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DREAM CLINIC - Orthopaedic Department

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In this paper an opportunity to redesign an orthopaedic department from a logistical efficiency perspective is presented. With the theories of the Delft System Approach to understand the process flows through the healthcare industry, then using the Theories of Constraint to identify bottlenecks and finally using the methods of Lean to isolate opportunities to reduce Waste and improve the Value Stream Map.

Throughout this research many interviews took place with a number of different hospital departments at different locations through the Netherlands. The information was not always applicable to the orthopaedic department but logistical solutions from other departments are also applicable to the orthopaedic department. In addition companies who work closely with the healthcare industry, such as supplier, architects and consultancy agencies are also interviewed to understand the approach to such problems.

The initial assignment was to redesign the orthopaedics department of the Maartenskliniek in Nijmegen, the Netherlands. The scope limited the project to the walls of the current process and the input parameters of the current patient flow and doctor, nurses and other staff capacity. However after a few discussions it was quickly shifted towards a complete clean slate and the opportunity to design a department with all the process flows from beginning to end with the focus on logistical efficiency. The process of this design is described in this paper with all the recommendations of the experienced people in the industry.

The structure of this paper will be first of all, the process will be illustrated through the methods of the Delft System Approach. This is used to understand what is happening from beginning to end. After which the Value Stream Map from the Lean theory is created for all the separate steps for both patients, staff and medical supplies. With this current state Value Stream Map and research on modern methods and future ICT and smart systems to improve this flow a new Value Stream Map is created. This is done through eliminating the wastes and using the Theory of Constraints to understand where the hiccups are in the current system. This lead to a potential new system of which a model could be created. Ultimately this is designed in a simple simulation which measurable KPI’s where the system is placed. This model however only presents an ideal situation as the healthcare industry is a very emotional and personal industry there are variables cannot be simulation, therefore an additional list is created with KPI’s which could be implemented in reality to see where more opportunities lie. Finally conclusion is provided stating the solution as a One Stop Shop opportunity and potential to implementation. Recommendations follow from the conclusion.
In this chapter the background information regarding the assignment will be discussed. How the assignment came to be and further details regarding the assignment. The goal and targets of such the assignment are highlighted. In addition the approach of the very unknown topic is discussed.

2.1. ASSIGNMENT REASON

The project arose from a personal interest in the healthcare industry. I, myself have always been interested in the supply chain aspects of technical production facilities, but with the continuous discussion in the media that hospitals are having problems financially, I thought it might be interesting to take a look at this from a technical perspective. In addition, my mother's side of the family is well known in the healthcare industry, especially oncology. So somewhere in my genes there might be some hidden interest. With this combination and the interest of the master Transport Engineering and Logistics department including a very enthusiastic teacher, Wouter Beelaerts van Blokland, the assignment was set up. Starting with a clean slate, and no boundaries, it was a great opportunity to apply the theories, learned in the previous years, to reality. With no knowledge of the healthcare industry and especially no knowledge of the logistics in this complex world of patients, medical supplies and staff, the interest was very high to jump in and get a feel of what is going and for what reason. Heavy discussions why current processes are the way they are and how they could be from an engineering perspective was the result.

2.2. ASSIGNMENT DETAILS

In this section the scope and boundaries of the selected topic in healthcare operations are discussed. The selected assignment depth is explained and the direction in which the results will fall are explained. This assignment falls under the 'Design' criteria and therefore a proposed results will be explained in the end.

2.2.1. DEFINITION OF HEALTHCARE OPERATIONS

The definition of healthcare operations can be broken into many small aspects which all come together. These are the aspects in Figure 2.1.
Not all of the 8 aspects are considered and all their sub categories, but it shows the immens diversity of the healthcare industry and everything that needs to be considered. Companies such as GE, Philips and many healthcare consultants try to take a few of these under their wing and specialize in them to improve the processes. To summarize and simplify it, it comes down to the two words them self, ‘healthcare’ and ‘operations’. 

The definition of healthcare is:

*The act of taking preventative or necessary medical procedures to improve a person’s well-being. This may be done with surgery, the administering of medicine, or other alterations in a person’s lifestyle. These services are typically offered through a healthcare system made up of hospitals and physicians.* [2]

The definition of operations is:

*Jobs or tasks consisting of one or more elements or sub-tasks, performed typically in one location. Operations transform resource or data inputs into desired goods, services, or results, and create and deliver value to the customers. Two or more connected operations constitute a process, and are generally divided into four basic categories: (1) processing, (2) inspection, (3) transport, and (4) storage.* [2]

These two definitions provide the combination of healthcare operations.
2.2.2. Scope and Boundaries
In this section the scope with its boundaries will be discussed. As well as the goals of the assignment and the conditions provided from the client.

Reason for the selection of the orthopaedic department and not a different healthcare specialization is due to the fact that the orthopaedic department is very much manageable in separate steps with a fixed procedure time. This allows the strict technical approach to have a realistic impact on production facilities as well as this healthcare specialization. It is therefore very systematical and allows the theories from a technical perspective to be applicable. Another example which is also systematical in the healthcare industry are the eye clinics.

The scope limited to the orthopaedics department allows for a complete new approach to the design. Therefore a clean slate was the only option to redesign all the aspects that enter, exit and move around internally of the department. This leads to the 'Dream Clinic' from a logistical and technical perspective. All the flows are considered in this assignment and they will be discussed in depth. There are of course a number of areas in this industry which cannot be changed and some aspects are not to be lost either. An example of this is, that the patient-doctor relationship is highly important for the confidence and quality of healthcare, these are not to be removed from the process. It is not a solution to make 'butchers' of the experts (even though they like to call themselves that).

The assignment does not have the target to reduce the amount of staff in the department, or eliminate as many as possible human interactions, but it focuses on the opportunities to improve the healthcare process through modern and future technologies, which can be implement throughout the coming years. Its focus and goal is to increase the quality of care but also increase the flow through a hospital department to be able to service more patients and in a shorter time. This is good for patients, this is good for hospitals financial status and it allows the healthcare industry to focus more on research for illnesses that are difficult at this time.

Finally there are aspects of this design assignment which are not considered part of the scope. These are everything that have to do with the architectural aspect of designing. My knowledge is very limited and not part of my courses, therefore the design will be purely based on motion and not on how the corridors look and when or where a window needs to be placed. I simply am not able to do this. Certain decisions and conclusions can be drawn from this paper but the actual design needs to be checked, adjusted and confirmed by a specialist of this field.

To simplify the solution requires; standardization, automation, simplification and finally it must be measurable:
- **Standardization** - every room, ever office the same. Everyone is able to work everywhere at any point in time.
- **Automation** – reduction of (especially) communication through old methods, but automating this through ICT and other integrated systems. This can also include equipment automation or transport automation
- **Simplification** – Simple layout, shortest routes, simple process, reduces all levels of errors and improve asset usage.
- **Measurable** – Usage of current KPI’s and the creation of new KPI’s.

### 2.2.3. Additional Requirements
A list of the must have equipment, types of rooms, etc is provided below. This will be brought forward in the designing process. These have been observed and provided from the hospitals as they always need them close by:

- Outpatient examination Rooms
- Operations Room(s)
- Ward(s)
- Plaster room(s)
- Radiology
In this chapter all the research obtained throughout the study that is relevant is described and applied to the orthopaedic department. Often the examples are from different healthcare departments and have different implementations, but their core background is the same for this research. First of all, literature research is discussed from scientific journals, after which a number of hospitals and companies are brought forward which had been improved or working with improvements over a period of time. Many of the examples are therefore not from orthopaedics, but the solutions provided can almost always be molded towards a solution in the orthopaedics department as well. Therefore all research provides a huge opportunity to find solutions or methods to increase the quality of healthcare.

3.1. Literature

Throughout the research conducted to design the Dream Clinic, many different sources were used to get a better understanding of all the solutions that are already investigated. In the following paragraphs a number of these solutions have been pulled forward as they are relevant for this topic.

- The evaluation of hospital design [3] is something that is happening more frequently. Through the experiences that industrial companies [4] are having, especially the great successes they are achieving in making their operations more lean, the healthcare industry is starting to understand this is also becoming more relevant to them. That the adoption of these industrial implementations can be beneficial in their own processes. The use of modern logistical models and new technology in combination with slow implementation the healing of an ill patient can become a much more pleasant process. With the aid of today possibility to simulate new design, small bugs and issues can be eliminated and the larger bottlenecks can be discovered. These are the steps that will create a better process towards hospital design. The industry of healthcare has always been an push mechanism, but in the future the patients will switch to a more pull nature with new proposed logistical concepts.

- Not only does the improvements of the healthcare operations increase the throughput of patients, reduce their time in the hospital and allows more patients to be handled in a given year, it also reduces errors and the spread of diseases in hospital through infections (which can lead to deaths). It saves money and creates the opportunity for hospitals to increase their research in areas that require attention, or even completely new investigations to which the market is starting to show a demand. It reduces the amount of supply materials or equipment [4] needed and provides hospitals with a better overview of what they have and what they need to have.

- There are so many different things going on in a hospital, with so many people, ICT and equipment involved, it is difficult to keep track of what happens where and where what is going. However, information and data is the key to making this all a lot easier. When this is monitored and controlled it
allows a hospital management or a department unit head to more successfully control assets, people and equipment. Currently not so much research is conducted by the hospitals themselves, but there is so much potential to improve. The data can lead to standardization, to separation of unnecessary combined flows, to capacity planning at high level, visualization of flows and the synchronization of these flows[5].

• Not only are there opportunities in the way the process is setup and the planning of everything that has to do with it, but there are numerous new gadgets, equipments, tools and technologies available that will allow the workload to be reduced and the productivity to be increased. For example through the uses of RFID[6] a lot more information can be monitored from documents, patients, surgery tools, equipment, etc. These examples or the options that are currently out there which will create a much more controlled environment in a hospital and allow the staff to quicker get what they need and the supplier to quicker replenish when something is depleted.

• Because there is, of course, a lot going on in the motion of patients through the healthcare process, it is sometimes not realized how much there is also going on behind the scenes. All the medical supplies, pharmaceuticals and all the equipment that are being used during the process. These flows are complex enough on their own and therefore also require a lot of attention that can be optimized. Sometimes these processes are done through external companies within the hospital, such as logistical companies who work together closely with suppliers. This supply chain[7] has so many suppliers with so many different products and different destinations that this can have great effects on the healthcare.

• In addition there is the service perceived quality by the patients, which creates the reason why a patient would come back or recommend the healthcare at a particular institution[8]. Are the doctors really interested to you, is the service personal, are you able to be served quickly are all KPIs that affect the 'feel' of the service. This can all be improved through methodology of lean as it creates a stable working environment. These can be measured and quickly and visually shown through tools as scorecards.

• In India a hospital was set up for the cardiac care for everyone [9] by Dr. Devi Shetty. The idea of this hospital was that the healthcare should be available to all the locals from which most were relatively poor, therefore the service had to be cheap. This presented an opportunity by the doctor and decided to create this service. There are many tricks delivered of which some are not possible in Europe or in the USA, such as working days of 12 hours, but these are not the only method of making such a successful business. Creating a ‘Wal-Mart’ type of structure in the healthcare was his vision by working closely with the suppliers and finding a level of collaboration with them to reduce cost in return for certain more operations per year. The implementations together create a cheaper service for the patients and a better name for the hospital. In his aspect is all about working together to achieve a common goal.

With this information and all the opportunities from literature research it was possible to conclude that there is a lot to do in this industry but there is also a lot going on. People are determined to find solutions to increase the quality, the service and reduce times in the process for the patients. However it is also interesting to see what the hospital think about this themselves, therefore the rest of the research was conducted in hospitals and with employees who work there. This will be discussed in the following paragraphs.

