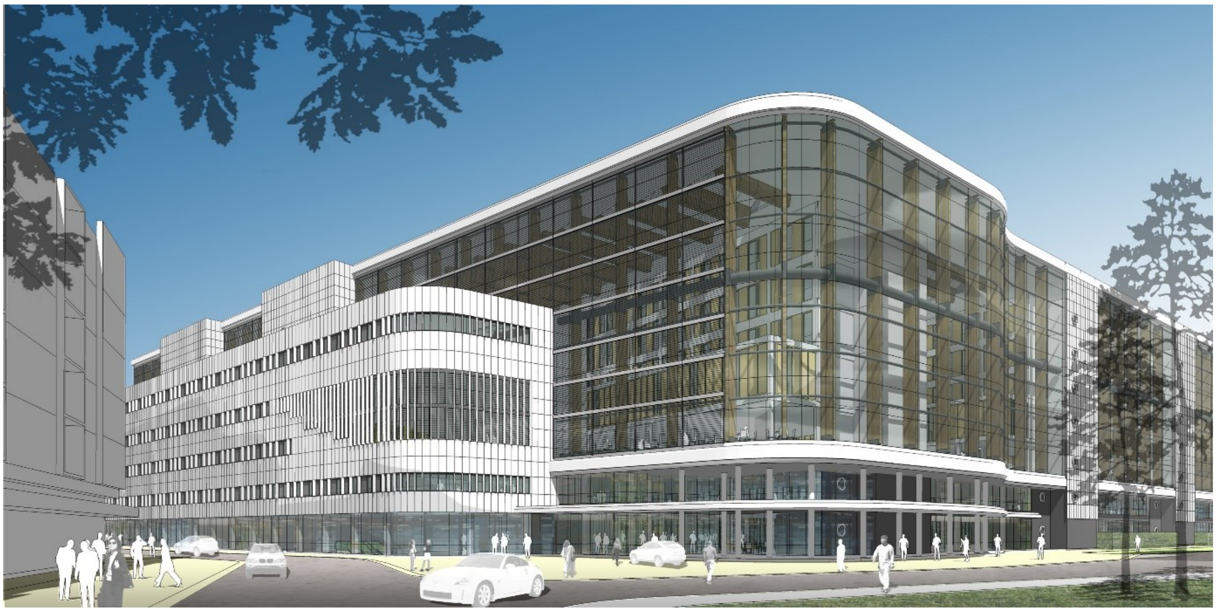
A forecasting model for the requests for MRI scans



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Management summary

Problem description

This study investigates the arrival of patients in need of an MRI at the diagnostics department of a hospital. At this moment it is unclear for the diagnostics department how many patients will arrive with an MRI request and which department they come from. Every patient arrives unannounced, which means that there is also no insight in how busy it will be the next weeks or month. Patients are sent to the diagnostics department by the various specialties, but communication and collaboration between departments is lacking.

Objective of the research

The objective of the research is forecasting the number of MRI requests that will be received by the diagnostics department in the coming six weeks. Such a forecast allows scheduling of patients and a more efficient allocation of personnel.

Approach

To solve this problem we develop a causal forecasting model in Excel, which uses scheduled number of consultations as input variables and predicts the number of MRIs needed in the coming six weeks. This model is partly based on the model developed by Ooms (Ooms, 2014), which is a model for forecasting the amount of OR days by the Orthopedic Department in the Medisch Spectrum Twente (MST). We extensively analyze the historical data of last year by using data on both the outpatient clinics and of the diagnostics department. We hypothesize that the amount of consultations at the outpatient clinic will influences the number of MRI requests for the diagnostics department. We perform a correlation analysis to check this hypothesis.

Measurements/findings

We have used historical data (Jan-Dec 2014) of both the outpatient clinics and the diagnostics department and managed to link 7865 MRI requests (74.6%) to the consultations that led to these MRI requests. We extensively analyzed these data and found that there is indeed a strong correlation between first visit and follow up consultations and a moderate correlation between emergency and peer consultation. The specialties that contribute the most MRIs are: Neurology (27%), Orthopedics (19%), Surgery (12%), General Practitioners (7%), Neurosurgery (7%), Cardiology (4%) and Otorhinolaryngology (4%).

Model

Our forecasting model predicts the number of MRI requests per week in a six week planning horizon. As input values for the model we use two different methods. The first part is a causal forecast method which uses the number of planned First Visit Consultation and Follow up Consultations per week for the departments Neurology, Orthopedics, Surgery, Neurosurgery, Cardiology and Otorhinolaryngology. For the General Practitioners and other specialties we assumed a constant amount of MRI requests per week. For the second part we use the time based methods: Exponential Smoothing and Moving Average which uses the difference between the previous demand and the forecasts of the last five weeks as input values. The outcome of the model shows the forecasted MRI requests for the next six weeks in total and per specialty.

To validate the model we used the number of first visit and follow up consultations in the period of January 2014 to December 2014 (week 2 to week 47). We compared the forecasted outcomes of the model with the dates the diagnostics department scheduled the MRIs. Our forecast model has a Mean Average Percentage Error (MAPE) of 8.0% and a correlation of 0.72.

