Improving service delivery of the MR department of MST

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Inleiding

Op de MRI afdeling van Medisch Spectrum Twente is de toegangstijd voor het maken van een MRI scan erg hoog. Het kan voorkomen dat een patiënt meer dan 40 werkdagen moet wachten voordat hij/zij gescand kan worden. Dit leidt tot een vertraagde diagnose stelling voor patiënten die afhankelijk zijn van de MRI scan. De MRI afdeling vormt zo een vertraging in het diagnostische proces. Hierdoor is er door de lange wachttijd een continue druk op het proces en de medewerkers (laboranten en radiologen) om zoveel mogelijk patiënten in een zo kort mogelijke tijd te scannen. Deze druk op het proces zorgt voor een onwenselijke werkomgeving waarin de medewerkers hun werk moeten verrichten. De afdeling herkent deze problemen, is echter niet in staat om de oorzaken hiervan zichtbaar te maken, voornamelijk vanwege het ontbreken van logistieke prestatie indicatoren.

Doel

Deze studie onderzoekt en beschrijft het proces van het verrichten van een MRI scan, en geeft interventies die het proces kunnen verbeteren. We meten de prestaties van het proces op basis van verschillende van te voren gedefinieerde prestatieindicatoren. De prestatieindicatoren zijn ontwikkeld met behulp van een tijdsregistratie model. Dit model zorgt ervoor dat er eenduidige definities bestaan voor de te meten prestaties. We hebben vervolgens een tijdsregistratie uitgevoerd om de benodigde data te verkrijgen. Deze data is op sommige punten aangevuld met data uit het RADOS (Radiologie informatie systeem). De data is de basis voor de te ontworpen interventies ter verbetering van het proces. De interventies zijn vervolgens doorbesproken met actoren in het proces om de te verwachten gevolgen in de praktijk zichtbaar te maken. Tot slot worden er aanbevelingen gedaan die het proces kunnen verbeteren.

Context analyse

Handmatige analyse van de RADOS data laat zien dat in 2008 de toegangstijd voor poliklinische patiënten is toegenomen van 15 werkdagen in januari tot 40 werkdagen in december. Rond de vakantieperioden in mei en juli was de toegangstijd 20 tot 25 werkdagen. In september werd besloten om de capaciteit te verminderen vanwege de hoge werkdruk voor de laboranten. Dit heeft ertoe geleid dat de toegangstijd opliep naar 40 werkdagen.

Uit de tijdsregistratie van alle activiteiten die plaatsvinden tijdens een totale dag scannen blijkt dat tijdens bedrijfstijd 62% van de tijd wordt gebruikt voor het positioneren en scannen van een patiënt. 10% van de bedrijfstijd wordt gebruikt voor het voorbereiden van patiënten buiten de scanner ruimte en 8% van de tijd wordt gebruikt voor het afronden van het onderzoek. De tijd die nodig is voor het voorbereiden van een patiënt op de scanner tafel is erg onvoorspelbaar en kent een hoge mate van variabiliteit. De resterende tijd (20%) wordt gebruikt voor het schoonmaken/klaarmaken van de scanner ruimte en het wachtten op de volgende patiënt.

Het bleek verder dat het ongeplande onderhoud aan de scanners erg hoog is. Scanner MR1 is 90 uur buiten dienst en scanner MR2 55 uur, in een periode van een jaar. Omdat dit de pure 'down time' is, zal het echte verlies aan capaciteit nog hoger liggen.

Het laatste dat opviel aan de analyse van het proces en de prestatiemeting is dat al deze informatie over het proces verkregen moet worden door extra, handmatige, handelingen. Deze handelingen worden zelden tot nooit uitgevoerd. Dat betekent dat dagelijkse stuurinformatie over het proces, maar ook informatie naar de patiënten, niet beschikbaar is voor de actoren in het proces.

Literatuur

We gebruiken basisprincipes uit de logistiek voor het voorstellen van interventies die het proces moeten verbeteren. Deze principes zijn variabiliteit reductie, complexiteit reductie en verspillingen reductie. Deze principes helpen bij het aandragen van mogelijke interventies. Het primaire proces is vaak sterk beïnvloed door variabiliteit van de verschillende stappen in het proces. Het reduceren van de variabiliteit komt het gehele proces ten goede. Het proces is vaak te complex. Verschillende stappen worden op allerlei verschillende momenten uitgevoerd. Een simpel overzichtelijk proces leidt tot een effectievere output. Veel processen kennen hoge mate van verspillingen. Deze verspillingen dragen niet bij aan een efficiënt proces. Interventies die deze verspillingen tegengaan, verbeteren daarmee het totale proces. Op basis van deze principes evalueren we vier mogelijke interventies.

Interventie 1 omvat het updaten van de huidig gebruikte onderzoeksprotocollen. Deze protocollen zijn niet specifiek genoeg en resulteren in een uitloop van de MRI afspraken. Interventie 2 omvat het toedienen van contrast vloeistof met behulp van een infuus buiten de scanner ruimte. Het doel is het voorkomen van het bezetten van de scanner ruimte zonder dat de scanner wordt gebruikt. Dit zal leiden tot extra capaciteit. Interventie 3 omvat het gebruik van verrijdbare MRI tafels met of zonder spoelen. Het doel is om de voorbereidingstijd per patiënt zoveel mogelijk buiten de scanner ruimte te laten verlopen en zodoende extra capaciteit voor de scanner te creëren. Interventie 4 omvat het uitbreiden van de bedrijfstijd, waarmee extra capaciteit wordt gecreëerd. Vervolgens worden de gevolgen van de aanschaf van een derde MRI systeem besproken. Deze beslissing is al genomen en wordt derhalve niet gezien als een mogelijke interventie. Het heeft echter wel enkele gevolgen voor het gehele proces en zal daarom wel worden besproken.

Interventies in de praktijk

De mogelijke interventies zijn voorgelegd en besproken met de verschillende actoren in het proces. Interventie 1, het updaten van de onderzoeksprotocollen moet worden gezien als een belangrijke interventie om twee redenen. (1) De nieuwe onderzoeksprotocollen zijn reeds herzien en opgesteld per specifieke indicatie in plaats van per orgaan. Dat betekent dat de onderzoekstijd per protocol exact gestandaardiseerd kan worden omdat precies bekend is hoe lang de scans gaan duren. (2) Deze nieuwe codering van de onderzoeksprotocollen maakt het mogelijk om meer stuurinformatie te gaan verzamelen per groep patiënten, omdat er nu onderscheid gemaakt wordt tussen specifieke groepen patiënten. Deze informatie kan men terugkoppelen naar het proces. Het planningsschema kan nu worden aangepast op basis van procesinformatie. De verwachting is dat deze interventie de patiëntaantallen in één jaar tijd kan verhogen met 10%. Dit betekent dat ongeveer 1.000 patiënten per jaar meer gebruik kunnen maken van de MRI scanner binnen dezelfde capaciteit.

Interventie 2, het toedienen van contrast vloeistof via een infuus buiten de scanner ruimte, moet het mogelijk maken de tijd voor bepaalde onderzoeken in de scanner ruimte te verkorten. In de scanner ruimte wordt de patiënt alleen nog maar gepositioneerd en gescand. Er moet gewerkt worden met 2 laboranten per scanner en de processen van 2 patiënten moeten deels simultaan lopen. Een recente studie toont aan dat ongeveer 5 minuten per contrast onderzoek kan worden bespaard (Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007). Met bijna 2.000 contrast onderzoeken per jaar zou dat een extra capaciteit van 10.000 minuten betekenen. Dit staat gelijk aan 250 patiënten extra per jaar.

De effecten van interventie 3, het uitbreiden van de bedrijfstijd zijn moeilijker in te schatten. Dit komt voornamelijk doordat de mate waarin de bedrijfstijd wordt uitgebreid van invloed is op de gevolgen. De FTE analyse laat zien dat met het huidige aantal FTE niet mogelijk is om de bedrijfstijd uit te breiden zonder dat daarbij de werkdruk voor de laboranten onaanvaardbaar hoog wordt. Het aantal FTE MRI laboranten zal dus moeten worden uitgebreid wil de bedrijfstijd kunnen worden uitgebreid. Vervolgens moet er tijdens de extra bedrijfstijd ook een radioloog en anesthesist beschikbaar zijn die tijdens deze tijd oproepbaar zijn. Het aantal patiënten die extra gescand kunnen worden is dus afhankelijk van de gekozen werk procedures tijdens de extra bedrijfstijd. Ook moet er rekening mee worden gehouden dat wanneer de scanner met 1 laborant bemand is er geen contrast onderzoeken mogen worden gepland. Alleen 'eenvoudige' standaard procedures zoals de knie en enkel onderzoeken zouden in die extra tijd kunnen worden gedaan. De keuze voor 1 of 2 laboranten per MRI scanner heeft dus ook invloed op de hoeveelheid en soort patiënten die extra gescand kunnen worden.

De 4^{e} interventie, de verrijdbare MRI tafel, heeft enkele negatieve gevolgen voor het proces. De tafel die gebruikt moet worden is log en zwaar en daarmee moeilijk om mee te werken. De service voor de patiënt zal verminderen doordat de meeste patiënten al van te voren klaar moeten liggen in de goede houding (positioneren) voor het maken van de scan. Daarom zijn ook dubbele sets spoelen nodig omdat er anders gewacht moet worden op de spoelen die al in gebruik zijn. De verwachte tijdswinst van een verrijdbare tafel zal daarbij niet erg groot zijn omdat deze niet opweegt tegen de hierboven benoemde nadelen.

Een andere mogelijkheid is de MammoTrak over-the-table (Philips). Dit is een andere versie verrijdbare tafel speciaal voor mamma onderzoeken. Deze tafel maakt het mogelijk om borstonderzoeken en biopsie onderzoeken in een kortere tijd te verrichten. De kwaliteit van de scans zal ook omhoog gaan door de ingebouwde spoel in het tafelblad. Voor met name de biopsie onderzoeken zal het de service verhogen omdat de onderzoekstijd ingekort kan worden. De biopsie kan zelfs deels buiten de scanner ruimte worden verricht. De tijd die gepland moet worden voor een biopsie procedure (tijd in de scanner ruimte) kan met 15 tot 20 minuten worden teruggebracht.

De aankoop van een 3^{e} MRI vergt een grote investering. We zien dat de huidige MRI systemen een bezetting kennen van rond de 65%. Er kunnen daarom vraagtekens gezet worden bij de noodzaak tot investering in de 3^{e} MRI vanuit economisch oogpunt. De verwachte patiëntaantallen op de 3^{e} MRI (bij een bezetting van 65%) zullen wel voldoende zijn om de wachtlijst weg te werken. Vanuit medisch oogpunt kan de investering verdedigd worden. De nieuwe MRI ondersteunt het ziekenhuis in de ontwikkeling tot 'centers of excellence'. Verder is het mogelijk om wetenschappelijk onderzoek te gaan uitvoeren op het 3^{e} MRI systeem.

Conclusies en aanbevelingen

Uit de analyse van de interventies kunnen we concluderen dat het updaten van de protocollen in combinatie met het vergaren van de juiste prestatie informatie de meest winstgevende en uitvoerbare interventies zijn. Dit moet dan ook de eerste stap in het verbeteringsproces zijn. Deze interventie geeft meer inzicht in het huidige proces, maakt bottlenecks zichtbaar, geeft aanwijzingen voor verbetering en maakt het mogelijk om het planningsschema aan te passen aan de werkelijke aantallen patiënten in specifieke groepen. Op basis van ervaringen van de radiologen uit praktijksituaties wordt verwacht dat de patiëntaantallen per jaar met 10% moeten kunnen toenemen.

Het toedienen van contrast via een infuus in een voorbereidingsruimte buiten de MRI kamer is een goede volgende stap. De huidige werkwijze, met twee laboranten per MRI scanner ondersteunt deze nieuwe manier van werken. Voorbeelden uit praktijksituaties geven aan dat per onderzoek ongeveer 5 minuten bespaard kan gaan worden (Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007). Met meer dan 2.000 contrast onderzoeken per jaar betekent dit een extra capaciteit voor ongeveer 250 patiënten.

Deze beide stappen hebben volgens dit onderzoek het grootste positieve effect op het MRI proces. Verder kunnen deze stappen als basis dienen voor andere verbeterslagen zoals het uitbreiden van de bedrijfstijd en het gebruikmaken van verrijdbare scannertafels.

Het uitbreiden van de bedrijfstijd is in de theorie een simpele manier om extra capaciteit te creëren. In de praktijk zitten hier nog een aantal haken en ogen aan. Het effect op het aantal patiënten en type patiënten dat extra geholpen kan worden is afhankelijk van de laborantenbezetting. Beman je de MRI scanner met 1 laborant dan kunnen tijdens deze tijd alleen standaard niet contrast onderzoeken worden uitgevoerd. Wanneer de scanners met 2 laboranten worden bemand dan kunnen ook de contrast onderzoeken worden uitgevoerd. Supervisie door een radioloog is echter wel noodzakelijk en een anesthesist moet oproepbaar zijn. Een voorwaarde voor deze interventie is dat er een degelijke FTE analyse wordt uitgevoerd. Hiermee wordt voorkomen dat er te weinig MRI laboranten zijn om de extra diensten te draaien waardoor de werkdruk te hoog zou gaan worden.

In de praktijk wordt de verrijdbare MRI tafel niet als voordelig gezien. De tafels zijn log en zwaar en zijn daardoor moeilijk in gebruik. De tijdwinst zou daardoor minimaal zijn. Verder verwachten de laboranten dat de patiënt service dermate lager gaat worden omdat de patiënten langere tijd in een bepaalde houding op de tafel moeten liggen. In tegenstelling tot de verrijdbare tafel zien de radiologen en laboranten wel een voordeel in het gebruik van de MammoTrak tafel. Deze tafel bevat een ingebouwde spoel voor MRI borstonderzoek. Deze spoel verhoogt de kwaliteit van de scans omdat de spoel continu op dezelfde plaatst ligt. Met behulp van deze tafel is het zelfs mogelijk om een deel van de biopsie procedures buiten de scanner ruimte te laten plaatsvinden. Hiermee kan een biopsie onderzoek wellicht 20 minuten minder lang in de scanner ruimte plaatsvinden.

Uiteindelijk kunnen we concluderen dat in het huidige proces het ontbreken van de juiste stuurinformatie ervoor zorgt dat verbeterprocessen niet van de grond komen. De hierboven beschreven interventies en aanbevelingen dichten dit gat en geven de verbetermogelijkheden aan.

Management summary

Problem description

This study investigates the process of conducting a Magnetic Resonance Imaging scan (MR-scan) in the radiology department of Medisch Spectrum Twente (MST). The MR scanning process is a supportive step in the total diagnosing process of the hospital. An MR scanning process which produces high quality scans within a relative short period of time is therefore beneficial for the entire hospital. The access time for conducting an MR in Enschede is very high at the moment, sometimes even higher than 40 working days. Patient diagnosis is heavily delayed as a result. The technicians experience a high work load and a high work pressure due to the fully planned schedule. However, process data is largely unknown, which makes it impossible to assess the service level performance of the MR scanning process.

Objective of the research

The objective of the research is to describe the MR scanning process and develop distinctive performance indicators. We gather data about the relevant performance indicators that is important for the process, steering and analysis. We analyze bottlenecks, and give interventions and propose recommendations to improve the process.

Approach

We analyze and map the process to get an overview of the process steps of an MR scan. We gather data from RADOS (radiology information system) to acquire an overview of the process. Furthermore we investigate the organization of the planning and control, which gives us an insight in the way how patients are scheduled and what the effects and consequences of this organization are. We perform a time registration study to acquire data on logistical performance indicators such as patient access time, patient waiting time, utilization of the process, no-shows and maintenance.

Measurements/findings

- Access time: has increased in 2008 from 15 working days in January to 40 working days in December. A decrease in capacity is the main cause of the increase of the access time.
- Utilization of capacity: During opening hours 62% of the time is used for positioning the patient and performing the scans. 10% of the time is used to prepare a patient outside the scanner room and almost 8% is used to finish the appointment. The time to prepare a patient on the scanner table is very hard to predict and showed high variability. The other 20% of the time is used for to clean the room and to wait for the next patient.
- Corrective maintenance is high on both machines: 90 hours on MR 1 and 55 hours on MR 2. Real loss of capacity due to this maintenance is higher because programs must be cancelled.
- In the current situation, no actual performance data is acquired out of the process. Steering information is therefore not available for the management.

Interventions

We use basis principles of logistics to propose our interventions for the improvement of the process. These principles are *variability reduction, complexity reduction* and *waste reduction*. The primary process is strongly affected by the variability of the different steps within the process. Reducing the variability is the primary goal of our interventions. Furthermore, the goal of our interventions is to reduce the complexity of the organization of the process. These complexity leads to a longer production process than necessary. Finally, a goal of our interventions is to reduce waste that exists in the current operational procedures. Based on the process analysis we found possible interventions to improve the process. We investigate the effects by discussing the interventions with the key actors of the process. We discuss the following interventions:

- Update of the protocols that are in use for MR inquiries.
- Insertion of intravenous lines for the insertion of contrast fluid in a preparation room outside the scanner room.
- Expansion of the business time.
- A dockable MR table with inserted coils.

The decision has been made to expand the business time by investing in a 3rd MR scanner. The decision has an effect on the total process, therefore the effects of this decision are explained too.

Conclusions & Recommendations

Our analysis of the proposed interventions showed that update of the protocols in combination with acquiring more and accurate performance data appeared to be the most feasible opportunity. This must be the first step to improve the current process and serves as a basis for further improvements. This intervention makes bottlenecks visible, shows areas for improvement and makes it able to adapt the planning schedule to real-time demand. It is expected on basis of experiences of the radiologists that patient numbers can increase with 10% if this intervention is put through. The insertion of intravenous access lines in a preparation room appeared to be a good next step. The current operational procedures with 2 technicians per MR facilitates this intervention. Examples in practice (by Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007) show that up to 5 minutes per contrast inquiry can be saved. With over 2.000 contrast inquiries a year the extra created capacity is enough to treat 250 patients extra a year.

Expansion of the business time could be feasible but the profit (in patient type/number) depends highly on the chosen operational procedures. Two technicians per MR during the extra business time allows to perform contrast inquiries where one technician per MR allows only standard non contrast inquiries to be performed. A precondition for success of this intervention is a thorough FTE analysis of the number of MR technicians available. This should avoid that the work pressure becomes to high for the technicians. The dockable table intervention does not appear to be a feasible opportunity to improve the process. The tables are big and heavy and thus difficult to work with, while technicians expect that the service delivered to the patients would decline by the new operational procedures. However, the MammoTrak table improves the quality of mamma inquiries and makes it possible to shorten the appointment time for mamma inquiries and biopsy procedures.

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Preface

After 4,5 years of studying the moment is finally there: I have finished all my courses and all that remains until my graduation is the finishing of my master' assignment. Looking back at the start of my assignment, for a student of Business Administration the options and possibilities to perform a master assignment are diverse. However, finding an assignment of your interest is not an easy challenge. Around April 2009 I got in contact with Michiel Klatte, manager of the radiology department at the Medisch Spectrum Twente, who asked whether I was interested in performing my master' assignment there. I was hesitant at first because of my lack of domain expertise of the healthcare sector but I decided to give it a go. My meeting with Michiel Klatte en Antoine van Straalen, coordinator of the cooperation of radiologist, sparked my interest. They had discovered a lot of problems in the current process of the radiology department but saw no clear solutions. Although the problem description was vague, I saw a lot of opportunities for me to conduct a research.

The end of the summer 2009 marked the start of my project at MST. The first couple of months showed me that the initial advantage of the broad research focus could easily turn into a disadvantage. I gathered a lot of data of all the processes in the department but I was struggling to converge and bring focus. Luckily the information and recommendations I received from my internal and external supervisors helped me to narrow the focus and get an overview over the total department. This changing point was very important for me and for the quality of my assignment. I was now able to give detailed information about the process and produce meaningful recommendations.

I thank a lot of people who supported me during my thesis, especially my university supervisors Dr. Ir. Erwin. Hans and Dr. Sabiene Siesling. With your knowledge on this research area you guided me, and showed me how to improve my project. Above all, your enthusiasm was very important for the quality of my project. I thank my internal supervisors Michiel. Klatte MBa and David Edelenbos, you where of great help during my project. With your support and recommendations I was able to improve the quality of the project. A special word of thank for Antoine van Stralen and Roland Bezooijen, radiologists, for giving me important recommendations about the total process of the MR department. I would like to thank all the employees of the radiology department for helping me to understand the department and the total process, and particularly Istvan, Casper, Monique, Annemieke, Sandra, Wendy, Monique, Annelies, Gerrit, Martin, Roy and Sander. Finally, I thank my family and friends for their continuous support!

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Marcel Koenderink

1. Introduction

High waiting times for treating patients are a major concern for hospitals all over the Netherlands. These high waiting times cause a series of ‘problems’ such as unsatisfied patients who have to deal with a larger time of uncertainty and work pressure which results in unsatisfied physicians. These problems are of interest for anyone involved in the health service delivery process.

The Radiology department of Medisch Spectrum Twente (MST), a large top-clinical hospital in the Netherlands has to deal with the same issues everyday. The department uses the application of imaging technology, like for example x-ray and radiation, to diagnose and treat diseases. Radiologists operate an array of imaging technologies, divided over various rooms and locations. The number of patients which rely on the services of the radiology department is growing rapidly, due to the increased possibilities of imaging techniques in increasing types of diseases. The same developments are experienced by the people that are involved in the MR scanning process. The number of patients grows, the workload is very high and the waiting lists for the MR are long. In this study we make the bottlenecks visible, and we give an overview of the process. We propose interventions and recommendations which improve the process of service delivery of MST.

Paragraph 1.1 introduces MST and the department Radiology. Paragraph 1.2 introduces the problem which the Radiology department is facing currently. Paragraph 1.3 introduces the research structure of the study.

1.1 Background Medisch Spectrum Twente

MST is a top clinical integrated hospital whose core competence is to advance the health of the residents in the region. This is done by offering specialized medical care. In addition to the basic care, which is the fundament of MST, it has a lot of professionals with special knowledge and skills and a couple of special facilities at their disposal. MST is one of the biggest non-academic hospitals of the Netherlands. Currently the hospital has locations in Enschede and Oldenzaal and outposts in Haaksbergen and Losser, which serve an area with circa 264.000 residents. Some facts:

- 1070 beds
- 29.500 intakes a year with a length of stay > 1 day
- 24.000 intakes a year with a length of stay < 1 day
- 439.000 outpatient visits

The organization employs about 4.000 staff and around 200 specialists, which are organized in a cluster structure (http://www.mst.nl/).