3.2. EGM ARCHITECTEN[10]

An architectural office in Dordrecht, the Netherlands, who often design hospitals, both completely new and redesign departments. This was a contact obtained through the TU Delft and the first meeting regarding the healthcare operations in a hospital. An excellent place to start because they provided a lot examples in the healthcare industry which showed that there are aspects going very well and areas that are going well and required attention. The company provided this paper with start information to start having a look at how many beds and patients are required to push through the system. In actual fact it became very clear that the system needed to be of the pull nature.

Finally EGM Architecten, also provided me with an example in the healthcare industry where these rapid changes were taking place. This was the eye clinic aspects of the healthcare. There have been plans in the Netherlands where patients could be served for extremely low cost and for the same quality for certain stan-
3.3. **HAGA ZIEKENHUIS**

Standard operations. The knowledge for this new eye clinic was obtained from an example in India, where patients were being treated with very low cost but all with the correct and same level of care. This knowledge came back to the Netherlands and someone decided to build further on this concept. In the end the product was presented to a number of healthcare insurance companies whom thought it was, of course, extremely beneficial to them. So they provided the designed with a contract for a large amount of patients per year. However there was one mistake for the implementation of this concept. It is the fact that when you create such a low budget healthcare operation, you are going to create a lot of enemies. The whole healthcare system is based on the fact that you need to make money in certain sectors, because other ‘extremely’ expensive sectors cannot make this kind of money, the care is simply too expensive. When you create this low budget eye clinic, all the other eye clinics in the Netherlands cannot compete with you and they fail. This is not a risk that can be taken and therefore the design was blocked or pulled (unknown, but it never came to be). The fact that this design is blocked is very interesting, as it shows that creating a Dream Clinic can only be achieved if not only you benefit from it, but also the larger scale healthcare. I will not take this forward in my design as I would like to go for maximum capacity patient service, but it is something to consider when these plans become more real in the future.

### 3.3. **HAGA ZIEKENHUIS**

The HagaZiekenhuis is a hospital in the Hague, the Netherlands, with many different departments. The hospital has just been renewed and a visit was planned to have a look at both the oncology department including their pharmaceutical and medical supplies process. A second visit after was setup with the orthopaedics department to have a look at the step by step process and to create a Value Stream Map (VSM) at a later stage. There was the possibility to have a discussion with both departments and get a better feeling for how they work towards their patients.

As all hospitals these days, the atmosphere in very comfortable and very safe, the people are kind and greet you, but there were some interesting observations and discussions when you speak to the personnel when they are not around colleges and able to speak freely. This was applicable to all hospitals

#### Oncology

The oncology department in the HagaZiekenhuis was my first meeting in a hospital, where I could see how patients are treated, but the main focus of this meeting was to understand how the staff collect medical supplies and how the pharmacy delivers medicine. There is a collaboration with a company called ZorgService XL who supply all the medical supplies. From a centralized warehouse in the hospital all these supplies are delivered and stored, from here on are all of them distributed throughout the hospital, each department in particular. The department have their own walk-in closet with shelves behind doors. These closets are organized and very easy to oversee. However the procedure of replenishment is still very old fashioned. Whenever a medical supply is not in the departments closet, the tab of the product is placed on the inside of the door and this means it needs to be refilled. Every day an employee of ZorgService XL walks around and tries to replenish this as quickly as possible, but due to the fact that this is all a human motion a lot of links can create a lot mistakes which affects the healthcare. The continuous motion through ZorgService XL employees and staff moving products cards about creates only potential mistakes. The second aspect of the walk-in closet was that there are sometimes products required which are not delivered by ZorgService XL and need to be ordered in. Often relatively expensive products and have some serious lead time. These products are also used in different departments of the hospital, but knowledge of their availability is not clear. Therefore they are always ordered even though they could be on stock in the hospital.

The pharmacy was a different aspect of the system, completely done by a different company and the hospital staff is not allowed in the room. The pills, etc are all prepared by patient and delivered to the patients, which allows for complete focus on the service of this product. The department was very positive about this and preferred this way.

#### Orthopaedics

The orthopaedics department worked with the modern method of flexible doctors and patients going to rooms before they arrived. This flexible system and standardization of rooms was very clear and easy to understand for patients as well. Centralized waiting area created a comfortable area with coffee and entertainment for the waiting time. However the most interesting of this department was that they still worked with paper, huge orange documentation of patients history were being distributed around and showed a lot potential mistakes, getting lost, not being able read, etc. There were planning staff available whom were always planning the days of the doctors whether it was the outpatient examination days or the days for surgery.
Interesting of this was that the person spoken to said that he biggest unbalance was in the capacity of surgery and outpatient hours.
The surgery aspect I was of course not able to see, but the process was explained to me. The most interesting of this process is that the patient is transported in the bed to the OR and back by the nurses. These were estimated to be walking around per day at a out 1.5 to 2 hours, which is about 25% of their productive hours. The cause of this was purely the long distance they had to walk which are extremely difficult when the OR is at the other side of the hospital. The bottleneck were presented in the total process of the ortopaedics department when it comes to process where surgery is required are the doctors. They have limited time available compared to the outpatient hours and therefore there is always a buffer prior to the operations step.

3.4. Diakonesshuis[12]
The Diakonessenhuis is a hospital in Utrecht, the Netherlands, with all types of departments. It is a typical city hospital, central location and easy to access. It is a relatively modern hospital and continuously searching for new opportunities. A meeting was setup here to have a look at the outpatient department of oncology where the patients receive a meeting with the doctor and if they have an appointment get their treatment. Also a visit to the pharmacy was setup, to have a look at how the pharmacy distributes the medicine throughout the hospital as well as makes medicine for specialized patients who require extra careful dosages or personalize medicine.

Oncology
First of all, a visit to the daycare oncology was on the program, where I met with a doctor and got a closer look at they way they work. It was very clear that oncology and orthopaedics are two very different fields. Oncology requires a lot more personal care towards the patients, which is realistic as these patients are very ill, sometimes terminally ill. Therefore the meetings are longer can results in overtime and are planned more carefully. However, because this was the oncology department and only the day care they did have a lot tricks up their sleeves to making it patient friendly, personal and especially very pleasant to walk around. This is where patients are given their chemotherapy for a few hours. There were comfortable chairs, some in areas where you were able to speak to other patients, some more private to accommodate all the needs of the different patients. Ipad were spread around where patients could entertain themselves, all and all for such a difficult moment in their lives a very pleasant place to be.
Where the department and hospital really distanced themselves from previous hospital visits is the software they used. They do not work anymore with paper files, but everything was digital. The patient was given a profile with their information and all the doctors had access to this information and can add meetings when a patient comes in. This way all doctors at any time can prepare themselves for what the patient had already been through and therefore be more accurate in their next steps. Besides that it was possible to prepare things from home offices. After speaking with the doctors they were explaining to me that the next step was to implement personal pages for the patients to see themselves and show their progress and process in their current healthcare operation, which makes it easier for the patient to see where they are and what possible direction there are. Their next meeting is known and an image can be seen of the their doctor, they are always in control of the appointments and can mentally prepare themselves a little more. To conclude, with simple implementations of technology products many new helpful steps can be taken.
An observation regarding the schedule planning was a new program the doctors used to plan their days, weeks, months and years. When working together with a number of doctors and all having younger children, the planning of holidays is sometimes difficult. The development of this planning tool created a visual overview of all the doctors and their schedules which made everyone life just a little bit easier and a lot less stressful, which all leads to improved healthcare.
Finally the headway that this hospital has made with breast cancer is also groundbreaking. In the past the process of breast cancer diagnosis and removal was extremely long. When females are worried that they have a lump in their breasts they were able to make appointments for weeks ahead and this did not even concern a possible surgery to remove lumps (or previously the whole breast). Nowadays the planning and process has been planned so well that if there is an issue, it is almost always possible to come in the next day and have an examination take place and at the end of the day the full diagnosis can be made and if necessary schedule for surgery can be made as well. This way the patient is directly fallen into high speed service and must feel such levels of relief compared to the previous method. Additionally breast surgery these days can be done without removing the complete breast, not a supply chain improvement but of course a great improvement for the women in this scenario. Always worth mentioning that when improving the supply chain the time available...
to improve the operations by the research and doctors is always made more accessible.

**Pharmacy**

A short visit to the hospital pharmacy showed a lot of insight into the highly complex operation they are running. The principles of Lean and Six Sigma apply well here. The pharmacy distributes pharmaceutical products throughout the hospital, but also makes products that are very patient specific. This is done in the hospital self and in very special medical clean rooms by highly specificity trained personnel and equipment. The system seemed to be doing well and there were no imitate waste opportunities to be found but one. They are currently working with paper as well as computer systems, which is very old. In the future they want to take the step to only computer but there currently was not software available for validation, which should show huge opportunities in the market. Regardless of the lack of these computers, the products are hand picked from a small warehouse and brought around the hospital in cart but exact knowledge of how much there is on each department or in the hospital was not there. Therefore it became very clear that especially here with chemicals and products that can be also harmful to patients, that the knowledge of products is very powerful information.

### 3.5. **Berenschot** [13]

A consultancy company which works closely together with the healthcare industry on many projects in the Netherlands but also abroad. A meeting was set up to discuss the previous projects conducted of which many were in eyecare clinics. This is a very similar environment as the orthopaedics healthcare, because both can be approached with a systematical perspective. The eye clinic in Rotterdam (The Rotterdam Eye Hospital) is where fast steps were taking in improving this supply chain. For example taking the following numbers:

- 510 patients visits per day
- 50 operations per day
- additional 70 emergency visits per day

These are some serious quantities for a hospital and it takes great planning and excellent knowledge of the process to be able to perform such high level surgeries and patient care per day. The employee of Berenschot with whom I spoke was part of the development in making this happen. In particular the KPIs that were used at the time and still are now were very interesting. The first thing that was done, was get a better understand of what they currently have and what they are trying to do. In the image below (in Dutch), this is described:

![Image: Figure 3.1: Current capacity calculations [14]](image)

The next approach was to understand the procedures and place them in line with their duration. In the Netherlands this is possible to do through the DOT system. This system hold all information regarding the procedures in the healthcare with their prices. This can be calculated back towards how long they take and how much they cost for a hospital. From the image above, the visualization of KPIs shows a lot of information. In particular the fact that all the information from a hospital can be displayed by FTE in particular but even better by doctor in particular. This way the doctors can be analyzed next to each other and they create the ability to compare them. This can have a dangerous affect as you create unwanted competition, however if
this is brought in a different manner, and that the doctors can learn from each other, then there is suddenly a lot more interest. These are KPIs which will create discussions and ‘stirs’ the system in search for more improvements.

Figure 3.2: Calculations balance [14]

From this eyecare operation it shows that the capacity of the staff is not sufficient to provide enough care for their goal. This means that there is an in balance and they will not be able to meet it. So something needs to be done to make this possible. Their approach was to understand what is standards, what is routine and finally what is something ‘in their nature’ (cultural).

**Standard:**
- Identical repetition
- Compliance
- Procedures
- Deviation

**Routine:**
- Similar but not identical repetition
- Selection
- Clinical guidelines
- Error

**Non-routine:**
- Non-repetitive
- Interpretation
- Intuition
- Failure

The above lists are only an indication of what is possible in this field. Many different and more alternatives can be found in different processes. It often occurs that a few of the KPIs are used for a period of time till the improvement has made significant changes and then the KPI is dropped when it has set in. Then a new focus is placed on it again. This is not an issue, but it is safer to continue to measure something as the power of this information can always be used again.

From here on it is possible to create a production control program with all the subcategories that are required to manage staff, patients and medical supplies in their process. All these are applicable to create a well-controlled system and to allow it run smoothly.
The result of these general steps is that the entire healthcare products is dissected and displayed in detailed accessible process steps. Each can now be attacked individually. The final observation of this meeting was that there are so many opportunities in the process, However they can only be made clear with data analysis and this requires data/information. Therefore it is important that this is made accessible but also is actually measured. This is step one and might not always be done so well as it is not directly of interest by all the very busy medical staff whose concern is not directly with healthcare operations but with the healthcare itself. The mentality needs to be shifted and it should be part of their jobs to return measurements, data, complaints and observations to management levels.