Conclusions

Our forecast model can be used as a tool to forecast MRI requests and can help the diagnostics department with the allocation of personnel and scheduling of patients in order to reduce the variation in access time. Furthermore it can be used by the diagnostics department as a negotiation and communication method to other specialties to give insight in their variation and to allocate different MRI slots to specialties.

Recommendations

We recommend the MST to keep track of MRI requests, from which specialty the MRI requests come from and when the MRI is requested as it is required to run our model. Using the model without these data is possible, but will decrease its forecasting power. Furthermore we recommend the diagnostics department to get access to the data of the number of consultations specialties have scheduled for the coming six weeks. These data help improve the outcome of the model. We recommend MST not to implement this model immediately, but assess its forecasting strength during a six month shadow run. After a successful implementation this research and model can be adapted for use in other applications as well, such as forecasting of CT requests.

Preface

I got my Bachelor's degree in Technical Medicine in 2012 when I decided to do something else and started with a pre-master Industrial Engineering and Management. After following two years of various courses I started with my Master's Assignment at the MST and 14 months later I am about to finish my Master's thesis. A lot has happened this last period, good and bad things. I was really enthusiastic about this assignment and really wanted to collaborate, but it did not always go as I wanted. Words did not come to me and I had trouble focusing. I doubted my decision to change to another Master, although I knew that I really liked the topics and work field. But I kept writhing and doing research and eventually with a massive sprint at the end, I managed to finish this thesis before starting my next adventure, the Eerst De Klas Traineeship.

I thank my family, friends and Erwin Hans for believing in me and supporting me even when I did not believe in it anymore. I can imaging it was not easy for seeing me struggling, but you are the reason I kept going on. In December 2014 I joined the graduation group of the University of Twente, they helped me by stimulating me to continue with my research and showed me the progress I made; thank you for that. I want to thank Irma de Vries and Marcel Koenderink for answering my questions about the MST and providing me with the correct data.

I really enjoyed solving the problem and building the forecasting model and I am grateful for this opportunity. The model I made can be helpful to the MST and the patients in need of an MRI. I am proud of the end result and I wish to help the MST further with the implementation of this model. In Appendix B – Manual Forecasting ModelAppendix B – Manual Forecasting Model I included a manual for the MST to use and I will be available to answer questions or solve problems.

Enschede, August 2015

Jurre van Schaik

Contents

1 Introduction

This report is about forecasting the number of patients coming from outpatient clinics whom have a referral for an MRI at the diagnostics department in the Medisch Spectrum Twente (MST). With the use of correlation analysis on historical data of the outpatient clinics and the diagnostics department a model has been built to forecast the arrival of patients for up to six weeks in advance.

Chapter 1 is an introduction to the report. After a description about the Medisch Spectrum Twente and the diagnostics department (1.1) we describe the problem (1.2) and come up with the research objective (1.3). Chapter 2 follows with a description of the context and the current performance of the outpatient clinics and the diagnostics department. We do an extensive data analysis of historical data and a correlation analysis in Chapter 3. In Chapter 4 we build the model which will be used at the diagnostics department to predict the arrival of patients who need an MRI. We end with the conclusion in Chapter 5 and the discussion and some recommendations in Chapter 6.

1.1 Medisch Spectrum Twente and diagnostics department

Medisch Spectrum Twente (MST) is with approximately 3700 general employees and 235 medical specialists one of the biggest non-academical hospitals in the Netherlands. On a yearly basis approximately 520.000 outpatients visit the hospital, this results to 35.000 day care admissions. There are around 34.000 ordinary admissions with a total of 175.000 nursing days.

MST is together with five other top teaching hospitals (Canisius-Wilhelmina Hospital, Catharina-hospital, Martini Hospital, Onze Lieve Vrouwe Gasthuis, and St. Antonius Hospital) part of Santeon Hospitals. Together they have one of the biggest laboratories of the Netherlands and they treat around 10 percent of all patients in the Netherlands (academic hospitals included). The collaboration between these hospitals leads, besides knowledge sharing, to new innovations and improved treatment methods.

In the region of Twente, MST has three hospitals and two outpatient clinics. Two of the hospitals are located in Enschede and one in Oldenzaal, the outpatient clinics are located in Haaksbergen and Losser. The catchment in the region of MST is around 264.000 people. In 2016 a new, modern hospital in the center of Enschede with 620 beds will be opened (Medisch Spectrum Twente, 2012). In order to fit into the new hospital, the board wants to reduce 170 fulltime hours. To achieve an economic end result the board wants to get an higher labor productivity and reduce the number of diagnostics and get more procurement savings (Medisch Spectrum Twente, 2013).

The number of patients who rely on the diagnostics department is growing rapidly, especially those in need of an MRI. This results in higher access times for the MRI and higher total throughput time for individual patients in the care pathway. There are several causes for this trend. First of all, extended research has opened up a lot more possibilities for the MRI. What was not possible to scan a few years back because of the quality of the scan or the techniques required, is now a standard procedure. Another reason for these increasing access times could be the growth of the overall number of patients. Patients grow older, and the disorders are more complex due to comorbidity. This also means that the need for medical imaging grows. In contrast, the MRI itself is being further developed (Koenderink, 2010). In 2010, the radiology department of the MST purchased a 3 Teslan MRI, which can produce more detailed scans and uses less scanning time. Through this purchase more capacity is available. Still, access times for an MRI are still growing.