1.2 Problem formulation

Since imaging techniques are used to certify the diagnosis of the patient many patients have to deal with the department radiology. Most of the time, the executed actions are supportive for the clinical process of the hospital or from the general practitioners. Sometimes the executed actions are the treatment itself like the angiography interventions. The supportive step facilitates the total process of healthcare delivery. The waiting times should thus be as low as possible and the image with report should be available directly for the requestor. However due to the growing patient numbers this is not always possible. As a consequence of the growing number of patients relying on the services, the radiology department experiences a high workload (and thus works pressure). The number of patients is growing disproportionately in comparison with the capacity of the radiology department (Annual report radiology, 2008).

The radiology department of MST is not the only department that has to deal with these issues. These issues are common issues for almost every hospital. Therefore a commission proposed guidelines (in Dutch: ‘treeknormen’) which tell us which waiting times, or access times, are acceptable. These guidelines make clear how the various hospitals are performing and give more importance on the subject. The problem(s) should therefore be made visible to all stakeholders who are active in the process.

It is difficult to forecast the number of patients and the time it takes to serve them, because every patient has unique needs and should be treated in a way that suites his/her circumstances. Standardization of the patients’ process is therefore not easy to adapt. These circumstances make it difficult, but not impossible, to have a meaningful insight in the patient’ streams. A patient cannot be told that ‘we ran out of time and will therefore continue the diagnostic tomorrow.’ This makes it difficult to plan resources and capacities. We visualize these patients’ streams and forecast the number of patients and the time it takes to serve them so we are able to make clear recommendations for the improvement of the process. In the MR process the above stated problems are visible in practice. Every patient needs a different type of scan, which takes a different amount of time. The total scan time per patient is estimated and reserved up front, but numerous factors could be involved why this time is exceeded. This could eventually lead to overtime and thus more work pressure.

The MR scan is one of the latest high-end technologies in radiology which makes it possible to make very detailed images, to make accurate diagnosis possible and is thus a very popular type to use. The availability of this type of technique itself creates new (extra) demand. Demand is exceeding capacity which leads to high access times and this trend is continuing. This taken into account leads to the following problem formulation:

‘Unknown patient process’ data for the MR scan lead to high work pressure and thus a possible decline in service delivery towards the patients because not all patients can receive the appropriate and necessary care within a reasonable amount of time.

The relevance of this study can be seen from different point of views. This study is relevant in a social way, because the proposed interventions foresee a decrease on the length of the waiting times, or can improve the service delivered to the patients. A report from the 'signaleringscommissie kanker[1]' of the Dutch institute for cancer control, signals an increase in the demand for MR scans in the period until 2015 for fighting cancer. Especially with cancer it is very important that it is recognized in an early state (SCK-rapportBVT, 2005). Long waiting lists are thus a very disturbing problem. To decrease the length of these waiting lists is very important for society. Another relevant point is the positive influence it could have on the working atmosphere of the physicians and the radiology technicians at the radiology department. If the process is running more smoothly, fewer problems will arise and the work pressure will decline. At last there is the scientific relevance. This study could contribute in a social way by addressing problems that cause the problems like high waiting times and work pressure. Searching for methods that could address these issues could give new insights in how departments like the radiology should be structured, or could address question like how to operate a good working patient process for a MR department.

1.3 Research objective and questions

The objective of this study is to give insight in the service delivery process of the radiology department and to propose interventions/make recommendations for improvements of the process. We acquire data about the performances of the service delivery process. We chose the MR scan modality of MST as case study. Based on the problem formulation the research objective is:

To acquire relevant performance data and design interventions and make recommendations to improve the service delivery process of conducting an MR scan.

To attain the research objective, the following research questions are proposed.

1. How can the existing patient process for conducting a MR scan be described and what are its major bottlenecks?

Chapter 2 describes the process of the MR scan its planning & control and its performance. Data is acquired from obtained work documents and interviews with employees of the department. A time registration study is performed to get information on predetermined performance indicators. Bottlenecks are discovered by analyzing the acquired data of the process.

2. What existing literature about process improvements in healthcare businesses is relevant to our research and what are its implications?

In chapter 3, relevant literature on this subject is obtained and examined. This literature serves as a basis for the proposed interventions. There is much literature about improving hospital productivity or decreasing costs, but little research is known that focuses on both.

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[1] *Signaleringscommissie kanker: Project group of the Dutch Cancer institution KWF Kankerbestrijding.*

3. What interventions and recommendations can be proposed to eliminate the bottlenecks?

Chapter 4 proposes the interventions which are determined on basis of the earlier research in chapter 2 and 3, and examines the effect of the proposed interventions and recommendations. What are the expected effects on the process, on the service delivered towards the patients and on the costs for the department.

4. Which interventions and or recommendations would be most beneficial?

Chapter 5 describes the conclusions. The conclusions summarize the implications which can be drawn on basis of the research. The recommendations explain which steps should be taken to improve the current situation. Chapter 6 deals with the recommendations and implications of the research.

2. Context MR: the present situation of service delivery

Chapter 2 describes the present situation of service delivery of the MR scanning process. Paragraph 2.1 describes the process in general terms. In paragraph 2.2 the organization of the process is analyzed, by describing the appointment process, the scanning process and the report making process. Paragraph 2.3 describes the planning and control of the process. The performance of the system is described in paragraph 2.4. The bottlenecks in the service delivery process are analyzed in paragraph 2.5.

2.1 Process description

Magnetic Resonance Imaging is the technique where diagnostic images are produced by putting the patient into a giant magnetic field. This magnetic field is capable of 'scanning' the small magnetic field within the body without being distracted by the 'bigger' outside magnetic field of the body. Hence it is possible to make very detailed images of almost the entire body. MR scans play a big role in the diagnosing process of various specialties. MST has two MR scanners, MR1 (ZQC3 INTERA 1.0T POWER) and MR2 (ZCR5 INTERA 1.5T MASTER).

Table 1 shows the total numbers of patients divided per specialty over the year 2008.

Applicant	Inquiry			
	MR		MR	
General Pr.	255	Neurosurgery	792	
Anesthesia	47	Neurology	2927	
Cardiology	421	Orthopedics	1577	
Cardio. Surgery	12	Plastic Surg.	48	
Surgery	1356	Psychiatry	37	
Dermatology	1	Rheumatology	193	
Gynecology	53	Urology	85	
Internal Med.	439	Radiotherapy	295	
Pediatrics	123	Physiotherapy	25	
ENT Med.	289	Unknown Specialists	45	
Pulmonary Med.	146	Other Specialists	3	
Gastroenterology	265			
Total	3407		6106	= 9513

Table 1: Number of inquiries per requestor (2008), Synapse data MR

The most of the inquiries are requested by a select group of applicants. These groups are surgery, neurology, orthopedics and neurosurgery. Table 2 shows the four groups with respect to the other applicants:

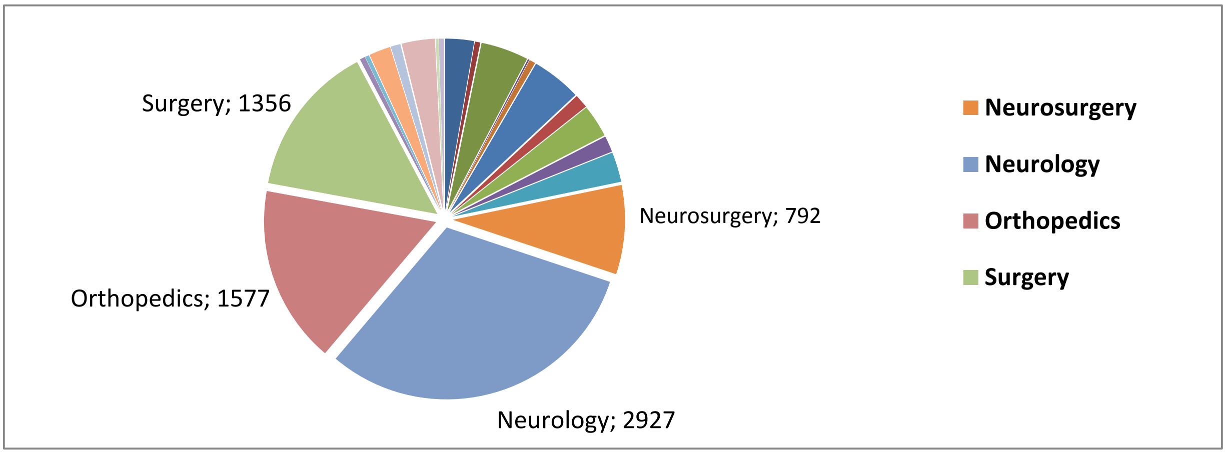

Table 2: The four main requestors for a MR scan in 2008 (Total request 9513)

Information systems

The MR department is highly dependent on information systems. Without these systems, the primary process would not be able to produce the scans or even plan the patients. The main information systems are RADOS, PACS and G2 Speech.

RADOS is the Radiology information system. This system is used for all data information about patients, patient scheduling, production information and other performance data. The system is daily used by the technicians and application staff to support the primary process. PACS, the picture archiving and communication system, is the central imaging database. All produced images are sent to PACS after they are made. Radiologist can enter PACS to analyze the produced scans. The total process is heavily delayed if PACS does not work because the produced images can not be analyzed. G2 Speech is the speech recognizing program for the radiologists that is a tool to produce the digital reports. The radiologist dictates the information and the reports are made. This program makes report making easier and more efficient.

Lay-out

The lay-out planning of the MR rooms is derived from the type and the number of inquiries that must be performed in the room and according to guidelines for the required space and number of rooms. The furnishing of the MR scanner rooms is in consensus with the requirements of the radiation law (in Dutch: kernenergiewet) and the guidelines of the labour inspection. The capacity of the waiting rooms is adjusted to the number of patients which have to be treated. The MR has their own waiting room at their disposal. The administration is located in such a way, that guidance on the waiting patients is not possible by the administration. Figure 1 gives an overview of the MR department.

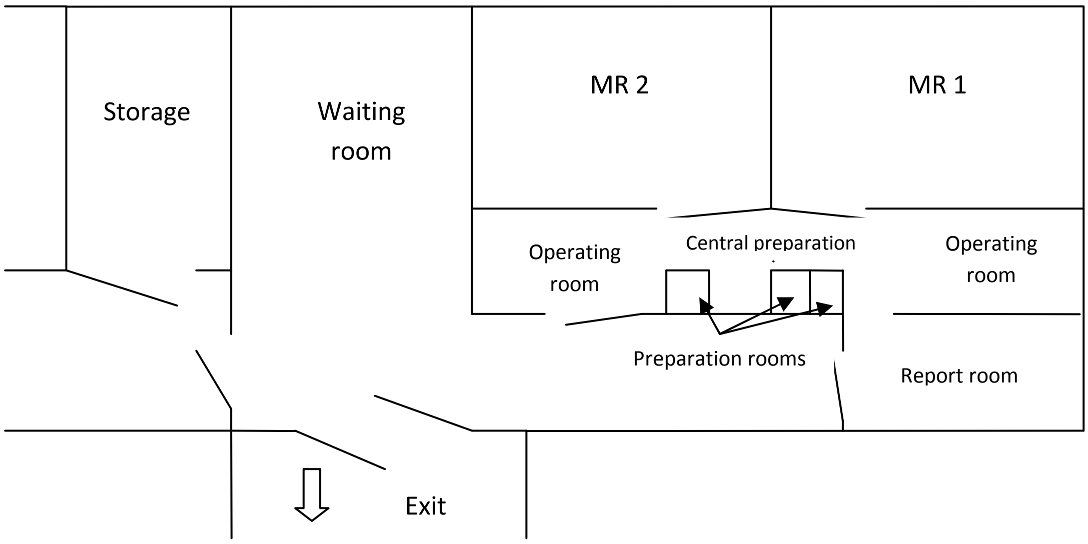

Figure 1: Lay-out of the MR department

The MR scanners are placed in two rooms. Each of the rooms has an own operating room where the patient is monitored during the actual scan. There are three preparation rooms where the patients are prepared for their scans. Patients who are restricted to a bed must be moved to another bed which fits into the scanner. This movement is performed in the central preparation room. The central administration is about 50 yards away from the MR department.

2.2 Organization of the MR process

The organization of the total MR process is described in three parts. Paragraph 2.2.1 describes the steps in the appointment process. Paragraph 2.2.2 describes the process of conducting the scan. This is done by developing a time registration model of all the different steps in the scanning process. Finally, paragraph 2.2.3 describes the steps in the reporting process.

2.2.1 Appointment process

The first part shows the steps in the process from the moment that the patient requests a MR scan, until the moment where he/she has made an appointment. In 2008, permission for a MR scan was granted for 9513 patients which resulted in 12336 MR scans performed.

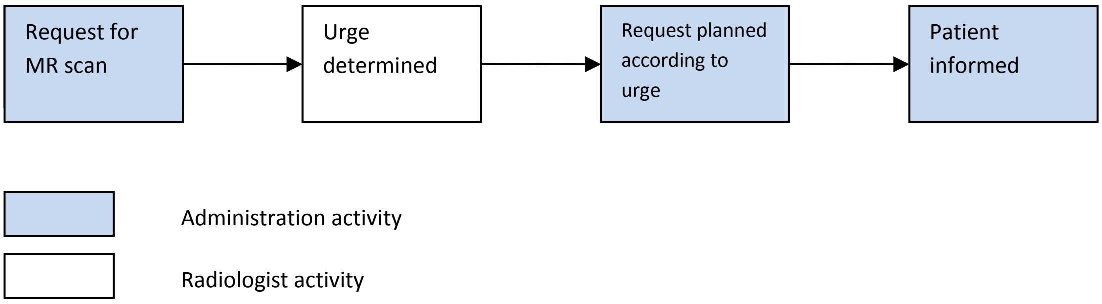

Figure 2: Steps in appointment process

We distinguish emergency and elective patients. The emergency patients are in immediate need of care and can therefore not be planned in advance. Elective patients 'arrive' through the 'normal' routes. This means that patients can arrive from specialists within the hospital, from the outpatient department or patients could arrive in the process on request from general practitioners. The filled-in request forms are assessed by a radiologist to determine the urge and the protocol that must be used. After the assessment, the appointment is planned by the administration according to the adjusted protocol.

2.2.2 Time registration model scanning process

After the application process, the second step consists of the actual appointment itself. We design a time registration model, with different registration moments, as approach for obtaining the empirical data that described the process of conducting a scan and reporting the scan (Shojania & Grimshaw, 2005). These different registration moments serve as the basis for the performance indicators. We determine these registration moments to be able to measure the moments and periods in the process we think are necessary for the management to have information on. The model is based on the time registration model for surgery of Van Hoorn et al. (2006). We discussed the model with the technicians and received input to optimize the model:

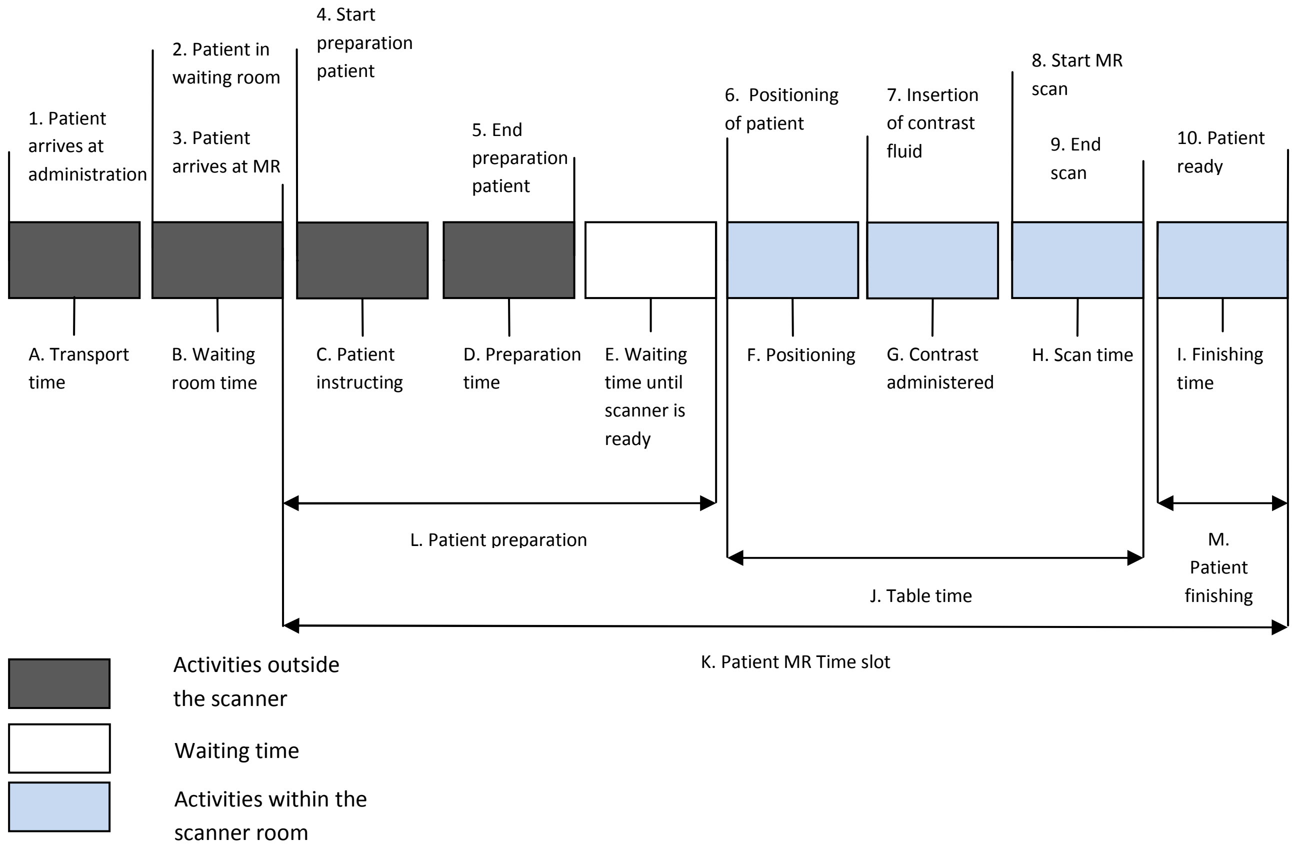

Figure 3: Time registration of imaging process

The process starts at the moment that the patient arrives at administration (1). The patient checks in at the administration with his/her data. When all the data is correct the patient continues to the waiting room. The registration moment patient in waiting room starts when the patient enters the waiting room (2) and ends when patient arrives at MR (3). Patient arrives at MR starts when the patient is called by the technicians for their appointment. The preparation of the patient starts when the technicians give the last instructions to the patient (C), and end when the patient prepares him/her self in a changing room (D). The preparation of the patient starts on the first moment after arrival at the MR (4) and ends when the patient is ready to proceed to the MR table. Extra waiting time occurs when the scanner is not prepared or cleaned (E). When the scanner is ready, the patient is put on the MR table to be positioned for the scan. (6). For a scan without contrast this registration moment ends when the scan is started. For a scan with contrast, the contrast fluid is administered when the patient is positioned correctly (7). Then the scan is started (8). This registration moment ends when the scan is finished (9). After the scan is performed, the patient leaves the scanner to the preparation room. The inquiry ends when the patient is ready (10) and leaves the MR department.

Patient preparation is defined as the first moment when a patient arrives at the MR (3) until the moment that the technician starts with the positioning of the patient (6). Table time is the registration moment that starts when the technician start with positioning of the patient (6) until the moment that the scan ends (9). Patient finishing starts when the scan ends (9) until the moment that the patient is ready (10). The total time slot of the patient starts with patient arrives at MR (3) until patient ready (10). These registration moments provide the information that the mangers need as a basis for their analysis of the performance of the process.

We discover more relevant factors influencing the organizations of the process:

- Patients are asked to report 15 minutes before their appointment.
- No restriction with regard to eating, drinking or medicine use before inquiries. There are however three exceptions:
    - MRCP: requires soberness from midnight
    - MR narcosis: patient must be sober 6 hours before the inquiry
    - MR portaflow: patient must be sober from midnight
- Patients have different appointment durations varying from 15 to 75 minutes.
- Sometimes the contrast fluid is inserted by means of an intravenous access line. When the artery can not be found, the radiologist is called to perform the procedure.
- Before every inquiry the patient needs to fill in the ‘safety form MR’. An unfilled safety form is a contra indication for a MR inquiry.
- Patients must be transferred into the MR machine, even patients who are already lying in bed.
- MR mamma patients must lie on their stomach.
- Every type of inquiry has a standard MR on which it is performed. Both machines are not interchangeable. Some inquiries can be performed on both; some are restricted to MR 1 or MR 2.

The MR scanners are opened during the whole business time. Lunchtime or coffee breaks are not planned. The MR scanners are closed 4 times a year for planned maintenance. Breakdowns occur randomly and know a high degree of uncertainty. No test trails or protocol updates are planned for.

2.2.3 Time registration model reporting process

The last part of the process of performing an MR scan consists of the reporting process. Radiologists make the radiologist report which can be displayed:

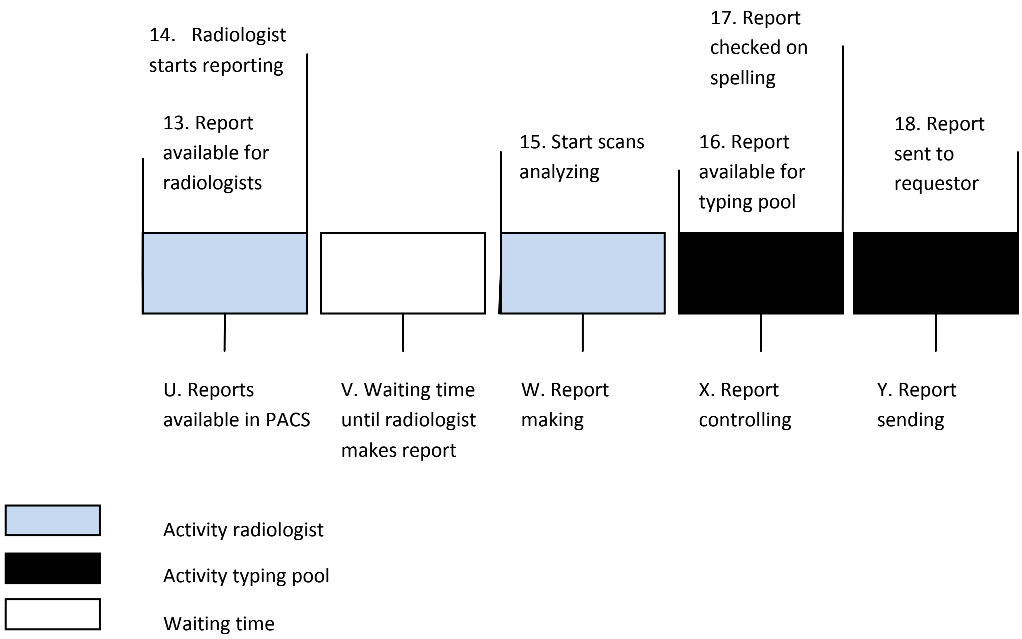

Figure 4: steps in reporting process

The produced images by the technicians are directly after that the patient is unregistered in the RADOS, available for the radiologist (13). The radiologist has to examine the images and make the radiologist report (14). There are a lot of images produced so radiologists have to deal with a large number of images, with as a consequence that the produced images can not always be reported directly after they are produced, resulting in waiting time until the radiologists are ready (V). When the radiologist has produced the reports, they are sent to the typing pool for a spelling check (16). This has to be done because the reports are made with the help of a voice recognition program (called G2), which sometimes leads to mistakes. This registration moment ends when the report has been checked on spelling (17). When all the mistakes (spelling/grammar) have been corrected the digital reports and images are sent to the requestor (18). Requestors within the hospital receive the report and images digitally whilst requestors from outside the hospital receive the images and report on a CD.