3.6. **BIOMET HEALTHCARE INITIATIVES [15]**

Biomet is a company that manufactures medical devices in particular the reconstruction of hips, knees, shoulders, fixation devices and other orthopaedic support devices or tools. The company creates the products in many different size and shapes to be applicable for all the patients. The installation is done by the orthopaedic surgeon and not by Biomet. Biomet does not only manufacture these implants in Warsaw but also does has a sub department called Biomet healthcare Initiatives (HCI) that look at the end-to-end supply chain. Previously there has been a collaboration with the department if Industrial Design and Biomet HCI to get a look at this supply chain. There the following was created:
This images provides a relatively high view (helicopter view) on the process and does not go into deep specifics of all steps of the process, however it does provide an insight in how many steps a patients goes through before being diagnosed healthy again. In this image, this paper focuses only on the process steps from Diagnosis to Hospitalized (maybe a small step into Rapid Recovery).

Biomet HCI, tries to focus on all of the steps and create a method of making everything easier for the hospital and the patient. The delivery of the products they deliver, consists of two parts. First of all there is the actual implant, of which there are many options, with difference in texture, size, etc. The implant has a lead time of less than 24 hours, these are on stock and quickly deliverable from their centralized warehouse in Europe. However this is not a very personalized products, the personalized product lies in the piece of equipment that needs to cut into the bone where the implants are placed. This is the second product which they deliver. From an MRI scan, the bone shape can be determined, this scan is digitally sent to another company which works together with Biomet to make the personalize mold. This is where the bottleneck shows up as it takes 6 weeks before this personalized product can be delivered at the hospital. This is only from a suppliers side as there are of course of bottlenecks in the planning of ORs.

Interestingly enough the Biomet company suggest that this is not a bottleneck seen by the patients. Their experiences say that the patients often need time to process the fact that they will need surgery and want to maintain their personal relationship with the doctors and not see them as 'butchers' who quickly screw in a new pin. Therefore these 6 weeks are not an issue and the patients is happy to do so. Chances are that in the future this will change and that the implementation of an implant is possible on the same day. Which leads to the latest success of Biomet, the diagnosis and implementation of an implant all in one day[34].

This is the future, maybe not in the next years, but slowly the healthcare will start to develop towards this level of rapid implementation and straight into recovery. Interestingly enough the focus of Biomet is 'first better then faster' but they actually believe that by going faster it will also get better, they go hand in hand. However the 'one stop shop' concept is something that is starting to become more and more interesting in the healthcare operations if the diagnosis and (if necessary) operation chain. They were able to achieve this concept by pre-planning the whole operation. Of course this was more a simulation to see the possibility and to show their capability, but they were able to to this with a real person. The whole process from patient (who was prepared and knew about the day) walk in, got diagnosed, scanned, placed in a bed, operated and returned to the ward, all in the same day. The patient was even able to go back home at the end of the day. The condition was for the a hip replacement patient. This change in healthcare operation and especially the speed, creates a lot of questions, but not really on the healthcare side of it. The healthcare operations are able to manage the change and the impacts on the changes in their supply chain. Actually it makes things much more manageable as patients are going home at night. The patient, however, is asking many more questions, because nowadays going to a doctor for diagnosis is not the same as being operated on the same day. No patient is looking to be operated the same day as they go into get their hip checked. Especially since most patients are not able to function (walk, move around, drive, take care of children/family members, etc) completely the same as normally. People need to mentally prepare themselves for the changes in their coming days, they need to create a back up plan and find someone to take of themselves. For this reason the one stop shop is something that will not be implemented in the near future, but as soon as the technology and the healthcare start to reduce the duration of the aftercare process. Then this becomes very realistic and will be implemented very quickly.

3.7. LOGIZ CONGRESS [16]

A congress was organized by three companies who work in the healthcare sector, Logiz, Rivas and King. Their focus was mainly on the care fore elderly and therefore the home's for elderly. However as they pointed out it was not a slow moving environment at all. There are a lot demands and especially a lot methods to ensure safety for these patients by carefully constructing a layout of the building. A lot of precautionary aspects come into the design when it comes to the many unknown variables.

There they used a guideline structure of something that was called 'Planetree'. This contains 12 aspects on which the home should focus on in order to ensure that the environment for patients, employees and visitors is as stable as it can be. The Dutch image below describes to content:
The goal of the nursing home for elderly on this location was able to supply the same care as any other home or better in the Netherlands, but also for the same price as the government has set for the simplest care. This results in best quality combination when it comes to the elderly patients. They achieved this goal and therefore have long waiting list for new patients when rooms become available. The areas where they focused their logistical efficiencies were everywhere but when came to the patient. Areas, such as food distribution, bed linen, medicine and staff transport optimization were all areas where they placed their focus as they let the patient go about their own being. The patients were most comfortable due to this, but even more comfortable as they could be served well. The staff had plenty of time to really get to know the resident patients and bond together. The care became personal to each of them and therefore, again, comfortable.

3.8. Future Opportunities

In this section other opportunities are described which have been collected from internet research. There are numerous companies who are specialized in just a small aspect of the healthcare industry and have created solutions to further improve the process. Therefore the following list is setup to describe a few of these options, which are very realistic to be implemented in the near future.

**Smart Healthcare** – with smart phones guiding you to your meeting and ensuring that you will know in time what is waiting for you. Company is called Proxible [17]. This product can also help track down patients, doctors or other staff when they are needed and not contactable by phone. Allows the measurement of walking and movement. This is done through Bluetooth.

**AGV** – using automatically guided vehicles[18] to help aid the patients who are in wheelchairs or have difficulty moving themselves.

**Airport Check-in counters** – Like in airports [19], where you have check-in counters via a touchscreen computer, this can also be implemented in the hospital to provide information where to go. It also tells the hospital system that the patient has arrived, early or late. Ultimately this could be linked to a smart phone.

**Personal page** – The use of a website [12] where the patient can login and find their own personal page and their progress in the process with the steps that were prior to this and the steps that are to come.

**Digital dossiers of patients** – Digital program called CHIPSOFT [45] that allows the doctors to all work to-
together in the dossier of a patient in a hospital system and at home. This eliminates the loss of data and the loss of papers. More details will follow.

**RFID** – Through the use of RFID technology [20] the knowledge of quantities and location of medical supplies, Pharmaceutical supplies, increase asset use can be increased. A company who uses this already is Combister in collaboration with Reinier de Graaf Hospital in Delft.

**Patient identity methods** – The identification of a patient is of course very important, especially when the patients are older or going into surgery. There are technologies available with the use of RFID [20], which allow the monitoring of the patients through scanning their tag for example on a wristband.

**CT Scan and 3D printers** – With the upcoming technology of 3D printing[21] and the current CT scanning technology it is possible to create a complete 3D digital model of a patients skeleton. This can be printed in 3D by a 3D printer. The reason for doing this is because the companies(suppliers) who make the prosthetic implants need to make sure that the new hip is an exact match for the patient. The new hip can therefore be tested on a 3D model [22] before going to real patient, this can reduce mistakes and errors in the making of the prosthetic implant and therefore the principle of First Time Right can realized.
The Delft System Approach is a systematic approach of an industrial system situation. With this method it is possible to clearly obtain the process streams in a system. Therefore this method is selected to break-open the healthcare operations in an orthopaedic department. The use of a PROPER model allows this to be possible. In this chapter the PROPER model is applied to the orthopaedics department.

The PROPER model represents an industrial system as a subsystem of the organization as a whole. It contains a subset of the elements but includes all of the relations. The aspects are the Order, Products and the Resources. These are transformed through Performance, Operation and Using. Between these transformations there is also communication. This results in the final products being delivered, resources used and ultimately a handled order. Ultimately there is an overpowering Control function which manages, with Standards and the Results from the industrial system, the system and final is also placed in the Environment.

In the below figures the standard PROPER model is shown and the one for the healthcare operating system at the Maartenkliniek. Finally, it is possible to zoom into an area where different sub categories take place. In figure 4.2 the overall PROPER model is shown. After which the flows will be explained in further detail.
The patient status is very relevant in this situation as it provides the information of what kind of order is placed. The next step therefore is the operation to be conducted on the patient, either outpatient appointment or a surgery (depending on how far the patient is in the process). The second process is the most well known, the operation itself, which can be broken down into sub categories and sub operations. The final process is the one where all the resources enter the system and are used to service the patient. On top of the healthcare operation there is the control system which reflects the status of the system, results, back to the standards that are set to ensure that everything is going according to the guidelines set. Otherwise it steps in and adjusts the healthcare process.

In figure 4.3 the different type of process flows are shown that enter the system of an orthopaedic department. For instance, there are patients who stay longer and therefore they fall under 'long stay'. All the resources that enter a hospital have many different subcategories and therefore different process flows. These are all illustrated below.

The next step is to take a closer look at what the patient goes through in the operate process. Therefore the Value Stream Map from chapter 5 will be used in this patient process flow. An alternative way of showing
this, but is not always as clear is in figure 4.4. This is a small zoom into the patient process

![Patient process diagram](image)

Figure 4.4: Patient process

The patient has two different processes, the first two steps of the process are the same for all patients, where they enter the system by making an appointment and attending this appointment. However, some patients require surgery for their orthopaedic problems, therefore these patients enter the process with a surgery and an aftercare process (sometimes the aftercare is limited to a few hours). However, there are therefore two different routes the patient can take to reach the status of a serviced patient. There is sometimes some jumping from boxes to boxes (procedure to procedure), which is not clear here. For example, some patients might go from outpatient meetings into aftercare, as this also contains physical support.

Next is a step into the outpatient process. With that in mind, it is often a process of either repetitive outpatient appointments or leaning more towards an operative approach. This depends very much on the status of the patient. The first appointment of a patient can go into two different directs depending on the diagnosis which is dependent on the results from supportive imaging. See figure 7.8.

![Outpatient process diagram](image)

Figure 4.5: Outpatient Process

In this process flow, the supportive imaging plays a very strong role, as it is the main tool (besides the doctor) which creates the possibility to diagnose a patient properly. It is almost always necessary for the doctor to use an imaging option to understand where the pain is coming from and to make an accurate decision. Therefore almost all patients receive this after their first appointment. There are a few different ways to be able to look into the human body for the diagnosis of an orthopaedic patient:
• MRI scan
• CT scan
• X-ray scan
• Echo

All of the four methods above are done through a machine, some take more time some take less. The first three have one thing in common and that is that you have to go to a radiology department to have these tests done. They create an exposure of radiation which is not very healthy for the patients and therefore also requires a radiologist who takes the images. The last one, echo, is something that every doctor is able to do and simple can be done in an outpatient examination room. This is the supportive imaging for an orthopaedic department. The results of these images are looked at by the doctor who draws a conclusion and decides the next steps for the patient. Either operation, physical support (through exercise) or sometimes nothing. When a patient goes into operation it is important to realize that there are a number of pre-operative measures to be taken. There are some variables of which the doctors need to decide. First of all, there are more than one doctor in the process now. This is because the patient will need to go under, it is done by the anesthesiologist. There are pre-meetings with him/her before a patient gets the operation. In addition the implant for the patient needs to be ordered, which requires a detailed scan of the patient’s pain location to make a personalized mold and the correct size needs to be ordered. Therefore there are these process steps, pre-surgery consults.
In this chapter, four aspects of Lean will be discussed in detail to remove unnecessary steps, reduce waste, eliminate bottlenecks and increase the measurements of the end to end process. With these procedures from the Lean Toolbox the process will be dissected and restructured for a more lean process for patients, pharmaceuticals, medical supplies and staff.