1.2 Problem Description

The number of patients in need of an MRI differ from day to day. The diagnostics department has no insight in the number of patients who will be in need of a diagnostics procedure. It is not known beforehand how many MRI requests will arrive each day, where they come from and therefore how busy it will be in the next week or month. Furthermore, there is little communication between the departments and there is a lack of collaboration. Consultation visit data are available, but it is not being used for this purpose. Insight in the amount of upcoming MRI requests will make scheduling of patients and allocation of employees more efficient.

1.3 Research Objective

The objective of the research is:

To develop a forecasting model that uses consultation visit data to predict upcoming MRI requests for a six week period.

To attain the research objective we will answer the following research questions:

1. What does the current care pathway for patients who arrive at the outpatient clinic and need an MRI at the diagnostics department look like?

Chapter 2 describes the research context of the outpatient clinic and the diagnostics department including its performance such as access time and throughput. We have to know what the different clinical pathways to the diagnostics department are. Also the number of patients and the division of the different inputs have to be known per department per workday.

1. Is there a correlation between the different consultations and the requested MRIs?

Chapter 3 is an extended data analysis which uses data from the outpatients clinics and the diagnostics department to analyze a possible correlation between the number of consultations and the requested

MRIs from these consultations. It also explains what this means and how we may use it to build a model to forecast the arrival of patients at the diagnostics department in need of an MRI.

2. What input, calculations and output do we need to make a model to forecast the arrival of patients at the diagnostics department in need of an MRI.

In Chapter 4 we build our model. We determine what we need to transform this information to build a reliable model which the diagnostics department can use as a tool to indicate the arrival of patients in need of an MRI.

3. What configuration and recommendations would be most beneficial for the diagnostics department??

Chapter 5 describes the conclusions of this research proposal. Chapter 6 describes the discussion and further recommendations to adapt the model.

2 Context Description

This chapter describes the research context. In Section 2.1 we analyze the process by following the care pathway of the patient from outpatient clinic to the diagnostics department. . Section 2.2 describes the planning and control of the outpatient clinic and diagnostics department. In Section 2.3 we research the performance of the system by calculating the access time and throughput of the system. Finally in Section 0 we will end with a conclusion.

2.1 Care Pathway

The care pathway of a patient is the route a patient follows when arriving at the hospital to the point the patient leaves the hospital (Figure 1). In other words a whole care pathway starts with opening a new DOT and ends with closing this DOT. A DOT is a diagnosis-related group used in the Netherlands as the basis of payment for care provided by medical specialists and hospitals (Busse et al., 2013), (Gartner & Kolisch, 2014).

For new patients, the process starts with a referral from the general practitioner to a specialist. The patient makes an appointment by the outpatient clinic or gets an invitation from the outpatient clinic with an appointment date. After visiting the outpatient clinic it may be needed to perform some tests in a lab or use diagnostics. If this is the case an appointment is needed at the lab or diagnostics and at the outpatient clinic afterwards to discuss the results. When treatment with medicine is sufficient, a new recurrent appointment will be made. If surgery is required, the patient will go to the preoperative screening and will have an appointment at the Admissions office. On the day of the surgery, the patient will arrive at the ward. From the ward the patient will go to the holding, the OR and, after the surgery, to the Recovery Room. After waking up, he/she will return to the ward until dismissal. Sometimes the patient will need to go to the diagnostics department again to check whether a drain is placed correctly or to assess the effect of the operation on the tissue. After discharge the patient will make a new appointment with the specialist for a checkup at a later moment.

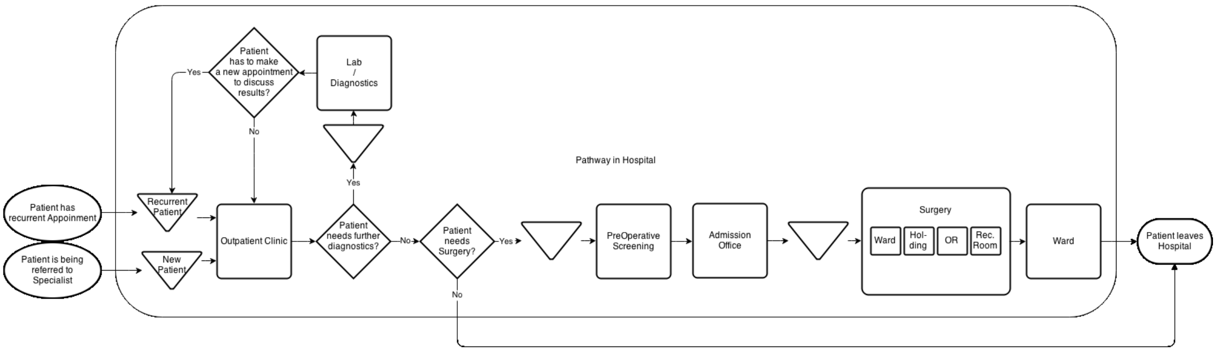

Figure 1 Care Pathway of patients in the MST, divided by follow up and first visit consultation

2.1.1 Outpatient Clinic

In the outpatient clinic new and recurrent patients arrive. New patients are patients new to the care pathway, so those for whom a new DOT starts. Most of these patients arrive after a consult with a general practitioner. Recurrent patients are patients who come for a checkup, patients whose DOT is still opened. The last type of patients are patients who had to go for lab or diagnostics and return to discuss the outcomes with the specialist. These appointments and the walk-in principle appointments at the lab or diagnostics department are considered the same.