We have described the total process of conducting an MR scan with the help of distinctive definitions. We are now able to design performance indicators and to monitor the performance of the process. The process analysis serves as a basis for the performance evaluation in chapter 3.

Appendix C gives a schematic explanation of the different steps in the time registration model.

2.3 Planning and control

In this paragraph we analyze the relevant planning and control issues that play a role in the process. We use the framework of van Houdenhoven et al. (2007), called 'the framework for hospital planning and control' to analyze the planning and control functions that are involved on four hierarchical levels of control. This framework is an excellent basis for the recognition and positioning of the bottlenecks and recommendations to encounter them. The 4 x 4 framework describes two main dimensions, (1) the planning and control areas and (2) the hierarchical planning levels. Together they form 'a common language for managers, clinicians and experts on planning and control to formulate objectives in terms of performance indicators on all organizational levels and in all areas of interest' (van Houdenhoven, 2007).

	Medical planning	Resource capacity planning	Material coordination	Financial planning
Strategic	Research and treatment methods	Case mix planning, layout planning, capacity dimensioning	Supply chain and warehouse design	Agreements with insurance companies, investment plans
Tactical	Definition of medical protocols	Allocation of time and resources to specialties, rostering	Supplier selection, tendering	Determining and allocating budgets, annual plans
Operational offline	Diagnosis and planning of an individual treatment	Patient scheduling, workforce planning	Purchasing, determining order sizes	RNG billing
Operational online	Diagnosing emergencies and complications	Monitoring, emergency coordination	Rush ordering,	Billing complications,

Managerial areas / Hierarchical decomposition

Table 3: framework for planning and control

For our analysis of the planning and control in the process we draw our attention on the medical planning and the resource capacity planning area. The material coordination and financial planning area are not further analyzed because they take place outside the focus of our research.

Medical Planning

The total medical planning is the responsibility of the cooperation of radiologists and especially for the radiologist dedicated to the MR. All medical decisions on strategic, tactical and operational level are performed under their responsibility. Examples of strategic medical planning are the medical decisions made by the radiologists with regard to treatment methods and diagnosis. This is an important part in the planning and control area because decisions that are made here effect all other decisions in the department. Radiologists determine the total medical strategy of the department. Tactical medical planning consists of translating these strategic medical plans into medium term objectives like for instance the definition of medical protocols. We talk about operational medical planning when decisions are made with regard to the treatment of specific patients. Radiologists are responsible for the used protocol for every patient who is scanned. Furthermore they diagnose the patients and report it back to the requestor.

Resource capacity planning

The strategic resource capacity planning concerns capacity dimensioning, which for example specifies the case mix lay-out (e.g. only 2 MR systems), or specifies the number of MR technicians or the preparation space required per MR. These decision have a direct effect on the tactical capacity planning. There is restricted capacity allocated to the specialties in the week rosters. Only cardio therapy and orthopedics have reserved slots during the week. Both MR systems have their own roster. Every roster has a certain number of free slots per day for inquiries and some slots are reserved for emergency cases. The guidelines with regard to planning:

- Planning per 5 minutes. Inquiry time is increased by 5 minutes to get the slot time.
- Between 12:00 – 13:00 p.m., standard inquiries are planned to create lunch time for the technicians. The scanner is not closed during lunch time.
- Between 12:00 – 14:00 p.m., no clinical patients are planned because of restricted capacity for the transfer of these patients.
- MR Cardio, MR mamma and MR orthopedic should be planned in clusters.

MR 1 is planned according to the following slots:

- Standard inquiries slots: Non-clinical standard inquiries with no contrast (SO).
- Emergency slots: Slots are free every day for emergency patients, most of the time filled with clinical patients (E).
- Cardio inquiries: Slots reserved for the cardio inquiries (C).
- Narcosis inquiries: Slots reserved for patients who need narcosis (N).
- Normal slots: These slots could be filled with all other inquiries which are allowed on MR 1 and can not be placed into one of the categories (O).

Schedule for MR 1																				
	8-9		**9-10**		**10-11**		**11-12**		**12-13**		**13-14**		**14-15**		**15-16**		**16-17**		**17-18**	
Monday	SO	O	O	O	O	O	O	O	O	O	E	E	E	O	O	O	O	SO	SO	SO
Tuesday	SO	O	O	O	O	O	E	E	E	O	O	C	C	C	C	C	C	SO	SO	SO
Wednesday	C	C	C	C	C	C	C	C	C	C	CE	CE	CE	CE	E	E	E	SO	SO	SO
Thursday	SO	O	O	O	O	O	O	O	O	O	E	E	E	O	O	O	O	SO	SO	SO
Friday	SO	O	O	O	O	O	E	E	E	O	O	N	N	N		O	O	SO	SO	SO
Saturday	SO	SO	SO	SO		SO	SO	SO	SO		SO	SO	SO		SO	SO	SO			
Sunday	SO	SO	SO	SO		SO	SO	SO	SO		SO	SO	SO		SO	SO	SO			

	O	Normal slots	SO	Standard inquiries
	E	Emergency slots	N	Narcosis inquiries
	C	Slots reserved for Cardio	CE	Cardio Emergency

Figure 5: Business time of MR 1 (2009)

MR 2 is planned according to the following slots:

- Standard inquiries slots: Non-clinical standard inquiries with no contrast (SO)
- Emergency slots: Slots are free every day for emergency patients, most of the time filled with clinical patients (E)
- ARTHRO slots: slots reserved for orthopedic inquiries (A)
- Normal slots: These slots could be planned with all other inquiries who are allowed on MR 1 and can not be placed into one of the categories (O)

The emergency slots are on Monday at the same moment for both MR' (Both from 13:00-14:30). This is done because all emergency patients from the weekend who need to be helped within 1-3 days are planned (the actual planning of the inquiries) on Monday morning. Emergency slots on Monday morning are therefore of no use. The emergency slots on Monday morning on MR 2 are rescheduled to the afternoon:

Schedule for MR 2																				
	8-9		9-10		10-11		11-12		12-13		13-14		14-15		15-16		16-17		17-18	
Monday	SO	O	O	O	O	O	O	O	O	O	E	E	E	O	O	O	O	SO	SO	SO
Tuesday	SO	O	O	O	O	O	O	O	O	O	E	E	E	O	O	O	O	SO	SO	SO
Wednesday	SO	O	O	O	O	O	O	O	O	O	E	E	E	O	O	O	O	SO	SO	SO
Thursday	SO	O	O	O	O	E	E	E	O	O	O	A	A	A	A	A	A	A	A	SO
Friday	SO	O	O	O	O	O	O	O	O	O	E	E	E	O	O	O	O	SO	SO	SO
Saturday	SO	SO	SO	SO		SO	SO	SO	SO		SO	SO	SO		SO	SO	SO			
Sunday	SO	SO	SO	SO		SO	SO	SO	SO		SO	SO	SO		SO	SO	SO			
O	Normal slot									SO	Standard inquiries									
E	Emergency slot									A	Slots reserved for Orthopedics									

Figure 6: Business time of MR 2 (2009)

The operational capacity planning is divided into an online and an offline part. The online operational capacity planning involves all control mechanisms that deal with monitoring of the process and reacting to unforeseen events. This consists of activities like emergencies, no shows, and unexpected absenteeism of technicians. The offline operational part of the capacity planning is explained in more detail.

The planning of the MR technicians (workforce planning) is performed by two technicians. The MR department has two shifts. The early shift works from 8:00 until 16:30 and the late shift works from 9:30 until 18:00. This has an effect on the equipment of the scanners. There are three technicians working from 8:00 until 9:30. From 9:30 until 13:00 there are four technicians working. From 13:00 until 16:30 there are three technicians working and from 16:30 until 18:00 are there two technicians working. The rosters are made three months in advance. The number of technicians that are needed to equip the two scanners per day and the number of technicians that are available:

MR 1 and MR 2: 5 technicians	5 technicians per day
Compensation for weekend and regular shifts	2 technicians per day
Absenteeism	2 technicians per day
Other specialties	2 technicians per day
Total number of technicians needed per day	11 technicians per day

Available MR technicians	13 technicians
Long term absent	1 technician
End of training for MR technician	2 technicians
Start training for MR technician (not available yet)	3 technicians

Table 4: Number of technicians to equip two scanners per day (available & needed).

This analysis shows that at this moment 16 technicians can perform MR shifts. Due to other shifts (because of extra specialties) not all technicians can be used to perform MR shifts every day.

The planning of the inquiries (patient scheduling) is performed by the planning department of the radiology. This department is part of the central administration of the radiology. Planning of MR inquiries is done manually. The choice of the protocol used for the inquiry is determined by the MR radiologist (at the same moment when the permission is determined). Each type of request has a different way on which it should be planned with respect to the urge. In case of an MR scan it is not possible to perform it at another department, because there are only two MR scans, both at the radiology department. After the request is granted, it is planned on the first possible date. In 2008, 1316 patients are scanned on the same day and 1801 patients within 1-3 days. 6396 patients are planned according to the first free time slot for there request.

The department Radiology at MST is opened 24 hours a day. The MR scans are in use for scheduled scans from Monday to Friday from 8:00 p.m. (11) until 18:00 a.m. (12) and Saturday and Sunday from 8:00 pm until 16:30 a.m. The break is 15 minutes per morning and afternoon, and 30 minutes for lunch. Only 'standard inquiries' (which can be performed by one technician) are performed during lunch brakes and therefore the MR scanners will not be closed during the breaks. The business time is thus fully planned with inquiries (N). A side from the registration moments with respect to individual patient, we also need registration moments throughout the day.

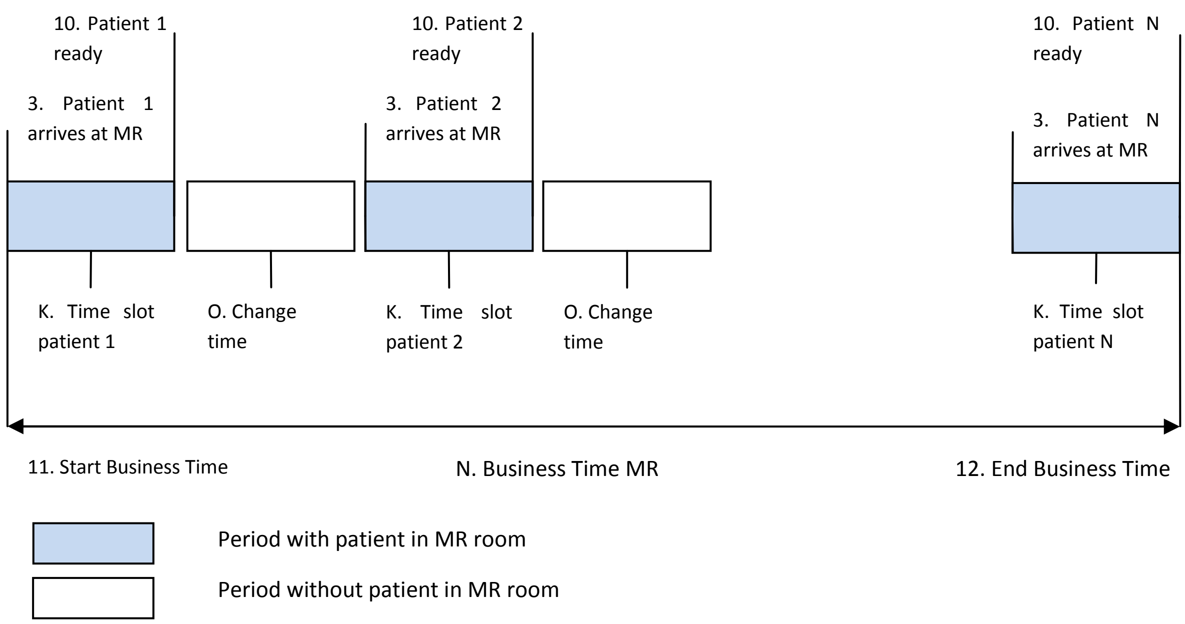

Figure 7: Business time planning

The realized business time is however not the same as the planned business time. In the planned situation, the business time is fully planned with patients (K). The period between patient ready (10) and patient N+1 arrives at MR is called the change time (O). However, in practice, such a tight schedule is not realizable.

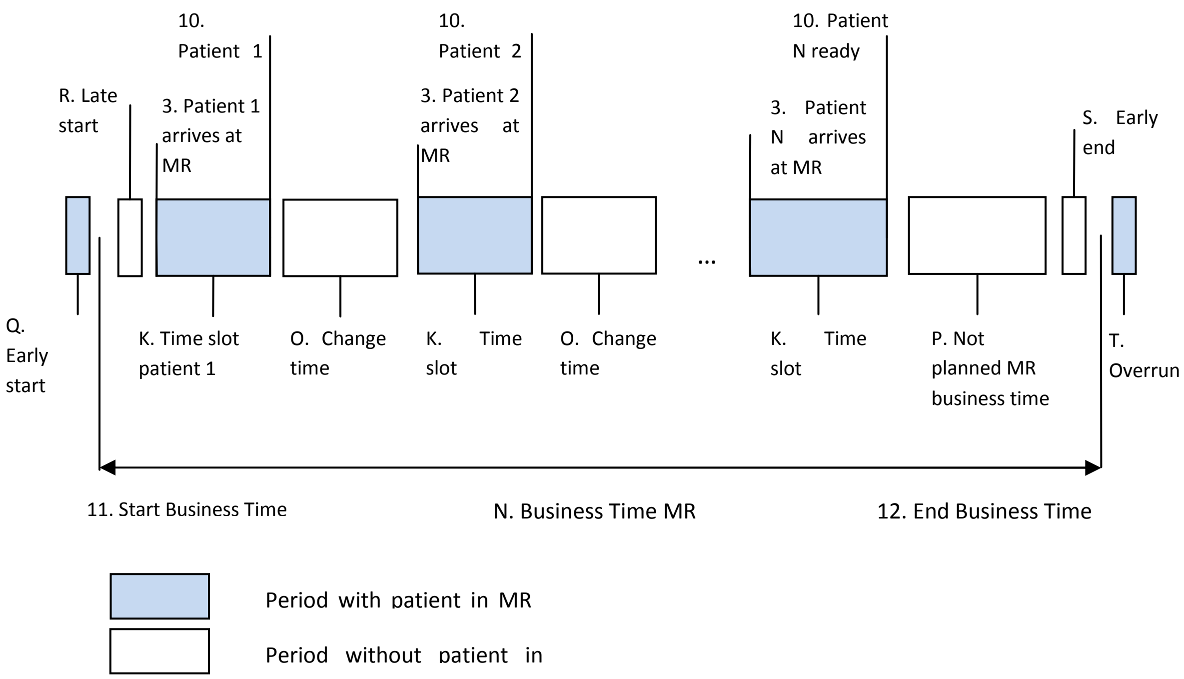

Figure 8: Business time realization

Figure 8 shows the reasons for this. If a patient arrives at MR (3) before the business time starts (11), then we register an earlier start (Q). If a patient arrives at the MR (3) after the business time starts (11) we register a late start. Both have an effect on the planned schedule. Another reason why the planned schedule is not always realized are the unplanned activities which have to be performed (P) resulting in an early end or overrun of the business time.

2.4 Performance of the system

This paragraph assesses the performance of the system. The performance is measured by means of a data analysis of the performances of the year 2008. Furthermore, a time measurement of MR inquiries of 10 working days provides information about utilization, planned versus realized performances and real-time waiting times of the patients. The performance indicators that we identify to assess the performance of the system are:

- *(Paragraph 2.4.1)* Productivity: information about the number and types of inquiries performed in a given period.
- *(Paragraph 2.4.2)* Access time: this is the time between the request for a MR scan and the actual appointment in working days (Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007).
- *(Paragraph 2.4.3)* Waiting time: involuntary waiting time in the waiting room in minutes (Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007).
- *(Paragraph 2.4.4)* Utilization of the capacity: distribution of time spent to several predefined categories of activities (Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007).
- *(Paragraph 2.4.5)* Planned versus realized inquiry time. This indicator describes the time (in minutes) that the realized inquiry time deviates from the scheduled time for that particular inquiry.
- *(Paragraph 2.4.6)* No-shows: The number of people who do not show up for their appointment, resulting in loss of scan time (percentage).
- *(Paragraph 2.4.7)* Maintenance: downtime of the scanners due to maintenance, preventive and corrective.
- *(Paragraph 2.4.8)* Health related absenteeism: absenteeism of technicians could eventually lead to downtime.

2.4.1 Production

Table 5 shows the production data over 2008. All scans made in 2008 are registered. We made a distinction between the type of requestor, emergency or elective patients and scans that require contrast fluid or narcosis.

Production days	252
Number of scans performed	12336
Number of patients	9513
Clinical patients	1626
Outpatients	7357
General Practitioners	235
Other hospitals	298
Emergency Patients:	
Within 1 day	1316
Within 1-3 days	1801
Scans require contrast	1814 (19,06%)
Scans require narcosis	109 (1,14%)

Table 5: Performance data MR scanners 2008 (Rados)

In 2008, 12336 scans are performed on 9513 patients. Most of the patients entered the process from the outpatient department. More than 3100 patients where treated within 1-3 working days. Almost 20% of the scans (N = 1814) required contrast fluid inserted and a small part (N = 109) of the scans must be performed under narcosis.

Furthermore, we measured the capacity and production per month in 2008:

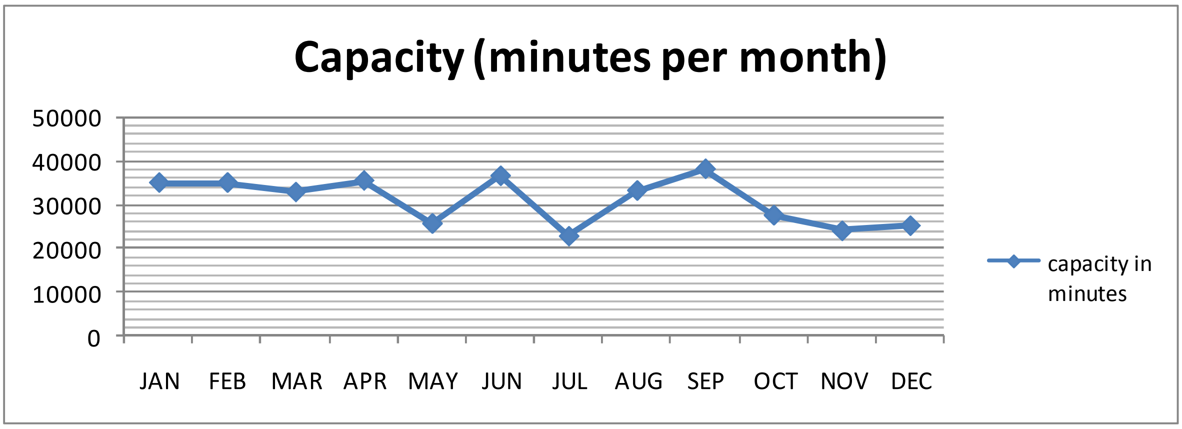

Figure 9: Capacity per month in minutes (Rados)

We can make some remarks with regard to the available capacity over the year. From January until September 2008 the MR was also opened in the evening hours (8:00 am- 9:00 pm) and on Saturdays. In May and July the capacity was temporary reduced due to holidays. At the end of September, the technicians experienced a very high working pressure and therefore from October the capacity was reduced permanently (8:00 am – 6:00 pm, week, no weekends). This decrease in capacity had an immediate effect on the production per month:

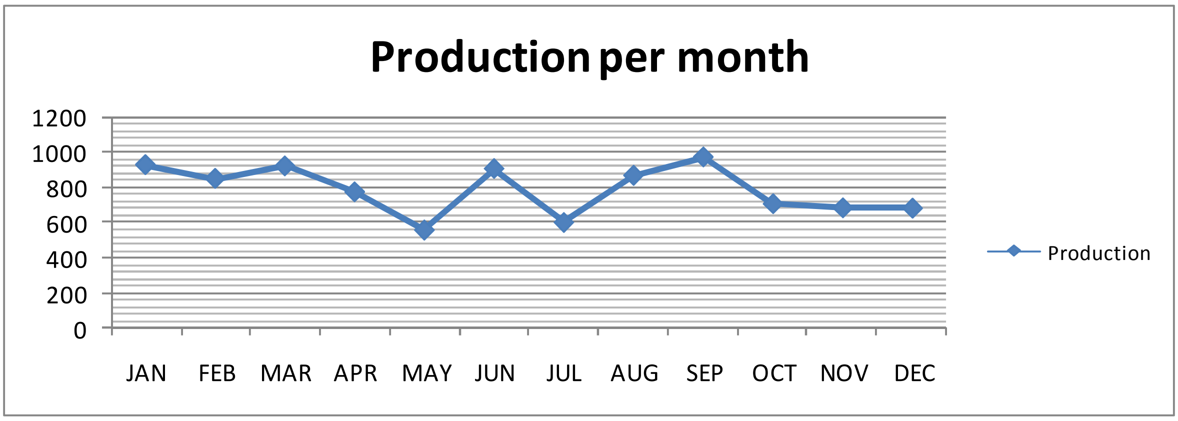

Figure 10: Production per month (Rados)

2.4.2 Access Time

The access time is the time between the date of the request for an inquiry and the date of the actual inquiry, measured in working days. We measure the access time for the outpatient department patients. Emergency patients and patients with reserved timeslots (Cardio) are not taken into account. According to Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker (2007) there are two ways to measure the actual access time. The authors make a distinction between retrospective and prospective access times. Prospective access times are measured by measuring the third possible appointment twice a week. Distinctions have to be made between categories of patients. Retrospective access times are measured by investigating all appointments, and calculate the working days between referral and scanning date. For emergencies there are no waiting times, and for clinical patients the rule 'within three working days' counts. During the summertime, the access times may increase because of the availability of fewer employees and consequently less production time.