**The theory of Lean:** Lean manufacturing, Lean Enterprise, or lean production, often simply, "lean", is a production philosophy that considers the expenditure of resources in any aspect other than the direct creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the client who consumes a product or service, "value" is any action or process that a customer would be willing to pay for. [Wikipedia]

From the above paragraph the focus is to find all the value adding aspects of the healthcare industry in the orthopaedic department, put them in line with each other in the most efficient manner, with focus on time and finances to improve the care. The first step in this process is to create a VSM (Value Stream Map). This will be used a tool to understand how a patient flows through the process of the healthcare industry from beginning to end. After which the waste aspects are illustrated and selected from the VSM. Then decisions are made to reduce these wastes and place the process steps closer to each other.

### 5.1. Value Stream Map

A value stream map is a lean enterprise technique used to document, analyze and improve the flow of information or materials required to produce a product or service for a customer[24]. Value Stream Mapping [25] visually maps the flow of production (current and future states) using a defined set of symbols and techniques and

- Provides a foundation from which to work when identifying the constraint. For example, the cycle time of each stage can be marked on the map.
- Engages teams and useful for problem solving exercises.
- Helpful for documenting complex processes.

Value Stream Maps are created of the orthopaedic department as well. They are made for all the different process steps that are currently in place. There are 4 different processes in this department:

1. Appointment making process
2. Appointment process (outpatient)
3. Operation process
4. aftercare process
For each of these different processes a VSM is created to understand what the current situation looks like and from there the Theory of Constraints and Waste elimination/reduction is applied. First of all this is the overall VSM of the four process steps:

**General VSM:**

![Figure 5.1: General VSM](image)

Here it is clear that there are maximum four steps before an orthopaedic patient is completed through the process. The patient does not always have to go through all four steps as there are many patients who do not go into surgery.

**First appointment making process:**

![Figure 5.2: Making first appointment VSM](image)

The result is that the patient has an appointment with a doctor at the hospital on a specific date. The patient has to get him or herself to the hospital and back. If the patient does come to the first meeting, it has an effect on the overall process of the planning of the day and the patient has to wait again for a new appointment. Often takes a few weeks to do so (again).

**Appointment(s) process:**

![Figure 5.3: Outpatient appointment VSM](image)

In the Netherlands, therefore not applicable in all hospitals there is an additional step of creating the Hospital Polis Card (Poliskaart in Dutch). This card is related to the hospital information system and has to be made the first time you enter a hospital. However sometimes it needs to be replaced and therefore has to be done again. All personal information is on this placed on this card to make it accessible for all the departments in a hospital. The step adds significant amount of waiting time and card creation time. The step is placed directly after entering the hospital. (The assumption is that all patients know this and do not forget, which is not always the case and it can add more time and delay to the process).

**Operation (surgery) process:**
5.2. THEORIES OF CONSTRAINTS

The operation process is the most time consuming process of them all. It takes a lot of staff and planning to get the patient to the OR, operated and finally back to the ward. There are so many people involved that this has to be a well oiled machine. From the image it is possible to see that it is however a one flow process. There are no cycles which allows the planning to be very simple and structured. There are only difference in operation times for different types of operations, but mainly these time are relatively constant.

**aftercare process:**

From all of the previous images it can be seen that the patient goes through a large amount steps to become a serviced patient. This is a results of many precautionary steps and diagnosis steps that need to take place before a patient can be directed to next step. The reason for this is that some of the steps can have a health influence on patient which is not always necessary. The next step of this assignment is to take the knowledge obtained from the VSM through a filter which shows where there are unnecessary steps or where some steps can be bypassed. First the theories of constraints are discussed, after which the wastes are determined. Finally a new VSM is created for the Dream Clinic.

5.2. THEORIES OF CONSTRAINTS

The Theory of Constraints is a methodology for identifying the most important limiting factor (i.e. constraint) that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor. In manufacturing, the constraint is often referred to as a bottleneck. The Theory of Constraints takes a scientific approach to improvement. It hypothesizes that every complex system, including manufacturing processes, consists of multiple linked activities, one of which acts as a constraint upon the entire system (i.e. the constraint activity is the “weakest link in the chain”) [25].
The image above provides a number very important steps that are still to be taken in this process of improvement towards a Dream Clinic. Currently this document only focus on the Identity step and partially on the Exploit. But the rest of the three steps are very important as they ensure that the placed improvements are maintained. In addition as this is a circle, new improvements will be found again when going around it. The circle has been completed a few times for this design of the Dream Clinic except the Subordinate step and Elevate step are virtually done and not completed on paper. The result of TOC is that every change made in the process is reevaluated and it allows for continuous improvements. Value stream map has been made, next is to find the wastes and create standardizations to simplify the process.

5.3. **WASTE**
There are 8 types of waste known in the theories of Lean Manufacturing. These 8 types of waste should either be eliminated completely if possible, or reduced to the lowest level if that it is not completely possible to remove. These are the 8 types of waste with an explanation for it in the healthcare industry:

- **Transport** – found in movement of all process streams in a hospital, this include the patients, physical items and data.
- **Inventory** – warehouse management of the inventory in the department or in a room.
- **Motion** – where the staff are in motion (moving from A to B to C).
- **Waiting** – Patient waiting time, or staff waiting on patient time.
- **Overproduction** – helping more than necessary.
- **Over processing** – Putting more time into a patient that necessary.
- **Defects** – broken equipment or broken tools.
- **Skills** – a loss of experienced people who worked there.

Having stated the above 8 types of waste, it is important to note that all are very relevant in this case of the assignment. However for simplicity some are left out of the scope. The defects of broken equipment and broken tools is not part of the assignment and therefore the assumption is made that there are always functioning. In addition, there is no loss of experienced people in the assignment. Finally there is the topic of overproduction, which has also been removed from the scope as it is not possible to helping more patients than necessary. The healthcare is always at the first priority level and if doctors and/or nurses are helping more than necessary than this is not a waste but an addition to the overall hospital service. So the focus will be on TIMWO.
Going into detail on all of these 5 with examples:

**Transport** - Patients who are moving around the hospital is a type of waste as it can result in delays, therefore these distances should be minimized, but mainly they should clarified as there are more wrong walked distances than distances that are too far. Therefore a clear layout and especially logical layout can reduce a significant amount of delays. However the transportation of equipment, medicine, medical supplies and other tools are also considered a waste. These are also possible to minimize and oversee for a more clear structured supply chain.

**Inventory** - Hospitals are a very dynamic environment and the patient care is not directly predictable, therefore safety stock is important and not possible to eliminate. However some of the products are possible to deliver with JIT methodology and should be done so. Also the way the stock is currently being moved around in hospitals, is very old fashioned and there are new methods possible to implement which can create a huge benefit for the hospital. It is all in the communication.

**Motion** - The transportation of the patients around the facilities is an intensive job. Walking around with a wheelchair or a hospital requires at least two people to do an intensive and rather useless job. This can be an large waste in terms of overall day occupation when they could be doing something much more useful if these tasks can be prioritized.

**Waiting** – The waiting of the patient in the process is not directly a perceived waste when it comes to the hospital flow. The patient won't leave when it's not being serviced, such as in other cases. In a hospital the patient will wait till he or she is helped. However the less the waiting time, the higher the perceived quality appears to the patient. The overall emotional state of the patient is very important as it improves how collaborative he or she will be.

**Over processing** – The idea of putting more time into a patient than necessary. Although this can be perceived as a loss in quality towards the patient, but this does not have to be the case. The doctor is the most expensive tool on the hospital work floor and therefore has to be put work as efficiently as possible. This means that chatting to patient when the next is waiting is perceived as a loss, it can result in overtime and long delayed days. Therefore the over processing of such a patient is loss which can be prevented with planning and ending a discussion when it's completed.

Just having a look at these 5 potential wastes, it can be given that there is enough to do in the process itself. Therefore we focus on this. Next are the KPIs use to measure the changes in the process.

### 5.4. Key Performance Indicators

The definition [26] of Key Performance Indicators (KPIs) is:

* A set of quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their strategic and operational goals. KPIs vary between companies and industries, depending on their priorities or performance criteria. Also referred to as "key success indicators (KSI)".

As the definition above states, it is possible to use KPIs for performance comparison. There are many different types of KPIs and they all have a different level of significance which is difficult to state as it is related to the strategy of the company and where they place their values. There are different KPIs for different locations in the hospital business. Everything should be measurable and when it measurable it should be manageable, which is the next step of control. Some general KPIs of the industry[27] are for example:

**General:**
- Death rate
- Patient satisfaction
- Admission waiting time
- no. yearly patients no. beds
- Bed occupation

**Physical Assets:**
- Equipment utilization rate
- Equipment maintenance
- Equipment idle time
- Bed utilization rate
Financial:
- Revenue per doctor
- Profit per department
- Clinical cost
- Doctor non-availability times
- Overtime hours
- Test result errors
- Consequence human errors

There are of course many more KPIs that can be implemented in a department of a hospital. Every aspect of every movement, financial income of payment, occupation, etc can be monitored and it very interesting to see that most of them can say something very useful about certain specific areas a hospital. Interestingly enough these KPIs seem like they would be enough to monitor the hospitals levels, however there is one step that can be added on top of it to make it even more effective. The main reason why it is so effective, is because it is very visual and it makes it easy understandable for all the employees. This way of visualization is called a dashboard and scorecards. The definition [28] of a dashboard is:

*A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance.*

The definition[28] of a scorecards is:

*A scorecard is a tabular visualization of measures and their respective targets with visual indicators to see how each measure is performing against their targets at a glance.*

The build up and content for a dashboard can be very different for the desired application. There are aspects that need to be monitored more closely, or aspects not even in existence. Therefore the following image shows what it could consist of, there are more potential KPI’s that could be added, but it provides an overview.

Figure 5.7: Dashboard build up [30]
These are some visual examples of the dashboards and scorecards.

Figure 5.8: Dashboard 1 [27]

Figure 5.9: Dashboard 2 [27]

Figure 5.10: Dashboard 3 [27]

What we are starting to see nowadays regarding the KPIs of departments is that they are becoming doctor or FTE specific. [29]

Most departments have a number of doctors walking around and are doing the same or similar things. This provides the opportunity[13] to compare certain employees to each other and draw conclusion from them. For instance, if two doctors are practicing the same field, and one doctor is able to service 2.8 patients per hour in an outpatient hour, and the other has this same KPI but at a level 2.4 patients per hour, then there is a clear difference. One doctor works faster than the other. The other doctor most likely will say that he or she services his or her patients better and is more personally involved, the fact remains, the other doctor is faster. In the end, for the practicing of orthopaedics, the personal aspect is not very relevant like it is in oncology. Therefore these doctors are able to discuss what they do differently and they can learn from each other. These implementations of KPIs[30] are the most successful result which could be provided. This can be done for all professions, nurses, administration staff, counter personnel, etc. It is not to create competition as it might seem that way, but to stimulate each other to work together to a common goal. This needs to be very clear in the explanation of these 'new' KPIs.
The image above provides the perfect example of what has been stated before, that there are different levels of priorities. For some companies, hospitals, institutes, there are different aspects more important. The OR, has the highest priority in safety, where as the waiting room might not. Therefore they can be rebalanced and given a weight level. Some companies combine all the sub-level KPIs and create one number, this is however not preferred as it does not show enough about the company as whole, but just a number. It is better to have a 10 sub level KPIs and remeasure and return to them continuously.

Taking a deeper dive into the aspect of KPIs, the focus on orthopaedics can be discussed with the following KPIs. This list is created from research and more are to be added throughout this research:

- OR change over time
- OR infections
- Average aftercare days
- Patients per day per FTE (appointment)
- Patients per day per FTE (surgery)
- Room occupation
- Bed occupation
- Waiting time (outside and inside hospital)
- Transport time from and to OR as % of day

It is these KPIs that will provide the overall supply chain with the possibility to analyze their quality. Some of these KPIs are used to design the final design.
CONCLUSION FROM RESEARCH

To conclude on the obtained research from all sources, it is possible to state that there are many things going very well, but also many aspects require some attention to improve further. It is these aspect that the focus lies on and this leads to a new design. These conclusions are based on observations from the industry and are simply listed in the list below. Each of these will be taken forward to the designing of a new department. The list of ‘must haves’ in Chapter 2 must of course be implemented in the final design.