Appointments in a hospital are called consults and the period of January 1 to December 16 2014, there were around 475.000 consults out of 43 different specialties (69 including sub-specialties) in the MST. Most specialties have an outpatient clinic. There are in total 13 different consultation codes (Internal Operation Codes). Most of these consultations are being held at the outpatient clinic, some consultations are from the inpatient clinic or the emergency room. These consultations can be divided in 8 different types: First visit consultation, follow up consultation, emergency consultation, peer consultation, multidisciplinary consultation, outside office consultations, co-treatment and others, see Table 1 (Nederlandse Zorgautoriteit, 2011a).

Internal Operation Code	Internal Operation Description	Consultancy type
090613	First visit consultation (old or new patient) by radiotherapist	First Visit
090614	Follow up consultation by radiotherapist	Follow Up
190009	Peer consultation	Peer
190010	Multidisciplinary consultation	Multidisciplinary
190013	Follow up consultation	Follow Up
190015	Emergency consultation at the ER	Emergency
190016	Emergency consultation outside the ER	Emergency
190017	Co-treatment (for IC co-treatment see 039672).	Co-treatment
190049	National neonatal follow-up protocol	Other
190060	First visit consultation	First Visit
190063	Intensive consult for the purpose of extra care	Other
ZCB	Outside office consultations	Outside office
ZHERN	Follow up consultation	Follow Up

Table 1 The consultation types used in the MST in 2014 and the consultation types we use

First visit consultation (FVC)

Type of outpatient consultation whereby the patient consults a specialist for the first time with a new demand for care. This consult is aimed at the determination of a diagnosis and the discussion of the policy conform the (believed) decease and treatment. This type of consultation is always the start of a new clinical pathway.

Follow up or repeat consultation (FUC)

Type of outpatient consultation whereby the patient consults a specialist to discuss the progress of the treatment, the results of (blood) tests or diagnostic imaging, or as a checkup after a treatment.

Emergency consultation (EC)

Face-to-face consultation between a patient and a specialist when there are acute care needs. This can be on the emergency department, but also on a different department.

Peer consultation (PC)

A diagnostic or screening contact of a medical specialist with a patient during a clinical in-take for another specialty, at the request of the responsible medical specialist.

Multidisciplinary consultation (MC)

Type of outpatient consultation with a face-to-face contact between patient and at least two medical specialist of different departments.

Outside office consultations (OOC)

Consultations which takes place after or before office times.

Co-treatment (CTC)

Type of consultation whereby a medical specialist at the request of another department joins the treatment in the same care pathway.

Other consultations (OC)

Other type of consultations, mostly very specialized consultations such as “follow-up of neonatal IC (190049)” and “intensive consultation for the purpose of carefully considering different treatments (190063)”.

2.1.2 Diagnostics department

There are different kind of diagnostic methods in the diagnostics department such as: echo, X-Ray, CT, MRI or Rontgen. This research will focus solely on MRI, though findings may be transferable to other diagnostic methods.

Most specialties use MRI as a diagnostic. MRI or Medical Resonance Imaging is an imaging technique which uses the phenomena of nuclear magnetic resonance. The MRI sends an excitation pulse into the tissue, the atomic nucleus starts to spin around its axis. This movement depends on the strength of the pulse and the sort of atom. The energy the atom nucleus has gained will be released in the form of electromagnetic waves. The MRI has antennas measuring these electromagnetic waves. The amount of radiation is proportional of the amount of the hydrogen density. Together with the relaxation times and the density a 3-D picture can be formed (van Oosterom & Oostendorp, 2008).

Specialty	# Consults	# MRIs	Specialty	# Consults	# MRIs
Radiotherapy	7451	279	Urology	17411	215
Cardiology	33090	466	Otolaryngology	35346	405
Internal Medicine	43478	342	Paediatrics	18314	123
Pulmonology	21277	99	Orthopedics	33181	2049
Gastroenterology	16518	394	Other Specialists	7120	36
Rheumatology	14712	173	Rehabilitation	2763	20
Neurology	24321	2911	Cardiothoracic Surgery	1059	6
Surgery	79565	1284	Psychiatry	7443	1
Dermatology	17807	1	Intensivists	5	10
Ophthalmology	22368	46	Radiology	613	0
Neurosurgery	5938	700	Oral Surgery	17429	48
Gynecology	29454	89	Clinical Neurophysiology	2	2
Plastic Surgery	9458	129	Psychology	5410	0
Anesthesiology	3750	146	General Practitioners	0	759
			Total	***475283***	***10733***

In Table 2 the number of consultations and MRI request in the MST is shown per year and specialty. In the period of January 1 to December 16 2014 almost 11.000 MRIs have been performed.