Figure 12 shows the average access time per month over the year 2008 (measured retrospectively). In January 2008 the access time was 11.9 working days (SD = 7.3), this increased to a peak of 45.37 (SD = 21.14) in November.

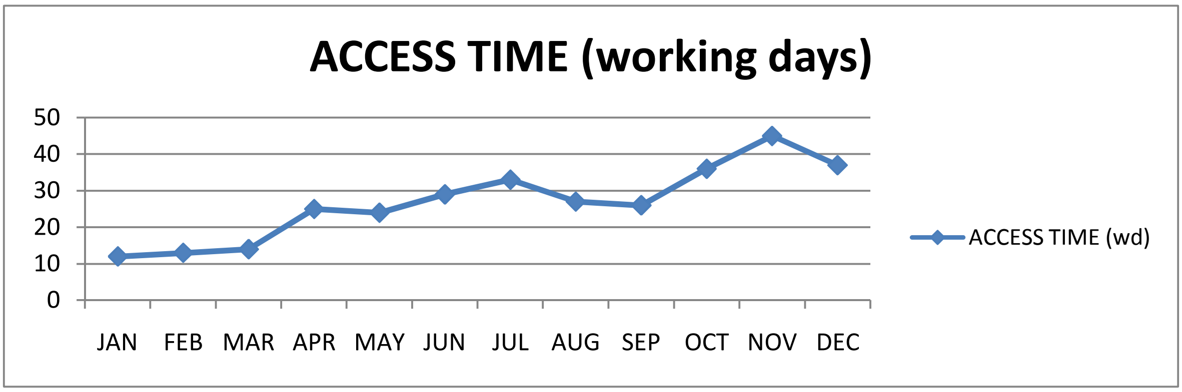

Figure 11: Access time for MR scan over 2008, RADOS (retrospective)

We see an increase in the access time for outpatient department patients in 2008 leading up to 40 working days at the end of the year. During the summer period (vacations) the access time was circling around 25 working days. With the used capacity until September, e.g. working days from 8 am until 9 pm and Saturdays, this seemed to be constant level on which the access time would evolve. After the vacation period, in October, the capacity was reduced, because of the high work pressure experienced by the technicians (See Figure 9). This action had an immediate effect on the access time which increased rapidly to more than 40 working days. In 2009 the capacity is expanded under pressure of the board of directors. This resulted in an access time circling around 35-40 working days. In the situation, with the current capacity, a production of 1000+ scans per month is possible. This will not increase or decrease the access time which will continue to be around 40 weeks. However, one factor has to be taken into account. Because of the access time of more than 40 working days, patients will seek other opportunities to undergo an MR scan. Patients are then referred to other hospitals or go to private organizations.

We can conclude that there is no capacity problem. The access time continues to be around 35 – 40 days in 2009. The capacity has been reduced drastically due to the increased work pressure in the end of 2008. This had a negative effect on the access time. The capacity could be expanded if there are more technicians available, which will result in a decrease of the access time.

2.4.3 Waiting time

The second type of waiting times is the actual waiting time in the waiting room. The time between the arrive at the reception desk and the time that the inquiry starts should be as low as possible. There is a distinction between voluntary and involuntary waiting time. Voluntary waiting time is the time between the arrive at the reception desk and start of the appointment. For example a patient who arrives 15 minutes before his/her appointment has to deal with 15 minutes of voluntary waiting time. Involuntary waiting time however is the waiting time for a patient when his/her appointment time is already passed. For our measurement (N= 190) we measured the time between the scheduled start of the appointment and the real-time start of the appointment. We found an average waiting time of 5.2 minutes with a standard deviation of 9.5 minutes. 56% of the patients (N= 107) experienced no involuntary waiting time. Figure 12 displays the involuntary waiting time:

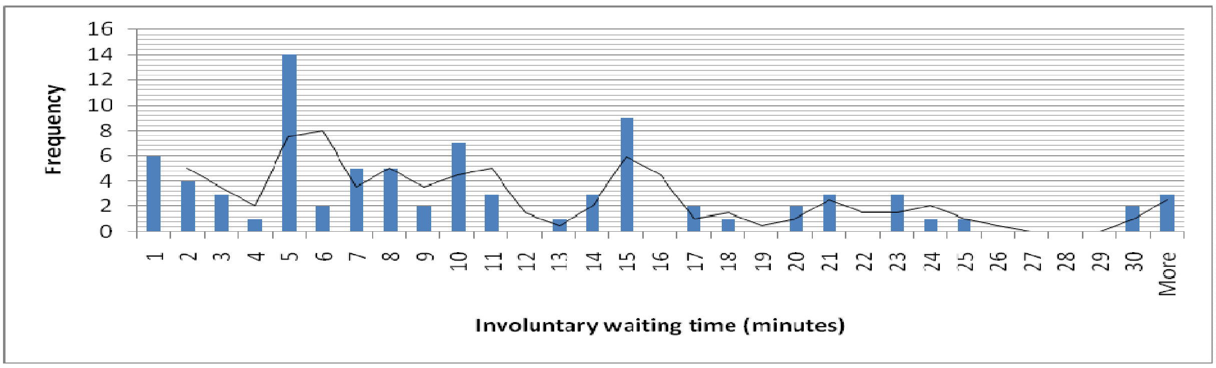

Figure 12: Involuntary waiting time in minutes, N = 83, 9 Novemeber – 18 November 2009

Almost 50% percent of the patients experienced involuntary waiting time. This waiting time exists because of the tight patient schedule. Inquiries took longer than they where scheduled for resulting in extra waiting time for the next patient. We can conclude that the used inquiry times are not accurate enough to display the real time inquiry times resulting in the involuntary waiting time.

2.4.4 Utilization of capacity

The utilization of the capacity is measured by recording the performed activities. This is done during opening hours over a period of one and a half week, weekend not included (November 9th – November 18th). Due to updates and planned maintenance on the scanners, performed during the two week period, no activities are measured on Tuesday November 10th and Wednesday November 11th on scanner 1 and on Friday November 13th on scanner 2. This results in a total capacity of 7800 minutes (equals two scanners). In this period 182 patients where scanned.

The distribution of time spent was measured according to categories of activities, earlier described in paragraph 2.2.2. The first category is the preparation of the patient. This category starts when a patient is called for its appointment and it consists of the necessary changing for the scan and a last check of the technicians on the safety criteria. The next category is the table time which includes positioning of the patient in the scanner, eventual inserting of contrast or narcosis (performed on the table) and performing the scan. Table time ends when the scan is finished. Finishing is helping the patient of the scanner towards the preparation room and it ends when the patient leaves the MR room to go to the waiting room. Then the room has to be cleaned and prepared for the next patient which is defined as the category room preparation. The last category is room empty which includes waiting on a patient when the room and the technicians are ready.

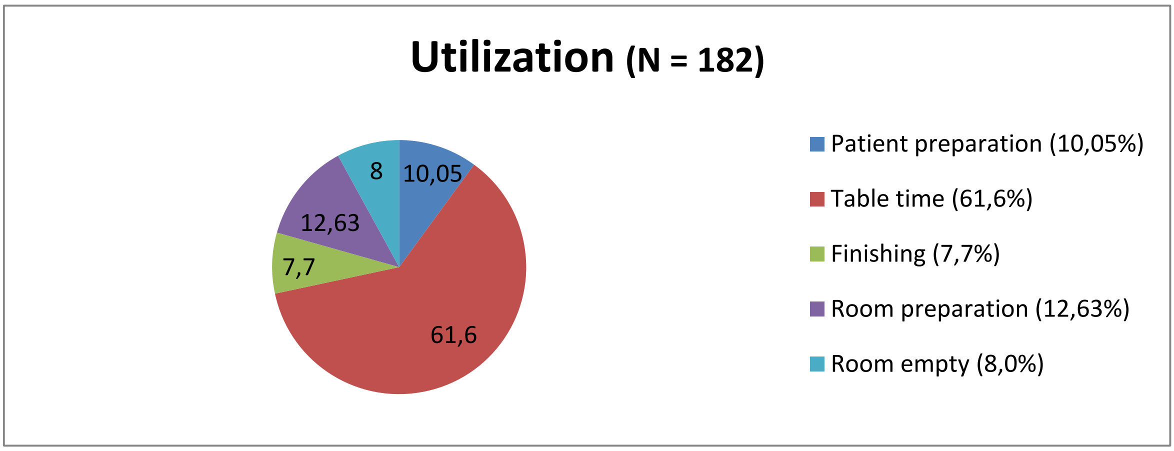

Figure 13: Utilization of capacity of MR scanners over the period 9 November – 18 November 2009

During opening hours 61.6% of the time is used to position the patient into the scanner, if necessary inserting of contrast or narcosis and performing the scan. The time that the scanners are used to do its core business (the scanning) is therefore lower than the 61.6%. Up next, 10% of the time is spent to prepare the patient outside the scanner room and 7.7% of the time is spent on finishing of the inquiry. The MR rooms are empty for almost 20% of the time, mostly used to prepare the room for the next patient. The time it takes to prepare a patient whilst on the scanner table is very hard to predict and varies for every patient. The table time and room preparation time are the two activities which are performed in the scanner room (74%).

Preparation of the patient is an activity which can be done whilst another patient is scanned. This part of the patient process thus has no influence on the total utilization of the scanner. However, practice shows that it is not always possible to prepare a patient up front. Some patients need a lot of help and should be supervised continuously. The two technicians try, whenever possible, to prepare the patient up front. This will increase the total utilization of the scanner room.

The overall equipment effectiveness (OEE) as proposed by Slack (2007) is another way of measuring the effectiveness of the operating equipment. The OEE is calculated by multiplying the availability rate (a) by the performance rate (p) multiplied by the quality rate (q), OEE = a * p * q. The availability rate is calculated by dividing the loading time by the total operating time. As earlier stated the capacity in the measured period was 7800 minutes, but planned maintenance and work meetings resulted in a loss of 255 minutes. Therefore this downtime is settled for and not incorporated in the measurement. The OEE is displayed in table 6:

OEE over the period 9 November – 18 November (working days)				
Availability rate:	Total operating time	7545		
	Loading time	7545	A = 1.00	
Performance rate	Total operating time	7545		
	Speed losses	2900		
	Net operating time	4645	P = 0.616	
Quality rate	Net operating time	4645		
	Quality losses	32		
	Valuable operating time	4613	Q = .993	
OEE				0.611

Table 6: OEE over the period 9 November – 18 November 2009 (working days)

No unplanned downtime occurred and there are no planned breaks therefore the availability rate is 1.00. Speed losses occur because changeover losses due to changing of patients. Quality losses consist of scans that have to be redone because patients moved during their scan. In our measurement 4 scans (or parts of it) had to be redone resulting in 32 minutes quality loss.

The table time has the biggest variability, making it very hard to plan accurately. In the table time different factors could be distinguished which have an effect on the variability. The positioning of the patient is different for every patient and very hard to predict. The same goes for the insertion of contrast. Other factors which are of influence are no shows, the discovery of metals in the body, scans that have to be re-done or immobile patients. This high variability leads to a higher mean flow time and a bigger probability of overrun of the planned appointment.

2.4.5 Planned versus realized inquiry time

We measure the planned versus realized inquiry time to acquire insight in the effects of the scheduling system of the inquiries. Every inquiry is scheduled according to the protocol that is adjusted by the radiologists. Every MR protocol specifies the time that needs to be scheduled for that particular inquiry. However, it is not always possible to stay within the scheduled time. In the researched period from 9 November until 18 November (working days) we measured the deviation between the realized and planned inquiry time:

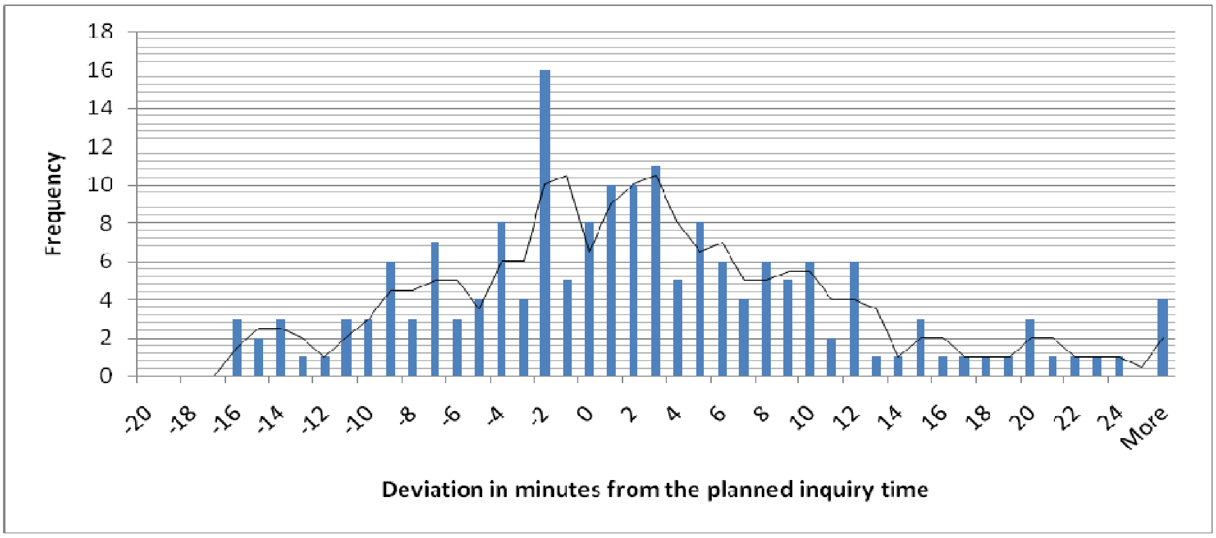

Figure 14: Deviation in minutes of planned inquiry time, N = 179 (9 November – 18 November, Rados)

In the researched period, 182 MR inquiries were performed. During this period, three patients would not continue the inquiry because they felt claustrophobic. These inquiries are not presented in the graph because they are not realized (N = 179). A total of 80 inquiries are performed within the scheduled time (zero minutes or less deviation from the scheduled time). Four inquiries are performed needing 25 or more minutes than scheduled up front.

We see that 99 inquiries took longer than they where scheduled for. We can conclude that the protocols are not representing the real time which is needed to performe an inquiry. The technicians have to work hard to perform all the activities within the scheduled time. Patients have to wait when the patient before them need more time. The fact that 99 inquiries took more time than there was scheduled for does not mean that 99 patients experience involuntary waiting time (figure 12). Some inquiries start before the actual appointment time, leaving more time before the next patient' appoitnment time starts. If the inquiry starts 5 minutes before the actual appointment time and takes 2 minutes longer than scheduled for, the effects will be seen in figure 14 and not in figure 12.

2.4.6 No shows

Patients who do not show up for their MR inquiry are labeled as 'no-shows'. The time slot is unnecessary empty with as a consequence that production time is wasted. Furthermore it has a negative influence on the waiting list. These negative effects of the no-shows make clear that no-shows should be avoided. Table 7 displays the no-shows over the registered months in 2009:

No-shows	Production	No-shows MR 1	No-shows MR 2	Total	Percentage
June	1052	7	7	14	1.33%
July	845	7	2	9	1.07%
August	883	6	9	15	1.70%
September	1107	6	2	8	0.72%

Table 7: Number of 'no shows' over 4 month period in 2009 in percentage of total production in that month

We measure a no-show percentage of around 1% a month. To encounter the no-shows it is useful to have an insight in the reasons why patients do not show up. Furthermore, we think it is important to monitor the no-show percentage on a monthly basis to take immediate actions when the percentage becomes too high.

2.4.7 Maintenance

The MR scanners are both closed four times a year for planned, preventive, maintenance. This maintenance is planned in front so the scanners are closed on these days. On the other hand, a scanner could be defect which leads to downtime. This type of maintenance is corrective maintenance. For the period 01-05-2008 – 01-05-2009 data is available on preventive and corrective maintenance for both scanners. The presented data displays the time that maintenance is executed, this means that the real downtime of the MR scanners is higher.

MR 1:

Type of Maintenance	Number of times	Total hours	Percentage
Corrective	20	90.15	83.9
Updates	1	1.00	0.9
Preventive	4	16.25	15.1

Table 8: MR corrective and preventive maintenance, period 01-05-2008 – 01-05-2009

The corrective maintenance can be further specified into P1 – P5 classifications:

Classification	Interventions
P2	1
P3	9
P4	4
P5	6

Table 9: Number of interventions per classification for MR 1 over the period 01-05-2008 – 01-05-2009

The mean time to repair on MR 1 is: 90.15 hours divided by 20 interventions resulting in 4.5 hours per intervention. Explanation of the P1-P5 classifications:

P1 Patient in danger, intervention urgently required

P2 System down: intervention required

P3 System interruption: intervention on appointment required

P4 Intermittent system interruption: intervention on appointment required

P5 Planned activities

MR 2:

Type of Maintenance	Number of times	Total hours	Percentage
Corrective	11	55.00	79.4
Preventive	3	16.50	20.6

Table 10: MR corrective and preventive maintenance, period 01-05-2008 – 01-05-2009

The corrective maintenance can be further specified into P1 – P5 classifications:

Classification	Interventions
P2	2
P3	6
P4	0
P5	3

Table 11: Number of interventions per classification for MR 2 over the period 01-05-2008 – 01-05-2009

Mean time to repair on MR 2: 55 hours divided by 11 interventions resulting in 5.0 hour per intervention. We see a high amount of time spent on corrective maintenance. A downtime of 90 hours for MR 1 on a yearly basis is too high. Programs have to be cancelled and patients must be rescheduled, resulting in loss of capacity and unsatisfied patients.

2.4.8 Health related absenteeism

An indicator for the 'general happiness' of all the employees is the level of health related absenteeism. Normally, unhappy employees have a higher level of health related absenteeism.

The average level of health related absenteeism at the radiology department is 4.8%, for monthly figures over 2008 see table 11. The objective from the board of directors is a health related absenteeism of maximum 4%.

Absenteeism (%)	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Illness	5.1	5.0	4.7	4.0	2.4	4.5	3.0	2.6	4.0	4.8	4.5	4.9
Pregnancy Illness	-	-	-	-	-	.2	-	-	.7	1.1	1.6	0.8
Pregnancy absenteeism	.5	-	-	-	-	.5	1.0	1.0	1.0	-	-	-
Total	5.6	5.0	4.7	4.0	2.4	5.2	4.0	3.6	5.8	5.8	6.1	5.8

Table 11: Absenteeism over 2008 (Annual report radiology, 2008)

On basis of the data we conclude that the health related absenteeism was too high in the beginning and the end of the year. We think that this high factor should be seen as a signal of the employees that they are not happy with the operational procedures. These problems could have multiple negative effects on the performance of the system.

2.5 Bottlenecks in the service delivery process

Based on the process analysis and the performance evaluation of the MR process, we identify different bottlenecks:

Bottleneck 1: MR inquiry time slots

The process of conducting the MR scan consists of different steps. Every step takes time. This time is settled for up front (within protocols). The problem however is that not every step is good to forecast. Our research shows a high variability in table time, e.g. the time that the patient lies on the scanner table. That means that you can schedule a patient for 30 minutes, but that there is a reasonable chance that the inquiry takes more (or less) time. The same holds for conducting inquiries with contrast. This inquiries require more time (usually 45 minutes are scheduled) and know a high variability. There are several reasons for this high variability:

1. *Every patient is unique*

It takes time to take good care of a patient and because every patient is unique you can not predict how long it takes to take care of a specific patient. This is one of the reasons why inquiries take longer than scheduled. For example, it matters whether a patient is arriving in a wheelchair, in a bed, or on feet. This high variance in patient characteristics makes planning of the inquiries difficult to do, which can be concluded from our research where almost hundred out of 180 inquiries took more time than scheduled for.

2. *Every MR technician work routine is different*

Every patient is planned by a radiologist on basis of a standard protocol which defines how long it should take to investigate the patient. This works in practice when the proposed time describes reality and when every MR technician has the same work routine. This difference in work routine leads to the fact that not every MR technician is capable of performing the same type of patient within the same amount of time. Important here is the capacity of the technicians to deal with unexpected events and are therefore able to reach the operational offline planning.

As a result of the high variability in the process it is difficult to forecast the right time that is necessary to perform the inquiry. When you are not able to forecast this time correctly, valuable time is lost because extra patient(s) could have been helped. On the other hand, the variability could result in overtime per patient, which increases the waiting time for the next patient and the work pressure for the technicians.

Bottleneck 2: To many steps in the process are performed inside the scanner room

In an ideal situation the only activity which is performed in the scanner room is the scanning of the patient. All the other activities should be performed somewhere else. Obviously, this is not possible. Patient should be carefully placed on the MR table and the scan should only start when the patient is at ease.

In the process, different steps are performed in the MR scanner room and other steps are performed outside the scanner room when the room itself is empty, for example patients who are prepared in a preparation room. It is not always possible to start with this preparation when for instance the other patient is still in the scanner. This preparation thus has an immediate effect on the utilization of the scanner. Other activities, a side from the scanning, that are performed inside the scanner room are the positioning of the patient, the administration of contrast fluid and the preparation of the room for the next patient.

All these steps influence the total utilization of the MR scanner negatively. Being able to perform (parts of) these steps outside the scanner room will increase the time that the scanner can be used.

Bottleneck 3: MR technicians

The MR requires radiology technicians who are specialized in performing MR scans. This concerns a small group of people. Absenteeism can have a direct effect on the capacity when the MR technicians can not be replaced immediately. The capacity was drastically reduced when there where not enough MR technicians to perform all the shifts. Every change in the operational procedures has an effect on the amount of work for the technicians. These effects should be taken into account.

Bottleneck 4: Lack of information on the performance of the system

Information of the process is necessary to evaluate the performance of the total process. With this performance information the bottlenecks can be detected and interventions can be proposed to encounter them. Furthermore the information about the process should be the basis for the management actions and strategies in the future. Detailed information should therefore be available periodically.