The first and most important conclusion for the research is that there is a clear separation between the two main tasks the orthopaedic department fulfills. First of all there is the outpatient hours and secondly there are the operations. These are the two main tasks and are very much linked to each other but they do not need to be accessible to each other because never will the patient go to outpatient hours and to the operations area in the same day. Therefore these are separated in the process and they are to be separated in in the new design layout. Keeping this in mind the following lists are conclusions from the research and are necessary to increase the efficiency of the system.

• Outpatient examination rooms and OR including beds can be clearly separated in the system (and layout)
• Walking distances should be reduced to a minimum for staff (motion)
• The traveling of patients is less relevant as they are more flexible in the system and are often earlier on location waiting in buffers
• The transport of patients and the motion of staff does not need to be through the same corridors, improved motion is when they are separated
• The occupation of the doctor is more important than that of the room
• Centralize Operation Rooms for easy and quick access
• RFID provides an excellent method to measure and control assets, patients and other movables in the hospital
• The implementation of an advanced ICT communication tool will provide a clear overview of the patients digital files and increase the quality of communication in the hospital
• Elimination of continuous patient staff interaction when it can be done through machines
• The type of scan (MRI, x-ray or CT) can be determined from the pain location (knee, shoulder, hip, feet) prior to the first meeting, therefore this can be the first appointment (dangers of unnecessary exposure to scans)
• Data and information is power, knowing where what is at what time, provides a huge insight into the process and creates a much better understanding of how things are moving around
• The planning of a doctors weekly schedule is a very complex system. But it results in the highest efficiencies or inefficiencies. Therefore this needs to be done well and accurately, set with boundaries to ensure that these patients diagnosis appointments and operations times are in balance
• Medical supplies and tools can be delivered with JIT principle, the knowledge and infrastructure is in place
• Small safety stock is suggested, but limited to single or double items, not weeks of stock
• Staff is extremely flexible, good communications helps speed up process
• Implementation such as AGVs and RFID are possible
• Appointment switching is possible if monitored
• Structured layout is simple and will make everyone life a lot easier

Overall conclusion of the research conducted so far is that the TO BE designed Dream Clinic will not be implemented soon, the healthcare industry is very slow in developing and too many changes come at once, the staff does not coop with this. Neither will the elderly understand these changes (whom are the most frequent visitors, especially in the orthopaedic department).

To improve the patients feeling of service quality there are a few things that can be done. These are options that create a more comfortable and service orientated environment which is optional, but recommend. The list below shows what type of implementations can improve the experience of this. But these are simple methods of making the hospitality of the hospital feel better, this does not actually improve the care. However, important to note, that if patients are more at ease in their environment they are more like to collaborate with the meetings and provide a better and more stable doctor-patient relationship. These are just a few of which can be considered in the final design.

• Self plan-able process
• WiFi
• Personalized patient web pages
• Daylight
• Spacious
• Clear overview

As this assignment focuses on the design for a layout of the Dream Clinic this is where a number of different options are considered. In the following chapters a few alternative options for well optimized 'job shop' layouts are considered. These are selected from previous successful implementations in industries that are often not healthcare. The remained of the paper is a design aspect and the research in the previous chapters have been the deciding factor to make certain decisions.
From the conclusions in the previous chapter, the new process can be created. There are many technological advantages which can improve the current chain of processes. Therefore a new VSM is created where the patient is given more control and throughput is increased. This new design is highly advanced and expects that patients know what to do in the new setting. The chances that this implementation will quickly be reaching its level of success is low as the new technology requires a long change. I refer you to Change Management, which aids the process. The same scope is maintained.

7.1. VSM To Be

When the patient makes a new appointment, her of he has to fill in the necessary area of pain. This knowledge, results in a number of doctors who are specialized in this area. Therefore the appointments that can be made are shown by doctor and by date. However the patient does not make an appointment with a specific doctor, but on a preferred date. This results in the quickest and most preferred (high service) date of the patient. A doctors availability schedule is of course running behind this and will only show those dates. Because a patient has to go in for pain in their knee, this means they need to have a scan take place at radiology. A meeting with radiology is planned prior to this meeting with the orthopaedic doctor, so that he already has his material to diagnose with. This is all done online by the patient, so that he or she has full control of appointment time and can schedule the first appointment by their own pain level and schedule. This is done, because it is the patients responsibility to look after their own health. As soon as they have entered the system of healthcare, it is the systems job to service them as soon and as well as possible. This from first appointment. See the image below for the improved VSM.

Figure 7.1: Making First Appointment TO BE

Here the patient enters the system and becomes part of the healthcare system. Now it is the responsibility of the hospital to service them as quickly as possible. We are now aiming for a ‘one stop shop’ approach. This can be only achieved if the patient is free for the whole day. This is not always the case (therefore a difficult assumption), also not all patients need surgery. The patients enters the system, gets their required scan take place at radiology and is in time for their meeting with the diagnosing doctor, who draws first conclusions. If the patients needs surgery or not, or goes into an aftercare process. The final option is that he/she gets an second meeting at a later stage to see if changes have taken place and new scans need to be made. See image below for the new VSM.
For the first time new appointment the creation of a Polis card has been removed completely. The assumption is made that all the patients have a card based on their information for their insurance company, which are all identical (except from their polis package, which is out of the scope). This can replace the making of a such a card in a hospital and increase the throughput of the system as it removes a complete step and irrelevant information collection.

Surgery process will not change in the steps to be taken, however the way the steps move next to each other can change. This means different methods of motion can be implemented. For example the first change is to have AGVs drive the patients to the OR and not have nurses run the patients around. The main task of a nurse is service and not transport. Therefore the equipment designed for this can better do so. The same goes for the aftercare process.

Resulting from these steps, have been that there are improvements to be found in the design and flow aspects of the outpatient stage, but not so much the stage there after. However, the biggest conclusion of the process has been that the planning of the patients, can improve all aspects of their service. Therefore the balance in the patients needs to be monitored more closely. This will be simulated later on.

When looking at the new process steps, it is became clear that is a lot transport and transport time between steps, now is that not the a very large waste when it comes to the patient, as their service of healthcare is not reduced, but it does influence the perceived service. The layout of the orthopaedic department is the next step.

7.2. **ONE STOP SHOP**

The definition of an One Stop Shop concept is:

‘A company or a location that offers a multitude of services to a client or a customer. The idea is to provide convenient and efficient service and also to create the opportunity for the company to sell more products to clients and customers.’

This concept of having multiple servicing steps placed directly after each other is what the ultimate goal of the assignment. It reduces the time a patient going to a hospital significantly and it means that the patient receives better care as he or she can go home quicker.

The solution is only applicable if all the process steps are able to be placed behind each other in a logical manner and the patient is able to go through the process. These steps are described in the previous paragraph of the New VSM and VSM of the current situation. The process of the outpatient process in the examination rooms and the operation process are considered here. The aftercare process is left out of the one stop shop as some patient need to stay longer in a hospital. This will be discussed in the next chapter. If the process steps of these two process are considered and placed directly after each other, the process still seems logical. The patient is able manage this kind of treatment. Therefore the process of an One Stop Shop in the orthopaedic department is the maximum efficiency process and is the solution for the Dream Clinic.

As previously mentioned, the company BioMed HCI has proven this concept and therefore is also the current starting point to implementation. However, there are a few additional to consider when implementing such a dominant new process. First of all only 20-25% of the patient that enter the system get serviced in the operation room. This is important because when a patient goes in an operation and receives anesthetics. This eliminates the bodies reflexes and therefore it prohibited to eat or drink about 18 to 24 before the operation (nuchter in Dutch). The danger of vomiting is very high and this can cause suffocation which is
not easy during an operation. This means that all 100% of the patients that enter the process need to be on an empty stomach as there is a possibility that they are operated on. This is possible as the patient knows what the process is of an orthopaedic department and can be instructed not to eat and drink before going to the hospital in the 'first appointment making' process. The final complication of operating on the same day is that the patient is not able to walk for at least 2 weeks, which is not something people plan in their daily lives. 2 weeks is considered a speedy recovery there are many more patients who take longer. Also are the patient that go in and out of a orthopaedic department considered elderly which means that some require care from family member or friends. This is also something that needs to be planned in advanced and cannot be done in a single day. Unless this care can be provided by the One Stop Shop process of course, but this has been left out of the scope and part of it is discussed in the next chapter. In the final paragraph of this chapter some calculations are provided to illustrate how quickly the process is and to prove its opportunity. The image below provides an insight in how a day would look. This is a proposal after having discussed it with a doctor who's preference were in this order.

As described previously, this does not apply to all operations and to all patients entering the system. It only applies to the standardized procedures and for about 25% of the patients that enter the system for their pains.

7.3. AFTERCARE
The aftercare process is not directly in the scope of this assignment, but throughout the research it became clear that a number aspects of this process are very essential to the quality of care for the patients. Therefore the following paragraph has been added to provide information to the reader of the aspects. This only considers the aftercare process where patients are still in bed or have significant 'openings' from the incision in the operating room. When patients are doing exercises to recover their mobility, they are considered so far along the process that they do not need to be protected from bacteria anymore. There are a number of different levels of aftercare, ranging from no time in the hospital up to sometimes 4 days for operations. However there are emergency operations (consider car crashes) where patients end up in the Intensive Care and also have orthopaedic support. This is a completely different process, these patients can stay weeks in the hospital. The length of time the patient stays in the hospital is determined due to the size of the operation. Very heavy operations with risks, will result in patients staying longer. The ultimate goal is for the patient to not stay in the hospital and go home. All of the interview hospitals, consultants or companies stated that the worse place to recover is in a hospital, even better they stated that the best place to recover is at home. The hospital is a location full of movement, bacteria, people entering, exiting, etc. This vast variety results in a very infected building where many different types of unknown bacteria are located. The opposite is the patients home,
where he or she has always been exposed to the bacteria and has become mostly immune to them. Therefore the environment is safer to recover from a surgery, if the other health states allow it. This is not always the case, but for standard (example, hip) operations it is. When considering patients that need to recover from surgery and they have to stay in hospitals for this period of time, the quality of care is not allowed to be reduced. Therefore in this Dream Clinic the possibility to implement clean aftercare rooms is something that is possible. The financial aspect of the proposal is not considered (it might be very expensive), but the health benefit is. If patients after their operation where to be transported into a clean room, where the chances of bacterial infection are minimized, the patients stands a better chance of not catching after-surgery-infections. If this is beneficial to the patient and the hospital (reduction of second operation due to infection and additional medicine), it is a method of improving the aftercare. It should be possible to create larger rooms for a few patients which are clean. One problem is that the family can not go an a visit the patient, but if this significantly benefits the aftercare process, then it should not be an issue. The process of clean aftercare rooms can be implemented in a hospital or in a separated building with only the ward. The room sterilization can be done on a regular basis. From this paragraph alone, there is another research topic which can be investigated from a transport, care quality and financial aspect.

7.4. **Layout Comparison**

In this section the different layout design are discussed. The reason for this is because there are many different layouts in the industry which have been used very successfully. Reason for this are:

- Flexibility
- Transport reduction
- Cost
- Oversee simply
- Safety
- Utilization
- Output
- Space use

These are some of the advantages that can be used by applying different layouts for a production process. For the Dream Clinic this can also be implemented. The following production layouts are selected as an option for the Dream Clinic:

- Straight line
- L shaped
- Scania U-Shape
- EGM Circle - Box

There are many more shapes and they depend on the way the existing building looks and what the speed of the product moving through is. These 4 are selected as they provide a good option for a Lean approach towards the healthcare production.