Specialty	# Consults	# MRIs	Specialty	# Consults	# MRIs
Radiotherapy	7451	279	Urology	17411	215
Cardiology	33090	466	Otolaryngology	35346	405
Internal Medicine	43478	342	Paediatrics	18314	123
Pulmonology	21277	99	Orthopedics	33181	2049
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Plastic Surgery	9458	129	Psychology	5410	0
Anesthesiology	3750	146	General Practitioners	0	759
			Total	***475283***	***10733***

Table 2 Number of consultations per specialty in the MST (Jan-Dec 2014), Business Objects MST

The biggest MRI users are the specialties: Neurology, Orthopedics and Surgery. Together they have more than 58% of the total number of MRI request (see Figure 2), which is around 6244 MRI requests of the total of 10733 requests. It is remarkable that there are more MRIs than consultations for the intensivists. This may be caused by these MRIs being emergency MRIs.

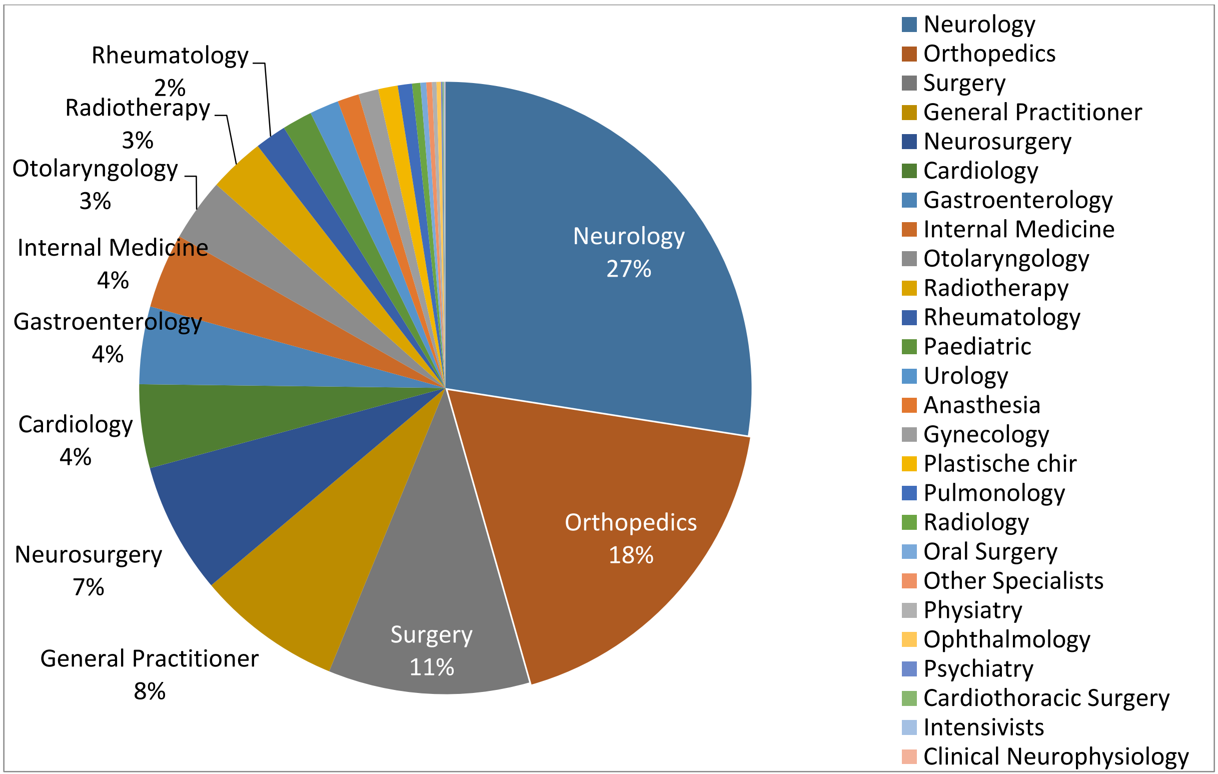


Figure 2 Percentages of MRI requests per specialty in the MST (N=10733 MRIs in the period of Jan-Dec 2014), Business Objects MST

The arrival pattern of patients in need of MRI is complex, because of the various routes to get an MRI. This makes it hard to schedule patients (Green, Savin, & Wang, 2006), (Carpenter, Leemis, Papir, Phillips, & Phillips, 2011), (Godin & Wang, 2010).

2.2 Planning and control

In this section we describe the planning and scheduling of the appointments for patients in the outpatient clinic (Section 2.2.1) as well as in the diagnostics department (Section 2.2.2). In the diagnostics department we also describe the allocation of personnel and the accessibility of the MRIs. There is decision making on different managerial and planning levels involved when running a hospital. To focus our research, this section discusses these different levels and decides on which level the forecasting model could support planning, based on the hierarchical framework of (van Houdenhoven, 2007), Figure 3.

The Managerial domains are:

Medical planning

Medical planning includes the planning of medical activities. These medical decisions are made by specialists and includes diagnoses and treatment. Typical performance indicators are quality of care or research output.

Resource capacity planning

The resource capacity planning deals with efficiently using the hospital's scarce resources, such as personnel, Operation Rooms, or MRIs. Typical performance indicators are utilization, overtime, and underutilization.