Currently almost no information is available on the performance of the process. No performance data is available. There is also little or no insight in why the process is organized the way it currently is. The information should be used to make the complex process simpler and should provide the management with the data to improve the process. In practice, some protocols that are currently used do not display the reality. This results in adjusted slot times which are too long or too short to perform the inquiries. The scan time is a fixed time, but upgrades and improved medical views can influence this time. Defining the medical protocols take place at the tactical level of the medical planning. Actual performance data of the time it takes to perform certain activities is the tool to be able to improve the protocols.

2.6 Conclusion

MST has two MR systems. The capacity of each MR is around 6000 scans per year (with the current business time). The developments of the latest years show a vast increase in MR inquiries. Furthermore, the quality of the scan is improving rapidly which makes it a popular medical tool for a growing number of specialties. Improving the MR process must be seen as an important task for everyone involved in the process.

Radiologists expect that there will be a continuous growth in requests for MR inquiries despite an equal potential patient number. There are a several reasons for this trend. The main reason is the aging of the population and thus a growing need of healthcare. Patients also get more demanding and will not be treated before there are good images available. Specialists nowadays are trained with the increased use of imaging techniques. The cooperation with the oncology department within MST is also of influence. MST wants to develop the oncology department to a centre of excellence, with as a consequence that the demand for MR scans will grow from this group of requestors.

The department Radiology has reached the boundaries of the growth. At the present situation the scan is used seven days a week full time (full business time) and despite the increase in working time the waiting list is 8 weeks again. All together this results in a high working pressure that has consequences for the way how the patients are being served. The weekly patient programs are filled to its maximum leaving little space for emergency requests. Thus the pressure is mounting for the technicians in its role to play an adequate service deliverer towards their patients and towards other specialties.

We analyzed the process by researching data about the production and performance. The performance data showed that with the current operational procedures, the MR department has reached the boundaries of its capacity. The performance data however registered a utilization of the MR scanner of 60-65% a day. This means that there is room for improvement in terms of the utilization of the scanner. The operational procedures however do not support that vision.

We discovered a lack of data on the performance of the system. The information which is important for the managers to evaluate the process, and which is the basis for proposing interventions that improve the process. We discovered a high variability in the steps that are performed during the inquiry. This makes it very hard to predict and schedule the inquiries accurately. We conclude that too many steps are performed in the scanner rooms which influence the utilization of the scanner negatively.

The overview of the process and its performance do not support the vision of the radiology department. The department wants to develop itself towards a partner for the whole organization that delivers in general very good radiologic care and to some parts excellent radiologic care. The other departments are currently satisfied about the quality of care which is delivered but think that the waiting times are to long. The current situation is not capable of supporting the vision of MST towards centers of excellence.

3. Literature review

Paragraph 3.1, discusses the literature on improving patient services and restricting healthcare expenditures. Most literature focuses only on improving hospital productivity or on restricting healthcare expenditures (Harper, 2002; Rozich and Resar, 2002; White, Beckingham, Calman & Deehan, 2007). Literature that focuses on both is scare, but there is research that show that this combination is possible (Hans, Elkhuizen, van Sambeek, Krabbendam & Bakker, 2007). Furthermore, research has been done on different levels of radiology departments identifying different improvement strategies. Paragraph 3.2 focuses on the theoretical concepts that prevailed during the context analysis phase.

3.1 Literature review

The big Dutch postal concern TPG was asked by the Dutch ministry to apply their knowledge of logistical processes on the healthcare market. This resulted in the project *Sneller Beter,* which showed remarkable quality improvement opportunities for the total healthcare industry. Applying logistic principles to different parts of the healthcare delivery could dramatically cut down the costs (TPG, 2004). Main focus of the study; the patient logistic has to be transformed from a push system to a pull system. The patient process in the Netherlands is based on a push system. The patient is pushed into the system, dependent on their urgency and on basis of the availability of capacity. This system has a couple of disadvantages. The patient is not the central element of the healthcare. Basic knowledge of the type and availability of the care process can not be provided. The process is difficult to manage because you have no knowledge about the time that it takes to perform each process step. Access times increases, because of the waiting times between the different process steps. Employees get unmotivated because of the uncertainty about the process. The mentioned problems can be resolved by introducing a pull system. Decisive in a pull system is the discipline to perform the steps in the process in a structured manner and strive to continuous improvement. The introduction of a pull system in the healthcare market means that the patient becomes the central factor in the process. The healthcare path will be made visible in terms of throughput time, capacities and necessary materials. The medical staff can be adjusted to every step in the process. By making every step visible, and measuring all steps in terms of time, productivity you are able to adjust the resources in a much more efficient and effective way (TPG, 2004)

Porter and Teisberg (2004) see a healthcare market where the players are dividing up value in stead of creating it. The healthcare market players want to perform all activities and cure all type of diseases in stead of excelling at different types of treatment conditions. Compete at the level of specific diseases and conditions thrives effectiveness and efficiency and lowers the cost.

Most of the existing literature however focuses only on improving the productivity (hospital or single department) and thus improving the patient care and service (Harper, 2002; Rozich and Resar, 2002; White, Beckingham, Calman & Deehan, 2007). Rozich and Resar describe the Unit Assessment Tool which is developed by a hospital based on the traffic light concept. The capacity is assessed and graded per unit. Each unit can instantly update its own status and query those of other departments. Experience with the tool showed a progressive decrease in use of the code red and an increase in staff satisfaction. White et al. (2007) analyzed the effects of extended working hours in the radiotherapy departments throughout the UK. Their research showed that if extend hours working is to be used successfully, it must be fully scoped before implemented. All the effects of the change should be made visible before the start. The results of the change, the effectiveness and efficiency of the change in practice, must be measured and assessed (White, Beckingham, Calman & Deehan, 2007).

Hans et al (2007) show that both is possible, improving the service whilst reducing the cost. By proposing interventions that would reduce the variability in the lead time for a CT scan, the total lead time for a CT decreased. The most promising intervention appeared to be to reallocate the insertion of intravenous access lines to a preparation room. The CT became less a bottleneck in the total patient process, which contributed to the patient service and indirectly to cost reduction. Furthermore, the production was increased by a higher utilization (Hans, Elkhuizen, van Sambeek, Krabbendam & Bakker, 2007)

Other research focuses only on improving the patient service on the radiology department. Kolfin (2007) performed a research to reduce the waiting times within the radiotherapy department at the AMC. The analysis of the process showed that there was a considerable fluctuation in capacity caused by the absenteeism of the residents. This resulted in a high variability throughout the total process. Another bottleneck was the long preparation time for one group of patients (called other patients), making it impossible to stay within the norm time and causing extra waiting time. A possible solution is to reduce the variance in the capacity by adapting to the absenteeism of the residents in an earlier stage. The residents can be temporary replaced or their shifts can be taken over. This will decrease the waiting times in the total process. Simulation studies showed furthermore that considerable profit can be gained by reducing the preparation time. Research should be done to find methods to reduce the preparation time for the patients (Kolfin, 2007). Huizer (2005) conducted research at the department radiology of the GELRE hospital. This department experienced problems adjusting the process to the digitalization. A thorough investigation of the total process gave insight in the bottlenecks and provided improvements. The process analysis showed the bottlenecks in the process. The first bottleneck is the waiting time for an inquiry. Research shows that the same waiting time can be achieved using fewer resources. The second bottleneck contains the report time. The report time is 4 days whilst the norm is 2 days. The waiting time for an inquiry can be achieved using fewer resources if joint inquiries are planned at the same time in an early stage. Resources are used more efficient in this case. Furthermore, the arrival of the patients can be influenced by filling the off-peak hours with patients from the General Practitioners. The service can be enhanced because a faster throughput time can be realized. Reports have to be made within one day to ensure that the norm of 2 days is not passed (Huizer, 2005).

The same type of research is performed on single diagnostic modalities. Kranenburg (2009) studies the effects of walk-in at the CT on the performance of the CT process at AMC. The effects of walk-in at the CT are largely unknown and this study tries to fill in this gap. The performed simulation study and process analysis showed that walk-in for all the patient types is not feasible, because some patients need large preparation time or require specific medical specialists. A combination of walk-in with an appointment based system can improve the patient service significantly. Inpatients can be scanned when the expected waiting time is low. Introducing a walk-in system enables the department to serve more patients under the same capacity with a shorter access time (Kranenburg, 2009). Van Harten (2005) performed a capacity study on the CT process of the AMC. He recommended to reduce the variability in the scanning process, by taking a step (the insertion of intravenous lines) out of the scanner room. This resulted in reduced access time for a CT scan.

3.2 Theoretical framework

3.2.1 Capacity management

'Capacity planning and control is the task of setting the effective capacity of the operation so that it can respond to the demands placed upon it' (Slack, 2007). This means to decide how the department should react to fluctuations in demand. For the MR department the demand originates from the specialists of the hospital (and other hospitals) and the General Practitioners in the nearby area. Planning and controlling of the capacity exist at three levels. The distinguished levels are long-term, medium-term and short-term capacity planning and control. Long-term capacity planning has to deal with decisions on a strategic level. The focus of the capacity planning and control in this research lies on the mid-term and short-term planning. Mid-term decisions are made on tactical level whilst short-term decisions are made on an operational level.

Different steps have to be performed to plan and control the capacity on mid- and short-term level:

1. Measure aggregate demand and capacity
2. Identify the alternative capacity plans
3. Choose the most appropriate capacity plan

The first step contains measuring the aggregate demand and capacity planning, that is, making overall, broad capacity decisions without all the details of the individual product or services offered. Identification of the alternative capacity plans are the plans which could be adopted in response to demand fluctuations. The third step is choosing the most appropriate plan for the circumstances. Before any decision can be made, quantitative data on both demand and capacity must be available.

Forecasting is a key input to capacity planning and control, it is therefore important to understand the basics for demand forecasting. For capacity planning and control there are three requirements for demand forecast. The forecasted demand must be expressed in terms that are useful for capacity planning and control. The demand must be forecasted as accurate as possible and it must have an indication of the relative uncertainty.

The capacity can be estimated on basis of the forecasted demand. The main problem with capacity is the complexity of most operations. The capacity can only be easily estimated when the process is highly standardized and repetitive. The MR scanning process however is not standardized and repetitive at the moment. The capacity of the MR department depends on the activity mix. The patient schedule has different type of slots for different groups of patients resulting in restricted capacity for all the groups. Furthermore, cardio patients have reserved capacity during the week due to medical reasons.

Van Bodegom et al. state that waiting lists emerge by pushing the system to a utilization of capacity of almost 100 percent. Every system is perfectly designed for reaching the performances that they reach. The system should be changed if you want to reach other performances or results. The authors suggest standardizing the type of care that you want to deliver and make the capacity flexible. Standardizing means defining the exact type of care that you want to deliver. The capacity can be made flexible when the planning horizon is shortened (van Bodegom, 2004).

Van Dijk et al. argue that the problems with the waiting lists should also be analyzed according to queuing theories. Interventions often propose an increase of the capacity. The queuing theories consider another factor of influence, variability. Managing this variability can decrease throughput times and waiting lists without increasing the capacity (van Dijk, 2004).

3.2.2 The effect of variability

Productivity in healthcare is strongly affected by the variability of arrival and service times. Variability in processing times, caused by rework, downtime, lack of consistency in work methods influence the performance of the system negatively (Hopp, 1990).

Two types of variability can be discovered in the MR scanning process. Arrival time variability, which is the randomness of demand for a MR scan and flow time variability which is the level of variation of the real process. Arrival time variability is reduced in the process because the MR process is completely appointment-based, but due to emergency inquiries not completely ruled out of the process. A standard appointment time is used per appointment (which is stated in protocols). This appointment time includes the flow time and planned slack. The flow time is the actual time that a patient is in the process and the planned slack is the buffer against variations in the flow time. All appointments are planned in succession.

The slack time is planned so that the actual flow time will not exceed the appointment time. If the variability in the flow time is high, there is a higher change that the flow time will exceed the appointment time. To encounter this, a higher slack time is planned to shorten the mean waiting time of the patients in the waiting room. Every time that the flow time is shorter than the lead time, capacity is unused and thus lost. Expanding the appointment time would lead to increased access times because fewer appointments can be scheduled. Figure 15 shows an example of this in a manufacturing environment (Hopp, 1990).

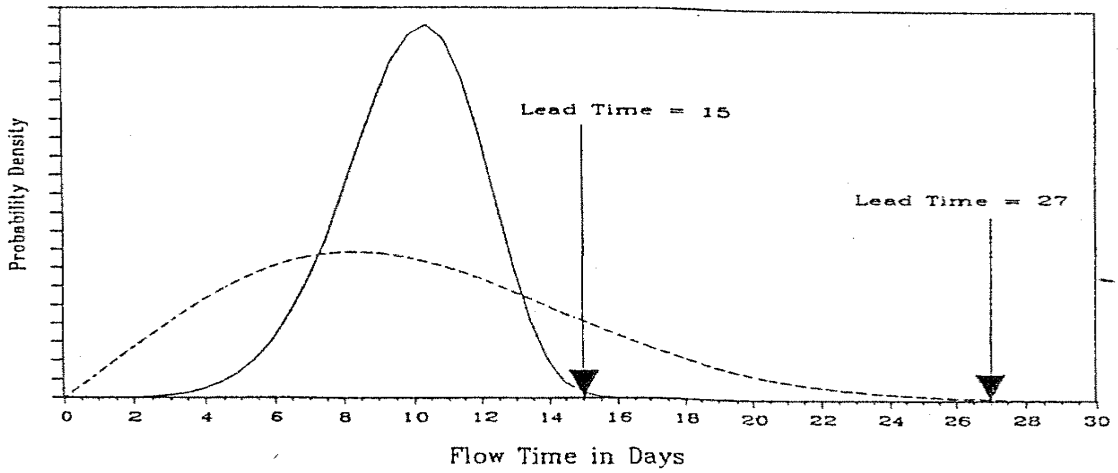

Figure 15: Two densities of flow time with different slack time

Figure 15 shows that 99% of the products in case of the smaller deviation would be done in 15 days, whilst where as the larger deviation requires 27 days. If this is translated to the hospital situation the '15 day lead time graph' can have a much tightened schedule and thus more appointments could be performed which will decrease the access time.

3.2.3 The effect of waste

Waste in a production process can be defined as 'anything other than the minimum amount of equipment, items, parts and workers that are absolutely essential to production'. Elimination of the waste develops a process that is faster, more dependable, produces higher-quality products and services and operates at lower costs. This can be seen as the key principle of lean operations (Slack 2007).

The lean approach is founded on doing the simple things well, on doing them gradually better and (the main principle) squeezing out the waste in every step of the process. The lean philosophy can be described by using the three key issues: the elimination of waste, the involvement of staff in the process and the drive for continuous improvement.

Eliminate waste:

The main principle of the lean philosophy is the focus on eliminating all the waste out of the production process. Waste can be defined as all activities that do not add value. Lean improvement activities try to eliminate the waste by using two tools: the 'seven forms of waste' to identify the waste and 'the 5S's' to reduce the waste (Slack, 2007).

The Toyota Motor Company, often seen as the leading practitioner of the lean philosophy, identified seven forms of waste which can be applied in many different operations:

- Over production: producing more than is immediately necessary for the next process can be seen as the greatest source of waste.
- Waiting time: waiting time of equipment, labour and items.
- Transport: moving items around the operation does not add value. A change in the lay-out that brings the processes together or transport improvements, reduce the waste in this part of the process.
- Process: the process itself may be a source of waste due to poor design or poor maintenance and could be eliminated.
- Inventory: all inventories should be target for eliminating.
- Motion: simplification of work can be a rich source of reduction of waste.
- Defectives: Cost of quality is often very significant in operations. Attack of these causes of such costs can reduce waste.

The 5S terminology is a simple set of principles for reducing the waste:

1. Sort: eliminate what is not needed and keep what is needed.
2. Straighten: position things in such a way that they can be easily reached whenever they are needed.
3. Shine: keep things clean and tidy; no refuse or dirt in the work area.
4. Standardize: maintain cleanliness and order neatness.
5. Sustain: develop a commitment and pride in keeping to standards.

The 5S techniques can be used to organize the work areas focusing on visualizing, organization, cleanliness and standardization. It helps to eliminate the waste throughout the process. The throughput time can be used as a surrogate for waste in a process. Looking at exactly what happens within a process is a method of identifying the sources of the waste (Slack, 2007).

Involvement of everyone

The lean philosophy must be seen as a total system philosophy. Its aim is to provide guidelines for everyone and every process of the organization. The organization culture is seen as being important in supporting these objectives through emphasizes on involving all the organizations staff.

Continuous improvement

Continuous improvement is one of the components of the lean philosophy. The predefined high goals are often ideals which can not be reached. However, these goals and beliefs drive the progress and strive anyone to cooperate. This is why the concept of continuous improvement is so important in the total lean philosophy.

Lodge and Bamford (2008) applied these principles in hospital setting and discovered three main lessons. Belief in the vision, get anyone involved and continuously try to reach the high goals and beliefs. Consistency in the message, everyone must understands the importance of the change and see the benefits. Hands-on training approach, everyone must get used to the new work routines (Lodge and Bamford, 2008).

3.2.4 The effect of complexity

Complex processes contribute to the total waste of the organization. Just-in-time techniques (JIT) are used to reduce this type of waste in the process. In practice, it is difficult to achieve all the basic working practices at the same time. We highlight some important working principles:

- Design for ease of processing: design improvements can dramatically reduce costs through changes in the number of components and sub-assemblies and better use of materials and techniques.
- Emphasize operation focus: focus within operations means that the process focuses on a limited set of resources and learns to structure operations objectives.
- Use small, simple machines: small machines are more flexible and robust. The advantage is perfectly shown in case of the MR department. The MR machines are big, complex machines. If one of these machines breaks down, it affects the total system.
- Lay-out for smooth flow: the smooth flow of materials, data and people in the operation is important in the JIT philosophy. Complex and long process routes are opportunities for all sorts of waste.
- Adopt total productive maintenance: aims to eliminate the variability in operations processes.
- Reduce setup times: setup reduction can be achieved by a variety of methods. Setup time reduction or single minute exchange of dies (SMED) is approached by converting work that previously was done while the machine was stopped (internal work) to work that is performed while the machine is running (external work).
- Ensure visibility: the more transparent an operation is, the easier it is to share in the improvement, or to detect problems. Performance measures that are visible on the workplace play a central role.

All these working principles are techniques which can make the work process less complex and strive the organization in its quest to continuous improvement (Slack, 2007).

3.3. Conclusion literature review: Possible interventions

The process analysis consisted of a qualitative process mapping of conducting an MR scan from the time that an appointment is made until the time that the reported scans are delivered back to the requestor. Quantitative data is gathered to support the process mapping and is the basis for the evaluation of the performance. The performance evaluation made the bottlenecks of the process visible.

The literature review and theory analysis in chapter 3 showed a number of possible interventions to remove the bottlenecks in the process. The following interventions appeared to be the most promising:

- Updating of the MR protocols
- Insertion of intravenous access lines in a preparation room
- Expansion of the business time
- Dockable MR table with or without inserted coils

Because the decision is made to purchase a third MR system, we will analyze the effects of this ‘intervention’ too. All the interventions will be explained in detail in chapter 4.

4. Scenarios: Interventions in practice

This chapter describes the expected consequences of the interventions proposed in chapter 3.3. The examined theory and earlier research about this topic serves as a basis for the analysis of the expected consequences. Furthermore, the interventions are discussed with the experts in the system. Their experiences give more body to the expected consequences of the interventions. Paragraph 4.1 analyzes the consequences of updating the used protocols Paragraph 4.2 analyzes the expected consequences of insertion of intravenous access line outside the scanner room. Paragraph 4.3 analyzes the effects of expanding the business time. In paragraph 4.4, the consequences of using dockable MR tables are analyzed, and in paragraph 4.5 the consequences of purchasing a third MR system are analyzed.

4.1 Protocol update

This intervention intends to create extra capacity by updating the protocols used for the inquiries. A protocol update can result in shorter appointment time needed for different types of inquiries.

Intended effect of the intervention:

The protocols that are in use are being revised. The new protocols are set up according to the type of indication. The new protocols should be a better representation of the actual time needed to perform the different scans. Valuable time is gained because less slack time needs to be planned.

The profit of this intervention must be seen two folded. First, the time that is gained when using shorter protocol times can be used to treat more patients and therefore decreases the access time. Second, the new protocols are developed according to the indication of the disease which has one big advantage over the current protocols which are developed per organ. In the new situation, the actual scan time is known when the inquiry is requested and the appointment time is developed to perform that inquiry within that time. The old protocols consist of different possible indications and know thus a variation in possible scan times within the same protocol time. Thus the protocol update leads to important management information out of the process, and is a very important step in understanding the process.

The cooperation of radiologists expect on basis of their experience and on basis of an example in practice that this intervention increases patients numbers with 10% per year. In practice, for the radiology department this means that 1.000 patients more per year could be treated within the same period (on a total production of 10.000 patients per year).

In the remainder, we address the consequences, and the conditions of the intervention for the work process, technicians, radiologists, patient planning and financial/other investments. The expected profit of this intervention is only gained when all the conditions are fulfilled.

Working process

The protocols that are used to perform the inquiries should be updated regularly. There can be various reasons why regular protocol update is necessary. The most important reason of them all is the improved medical view. This improved medical view can conclude that new type of scans should be used, or that other techniques must be used. The protocols must then be changed according to these new guidelines. This has consequences for the operational procedures. Types of inquiries and thus specific type of operational procedures what are used today can be outdated tomorrow. Other reasons why the protocols might be updated are MR updates, new techniques which can be used and improved patient logistics facilities. As a result, the time that is needed to serve a patient can be shortened.

At the end of 2009, the radiologists decided to upgrade the MR protocols. Until then the protocols were developed per specific part of the organ. The upgrade protocols however are developed on basis of the indication of the illness. The protocols are more specific and time can be gained compared to the more general protocols that where earlier used. For example, a patient with indication A need to get an MR. With the old protocols, the patient needs to get protocol X, appointment time 30 minutes. The actual scan time might only be 15 minutes. The reason behind this is that a patient with indication B also needs protocol X because the protocols are not specific enough. The scan time for indication B is however 25 minutes and therefore the standard protocol time is 30 minutes. With the updated protocols which are specified per indication, the patient with indication A gets another MR protocol, specific for his indication with an appointment time of 20 or 25 minutes.

This example shows that there must be some changes in the operational procedures with regard to this type of patients. Other procedures have to be followed and less time is scheduled to perform the scans. The technicians need to be instructed with these new procedures and should get time to get familiar with it. This change should be managed with care. The possible time profit of this intervention will not be reached if the technicians are not instructed well.