**7.4.1. Straight Line**

The straight line production layout is the most simplest of them all and is very useful simple processes which quickly happen after each other. The process looks as the following image:
This concept is used a lot in the assembly process of industrial processes. Many car manufacturers use this concept in their assembly of sub-sections, such as driving mechanism or interior. The concept provides a very simple and broad overview because it shows one direct, forward. This means that the employees can see what the starting point is and what the end is, this includes all the steps and the final product. A down side of this concept is that the end product varies a lot from the starting product and therefore there are a lot of input side streams which supply material or sub assemblies. Also if there are a lot of process involved the straight line concept can become very long and this might not be efficient with the spacing provided. What is also nice about this concept is that a number of the straight line layouts can run next to each other, this makes them flexible implementable and easy interchangeable. When the straight line concept becomes to long and employees need to be implemented more flexible, it can be broken in half and turned around, this results in the U shape, which will be discussed later.

### 7.4.2. L Shaped

The L shape layout is very similar to the straight line, except the advantage of this shape is that the employees can almost be at two positions at the same time. The layout looks as followed:

![L Shaped production layout](image)

The fact that the L shape provides a corner in the layout means that the employees can have two section under their control. If there are many different steps it can create a better overview. Also the physical layout is well implementable within building with corners. Apart from this the concept is the same as the previous section of straight line.

### 7.4.3. Scania U-Shape

This concept has been implemented by Scania in Zwolle[38], the Netherlands. There is a large assembly facility where trucks of many different kinds and variables are constructed. They are highly successful in constructing these trucks in a very short time and with low errors. Their layout has the shape of a U. This means that the trucks are moving up and down the production floor[39], in between them the sub assemblies and parts are being supplied which are added by the workers. There are a large amount of steps involved and this creates an excellent overview of the process and the status of the trucks. The steps have been standardized so that all employees can perform them and all can be flexible implemented. The image below provides an visualization of the concept.

![Scania U Shaped production layout](image)
7.4.4. EGM Circle-Box

The final layout that needs to be discussed was brought forward by EGM the architectural office in Dordrecht, the Netherlands. They provided the following image, which I found very disinterest as my research has lead me to something similar.

![Figure 7.7: EGM Circle-Box](image)

The reason why my research has brought me to something similar is because, here the outpatient examination rooms and ward with operating rooms are separated, one of my conclusions. In addition the concept is very simplistic and easily understandable by both staff and patients. It does not allow the wondering of patients and standardizes their movement to just a simple options. This is the selected option from the research, however some changes are suggested and the design within the walls is also provided.

7.5. SELECTED AND EXPANDED SOLUTION

From the conclusions it was stated that the outpatient rooms and operation with ward could be separated from each other. This is the first step to create in the layout. The reason why this is done is because you do not get staff, patients and visitors walking through and around each other, this simplifies things and reduces congested areas. Therefore there are two buildings 1. Outpatient examination rooms and 2. Operating Rooms & Ward. Now the two different 'departments' or buildings in this case are designed. The design of the new orthopaedic department needs to be flexible for a small amount of patients, but also a very large amount, so a design that can be increased in capacity over time is important. This is considered throughout the design.

7.5.1. Outpatient

The outpatient building is where patients come for their diagnosis. This means they are seen by a doctor in a room. The research showed a new method of being efficient and flexible with the rooms available. This is a preferred method for servicing the patients. The patients and medical staff are separated from each other and will only meet in the appointment rooms. In addition the rooms are all the same and equipped with the same tools and machinery. This way the standardized rooms are easy to use for all doctors. Quickly do their procedure and quick the next patient. The entrance of the hospital leads straight into the check in area and waiting area. The patient therefore does need to go look and search for this. Next in the design was the preference of daylight and spacious feeling. This can easily be created through the use of many windows. The exterior of the hospital can be made completely, or mostly of windows, allowing daylight to enter.
The concept above provides a very simple layout. The centralized waiting area is directly there when you enter the system. The red room is the radiology room where the patients can receive their first scan. The blue room is the room where the patients can be plastered if this necessary (this is not always the case, but preferred close to the outpatient examination rooms). Finally there are the green rooms which in this case are 16 of them, but this can be variable to the design capacity of the hospital. All the outpatient rooms are the same and are used in the same manner. This will be shown in the next image. The blue arrow shows the patient walking area, here only patients are found and the medical staff does not need to use these corridors. The orange arrow shows where the medical staff is able to move. This way they are separated. It is possible to cluster these rooms for specializations if this desired by the hospital. The sun shows where the outside sunlight can come into the building. The outpatient rooms look as followed:

![Outpatient Room](image)

Figure 7.9: Outpatient Room

From the image above, the design of a outpatient room is the same for each and everyone of them. Therefore the standardization simplifies the work for medical staff and increases the flexibility to work there. Each room has a desk with computer with 2 chairs on the patient side, a doctors chair, a examination bed and a sink with medicine cabinet. There are two doors, one for the doctor and one for the patient. Both will enter and exit through the same one they came into. On the doctors entering side, there is a 'blue' wall, this is a window, where sunlight can enter the room for a natural environment. To create the idea of privacy the windows can be made of tinted, non see through glass.

The flexible part of this building and room design is that it is adjustable and expandable. If the capacity were to rise of the patients entering the orthopaedic procedures, the building can expand left and right in the exact same manner as it currently is. This however is a capacity design change which is not in the scope at this time. Also, if there were to be worse case scenarios, where patients have to be serviced for something else
than orthopaedics healthcare (environmental disasters, military war, extreme casualties), all these rooms can be used for that as well. They are equipped with the standard necessary tools to treat patients. The same goes for the ward in the next chapter.

Finally, the most important part of these outpatient rooms is that they are planned well. The movement (transport) of the patient is not very important in the concept as it does not affect the quality of healthcare. However, the motion of the medical staff does. Therefore when the doctor is in room 1 (bottom left), the next patient he/she has an appointment with, is to be placed in the nearest available room to the doctor. This means that is room 2 is available, the patient will be sent here. By optimizing this concept, the doctors have to move minimal distances and the patient is served with maximum time and minimum waiting times.

### 7.5.2. Operating Rooms & Ward

The operational aspect of the process, is where the doctor places the implant in the patient in the OR. This is not an something that happens to every patient that enters the orthopaedic process, but about 20% do. Important about this process is that the patient is also placed in a bed before and after the procedure. This length of stay in this bed can depend from an afternoon up to 4 days. Therefore there are some patients who have to stay overnight. Neither the operating room or the ward is designed in this aspect. This is done for the reason that it can be flexible designed according to the hospitals service desires and required capacity. This means that if the hospital wants single patient room they can design it differently than a hospital which prefers 4 patients in a room. The sun shows where the outside sunlight can come into the building. But regardless of the room capacity and interior design the overall building design from a logistical point of view is the same. In the following image this can be seen:

![Figure 7.10: Ward and OR](image)

The reason why the concept has been changed from circle to square is because it makes the use of the ground much more efficient. This way 100% of the ground can be used effectively. The rooms of the patients are placed on the outside of the building. This allows for maximum sunlight and ‘outside’ experience. On the interior walls the corridor connection all rooms is placed, again on this side light is able to access the room and create an comfortable relaxed environment. These are the ward and they can be adjusted for each hospital as desired, with single patient rooms or multiple beds in a rooms. It is flexible for all strategies. See the image below for a comfortable patient room.

It has come to my attention that the building of an operation room directly in the middle of a ward might be the most transport efficient, but considering the fact that the equipment and the room becomes out of date after about 10 years and needs to be replaced a different solution might be more optimal from an architecture perspective. However from an logistical perspective this is still optimal an reduces the motion.
However from a logistical point of view the ward to operating rooms is the most important. Therefore the operating rooms have been placed in the center. Same distance from all rooms and without any elevators or long walking distances. They are placed in their own building, with sunlight also able to enter this room. This is done for the medical staff as they too need to be a comfortable quiet environment to do their work. Having all the OR the same, it can standardizes and simplifies this concept. Of course the building are concreted through corridors, but these are to be placed by the architect and hospital itself as they prefer. The image below show the amount equipment in an OR and also shows the spacious area, this is can be achieved through this concept.

In the past the unbalance of outpatient and operational services have been acknowledged. In a book [43] this unbalance is further discussed and step to be taken to reduce and great a better planning for the combination these main tasks is discussed.
7.6. INNOVATIONS

In this section the new innovations (currently on the market) are discussed and their place of implementation. Throughout the research study there were many discussions with companies that had obtained the knowledge over the years of new technology which could simplify and improve the processes in the healthcare. These are the ones that will be implemented in the Dream Clinic and will be discussed afterward:

- RFID
- Digital patient dossiers
- Personalize patient webpage
- Check in points
- TV to room system
- AGV to operation room

7.6.1. RFID

The implementation of RFID will help maintain a good knowledge of everything that is in the hospital and also at suppliers. With this system it easy to know exactly where tools, machinery, equipments are. The knowledge of asset is important and be at a higher level with this method.

Not only the knowledge of the physical products is now known, but if patients were given a 'personal hospital card', the system can detect where they are in the building, this can be useful for elderly patients who might get lost. The checking of patients data can also be done through this. If a patient were to go into surgery and the doctor does the check if this is the correct patient, they can simply do this through scanning the RFID tag on the patients wrist band.

7.6.2. DIGITAL PATIENT DOSSIERS

A digital patient dossier is also known as an Electronic Health Record. This allows a computer system to hold the diagnosed information from a doctor instead of it having written down on paper. The benefit of it is, that all the doctors using this system and being a doctor of the patient are able to access this information and can easily see into the history of the patient, without having a chance of over looking something. Previously all this was done through paper and paper trails, however with differences in handwriting and digital radiology photos this new method of connecting patient information to a patient is a lot simpler. In addition the patients information can be accessed from other locations than the hospital, therefore doctors can maintain contact with this information when away from their desk in emergency situations. The possibility to live monitor patients is possible in the future and this can all lead to preventive measures not responsive. An example company which provides the IT for this is CHIPSOFT. A Dutch company whom have been successful in setting up this software to aid the medical staff.
7.6.3. PERSONALIZED PATIENT WEBPAGE
A personalized patient webpage, provides an overview of what the patient has been through and what is to come. With this overview, that can be provided through a personal sign in code, on a website the patient can get a better understanding of the process. Some patients prefer to Google certain topics first before they are discussed. The appointments with the doctors can be linked to this website, this way the patient can already make contact with him or her, through a picture and their history. The patient gets a quicker feeling of personal healthcare even though nothing has been done yet. It give the patients a more relaxed and prepared feeling which can allow the doctor to do their work better. There are many opportunities is making certain aspects more easy to access.

7.6.4. CHECK IN POINTS
Like at the airport these days you are able to tell the flight system that you have arrived at the airport and are ready to flight with your selected flight. This is currently also done at hospitals when you go to check in at a counter with a lady who signs you in. Today, with the same personalized card that is able to place your location in the hospital, you can check in at a counter. There are no special fill in information or other data required. The only thing that is required is that you check in at a counter and the system can see if you are on time, late, etc. When appointments are going faster than expected, you can be serviced earlier, or the system can tell you there is a delay of a number of minutes. This change of check in process reduces the amount of people that need to sit behind counters and these can be used at different more healthcare service orientated jobs. Companies that are currently designing this for airports have the knowledge to so for other industries. The improvements of the checkin counters at airports have shown up to a reduction of 5 employees per 6 counters. This means that one employee is able to serve the same as 6 counters at once. This is a large reduction in human errors and simplification of the process.