Material coordination

Material coordination deals with the distribution of all kinds of materials to support the primary process. It includes functions like inventory control and purchasing. Typical performance indicators are service rate and response time.

Financial planning

Financial planning includes all functions regarding hospital finances, such as financial planning and control and investment planning. Typical performance indicators are profitability, liquidity and solvability.

	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

Figure 3 Framework for hospital planning and control (van Houdenhoven, 2007)

The four hierarchical levels used in this framework are:

Strategic planning

Strategic planning is planning based on long-term objectives or mission statements of an organization. For example the design of building a new hospital, where to allocate the diagnostics department and whether or not to acquire an extra MRI scanner. These decisions are mostly over the course of years.

Tactical planning

Tactical planning is based on medium-term objectives and deals with actual patients. For example how many and where do I allocate the personnel operating the MRI scanner? How many slots do I reserve for emergency patients? These decisions are mostly over the course of weeks or months.

Operational offline planning

Operational offline planning deals with the day-to-day control of expected activities. For example the scheduling patients who need an MRI. These decisions are mostly over the course of days or weeks.

Operational online planning

Operational online planning is the last hierarchical level. It involves all control mechanisms that deals with monitoring and reacting to unforeseen events. For example an emergency patient arrives and needs an MRI, or dealing with a no show. These decisions are mostly over the course of minutes or hours.

In our research we will focus on the Resource Capacity planning on an offline operational level.

2.2.1 Planning in the Outpatient Clinic

For the planning in the outpatient clinic we will focus on operational offline and online planning. There is a difference in planning at the outpatient clinic for first visit consultations and follow up consultations. There are also differences between the outpatient clinics, every specialty has its own way of scheduling. This research focuses on the overall method.

Patients who want a first visit consultation have to get a referral from the General Practitioner. The General Practitioner sends the referral to the outpatient clinic via fax or digital means. The outpatient clinic checks the referral and selects the best specialist and consultation matching the demand of the patient. The patients gets a proposal for an appointment date via the mail. The date of this proposal is based on a first come first serve principle. A new appointment has to be made when a patient is not available this date.

If a patient needs a follow up consultation after the first visit consultation, the patient goes to the desk and schedules a new appointment. The time for this follow up consultations is often shorter than the first visit consultation, since the anamnesis is already done. This is also done on first come first serve principle, but with the same specialist.

When the outpatient clinic gets an emergency patient, it depends on the type of emergency when the patient is helped. There are no special emergency block reserved, but the patient just gets added to the queue.

2.2.2 Planning and scheduling in the diagnostics department

In this section we will focus on operational offline and online planning. Section 2.3 and Chapter 3 will focus on strategic planning and tactical planning.

The scheduling of appointments at MST's diagnostics department is currently being done in Excel by the MRI administration. The administration gets paper forms from the other specialties or a phone call to schedule a patient. A patient gets an appointment in a predefined block corresponding to his medical treatment. The Head specialist Radiology determines when and which types of blocks to book. If a block is booked, only that type of scan is allowed (e.g. the upper extremities). As a result the access time for MRI can differ between blocks and specialties. Within a block the scheduling is done on a First Come First Serve (FCFS) principle, with the obvious exception of emergency patients. Some empty spots remain in the roster, and eventually these are being filled by the specialist or the laboratory technician for emergency patients.

The duration of an appointment is based on the actual scan time plus the time a patient has to change (7 minutes). These times are fixed for every type of scan, which means that it can be possible that an appointment does not fit in a block. This will leave a gap into the schedule.

Emergency patients will be planned 24 hours in advance in the reserved emergency slots. Real emergencies are done between regular blocks.

2.3 Performance

In this section we describe the performance of outpatient clinic and diagnostics department, using access time (Section 2.3.1) and the throughput of the care pathway (Section 2.3.2).

2.3.1 Access time

The access time is the time between the MRI request and the actual appointment and scan. Since 2005 there is a norm called: '*treeknorm*'. This *treeknorm* has been conceived and implemented by health insurance companies and health care providers as a solution to increasing waiting lists. The name suggests that the *treeknorm* is a norm, though not true. There are no consequences when the *treeknorm* is being exceeded and therefore the treeknorm is more of a directive (vergelijken-zorgverzekering.net, 2015). Since 2010 all health care providers are obligated to publish their access times (Nederlandse Zorgautoriteit, 2011). According to the *treeknorm* for diagnostics the access time should be no more than 4 weeks. The access time of MRI in the MST from July 2013 to May 2014 can be seen in Figure 4. The access time is growing in the last few months and exceeding the *treeknorm* regularly (Medisch Spectrum Twente, 2014).