Technicians

The technicians must adapt to the new protocols. It requires other operational procedures with regard to different patient categories. This new protocols and procedures must be instructed to the technicians. The technicians play a decisive role whether the possible time gain can be reached. Therefore these new operational procedures must be adapted by all technicians and used continuously without falling back in the old procedures.

There is an active approach needed, to make sure that these new operational procedures become standard. This means that it is not simply the way of telling the technicians to use the new protocols, but train and instruct them to familiarize them with the new system. This must be seen as an important task of the responsible radiologists and managers in the process.

Radiologists

The medical planning area is the responsibility of the cooperation of radiologists. They develop and update the protocols that are used. The radiologists continuously strive to update the protocols according to improved medical views. These updated protocols must be instructed to the technicians to gain the total advantage in time. Protocol updating should not be a 'one-time' activity, but an ongoing process between the radiologists and MR technicians.

Radiologists need to sign the requests correctly, otherwise the wrong protocol might be used during the inquiry, or the wrong types of scans are made. For example, a patient with indication A requires scan protocol X. Protocol X contains different types of scans, so the radiologist needs to determine which scans should be used. However, a patient with indication B also requires scan protocol X, but with a slightly different type of scans. The radiologist need to sign the request each time correctly so that the right scans are made. The updated protocols encounter this problem by using a standard set of scans in a protocol for each type of indication.

The update of the protocols, from organ specific to indication specific, must be the first step of the intervention. The next step is to monitor the performance of the process with actual steering information (we discuss the investments that are needed to obtain this information in the financial/other investment section.

Patient planning

One of the goals of this intervention is to reduce the protocol time for different types of inquiries. More capacity is created during the day and more patients can be served. The service delivered to the patient must not decline with the new protocols. Simply to reduce the time to serve the patient is thus not a target of this intervention. Every protocol needs to be assessed critically to determine whether or whether not a reduction of the protocol time is possible.

The new protocols make it possible to divide patients into groups (per specific indication, or groups of indications) and determine the access time for these groups. The tactical capacity planning can thus be adjusted if some patients groups experience a high access time. Actual steering information is the key factor in knowing the performance and making the adequate interventions to improve the performance.

Financial/other investments

The initial intervention requires no investment. However, for continuous protocol update it is necessary to understand the process. That makes it possible to reflect on the used protocols and eventually on an update of the protocols. Actual steering information is therefore necessary. The current operational procedures do not support that vision. No performance data is retrieved out of the process, and the only way how the protocols can be updated is due to the knowledge and experiences of the radiologists and technicians.

The lack of objective performance data can be overcome by a Utilization Services software tool developed by Philips (both scanners are bought from Philips). The software tool downloads workflow data for instance, number and type of inquiry, inquiry times, protocol mix and procedure mix. This performance data can be used to describe the problem areas in the workflow and identify the areas where improvements can be reached.

Costs of Utilization services:	Essentials	Advantage
1 Year		
1e Scanner	€ 7.500	€ 17.500
Extra Scanner	+ € 4.500	+ € 10.000
3 Years		
1e Scanner	€ 15.000	€ 35.000
Extra Scanner	+ € 9.000	+ € 20.000

Table 12: Cost of utilization services software tool.

There are three different types of utilization services available. The essential and advantage package and the consulting services. The first two packages deliver the performance data so the consulting services package is therefore not taken into account here.

The advantage package delivers the same performance information as the essential package. However the advantage package is expanded with a wide range of internal and external benchmark features to 'score' the process against others. In practice the essential package alone is enough to make the protocol update intervention possible. With this information and the new protocols the intervention must be able to gain up to 10 % more patients a year.

4.2 Insertion of intravenous access lines in a preparation room

The basis of this intervention is to remove the contrast fluid insertion activity outside of the scanner room.

Intended effect of intervention

At the moment, contrast fluid is administered whilst the patient lies on the scanner table. Our own time measurement showed that the time needed for this activity is hard to predict and shows a high variability in practice. For contrast inquiries extra slack time is included in the appointment time which increases the lead time. Removing this unpredictable activity out of the scanner room will increase the time that the scanner room can be used. This will increase the capacity of the MR department.

Studies of this intervention, showed that the total appointment time of contrast inquiries can be reduced with 5 minutes (Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, 2007). *With almost 2.000 contrast inquiries a year the expected time gained is 10.000 minutes. 250 patients extra can be helped during this time.*

In the remainder, we address the consequences of the intervention for the work process, technicians, radiologists, patient planning and financial/other investments.

Work process

In the current situation, the contrast fluid is administered on the scanner table. This activity, especially the insertion of the intravenous access line, knows a high variation in time. A lot of slack time has to be planned in the lead time for the appointment. Removing this activity out of the scanner room will decrease the total time spent in the scanner room.

This intervention has a couple of consequences for the operational procedures. The scanners must be equipped most of the time by four technicians (e.g. 2 technicians per MR). This makes it possible to let the process of 2 patients run simultaneously. When patient N is on the scanner table, patient N + 1 can be called out of the waiting room. The patient can be prepared for his/her appointment. This means that, if necessary, the intravenous access line can be inserted. Because this is performed outside the scanner room and during the time of patient N, there is less pressure to do it as fast as possible. When the scan of patient N is finished, he/she can be helped out of the scanner by one of the technicians, while the other technician helps patient N + 1 into the scanner and the scan can be started. Both patients receive the full attention of one single technician. The technicians can play a supportive role to each other. Another positive influence of two technicians per MR can be the increase in work satisfaction because of the intensive contact possibilities.

Some contrast inquiries require first a couple of scans without contrast before the contrast is inserted. After this blank inquiry, the contrast is inserted and the same scan is made. The intravenous access line however can still be inserted outside the scanner room, before the start of the scan, but the contrast fluid must be inserted after the first run of scans. Inserting the intravenous access line is a difficult procedure which must be performed by experienced technician. Because the intravenous access line is inserted in advance there is a possibility that the blood in the vain thickens. The intravenous access line requires therefore an adequate saline solution. The same type of contrast fluid is used for all types of contrast inquiries.

Every inquiry with contrast requires a thorough analysis whether inserting the contrast fluid outside the scanner room does not decline the service delivered to a patient. When this is not the case, the protocol times for these inquiries should be shortened according to the time that is used with the new operational procedures.

Technicians

The technicians need to adopt different operational procedures. When there are two technicians per MR they must continuously try to let the patients processes run simultaneously. As a technician you are now fully responsible for one patient at the time, but if necessary the second technician can help. The technicians can always decide to perform the contrast insertion in the scanner room itself, if problems occur with a patient receiving the contrast outside the scanner room. The number of FTE should be assessed critically to adapt the situation of 2 technicians per MR per day. An increase in the number of FTE should be considered to encounter problems relating to the working pressure.

The working routine of the cooperating technicians should be similar. Technicians with another working routine or different level of knowledge are not capable of reaching the same level of output as two technicians with the same working routine and knowledge level.

A major concern of the technicians by these interventions is the fear of 'pushing the patient through the system'. The appointment time for some types of patients becomes shorter and thus less time can be spend on treating the patient. The pressure to serve the patients within the appointment time has a negative effect on the delivered service. The tasks between the two technicians should therefore be divided clearly. Each technician is responsible for one patient and that makes it able to perform the processes of two patients simultaneously. Furthermore, each technician can dedicate all his time to the patient that he/she is responsible for.

Radiologists

The radiologists need to decide whether the protocol time for inquiries with contrast can be shortened. The medical protocol making is their responsibility. They need to assess whether the current level of healthcare is guaranteed in the new situation.

Furthermore, they need to be available directly when a technician has trouble finding the artery. When the radiologist can come immediately to insert the intravenous line the process is not further delayed and could continue without disruptions. If not, the process is delayed, and delays in the new situation have a bigger impact because of the reduced lead time per patient. An UV light to find the artery has no advantage according to the radiologists because of the high experience level of the technicians.

In the new situation more inquiries can be performed, which automatically results in an increase in report work for the radiologists. The amount of work related with this should be monitored closely because of two reasons. Too much report work can result in long waiting time before the results are back to the requestor. This would decrease the service delivered to the patient. Furthermore, the work pressure of the radiologists could become too high. This can be monitored by using *sanderspunten*[2].

Patient planning

The planning of the patients must adapt to the new situation. Inquiries with contrast can be planned with less time. The best situation is when inquiries without contrast are followed by inquiries with contrast, so that the inquiries with contrast are dispersed over the total day. This is however not a necessary condition. A necessary condition in the new situation is that patients need to be present 15 minutes before the start of their appointment. Otherwise the patients can not be processed simultaneously. Patients are currently asked to report 15 minutes before the start of their inquiry.

Mamma inquiries for example require 22 minutes of scan time. Removing the insertion of contrast fluid outside the scanner room will not influence these 22 minutes scan time leaving no room for reduction of the total appointment time. However, the effect of removing the contrast fluid insertion out of the scanner will be that it becomes easier to reach to appointment time of 30 minutes, and less extra time is needed per inquiry. This analysis must be made for every type of inquiry.

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[2] *Sanderspunten: A measurement tool to define the work pressure of a wide variety of radio diagnostic inquiries (Van der Velden, 1998).*

Financial/other investments

This intervention requires almost no investments. Perhaps the patients chair has to be adjusted to facilitate insertions of intravenous lines in a better way. The insertion of contrast fluid can easily be performed in the central preparation room. The current operational procedures; with two technicians per MR (most of the day) supports the insertion of contrast fluid outside the scanner room without an expansion of the FTE. Actual performance data is however necessary to make an analysis per inquiry type to see whether the protocol time can be updated. The Philips Utilization software tool is a necessary investment for this analysis.

4.3. Expansion business time

This intervention proposes an expansion of the business time by extending the opening hours of the MR department.

Intended effect of the intervention:

Expansion of the business time will decrease the access time because more time is available to perform MR scans. The capacity will increase and as a result the access time would decrease.

The effect of this intervention depends on the way how the business time is expanded, and more important how many technicians are available during the extra hours. If the business time is expanded during evening hours and the scanners are equipped with one technician, only standard non contrast inquiries can be performed then.

Standard non contrast inquiries have an appointment time of 30 minutes. During the expanded business time with three hours (until 9:00 p.m.) 6 patients extra can be scanned. During a full week with extra opening hours on two scanners 60 more patients can be scanned. It is not possible to expand the business time every week, due to holidays and vacations. If the business can be expanded in 40 weeks the number of patients treated can increase with 2.400. However this can only be patients who undergo a standard non contrast inquiry.

In the remainder, we address the consequences, and the conditions of the intervention for the work process, technicians, radiologists, patient planning and financial/other investments.

Working process

This intervention has no consequences for the operational procedures of the technicians. The working routine stays the same and the patient flow process will not be changed. The opening hours of the MR department will be expanded to increase the capacity.

Technicians

This intervention can only be carried through under one strict condition. The number of FTE should be expanded in order to perform the extra shifts. Otherwise the work pressure will become too high. This situation took place in practice in 2008. To decrease the access time for the MR scan, the technicians decided to expand the opening hours by performing extra shifts. Initially this was a temporary situation but eventually it turned out to be the daily business within the department. The number of FTE was not adjusted to this new situation.

A situation emerged where all programs remained fully planned, where emergency MR where put through the programs and there was still a high pressure of other departments to perform scans within a shorter period of time. The pressure on the technicians was mounting. The personal aspect of this working environment was undesirable and the risk originates that the technicians wanted to leave the department. Eventually the opening hours where reduced again to encounter this undesired situation.

This example shows that for this intervention to succeed, the process of analyzing of the current and necessary number of FTE is decisive. For example, we analyze the situation when the business time is expanded to 9:00 p.m. (the figures are based on the current situation, table 4):

MR 1 and MR 2: 7 technicians	7 technicians per day
Compensation for weekend and regular shifts	2 technicians per day
Absenteeism	2 technicians per day
Other specialties	2 technicians per day
Total number of technicians needed per day	13 technicians per day

Table 13: Number of technicians to equip two scanners per day (needed).

In theory, 13 technicians should be enough to equip both scanners in the situation of a business time from 8.00 a.m. until 9.00 p.m. We must compare this with the analysis of the current number of MR technicians:

Available MR technicians		13 technicians
	Long term absent	1 technician
	End of training for MR technician	2 technicians
Start training for MR technician (not available yet)		3 technicians
Total number of MR technicians		16 technicians

Table 14: Number of technicians to equip two scanners per day (available).

The analysis shows that currently 13 out of the total of 16 technicians are available for performing MR shifts. One technician is long term absent. Two technicians are almost fully trained to fulfill the MR shifts. This should be enough to cover all the MR shifts but the history showed that such a situation will have many negative effects in the long term. The social aspects are mentioned yet with the example of 2008. Other problems may arise with the planning of the technicians. There will not be enough technicians to perform the shifts in situations where more than 2 technicians get compensated for other shifts, are absent or have to perform other shifts.

A solution is to start with a group of MR technicians who are fully dedicated to the MR shifts. This group will not have to perform other shifts, and thus receive no compensation for this type of shifts. The pressure on the total group of MR technicians will therefore decline. Because these technicians will perform no other shifts, the group of general technicians has to be expanded. An expansion of 2 FTE in (general) technicians will be enough to compensate the loss of the fully dedicated MR technicians.

Radiologists

For the radiologists, this intervention has consequences on the amount of work that they have to do, and the number of shifts they have to supervise. This amount of work may not increase too much, from a personal point of view and from a service point of view. From a personal point of view, a high working pressure has negative effects on the perceived work satisfaction, which will be influenced negatively. From a service point of view, the extra work causes more time to report the inquiries, which influences the service negatively because it takes longer to report the scans.

A side from the radiologists who have to perform extra shifts, the anesthetists also have to perform on call duties during the extra opening hours of the MR department.

Patient planning

During the extra opening hours only one technician will equip the scanner. This has consequences for the planning of patients. Only standard (‘simple’) inquiries can be planned during these hours. No contrast or narcosis inquiries can thus be planned. The same restriction with regard to planning of patients in the weekend hours will count for the extra business time in the evening. During the day-time opening hours, when the scanners are equipped with 2 technicians each, the contrast and narcosis inquiries can be planned.

This restriction can be taken away, by employing a medical nurse. This medical nurse can help the two technicians who work during evening hours. Now contrast inquiries can be planned during evening hours. Furthermore this medical nurse can perform other duties which can not be performed during day time hours due to the work pressure. The medical nurse should however be trained and educated to be supportive for the technicians, otherwise the possible profit might not be reached.

For the patients the opening hours in the evening could be feasible for a large group of patients who work during the daytime. The service delivered towards these patients’ increases because they do not have to leave their work during their own working hours.

Financial/other investments

The analysis of the FTE showed that an increase of two (general) radiology technicians is necessary to support the expansion of the business time. The costs of this investment:

Extra technicians	2 technicians 8 hours a day x 52 weeks = 2080 hours business time		
	1576 hour per FTE per year = 2.64 FTE		
	(FWG 50/7 = € 35.000)		€ 93.000
	Social costs		€ 33.000
	Administration 0.5 FTE (FWG 35/7 = € 26.000)		€ 13.000
	Social costs		€ 4.600

Table 15: Financial/other investments by expansion of the business time

This intervention can be implemented in a lot of different manners. The business time can be expanded every evening, or just on one or two evening(s). The scanners can be equipped with two technicians (for two scanners) with as a result that only standard non contrast inquiries can be performed. Medical nurses of extra technicians can be used to encounter that restriction but that would result in extra costs. The effects of all these conditions are discussed above and the possible profit of this intervention is thus highly depended on the combination of interventions.

4.4. Dockable MR table

This intervention proposes to use a dockable MR table whereby the process of two patients can run simultaneously.

Intended effect of intervention:

Dockable patient tables make it possible to prepare a patient in a preparation room outside the scanner room. It provides an improvement in the workflow and supports an efficient patient throughput. The next patient can be fully prepared away from the MR scanner while the current patient is being scanned. Patient preparation and patient positioning are important activities, because it affects the quality of the scans. A dockable table gives the technicians more time to position and prepare the patient.

In practice, a large part of the inquiry times can be reduced. The exact time which can be gained per protocol must be estimated by the MR radiologist. It is expected that in practice, the protocol time for biopsy inquiries can be reduced with 20/30 minutes by using the Philips MammoTrak table. By a production of around 100 biopsies per year the total extra capacity will be 2.000/3.000 minutes. This is almost one week extra capacity on one MR scanner.

Figure 16: The dockable table (left) versus the Philips MammoTrak over-the-table (right).

In the remainder, we address the consequences of the intervention for the work process, technicians, radiologists, patient planning and financial/other investments.

Work process:

A dockable MR table results in some changes in the current operational procedures. The only activities which now will be performed in the scanner room are the docking of the table (with the prepared patient) onto the scanner, the scanning itself and the undocking of the table from the scanner. The time that the scanner can be used during the business time is maximized by this approach.

This intervention requires two technicians per MR per day. This makes it able to run the patient process of two patients simultaneously. Patient N is for example on the scanner table and the scan is performed. During that time patient N + 1 can be called out of the waiting room. The patient can be put on the dockable table and fully prepared and positioned for his/her scan. The positioning of the patient is important for the quality of the scans. When patient N is ready, patient N + 1 can be docked onto the scanner directly, and the scan can almost start immediate. Meanwhile one of the technicians can help patient N back to the waiting room and the other technician can start the scan of patient N + 1. There is still some time left before patient N + 2 needs to be called for its appointment, which can be used to help the other technicians or give/receive feedback. This will increase the work satisfaction.

With help of the dockable table the quality of the scans can be improved. The positioning of the patient has consequences for the quality of the scans. A big part of the inquiries is performed with coils to position the patient. The positioning of the patient is performed at the scanner table in the scanner room. The positioning is thus performed under some sort of time pressure. The dockable table makes it able to position the patient before he/she enters the scanner room and during another inquiry. The time to positioning the patient increases and will enhance the quality of the scans.

A similar type of intervention proposes the same advantages as the dockable table intervention. The dockable table is expanded with an inserted mama coil for breast inquiries. Again, the patient can be prepared and positioned outside the scanner room and especially breast biopsies can be performed largely outside the scanner room. The capacity of the scanner itself will increase by this type of intervention. An example of this intervention is the so called Philips MammoTrak table. This table makes it possible to perform biopsy procedures largely outside the scanner room. The current protocol time for biopsy scans is 75 minutes. Around 100 biopsy procedures per year are performed at the MR department. With help of this MammoTrak table sufficient time can be saved in the scanner room. In detail, time can be saved during the positioning of the patient, during the injection and afterwards when the radiologists directly can see if the injection is correct. The radiologists does not have to walk to a monitor outside the MR department to see whether the injection is correct (that monitor is currently away from the MR department so it takes a lot of extra time).

A condition is however that there should be an appropriate room to perform the actual biopsy in. This room must be situated directly towards the MR scanner rooms and must be large enough for a bed to fit in. This actions can be performed in the central preparation room if for example a curtain is used to secure the privacy of the patient. This room is essential for this intervention because a large part of the actual inquiry will be performed in there.

The Philips MammoTrak table can also be used for regular mamma inquiries. By using this table, the positioning of the patients is much easier to perform. This will enhance the quality of the scans. If the mamma inquiries are planned not directly after each other then it is possible to shorten the appointment time with 5 minutes. This does not mean that mamma inquiries only can be held during that specific blocks, because that will increase the access time for patients requiring a mamma inquiry.

Technicians

The task routine of the technicians must be changed. The tasks must be clearly defined and both of the technicians are responsible for one patient at a time, from beginning until the end of the inquiry. There will be more patients scanned during the day. The pressure will be higher if the tasks are not clearly divided, but at the end the time that you have to serve a single patient will increase.

The number of FTE, available to do MR shifts need to be analyzed and if necessary expanded. If this intervention is not properly implemented it can easily turn into a burden for the technicians. In stead of the advantages, like more time to serve a patient, a shorter access time and cooperation with other technicians the negative effects will be felt. For instance, a high work pressure and overrun of patient slots. Thus, the number of FTE should be high enough to perform the shifts (e.g. 2 technicians per MR per day) and the tasks should be clearly defined and distributed. The number of MR technicians that are needed per day (figures are explained in table 4):

MR 1 and MR 2: 5 technicians	5 technicians per day
Compensation for weekend and regular shifts	2 technicians per day
Absenteeism	2 technicians per day
Other specialties	2 technicians per day
Total number of technicians needed per day	11 technicians per day

Table 16: Number of MR technicians per day by dockable table intervention (needed)

The analysis of the current situation shows:

Available MR technicians	13 technicians
Long term absent	1 technician
End of training for MR technician	2 technicians
Start training for MR technician (not available yet)	3 technicians
Total number of MR technicians	16 technicians

Table 17: Number of MR technicians per day by dockable table intervention (available)

This analysis shows that currently 13 technicians can perform MR shifts. One technician is long term absent and two technicians are almost ready to perform MR shifts. This number is enough to perform the shifts in the current situation (e.g. 2 technicians per MR most of the day).

The technicians fear on basis of their knowledge and experience that there will be, in practice, negative side effects of this intervention. The dockable table is relatively heavy and large and thus difficult to work with. There are two dockable tables needed to optimize the patient process. This requires a sufficient amount of space to work with two tables at the same time. Furthermore, they feel that the patient is pushed through the process like a product. The service delivered to the patient will be in danger according to the technicians.

Radiologists

The radiologists need to decide whether the protocols (or some type of protocols) can be shortened with the new operational procedures. It is their responsibility that the new protocols and working routines reach the high level of care that they want to deliver. Again, the work pressure can increase by the expected growth of patients served. This has to be monitored closely with the help of *sanderspunten.* If necessary, adequate actions have to be taken to restore the balance in the work pressure of the radiologists.

Patient planning

This intervention requires an update of the MR protocols, like for example the biopsy procedure. Currently this procedure has a protocol time of 75 minutes. With help of the intervention it can be expected that the procedure can be performed in 45 minutes. These 45 minutes is the time that the scanner room is reserved for this patient. The other part of the procedure can be performed outside the scanner room and thus creating extra scan time for other patients. More patients can be planned during the day. The planning of mamma inquiries must be changed. To gain the time advantage by using the MammoTrak table, mamma inquiries may not be planned in succession. A solution might be to dedicate an afternoon to mamma inquiries combined with other standard inquiries.

Financial/other investments

This intervention requires considerable investments. With regard to the dockable table intervention the following investments must be considered:

- Two dockable MR tables. One extra table per MR to be able to run the process of two patients simultaneously.