7.6.5. TV TO ROOM SYSTEM
When patients are waiting in the centralized waiting are, they are at one point asked to go to a room. This is not through a doctor coming to collect them, but by the known TV screens, which tell a patient by name, or possible by number to go a specific room. For example, ‘Mr. Jansen go to room 6’. Every time a patient is asked to go to a room, a sound is played to announce the fact that the next patient is ready to get up and move to this room. This is the same method that is often used at post offices. This reduces doctors having to collect patients and walking up and down corridors.
7.6.6. **AGV TO OPERATION ROOM**

After a discussion with a nurse, it became clear that not only are they walking long distances the whole day, but they are also not happy with the fact that they are. It results in stressful times trying to be in two places at once. The largest proportion of this walking was back from and to the OR. This can be halved during the day. The patient that is going to the OR does not need to be escorted to the OR by a nurse. This patient is perfectly healthy and completely conscious and does not need assistant, but regulations do provide that patients are brought there in their bed and back in their bed to their room. So there is an opportunity of automating this through AGVs. The patient can be delivered to the OR with a small vehicle which knows where to go. The nurse can continue to work with personal patient assistant and the patient goes for a ride, family is able to walk next to it up to the OR. Simple and highly effective in transport reduction. There are many companies currently providing AGV products. Not only is this possible for the transport of patient, but also medicine, medical supplies and other equipment throughout the hospital. It can provide a great automated service. Other solutions as cleaning and motion to recreational areas for patients is also possible.

![Figure 7.18: AGV in a hospital](image)

7.7. **EXAMPLE CALCULATIONS**

This is the last part of the assessment. Where some basic calculations are done to understand the potential of moving towards the standardized outpatient system and a One Stop Shop concept. A little further down, a initiative of an simulation is presented.

It has occurred that the number of outpatient examination rooms required for an efficient throughput of patients and not a under capacity of doctors, needs to be 1 room more than there are doctors. This means the following:

<table>
<thead>
<tr>
<th>Doctors</th>
<th>Rooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
</tr>
</tbody>
</table>

![Figure 7.19: Room Capacity](image)

Additional to this is that the stay of patients is different compared to their surgery. Therefore the following table shows how many patients that enter stay for how many days.

<table>
<thead>
<tr>
<th>Stay</th>
<th>Percentage of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 nights</td>
<td>~ 60%</td>
</tr>
<tr>
<td>1 night</td>
<td>~ 20%</td>
</tr>
<tr>
<td>2 nights</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>3 nights</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>4 nights (MAX)</td>
<td>&lt; 3%</td>
</tr>
</tbody>
</table>

![Figure 7.20: Stay and Percentage](image)

The number of beds that are necessary in a ward is depended on how many surgeries there need be done. Calculation has shown this number of beds is about 2/3 of the surgeries.
For a small scale example calculation the following image will provide the necessary results. These will be discussed after.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Input of patients per day</td>
<td>100</td>
</tr>
<tr>
<td>New patients</td>
<td>60%</td>
</tr>
<tr>
<td>Repeat patients</td>
<td>40%</td>
</tr>
<tr>
<td>Minutes per doctor</td>
<td>240 min</td>
</tr>
<tr>
<td>appointment per day</td>
<td></td>
</tr>
</tbody>
</table>

| First meeting time       | 15 min |
| Second meeting time      | 10 min |

| Doctors                  | 6     |
| Rooms                    | 8     |

| Operation patients       | 20%   |
| Operation patients       | 12    |

| Operations per doctor    | 2     |
| Operation Room time      | 900 min |
| required                 |       |
| Operation Rooms required | 3     |

| Beds (After care)        | 8     |

Figure 7.21: Small scale example calculation

The calculation is relatively simple because all the on following steps are a resultant (even a factor) of the previous step. This means that I can prepare my next step if I (the doctor, planning staff) am currently working on something now. From the moment forward that the doctor decides that the patients needs surgery, the whole process till the end can be planned. If no surgery is required, the patient goes home and the process starts again. However, when running the simulation (explained here after), it showed that this is not a scalable situation. In the example above with 100 patients does not compare 10x when going to a 1000 patients. This means, not 80 outpatient rooms are required. This is significantly different because the rooms are occupied at a much higher rate. This also goes for the doctors. Lastly on this example, note that the number of doctors actually performing surgery on a day is 33% of the total doctors. This means that the other 4 doctors are able to continue to do outpatient meetings and followup meetings with patients in beds or in aftercare. This is ideal, especially since research has already shown that most doctors do not work the 8 hours shifts in hospitals but at least 9 hours and that most of the orthopaedic doctors work only 4 days a week.

Finally, a check is completed to understand to what extend the new design has an impact on the process. This also means that it can be checked if patients are able to be operated on on the same day as they are diagnosed. For this the created simulation provides an insight. From here on forward it is important to state that the simulation is an incomplete additional project. It has not been optimized and there are areas where some coding will improve the reality of the system drastically. This also means that the quantities presented by the model are not always accurate. However what the model has been able to show is that it should be theoretically possible to diagnose patients in the outpatient examination rooms and move them forward towards their operation within the same day (morning, afternoon), finally going home in the afternoon. The figure below shows what the simulation panel looks like.
From the figure above, it is possible say that a start has been made to simulate the process in an orthopaedic department. The variable on the left are the options that are able to be placed inside the simulation which allows the model to perform towards different scenarios. This, if the model were to be completed, would allow different kind of hospitals to check their own operation and model it. The performance output can be compared to their own. It would be a tool to start thinking towards improvements. On the right of the screen, the separate steps are show and how many passenger are in these steps. All the process steps are represented here. At the bottom some simple KPIs that can be monitored during the process are occupation of equipment or staff. The waiting time of patients and how many are currently in the system or how many have been in the system.

The model can be used to see how the room occupation and the doctor occupation are compared. When redesigning departments or when creating new department, this is a method to understand how many rooms are necessary to not over work doctors and also not have too much capacity. Therefore all the variables can be changed which will make them applicable to different scenarios.

There is still a lot to be done on this simulation, but it also requires input from the industry itself. To understand where the improvements lie, someone with experience needs to state where the KPIs need to placed which will allow the for better measurements. The most problematic part of the simulation is the initial planning design of the patients. Patients either want an appointment today, or tomorrow, some even a few weeks from now. This needs to be placed inside the simulation to make it more realistic, but this requires the design of a complete planning tool, which is rather complex (an assignment on its own). The start is available, but there are many more opportunities in it, but support from the industry will slowly make it better. There are however more companies that are able to provide simulare simulation tools which a much higher complexity, this can of course also be supportive in this [15]. The data used for the simulation is in Appendix A.
CONCLUSION & RECOMMENDATIONS

In this chapter the final conclusions of the Dream Clinic are discussed. The key design decisions are brought forward as a result of the research process. Finally some recommendations are made for further research on this matter. There were a large amount of observations which lead to decisions in the process, but these could have an impact on different areas of the healthcare industry. This is discussed in the final paragraphs.

8.1. CONCLUSION

The healthcare industry has appears to be a very hard world to compete in. All hospitals are trying to deliver the best results and increase the patients that will want their service. As natural as this may be, it is very important to work together as well. To learn from each others mistakes but also learn from each other successes. This document goes into the completely new designing of a department but with minute changes in process step links and standardizing procedures, it is possible to make a huge improvement from which all parties will benefit for a long time. Therefore it is urged to take a step back from the current process, evaluate it, discuss possible changes that will improve the service and work together to achieve this.

During this research study, many different interviews took place with parties in many different sectors of the healthcare industry. All of these provided many opportunities that can change their process, many also showed changes that had a very positive effect on their healthcare. All the observations placed together have provided me to create a layout for an orthopaedic department, both outpatient and operational. This concept provides the potential for changes in this healthcare sector. Sometimes the implementation of these changes might be a too automated and simplified for the current patient system, but over time it is very realistic they will come. The standardization of the layout and the larger tasks has been achieved and the reduction of waste has been completed. Finally the to be measured KPIs are also given and with these measurable the monitoring of the quality is possible.

One issue I can foresee happening rather often is the fact that the patient enters a room and the doctor is not there yet. They will be confused and wondering if they have entered the wrong room, especially with elderly people this will cause a certain level of stress which is unwanted. Therefore, it should be good if the patient is at least seen by an assistant in the room before the doctor comes, this is currently becoming a more regular process in hospitals. Also patients and staff need to get used to the changes if they were to be implemented. This is understandable, but it is also important not to resist against it as it will only slow down the process. Change Management can be a good concept for this.

It is possible to create a very patient comfortable environment, a servicing system where the patient feels at home and quickly can go home. There are so many opportunities out on the market that want to work together with the healthcare systems can make this process easier, quicker, cheaper and most of all better. It is the healthcare in hospitals which need to allow the discussion and implementations of the innovations to take part in the healthcare. At the moment I have heard from all sources that this is going to take a lot of time before we get to this level. However I urge all participating parties to do this now rather than tomorrow, because we all benefit from the profits. The Netherlands is highly advanced in healthcare, but there is enough to do to become even better. This is also the beauty of Lean and all the optimizing tools, there is not limit as it can always get better.
To come back to the assignment details set in chapter 2. The four focus areas to be able to improve an orthopaedic department were in the areas of standardization, automation, simplification and ability to measure. These four have been met to the level that is possible in a theoretical manner. The standardization in rooms and structure has been approached. The automation of information and data flow, which is also linked to the measurably has been shown to be possible. The simplification to a level that even patients can understand the basic flow of the process. The only difficulty is that when a hospital department needs to start measuring, there are so many options, it is not always clear where to start. This is something that I had an issue with as well, as I do not know where the first bottlenecks and problems could occur. Therefore the standard KPIs were discussed. More experienced personnel from the field will be able to shine more light on this. It is a very important aspect of maintaining quality.

Finally, regardless of how much there still can be done in orthopaedics and in the healthcare in general, it has come to my attention that everyone is eager to get to work and continue to perform at the best level. It is a very dedicated world with many principles that can not be broken and need to be maintained. A highly respected profession indeed. A fantastic technical research topic in a field where enough to do is and where people are happy to participate. Many more specific topics can still be created to investigate and help the healthcare to the next level.

8.2. Recommendations

I highly recommend that the current situation of a department, both operational and outpatient is simulated in a model where measurements can be placed on the information. From here on, the steps forward to reduce the time can be implemented. At first the information will be average, but as the implementation of new potential improvements start to take place, the data will be come more accurate. Therefore simulating a TO BE situation is the step taken after this. In addition to the simulation of these new changes in an orthopaedic department it is possible to look at the process before the orthopaedic department, in particular the medical supplies and pharmaceuticals. It is important that not only the planning is optimized but also products needed to service the patients are lean. Concepts such as JIT and FIFO can play a role here. All these product, patient and staff streams come together and when they are correctly integrated the system becomes highly efficient.

The information that I am really lacking in this case, is a VSM with a strongly under build time line underneath it. There was no sharing this information but it plays an essential role in the quality of the analysis and could reveal many more positive aspects of their supply chain as well as opportunities. The VSM is here, now the time line needs to be added in detail.

As a matter of fact, it would also be interesting to see what the impact would be of switching the patient walking path and that of the doctors in the outpatient process. The result of it would be that the doctor is able to access more doors from a shorter distance but if this significant is unknown. The analysis of this could provide more information on much the walking distances also have an impact on the speed of the healthcare and if in fact it also applies to short distances.