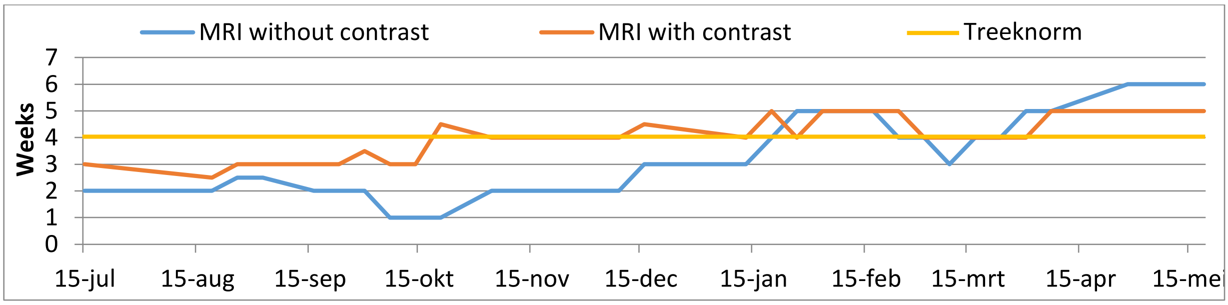


Figure 4 Access time of the MRI with and without contrast in the MST including the *Treeknorm* (Jul-May 2013), RADOS MST

The access time of the MRI is partly based upon supply and demand. In the Netherlands it is allowed to go to the hospital you like, even if you only want an MRI. When the demand is high, the access time of the MRI will grow, which leads to patients leaving the hospital to take an MRI elsewhere, for example to the ZGT (*Ziekenhuis Groep Twente*) or to an independent MRI Center. The same is happening the other way around.

2.3.2 Throughput

In the MST in the period of January 1 to December 16 2014, there were around 475.000 consultations. These resulted in almost 11.000 MRI requests (Table 3). Neurology and Neurosurgery generate the most MRI request per consult (12 percent) followed with Orthopedics (6 percent). Intensivist and clinical neurophysiology are not relevant, since the number of MRIs and consulted are too low to be of any interest. The high share values of these specialties are probably the results of emergency MRIs. Neurosurgery stands on the fifth place for most MRI request generated, therefore we will mainly focus on Neurology and Orthopedics as the most promising specialty.

Specialty	# Consults	# MRIs	Share	Specialty	# Consults	# MRIs	Share
Radiotherapy	7451	279	4%	Urology	17411	215	1%
Cardiology	33090	466	1%	Otolaryngology	35346	405	1%
Internal Medicine	43478	342	1%	Paediatrics	18314	123	1%
Pulmonology	21277	99	0%	Orthopedics	33181	2049	6%
Gastroenterology	16518	394	2%	Other Specialists	7120	36	1%
Rheumatology	14712	173	1%	Rehabilitation	2763	20	1%
Neurology	24321	2911	12%	Cardiothoracic Surgery	1059	6	1%
Surgery	79565	1284	2%	Psychiatry	7443	1	0%
Dermatology	17807	1	0%	Intensivists	5	10	200%
Ophthalmology	22368	46	0%	Radiology	613	0	0%
Neurosurgery	5938	700	12%	Oral Surgery	17429	48	0%
Gynecology	29454	89	0%	Clinical Neurophysiology	2	2	100%
Plastic Surgery	9458	129	1%	Psychology	5410	0	0%
Anesthesiology	3750	146	4%	General Practitioners	0	759	0%
				Total	***475283***	***10733***	***2%***

Table 3 Number of consultations per specialty per year (1 Jan 2014 to 16 Dec 2014), the number of MRI request as well as the ratio between number of consultations and the number of MRI requests per specialty, Business Objects MST

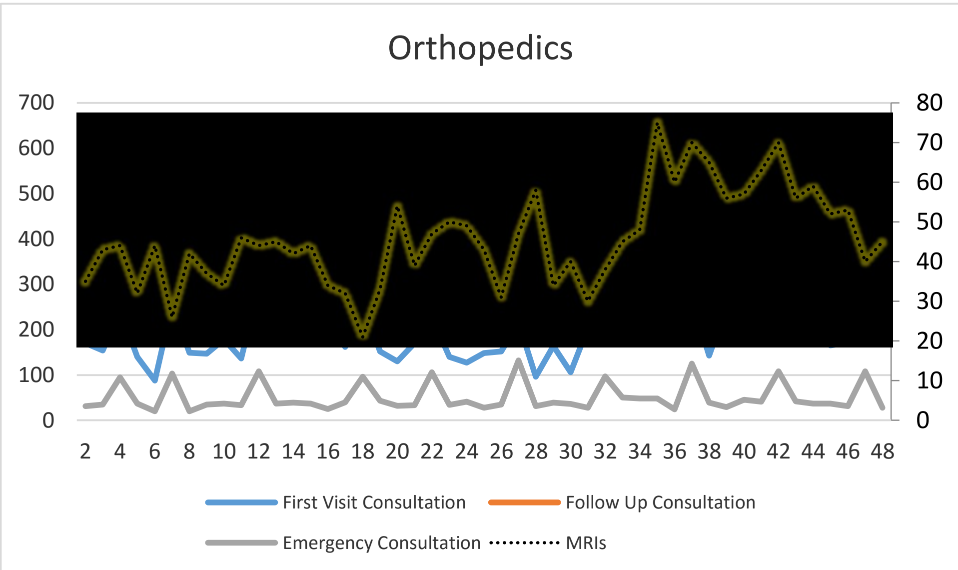


Figure 5 and Figure 6

Figure 6 shows the top two MRI appointment contributors, Neurology and Orthopedics, and the division of the different types of consultations, as well as the number of MRIs (secondary axis) per week. Remarkably there does not seem to be a relation between the amount of consultations and the number of MRIs.