- Two complete sets of MR coils.
- Adequate preparation rooms to prepare the patient. This room must have enough room for an MR table.
- No investment in MR technicians required. The current working structure (e.g. 2 technicians per MR almost the entire day) requires no changes with this intervention.

As we can see, this intervention requires a considerable investment in the lay out and in the materials of the department. If we compare this to the MammoTrak table intervention, which only requires an investment of the Philips MammoTrak table, we can see a significant difference in the costs. Because of the relatively low number of biopsies per year it suffices to purchase only one MR table per two MR scanners. This table can be used for both MR scanners.

4.5 Purchase of a third MR system

This paragraph discusses the effects of the purchase of a third MR system. This is not an intervention proposed in this study, but this already taken decision will have a influence on the total process. The effects of this intervention will therefore be discussed.

Intended effect of the intervention:

Purchasing a third MR system increases the capacity of the MR department of MST. This additional capacity will reduce the waiting list. Furthermore, the MR is increasingly seen as the imaging technique of the future. MR imaging techniques in a hospital should be available as soon as possible to serve the specialists. A new system, like the 3.0T MR, makes it possible for radiologists to offer better and more detailed images. The purchase of a third MR can thus be seen as an increase of the capacity but also as an increase in services that can be delivered by the MR department.

The third MR system can be used full time after 6 months. The inquiries will take the same amount of time as on the other two systems. With help of the current schedule we can make a overview of the expected patient numbers per year:

Business time: 8:00 a.m. – 18:00 p.m. no weekends	***4.000 patients***
Types of inquiries:	
Standard non contrast inquiries:	*1.000 patients*
Non standard and contrast inquiries: *Oncology patients*	*2.500 patients* *250 patients*
High end inquiries	*250 inquiries*

Table 18: Expected patient numbers for the 3rd MR

The above presented figures are expected patient numbers when the business time is form 8.00 a.m. until 18:00 p.m., and no weekends. The new MR system is partially dedicated to oncology patients. The expected number of oncology patients will be 250 on yearly basis. Furthermore a part of the business time will be used for high end inquiries and scientific studies. All figures are based on a expected efficiency of 60/65 % equal to the other two scanners.

In the remainder, we address the consequences of the intervention for the work process, technicians, radiologists, patient planning and financial/other investments.

Work process

This intervention has initially no consequences for the operational procedures. The new MR system however will be a 3.0T system. This system allows to make other parts of the body visible then with the current 1.0T and 1.5T systems. This 3.0T system requires specific knowledge of the technicians within same operational procedures.

The same type of scans will take less time on a 3.0T system than on the 1.0T or 1.5T system. However, using the same amount of time will improve the quality of the produced scans. The radiologist chose therefore not to reduce the scan time for inquiries on the 3.0T system.

The third MR system can not be placed by the other two MR due to space limitations. The definite location of the third system is however not clear yet. The choice of the location has consequences for the patient process. MR 1.0T and MR 1.5T are situated next to each other at the radiology department. The radiologist and technicians are, if necessary, quickly at the MR. A MR at another department does not have this advantages and other solutions need to be considered if the radiologists/technicians want to be on time in emergency situations.

With the current operational procedures and the continuous growth of request for MR scans it is expected by the technicians and other actors in the process that the capacity will be fully used rather sooner than later. This intervention will temporary reduce the problems and waiting lists if the same operational procedures will be used.

The first month on the 3.0T system will be used to insert the correct MR codes into the system. After the first month the system will operate on roughly 2/3 of its capacity to get used to the new system. After 6 months the system will be used full time.

Technicians

The new MR 3.0T system will have more diagnostic possibilities than the other 2 systems. This implies that the technicians will need extra training and development to have the required capabilities. Extra technicians have to be hired to equip the third MR system. The number of FTE should be high enough to prevent that the work pressure becomes too high.

An analysis is made to forecast the number of technicians that is needed to equip the three MR scanners per day (based on table 4):

MR 1 and MR 2: 5 technicians and MR 3: 2 technicians	7 technicians per day
Compensation for weekend and regular shifts	2 technicians per day
Absenteeism	2 technicians per day
Other specialties	2 technicians per day
Total number of technicians needed per day	13 technicians per day

Table 19: Number of MR technicians per day by 3rd MR (needed)

This analysis shows that a total of 13 technicians are needed per day to equip the three scanners. An analysis of the current number of available technicians shows (situation 2 MRs):

Available MR technicians	13 technicians
Long term absent	1 technician
End of training for MR technician	2 technicians
Start training for MR technician (not available yet)	3 technicians
Total number of MR technicians	16 technicians

Table 20: Number of MR technicians per day by 3rd MR (available)

If the technicians who are currently in training succeed in becoming MR technicians, and the long term absent technician will come back, the situation will be that 19 technicians are available for MR shifts. The availability can be divided per day over the week in this situation:

Monday	14 technicians
Tuesday	15 technicians
Wednesday	15 technicians
Thursday	13 technicians
Friday	16 technicians

Table 21: Expected number of MR technicians available per day from September 2010

One technician works on different days each week and can thus be used on every day. This analysis shows that there are enough technicians available to equip the three MR systems. However, the technicians in training are taken out of the general pool of technicians. This general group of technicians needs to be increased with 2 (general) technicians.

Of the group of 19 MR technicians (situation with 3 MRs), 9 technicians have beside MR other specialties and get more compensation during the week, which means that they are not always available for MR duties. This problem can be solved by dedicating the technicians fully to the MR.

For the technicians it is also relevant that the MR systems are relatively proximate. A concentration of MR production enables the technicians to concentrate and exchange their knowledge. The capacity of technicians will be used more effective and efficient.

Radiologists

An MR 3.0T system is from a medical point of view essential to secure the mission and vision of the hospital towards centers of excellence. As a result it can be expected that the 3.0T system will be used full business time, because all departments want to make use of the latest piece of technology.

The business time of the total MR department will be substantially enlarged. A side from that the type of inquiries which can be performed at the new MR system will increase too. Other departments like especially the oncology will have great benefits from the new system. As a result the number of inquiries will increase heavily. All these inquiries have to be supervised and reported by the radiologists. To encounter problems with work pressure, the availability of radiologists should be analyzed and possibly new radiologists must be hired.

The new MR system will support the oncology department to be a center of excellence. The oncology department is more and more dependent on quality images from the radiology department, and with the help of the 3.0T system the radiology department can deliver this high quality images. Furthermore the 3.0T system can facilitate high end inquiries and improve the possibilities to perform scientific research for the radiologists.

Patient planning

Not every type of inquiry will be performed on the new 3.0T scanner. Radiologists determine which inquiry will be performed on which scanner. This has consequences for the planning of the patients, because the location of the scanner is not clear yet. There is no space at the MR department so the MR scanner gets another location. There are two options:

- MR in Oldenzaal (Dependence of MST): This MR would then facilitate the treatment of mamma patients. The exploitation remains the responsibility of the radiology department.
- MR at Radiotherapy department: This department has space for an MR scanner and could use the facilities in its own patient process.

The new 3.0T MR supports almost all the healthcare that is located in Enschede (MST). The current capacity is high enough to support the other departments. Placing the third MR in Oldenzaal means that a lot of patient will need to travel to Oldenzaal for an MR scan. In Oldenzaal around 400 mamma treatments are performed, which means that more than 5000 patients need to travel Oldenzaal in stead of 400 to Enschede.

Financial/other investments

This intervention requires a lot of investments (the figures are based on a calculation of the project group 'third MR'):

		Sole costs	Annual costs
MR	3.0 Tesla MR Contrast pump Report station Depreciation	€ 2.000.000 € 50.000 € 50.000	 € 210.000
Building costs Enschede	Space available on radiotherapy department Adjustment cage of Faraday Architectural adjustments	 € 150.000 PM	
Extra technicians	2 technicians 8 hours a day x 52 weeks = 2080 hours business time 1576 hour per FTE per year = 2.64 FTE (FWG 50/7 = € 35.000) Social costs Administration 0.5 FTE (FWG 35/7 = € 26.000) Social costs		 € 93.000 € 33.000 € 13.000 € 4.600
Material costs	Contrast fluid, needles Service contract MR		€ 60.000 € 200.000

Table 22: Financial/other investments by extra MR scanner

If we see these large investments that have to be done and if we take in mind that there are two scanners currently in use that are not used to full potential, we can question the investment of a third MR scanner. The expected patient numbers on the third MR will be enough to decrease the waiting lists (expected utilization of 60/65%). But there is an unknown waiting lists of patients who will show up once the third scanner is operational.

From a medical point of view the purchase of a 3.0T scanner is defendable in the hospital development towards centers of excellence. The quality of the scans improves and by cooperating with the oncology department, the third MR system can increase the quality of the delivered care towards this department. Furthermore, the opportunity to perform high end inquiries and scientific research supports this vision of the hospital.

5. Conclusions

In our problem formulation we explained the critical position of the MR department. The MR functions as a supportive step for other departments and facilitates the total process of healthcare delivery. The radiology department MST experienced high access times for their services and the technicians experienced a high working pressure. The department becomes a bottleneck in the service delivery of the hospital. The adequate performance data was not available to detect the exact bottlenecks and to propose interventions to increase performance. The goal of the research was:

To acquire relevant performance data, design interventions and make recommendations to improve the service delivery process of conducting an MR scan.

We present the conclusion based on the research questions.

5.1 Performance of the system

The lack of actual performance data about the MR process made it difficult to define the performance of the system. No performance data is gathered, and it is very difficult to get access to the right performance data. Our context analysis stepped into this gap. We analyzed the process, step by step, and we developed relevant performance indicators that where the basis for the detection of the bottlenecks.

The patient planning schedule contains standard slots for the standard inquiries, which are non-contrast inquiries which can be performed by only one technician. These slots are at the beginning of the day and at the end of the day (and during weekends). The other slots are for non standard inquiries. Each MR has three slots (of 30 minutes) for emergency patients. Cardio and orthopedic patients are clustered on Tuesday and Wednesday.

Analysis of all patient inquiries in 2008 showed that the access time for non-emergency patients increased from 15 working days in January to 40 working days in December 2008. This increase in access time was mainly influenced by a decrease of capacity at the end of the year. The information is not specific enough to specify the access time per group of patients.

The time measurement performed under this study revealed that during opening hours 62% percent of the time is used for positioning the patient and performing the scans. 10% of the time is used to prepare the patient outside the scanner room and almost 8% is used finishing the appointment. The other 20% is used for to clean the room and to wait for the next patient. Furthermore, our time measurement showed that the time to prepare a patient table is very hard to predict and showed high variability.

Corrective maintenance is high on both machines. On MR 1 the total corrective maintenance in a one year period was 90 hours. On MR 2 in the same period the corrective maintenance was 55 hours. The real loss of capacity is even higher because programs must be cancelled or postponed.

5.2 Developing the interventions

We propose several interventions to improve the performance of the system and to reduce the long access times. As basis of the intervention are the logistic principles variability reduction, complexity reduction and waste reduction have been applied.

Productivity in healthcare is strongly affected by the variability of arrival and service times. Variability in processing times, caused by rework, downtime, lack of consistency in work methods influence the performance of the system negatively (Hopp, 1990). Waste in a production process can be defined as 'anything other than the minimum amount of equipment, items, parts and workers that are absolutely essential to production'. Elimination of waste makes the process faster and more dependable (Slack, 2007). Complexity in processes contribute to the total waste of the organization. Just-in-time techniques (JIT) are used to reduce this type of waste in the process (Slack, 2007). These principles in logistics form the basis for the proposed interventions:

- Update of the protocols that are used for the MR inquiries.
- Insertion of intravenous access line for the insertion of contrast fluid in a preparation room outside the scanner room.
- Expansion of the business time.
- Using dockable MR tables

The decision is already made to expand the business time by purchasing a third MR scanner. This decision has an effect on the total process; therefore the effects of this decision will be discussed as if it was an intervention.

5.3 Interventions in practice

All the interventions are discussed with relevant actors in practice. The expected effects of the interventions are described and evaluated.

The protocol update has two important advantages. First, the new protocols are developed per specific indication, which leads to a much more accurate display of the reality. This will result in specific protocols per patient groups and thus gain of extra time, because no unnecessary slack time is planned. Second, this new coding of the protocols allows that information about patient numbers can be specified per group of indications. There is thus more information, which is more easy to obtain from the process. The cooperation of radiologists expects that this intervention increases patient numbers with 10% per year. This means that approximately 1.000 patients more per year can be treated within the same capacity. Furthermore, no investments are needed to make this intervention possible.

However continuous performance data is still necessary. This intervention makes it easier to acquire this information, but human activities are still needed to get the information out of the process. Philips utilization data software fills this gap and delivers continuous performance data about the process. This investment is necessary to be able to reach the full 10% growth of patients.

Insertion of intravenous lines in a preparation room reduces the time that is needed to prepare a patient in the scanner room. By eliminating this activity out of the scanner room, more capacity is created to scan other patients. The process of two patients must be simultaneously. Recent studies of Elkhuizen, van Sambeek, Hans, Krabbendam & Bakker, (2007) showed that up to 5 minutes per patient can be gained. With almost 2.000 patients a year that undergo a contrast inquiry, the expected time advantage leads up to 10.000 minutes. This equals 250 patients extra per year. This intervention requires almost no investments. Only, the patients chair has to be adjusted to facilitate insertions of intravenous lines in a better way, which is a simple procedure. However, in line with the protocol update intervention, the Philips utilization software would acquire the performance data out of the process and help to gain the maximum benefit out of this intervention.

Expansion of the business time is a rather straightforward intervention. The expected profit in patient numbers depends on the way how the business time is expanded and how many technicians equip the scanners during that time. Only standard non contrast inquiries can be performed if the scanner is equipped with only one technician. The combination of extra business time together with the number of technicians available determines the profit. The FTE analysis showed that an expansion of 2 technicians is enough to facilitate expansion of the business time. Otherwise the work pressure becomes too high if the current workforce should perform all the extra shifts. The workload of the radiologists will also increase.

The dockable table intervention has certain negative effects according to the technicians. The tables are log and difficult to work with. The service delivered to the patients will decrease heavily if all patients are pushed through the process and different sets of coils are needed. The work pressure will decline and the expected time profit is not very large. The expected time gain will be minimalized by this disadvantages. However there is an exception. The Philips MammoTrak over-the-table is a dockable table designed for mamma inquiries. A biopsy inquiry can now be performed partly outside the scanner room by using this table. According to the radiologists 20/30 minutes can be gained by using this method. This equals a one week production on one single MR scanner (number of biopsies: 100). This table can also be used for normal mamma inquiries where it simplifies the positioning of the patient. The positive effects outweigh the negative side effects of this type of intervention.

The purchase of a third MR system requires large investments and if we take in mind that there are two scanners currently in use are not used to full potential, we can question the investment in a third MR scanner. However, the expected patient numbers on the third MR will be enough to decrease the waiting lists (by an expected utilization of 60/65%). There is an unknown waiting list of patients who will show up once the third scanner is operational. From a medical point of view the investment in a 3.0T scanner is defendable in the hospitals development towards centers of excellence. The quality of the scans improves and by cooperating with the oncology department, the third MR system can increase the quality of the delivered care towards this department. The third MR supports the vision of MST to perform high end inquiries and scientific research.

6. Recommendations

In this study we give an analysis of the current process of the MR department. These analysis and our experiences are the basis for some practical recommendations. These recommendations could be used to improve the current working process and work as a guide for the development of the new working process for the third MR system.

6.1 Practical recommendations

We propose different interventions to improve the process. We define a practical step by step implementation process to implement the interventions.

Step 1: Acquire performance data

The performance data must be used to discover bottlenecks and propose the interventions. The data can also be used to make the effects of the interventions visible. Day-to-day available performance information is necessary for effective steering of the process. The current operational procedures make it not possible to acquire the performance data that is needed. The RADOS does not acquire the right performances to get useful information out of the system. There is currently no way to obtain this information in a fast an easy way. Decisions about expansion of the capacity, about expansion of the business time or about buying extra equipment must be made on basis of real time performance data. Gathering of logistical indicators about the process must take place on a regular basis. The following information must be the basis for steering of the process:

- Patient scheduling: to detect mistakes or empty spots in the scheduling system
- Examination times: Exact data of the time that every inquiry took
- Procedure mix: How many inquiries of which type have we performed during a period
- Number of examinations: Basic management statistic
- Protocol mix: Helps to understand the protocols per inquiry and is a tool to update the used protocols
- Utilization data: detailed workflow reports of the process. Helps to detect bottlenecks in the service delivery process

The Philips software utilization tool delivers this information and is a perfect tool to fill the current gap. This software tool delivers this information on any requested moment, and is therefore an integral part of the improvement of the process.

Step 2: Implement the updated protocols

The first step contains an update and implementation of the current used MR protocols. The MR protocols are developed per organ, with as a consequence that they could be used for diagnosing patients with different indications. The scan times of these patients vary per indication but the protocol time stays the same. This new protocols are already made by the radiologists but the new codes are not implemented in the scanners. The first step should be the implementation of these new protocols in the operation procedures.

Step 3: Adjust the patient schedule

Step 3 must be adapting the patient schedule. With help of the new protocol codes we can discover different groups of patients. How many patients of which type do we get during a certain period is a very relevant statistic. At present there are reserved slots for orthopedic patients, we can now remove these reserved slots when we see that this group is not large enough to fill up all this slots. The patient schedule can be adjusted according to the real time development of the demand of MR inquiries. The access times should be known per patient group and the planning schedule should be adjusted according to these access times. A patient group with high access times should currently have more spots in the planning schedule (tactical capacity planning).

Step 4: Adjust the appointment times

The next step consists of adjusting the used appointment times (protocol times) to the exact time that is needed to perform a certain type of inquiry. Step 1 and 2 must be performed first before this step can be performed. The workflow information gives detailed feedback of the used protocols in practice. This information must be used to adjust the protocols to the time that is needed to perform all the activities. Furthermore it can be used to check if there is enough time in the protocols to change from patient or to clean the room. Without this information it is not possible to make the right changes concerning the protocols.

Step 5: Reallocate the insertion of intravenous access lines to a preparation room

The next step should be removing the activity insertion of intravenous lines out of the scanner room to a preparation room. Extra scan time can be created because a patient spends less time in the scanner room. Step 1 and 2 must be completed before this step can be performed because the data shows which appointment time can be shortened in practice. The technicians should get used to the new operational procedures to gain the maximum benefit out of this intervention.

Step 6: Discover more improvement areas

We recommend to perform the first five steps before the other interventions might be implemented. When these previous steps are implemented the effects of expanding the business time and using the MammoTrak table can be estimated. The actual steering information must be the decisive factor if the intervention is implemented. Step 6 is a continuous task for all the actors in the total process to strive to continuous improvement of the total MR department.

6.2 Managerial implications

Currently, the MR shifts are performed by a group of technicians partly dedicated to the MR. This group performs also other radio diagnostic tasks. This means that the group of technicians that are available for MR shifts is not always large enough. This results in a high work pressure for the MR technicians. Every intervention should be based on a thorough analysis of the total number of FTE available for performing MR shifts. A situation where MR technicians are fully dedicated to the MR and do not perform regular radio diagnostic duties will increase the number of FTE available for MR shifts but will reduce the overall knowledge and experiences of the MR technicians.

The radiologists will have to supervise or attend more inquiries. The number of inquiries that have to be reported will increase. This will have to be done within a reasonable amount of time (< 2 working days). The current situation does not facilitate a large increase in patient inquiries because the radiologists are up to the maximum amount of patients. Furthermore, supporting facilities like the anesthetist have to be on call on more occasions.

The interventions will increase the amount of performance data. This data will play a role in the steering of the process. The application department and information experts track this performance data and evaluate the consequences. The planning department must have an active role, because the patient schedules will have to be adjusted according to the latest performance data. Planning of the patients will become a more difficult, but also a more important task.

All the interventions will require a change of the current operational procedures. Every organizational change will bring problems and possibly resistance of all actors involved. Active involvement of key actors in the process is therefore essential. These actors will have to be the leaders in the change and need to show the positive effects that the change will bring. Without this active support any change is deemed to fail at the beginning.

6.3 Recommendations for further research

While more and more research is done investigating the logistical performance of a specific hospital process, less data is known about the patient preferences. It is assumed that patients do not want to be pushed through the process, but what if this new operational procedures have no consequences for the quality and will decreases the access time? Patients might choose these new operational procedures because it fastens their diagnosis process and more important it decreases the access time. Furthermore, detailed patient preferences can help to improve the total service delivery towards the patients. Patient preferences about opening hours of the MR department can help to adjust the opening hours to the need of a patient group. Do patients prefer to get scanned on a morning, evening, weekend or specific day? Thus research on patients preferences in the MR process can improve the total process of service delivery.

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Appendix A

The total numbers of patients per requestor are presented in the report itself, but it is also interesting to see how many patients come from each group apart. The groups are: general practitioner:

Applicant	Inquiry									
	Bucky	Thorax	Mamma	Dexa	Radiosc.	Echo	CT	MR	Angio	Total
General Practitioner	35.867	10.952	2.506	529	202	9.716	103	235	1	60.111
Total	35.867	10.952	2.506	529	202	9.716	103	235	1	60.111

The second group, patients from specialist of MST

Applicant	Inquiry									
	Bucky	Thorax	Mamma	Dexa	Radiosc.	Echo	CT	MR	Angio	Total
Anesthesia	38	1147	-	-	32	25	59	1	10	**1312**
Cardiology	152	3568	-	-	36	336	169	76	5	**4342**
Cardio. Su.	39	5717	1	-	10	100	41	4	7	**5919**
Surgery	1539	1974	315	2	740	903	636	65	1070	**7244**
Dermatology	9	17	-	-	-	-	2	1	-	**29**
Gynecology	48	78	2	-	1	103	40	9	13	**294**
Intern. Med.	662	2024	-	7	98	802	485	109	142	**4329**
Pediatrics	119	284	-	-	24	286	9	13	1	**736**
ENT Med.	5	12	-	-	6	3	9	5	-	**40**
Pulm. Med.	269	3046	7	-	41	209	460	53	46	**4131**
Gastroenter.	321	636	8	2	336	479	388	44	395	**2609**
Neurosurg.	315	128	3	-	257	19	180	134	7	**1043**
Neurology	255	412	10	-	30	663	479	1008	14	**2871**
Orthopedics	2367	150	2	1	167	55	34	22	6	**2804**
Plastic Surg.	40	16	-	-	25	9	3	3	6	**102**
Psychiatry	45	148	1	1	3	14	18	17	-	**247**
Rheumatol.	185	118	-	1	-	34	10	8	2	**358**
Urology	102	106	-	-	62	61	63	2	155	**551**
Radioth.	2	2	1	-	-	1	3	3	-	**12**
Physioth.	-	-	-	-	-	-	-	-	-	**-**
Total	**6512**	**19731**	**350**	**14**	**1868**	**4009**	**3072**	**1626**	**1837**	**38973**

The third group, patients from the outpatient department.