[12] Diakonessenhuis , Oncology, Pharmacy, (3 Oct 2014)


[16] LogiZ Nederland , Congress, (20 Nov 2014)


[34] Biomet periodieke uitgave Nederland, (summer 2014), Biomet in Beweging, Accessed: 17-11-2014


This appendix contains additional information regarding the quantities of the process of which the orthopaedic department was willing to share information about. The value are often the time a certain step will take to complete. Using this information the start of the simulation model was created. As stated in the conclusion the simulation not completed but provides significant proof that it is an option to show that a changed process can speed up the number of patients serviced by a hospital. Especially in one day, the One Stop Shop. See calculation in chapter 7 for more information. A few different hospitals were used (therefore some of the information is in Dutch), this is the data:

Hospital 1 regarding number of operations:

<table>
<thead>
<tr>
<th>Cijfers op jaarbasis</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aantal erkende bedden</td>
<td>284</td>
<td>308</td>
<td>317</td>
<td>317</td>
<td>317</td>
</tr>
<tr>
<td>Jaaromzet</td>
<td>145.8</td>
<td>15405</td>
<td>166.1</td>
<td>161.8</td>
<td></td>
</tr>
<tr>
<td>Aantal medewerkers</td>
<td>1656</td>
<td>1580</td>
<td>1699</td>
<td>1942</td>
<td>1890</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orthopaediecentrum</th>
<th>85165</th>
<th>84238</th>
<th>84529</th>
<th>73126</th>
<th>75061</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aantal polikliniek bezoeken</td>
<td>7185</td>
<td>7731</td>
<td>7459</td>
<td>7377</td>
<td>5670</td>
</tr>
<tr>
<td>Aantal dagopnames</td>
<td>33783</td>
<td>34190</td>
<td>33572</td>
<td>39369</td>
<td>36818</td>
</tr>
<tr>
<td>Aantal verpleegdagen</td>
<td>6249</td>
<td>6656</td>
<td>6682</td>
<td>7139</td>
<td>7111</td>
</tr>
</tbody>
</table>

Figure A.1: Table 1.a

<table>
<thead>
<tr>
<th>Operatie</th>
<th>2013 % diepewond infecties</th>
<th># diepewond infecties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totale heuprothese</td>
<td>1258</td>
<td>1.6%</td>
</tr>
<tr>
<td>Revisie heuprothese</td>
<td>259</td>
<td>0.0%</td>
</tr>
<tr>
<td>Totale knieprothese</td>
<td>1314</td>
<td>1.8%</td>
</tr>
<tr>
<td>Revisie knieprothese</td>
<td>308</td>
<td>0.0%</td>
</tr>
<tr>
<td>Totale schouderprothese</td>
<td>164</td>
<td>0.0%</td>
</tr>
<tr>
<td>Revisie schouderprothese</td>
<td>35</td>
<td>0.0%</td>
</tr>
<tr>
<td>Totale elleboogprothese</td>
<td>13</td>
<td>0.0%</td>
</tr>
<tr>
<td>Revisie elleboogprothese</td>
<td>15</td>
<td>0.0%</td>
</tr>
<tr>
<td>Knieoperaties</td>
<td>3698</td>
<td>0.0%</td>
</tr>
<tr>
<td>Heupoperaties</td>
<td>2156</td>
<td>0.0%</td>
</tr>
<tr>
<td>Schouderoperaties</td>
<td>1091</td>
<td>0.0%</td>
</tr>
<tr>
<td>Elleboogoperaties</td>
<td>184</td>
<td>0.0%</td>
</tr>
<tr>
<td>Pols/Handoperaties</td>
<td>499</td>
<td>0.0%</td>
</tr>
<tr>
<td>Voet &amp; enkeloperaties</td>
<td>1546</td>
<td>0.0%</td>
</tr>
<tr>
<td>Wervelkolomoperaties</td>
<td>696</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Figure A.2: Table 1.b
### Figure A.3: Table 1.c

<table>
<thead>
<tr>
<th>Wachttijden kinderen</th>
<th>aantal weken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rug- en nekklachten</td>
<td>5</td>
</tr>
<tr>
<td>Overige orthopedische klachten</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volwassenen</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Algemeen</td>
<td>3</td>
</tr>
<tr>
<td>Sportblessures</td>
<td>1</td>
</tr>
<tr>
<td>Knieklachten</td>
<td>5</td>
</tr>
<tr>
<td>Heupklachten</td>
<td>4</td>
</tr>
<tr>
<td>Rug en nekklachten</td>
<td>29</td>
</tr>
<tr>
<td>Klachten schouder/elleboog</td>
<td>5</td>
</tr>
<tr>
<td>Klachten hand/pols</td>
<td>5</td>
</tr>
<tr>
<td>Voet- of enkelklachten</td>
<td>25</td>
</tr>
</tbody>
</table>

### Pijn

| Afspraak pijnpoli | 6 |
| Pijnbestrijding (dagopname nieuwe patiënt) | 1 |

### Operaties

| Totale heupprothese | 4 |
| Totale knieprothese | 8 |
| Kijkoperaties knie | 2 |
| Hernia-operatie    | 8 |

**Hospital 2 regarding staff:**

<table>
<thead>
<tr>
<th>Type of staff</th>
<th>Number</th>
<th>Ratio per surgeon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management team</td>
<td>4</td>
<td>1/4</td>
</tr>
<tr>
<td>Orthopaedic surgeons</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Anaesthesiologist</td>
<td>10</td>
<td>9/16</td>
</tr>
<tr>
<td>Nurse assistants</td>
<td>2</td>
<td>1/8</td>
</tr>
<tr>
<td>Doctor assistants</td>
<td>5</td>
<td>5/16</td>
</tr>
<tr>
<td>Others</td>
<td>135</td>
<td></td>
</tr>
</tbody>
</table>

**Hospital 3 regarding time per step:**

**Average appointment waiting time 2-3 weeks**

<table>
<thead>
<tr>
<th>Prior to meeting</th>
<th>Type</th>
<th>Average time</th>
<th>Minimum time</th>
<th>Maximum time</th>
<th>People involved</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor refers patient to orthopedic department</td>
<td>Communication</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Patient, doctor</td>
<td>Doctor from different department</td>
</tr>
<tr>
<td>Patient calls secretary to make appointment</td>
<td>Communication</td>
<td>6 minutes</td>
<td>3 minutes</td>
<td>30 minutes</td>
<td>Patient, secretary</td>
<td>Secretary needs to know what kind of specialty doctor is required</td>
</tr>
<tr>
<td>SecretaryCourtesy appointment in doctors agenda</td>
<td>Communication</td>
<td>5 minutes</td>
<td>-</td>
<td>-</td>
<td>Secretary</td>
<td>Secretary plans for patient in the doctors agenda</td>
</tr>
</tbody>
</table>

**Preliminary**

<table>
<thead>
<tr>
<th>Type</th>
<th>Average time</th>
<th>Minimum time</th>
<th>Maximum time</th>
<th>People involved</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient arrives at hospital</td>
<td>Walking</td>
<td>-</td>
<td>-</td>
<td>Patient</td>
<td>Arrives early/late, on the parking or at the door of hospital</td>
</tr>
<tr>
<td>Patient enters the orthopedic department</td>
<td>Walking</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>35 minutes</td>
<td>Patient</td>
</tr>
<tr>
<td>Patient checks in at the counters</td>
<td>Communication</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>35 minutes</td>
<td>Patient, counterstaff</td>
</tr>
<tr>
<td>Patient is seated in the waiting area</td>
<td>Nense</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>40 minutes</td>
<td>Patient</td>
</tr>
<tr>
<td>Patient collected by doctor for appointment</td>
<td>Communication</td>
<td>5 minutes</td>
<td>3 minutes</td>
<td>7 minutes</td>
<td>Patient, Doctor</td>
</tr>
<tr>
<td>Patient moves to room</td>
<td>Walking</td>
<td>5 minutes</td>
<td>1 minute</td>
<td>5 minutes</td>
<td>Patient</td>
</tr>
<tr>
<td>Doctor examines the patient and next steps to take</td>
<td>Operational</td>
<td>15 minutes</td>
<td>5 minutes</td>
<td>20 minutes</td>
<td>Patient, Doctor</td>
</tr>
<tr>
<td>Patient goes to counter and makes next appointment</td>
<td>Communication</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>35 minutes</td>
<td>Patient, counterstaff</td>
</tr>
<tr>
<td>Patient goes home</td>
<td>Walking</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Patient</td>
</tr>
</tbody>
</table>

**Figure A.4: Table of staff**

**Figure A.5: VSM times**
<table>
<thead>
<tr>
<th>Operation step</th>
<th>Type</th>
<th>Average time</th>
<th>Minimum time</th>
<th>Maximum time</th>
<th>People involved</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient arrives at hospital</td>
<td>Walking</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Patient</td>
<td>Arrives early(ly), on the parking or at the door of hospital</td>
</tr>
<tr>
<td>Patient moves to the orthopedic surgical department</td>
<td>Walking</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>15 minutes</td>
<td>Patient, counterstaff</td>
<td>Patient is located in the emergency, patient asks central counter first</td>
</tr>
<tr>
<td>Patient checks in at the counter</td>
<td>Communication</td>
<td>15 minutes</td>
<td>10 minutes</td>
<td>20 minutes</td>
<td>Patient</td>
<td>Patient talks with doctor he or she will see at what time</td>
</tr>
<tr>
<td>Patient is seated in the waiting room</td>
<td>None</td>
<td>30 minutes</td>
<td>20 minutes</td>
<td>40 minutes</td>
<td>Patient</td>
<td>Waiting for patient</td>
</tr>
<tr>
<td>Patient collects for tests</td>
<td>Communication</td>
<td>5 minutes</td>
<td>3 minutes</td>
<td>7 minutes</td>
<td>Patient, Nurse</td>
<td>Collected for lab room</td>
</tr>
<tr>
<td>Patient moves to room</td>
<td>Walking</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>15 minutes</td>
<td>Patient</td>
<td>Waiting from waiting with nurse to room</td>
</tr>
<tr>
<td>Patient waits in room</td>
<td>Walking</td>
<td>2 hours</td>
<td>1 hour</td>
<td>3 hours</td>
<td>Patient</td>
<td>Waiting for patient in bed</td>
</tr>
<tr>
<td>Patient is prepared for surgery</td>
<td>Operational</td>
<td>20 minutes</td>
<td>15 minutes</td>
<td>25 minutes</td>
<td>Patient, Nurse, Doctor</td>
<td>Patient is prepared for surgery</td>
</tr>
<tr>
<td>Patient transported to OR in bed</td>
<td>Transportation</td>
<td>5 minutes</td>
<td>5 minutes</td>
<td>5 minutes</td>
<td>Nurse, Nurse</td>
<td>Patient is moved by nurse to OR</td>
</tr>
<tr>
<td>Pre operation steps in OR</td>
<td>Operational</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>15 minutes</td>
<td>Patient, Nurse, Doctor</td>
<td>Final preparation for OR entrance</td>
</tr>
<tr>
<td>Operation</td>
<td>Operational</td>
<td>1 hour</td>
<td>1 hour</td>
<td>3 hours</td>
<td>Patient, Nurse, Doctor</td>
<td>The operation until all staff</td>
</tr>
<tr>
<td>Post operation steps in OR</td>
<td>Operational</td>
<td>45 minutes</td>
<td>30 minutes</td>
<td>50 minutes</td>
<td>Patient, Nurse, Doctor</td>
<td>Changing the body and final checks</td>
</tr>
<tr>
<td>Patient moves from OR to recovery</td>
<td>Transportation</td>
<td>15 minutes</td>
<td>10 minutes</td>
<td>20 minutes</td>
<td>Nurse, Nurse</td>
<td>Back to room</td>
</tr>
<tr>
<td>Patient goes into aftercare</td>
<td>Operational</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Patient</td>
<td>Aftercare process</td>
</tr>
</tbody>
</table>

**Percentage of people leave same day as operation day**

| Number of people leave same day as operation day | 60% |

| Average number of after care days | 1.2 days |
| Average number of appointments after aftercare | 3 |
| Maximum number of after care days | 4 days |

Figure A.6: VSM times 2
In this appendix the final conclusion for the Maartenkliniek is designed based on the model developed in the paper. The result is a simple sketch which is relevant for between the walls that were available at this clinic. The image shows the clustering of rooms. The only issue is that the given area did not allow for there to separation between the motion of patient and doctors, which was a strong recommendation for the improved process. In addition this is only outpatient part of the clinic as there was no interest in upgrading the operation and ward at this time. Please see the images below.

Figure B.1: Maartenskliniek Layout

Figure B.2: 3D representation