the second major change almost fulfils the triage goals. If one of these is implemented it will lead to great improvements of the system performance which in turn leads to that the health care centre can receive more patients with less waiting time and thus get more pleased patients. It will also lead to a lower stress level for the personnel at the health care centre as the triage will end when planned, allowing the personnel to plan their work day and stick to it, which will result in a more sustainable work environment. Neither of this would have been possible if a simulation model had not been built since the health care centre had not considered that the districts nurses were a bottleneck at the triage. The simulation model would have been useless if the input data would not have been good enough for the model to pass the validation and thus not represent the real system well enough. The input data management methodology evaluated in this project turned out to be helpful to make sure the input data to the simulation model were valid.

The result of the evaluation of if this input data management methodology is that the methodology is suitable to use in the health care sector. It provides a good support to ensure that important steps are not forgotten during the input data management, especially for inexperienced users. The methodology is though somewhat stiff and more iterations than implied often occur and several steps are likely to be processed simultaneously. This is due to that some steps can be started before the previous is completed. Due to this it might be good to consider the methodology more as a guideline and not something that should to be followed to the letter.

An additional step could be added to the methodology due to that the personnel in a health care system are often not used to being clocked while the data is collected. It might therefore be good to add a step, where everything concerning the data management is explained for the personnel, in the input data management methodology. In this way this will be stressed and not taken too lightly.

It is believed that the input data management methodology will reduce the time consumption for input data management for health care simulation projects and thus reduce both the time and cost which will make simulation a greater option when improving patient flow in health care. This will lead to more effective health care systems and thus shorten the course of diseases, which in turn will lead to a healthier population and thus a more sustainable society.

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