Applicant	Inquiry									
	Bucky	Thorax	Mamma	Dexa	Radio.	Echo	CT	MR	Angio	Total
Anesthesia	21	35	-	-	584	3	8	46	-	**679**
Cardiology	118	1880	-	-	357	128	154	305	-	**2942**
Cardio. Su.	7	618	-	-	3	3	18	8	-	**657**
Surgery	16807	2793	3144	54	134	7156	1332	1144	115	**32679**
Dermatology	19	91	-	1	-	88	-	1	-	**200**
Gynecology	445	41	113	406	34	113	93	43	1	**1289**
Intern. Med.	1226	2094	71	161	67	1430	962	309	82	**6404**
Pediatrics	722	393	-	4	89	779	17	110	-	**2114**
ENT Med.	1170	76	-	-	265	83	690	284	-	**2568**
Pulm. Med.	789	6451	12	9	12	122	1328	93	6	**8822**
Gastroenter.	489	560	28	97	446	1043	666	221	16	**3566**
Neurosurg.	273	36	1	1	2	6	174	658	-	**1151**
Neurology	364	1087	-	-	1	254	1730	1899	6	**5341**
Orthopedics	12010	335	1	25	31	1072	143	1555	150	**15322**
Plastic Surg.	375	7	10	-	8	89	11	45	5	**550**
Psychiatry	1	2	-	-	-	-	7	20	-	**30**
Rheumatol.	6562	547	-	68	-	54	27	185	-	**7443**
Urology	680	158	-	1	72	1085	407	83	53	**2539**
Radioth.	75	109	423	4	26	125	93	292	-	**1133**
Physioth.	303	1	-	-	44	31	6	22	2	**409**
Total	**42456**	**17314**	**3803**	**831**	**2166**	**13664**	**7866**	**7354**	**436**	**95816**

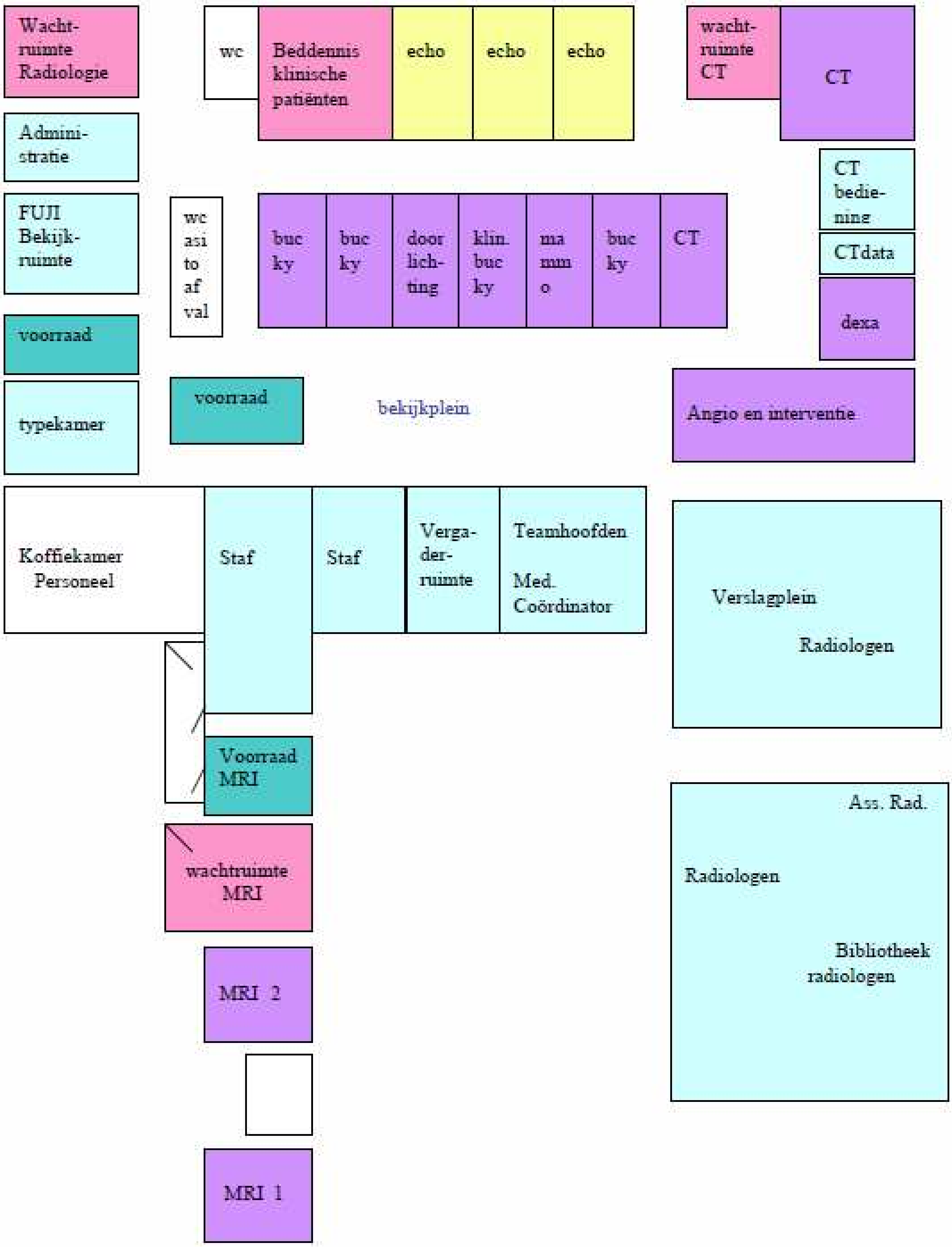
And the last group, patients from specialist of general practitioners outside MST (and it region):

Applicant	Inquiry									
	Bucky	Thorax	Mamma	Dexa	Radiosc.	Echo	CT	MR	Angio	Total
Cardiology	5	2	-	-	3	-	-	40	-	**50**
Surgery	-	-	8	-	9	6	10	147	1	**181**
Dermatology	-	3	-	-	-	-	-	-	-	**3**
Gynecology	-	-	-	-	-	-	-	1	-	**1**
Intern. Med.	1	-	-	-	19	1	9	21	-	**51**
Pulm. Med.	-	55	-	-	1	-	-	-	-	**56**
Gastroenter.	-	-	-	-	-	-	1	-	-	**1**
Neurology	2	1	-	-	-	-	7	20	-	**30**
Psychiatry	-	1	-	-	-	-	-	-	-	**1**
Rheumatol.	6	1	-	-	-	-	-	-	-	**7**
Physioth.	146	9	-	-	3	36	1	3	-	**198**
Unknown Sp	203	24	104	12	11	71	19	45	1	**490**
Other Spec.	382	236	5	2	3	101	14	3	-	**746**
Total	**745**	**332**	**117**	**14**	**49**	**215**	**61**	**298**	**2**	**1815**

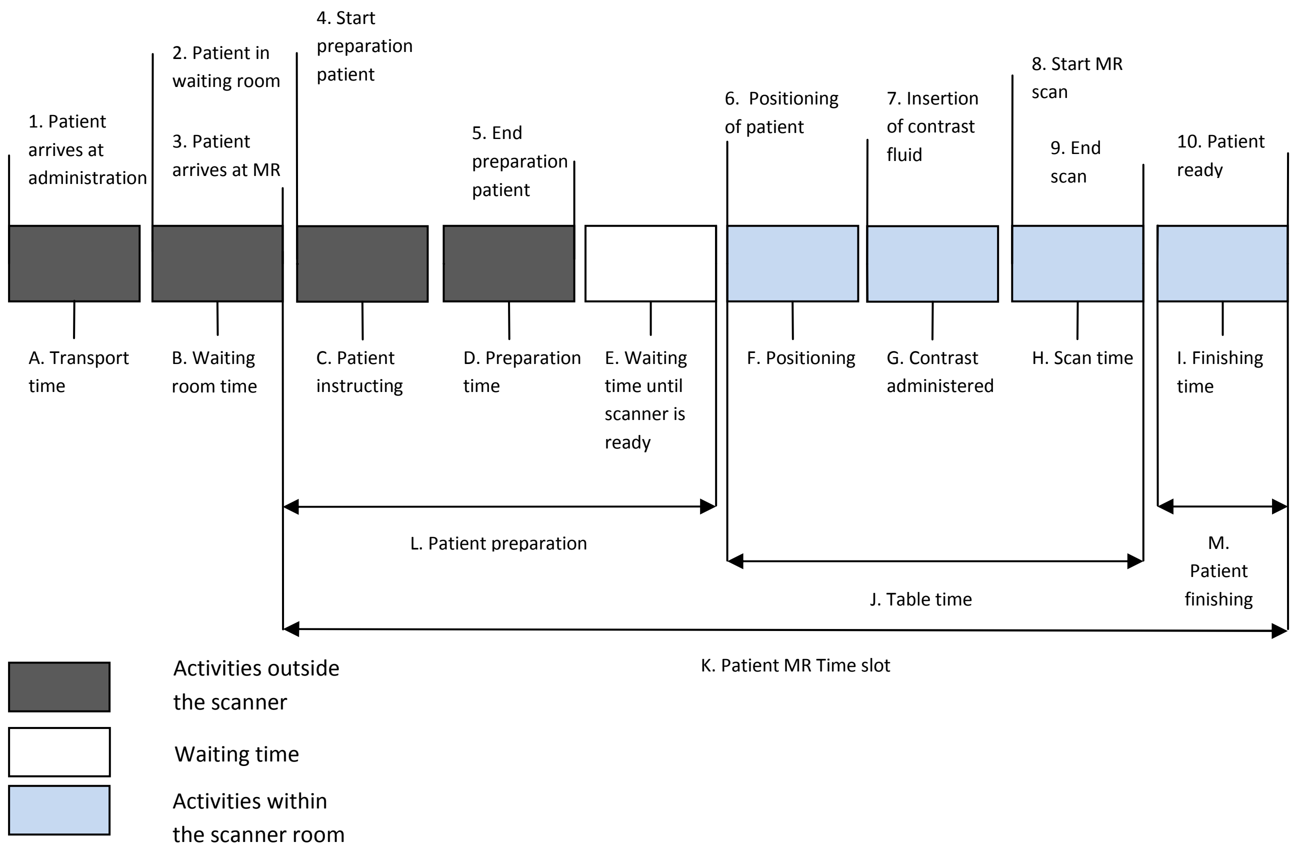
Appendix B

Lay-out of the radiology department:

Haaksbergerstraat:



Appendix C

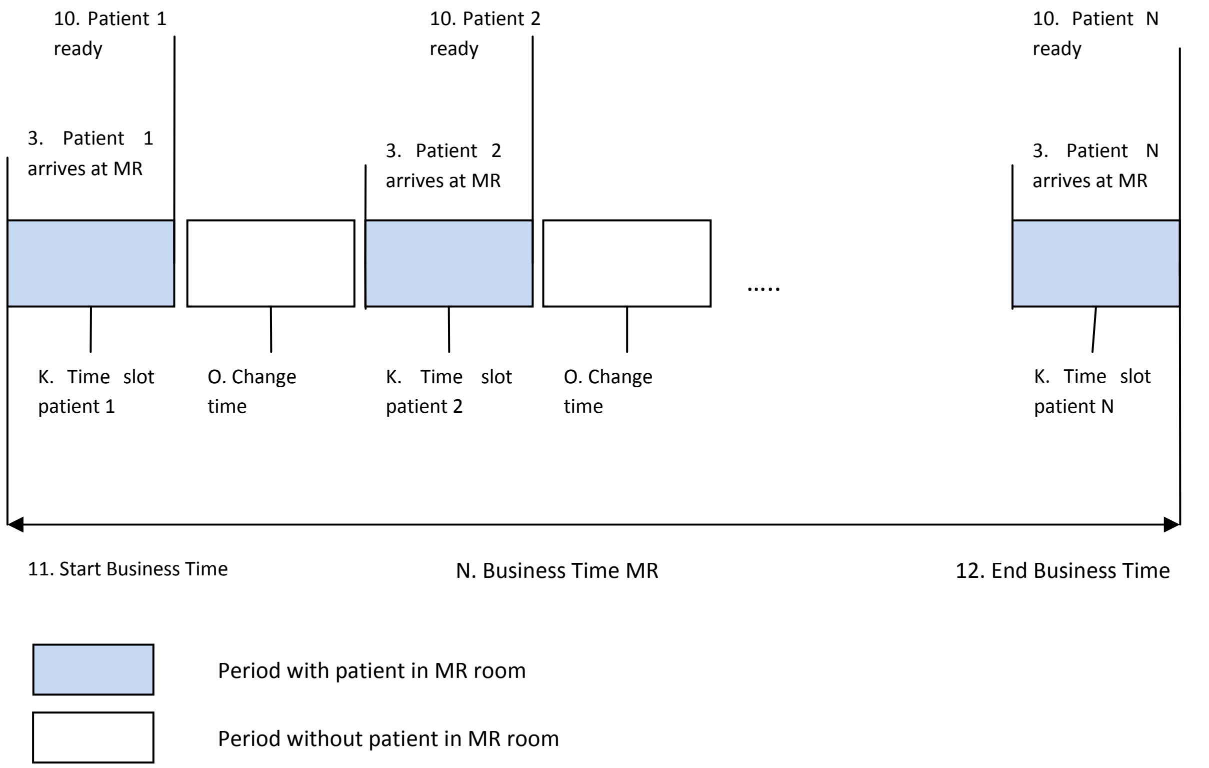


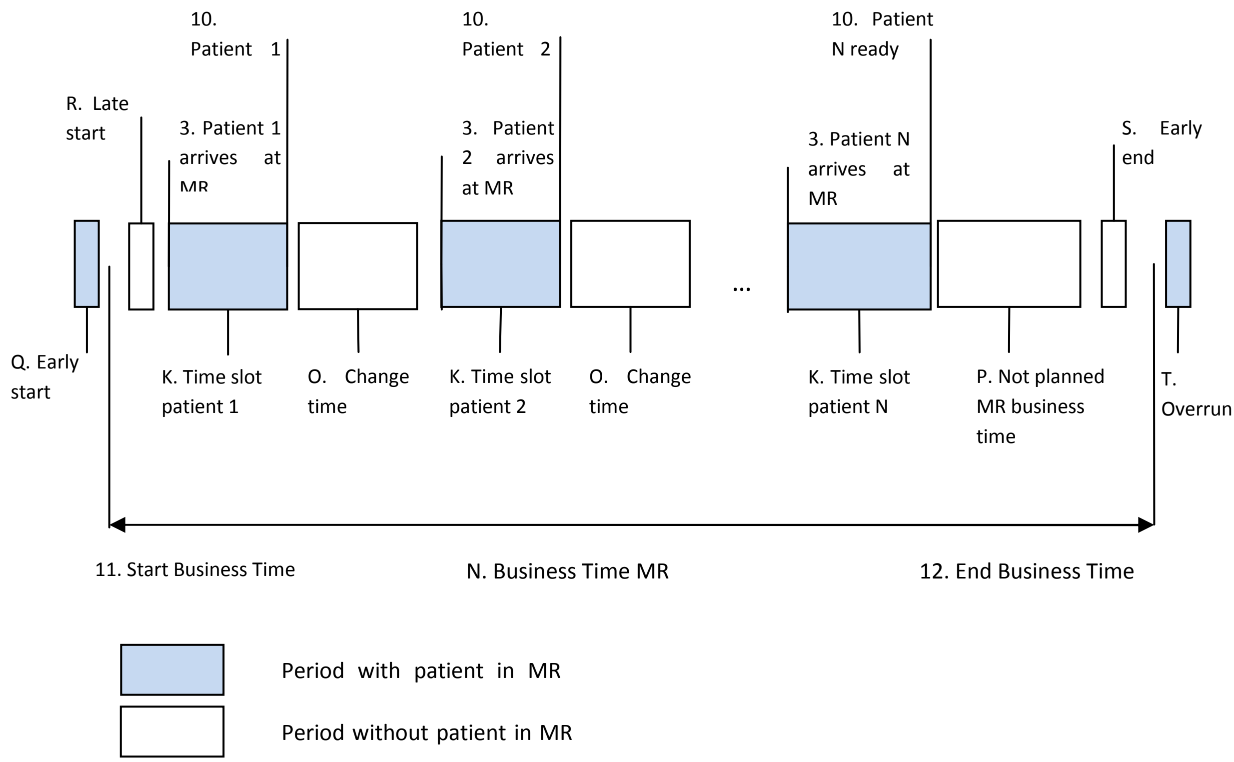
1. Patient arrives at administration:	The moment that the patient arrives at the administration to register for their appointment
2. Patient in the waiting room:	The moment that the patient arrives at the waiting room
3. Patient arrives at MR:	The moment that the patient is called for their appointment by a technician
4. Start preparation patient:	The moment that the technician starts to prepare the patient (changing, last instructions or making a patient feel comfortable) for its inquiry
5. End preparation patient:	The moment that the technician is ready preparing the patient for its inquiry.
6. Positioning of patient:	The first moment after the preparation of the patient when the technicians positions the patient on the scanner table.
7. Insertion of contrast fluid:	The moment when the technician administered contrast fluid to the patient

8. Start scan:	The moment that the MR scan is started
9. End scan:	The moment that the MR scan is finished
10. Patient ready:	The moment that the patient is ready to leave the MR department.

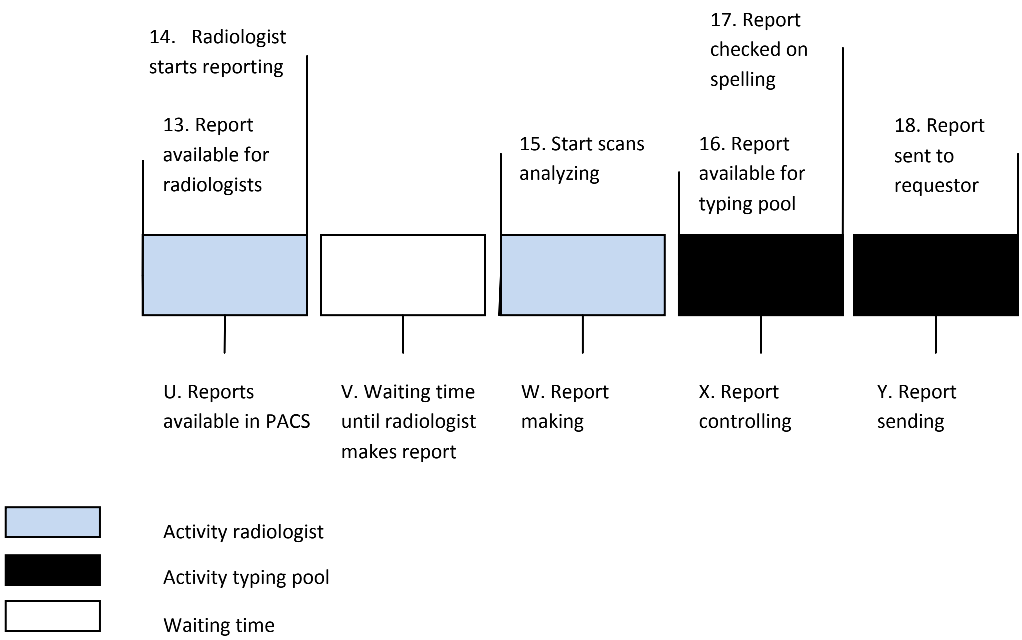
A: Transport time:	The period between patient arrives at administration (1) and Patient in waiting room (2)
B. Waiting room time:	The period between patient in waiting room (2) and patient arrives at MR (3)
C. Patient instructing:	The period between patient arrives at MR (3) and preparation patient
D. Preparation time:	The period between preparation patient and end preparation patient (5).
E. Waiting time until scanner is ready:	The period between end preparation patient (5) and positioning of patient (6)
F. Positioning (scans without contrast):	The period between positioning of patient (6) and start MR scan (8)
F1 Positioning (scans with contrast):	The period between positioning patient (6) and insertion of contrast fluid (7).
G Contrast administered:	The period between insertion of contrast fluid (7) and start MR scan (8)
H. Scan time:	The period between start MR scan (8) and End MR scan (9)
I Finishing Time:	The period between end MR scan (9) and patient ready (10)
J: Table time:	The time between positioning of patient (6) and end scan (9)
K: Patient MR time slot:	The time between patient arrives at MR (3) and patient ready (10)
L: Patient preparation:	The time between patient arrives at MR (3) and positioning of the patient (6)
M: Finishing time:	The time between end scan (9) and patient ready (10)

Planning and realization:





11. Start business time:	A predefined moment where according to the planning the first patient is scheduled.
12. End business time:	A predefined moment where the MR is closed, according to the planning.
N: Business time MR:	The time from the start of the business time (11) and the end of the business time (12)
O: Change time:	The period between patient N ready (10) and arrival at MR of patient N+1.
P. Not planned MR time:	The business time (N) minus time slots patients (K) and change times (O).
Q. Early start:	The period between arrival patient (3) and start business time (11) if arrival is earlier than start business time.
R. Late start:	The period between start business time (11) and arrival MR (3) if arrival is later than start business time.
S. Early end:	The period between patient ready (10) and end business time (12) of the last scheduled patient, if patient ready is earlier than end business time.
T. Overrun:	The period between end business time (12) and patient ready (10) of the last scheduled patient, if patient ready is later than end business time.



13. Report available for radiologist:	The moment when the patient is unregistered in Rados, making it available for the radiologists
14. Radiologist starts reporting:	The first moment when a radiologist has time to start reporting the finished scans.
15. Start scans analyzing:	The moment that a radiologist analyzes a particular scan and makes the report
16. Report available for typing pool:	The moment that a radiologist unregistered there report.
17. Report checked on spelling:	The moment when a typist is ready checking the report on mistakes
18. Report send to requestor:	The moment that the report is sent to their requestor.

U. Reports available in PACS:	The period when the finished scans are unregistered and sent to PACS (13) until the moment that the scans are analyzed (14)
V. Waiting time until radiologist:	The period between radiologist starts reporting (14) and start analyzing a particular scan (15)
W. Report making:	The period that a radiologist reports a particular scan
X. Report controlling:	The period when the typing pool checks the reports on spelling and grammar
Y. Report sending:	The period when the checked report (17) is sent to the requestor (18)

Appendix D

Various ways for capacity and the use of it (van Hoorn et al., 2007)