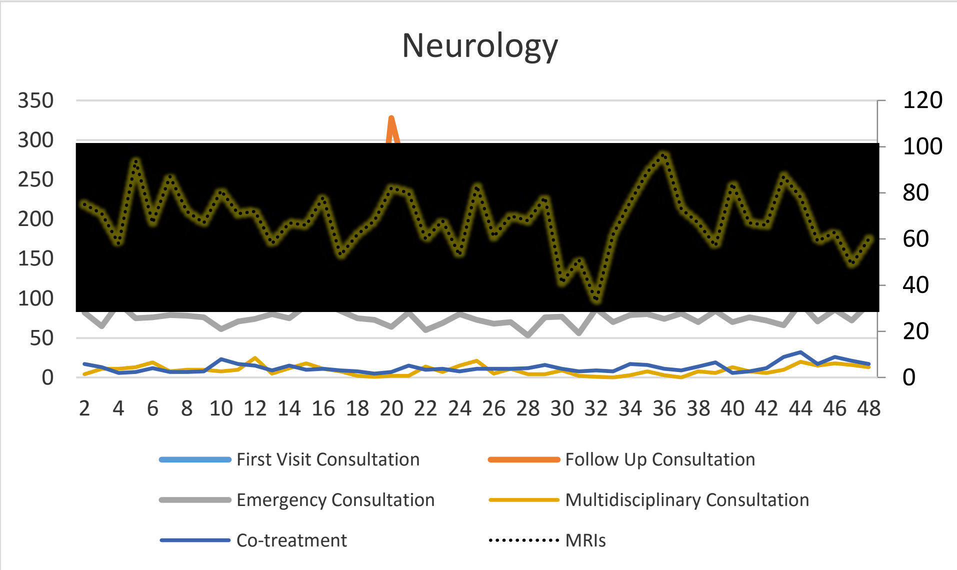


Figure 5 Number of consultations and MRIs per week of the Neurology Department per consultation type (Jan-Dec 2014)

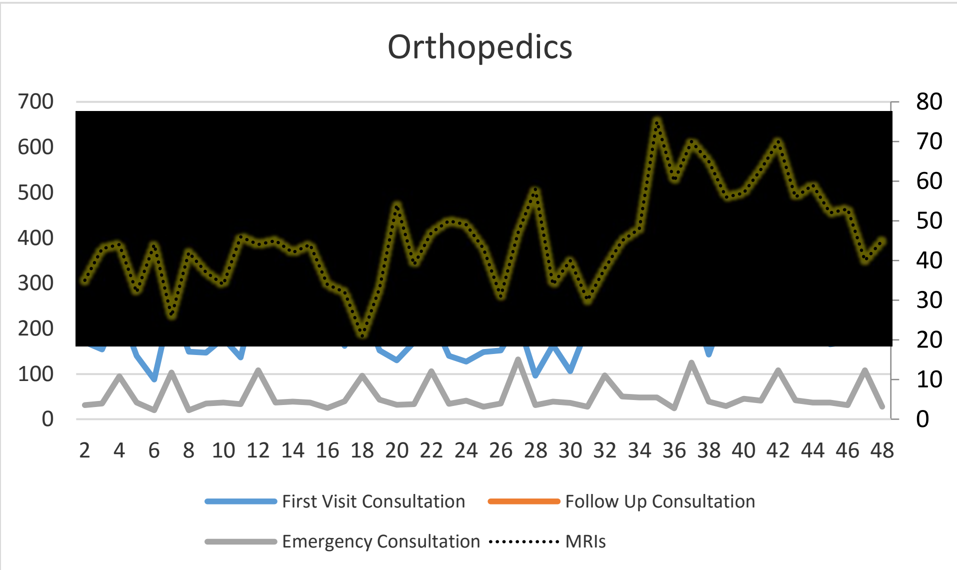


Figure 6 Number of consultations and MRIs per week of the Orthopedics Department per consultation type (Jan-Dec 2014)

An explanation for the absence of a pattern lies in numerous causes. First, there is difference in access time between the departments, although this does not seem to vary very much. The access times are based on averages, however looking at the dataset shows us that there is a great difference between these access times. Most consultations do not result in an MRI request. To say something about the access time and forecasting we have to filter only the consultations which do result in an MRI. Second, the term access time is incorrectly used. Access time should be the first possible appointment time after an MRI request, though in practice the patient has a great influence on the date of the MRI. Patients want to plan the appointment on a convenient time for them, which is not always the first available option. Lastly, there are also MRI requests which are planned well in advance. Most of these MRIs probably come from Follow up consultations, since they request a checkup MRI for the patient to monitor the patient's recovery after a period of, say, six months.

With these different sources of noise in the data, it is difficult to forecast the number of patients who arrive at the diagnostics department for an MRI with the current data.

2.4 Conclusion

The access time of the MRI is exceeding the *treeknorm* regularly, this is probably the result of the variation of the number of MRIs between weeks. We compared these number of MRI scans with the number of consultations, however, no pattern was found. The only conclusion we could draw is that there is also a lot of variation in the number of consultations. So far, it is not possible to say something about the forecasting of the number of patients who arrive at the diagnostics department for an MRI. In Chapter 3 we will do a more extensive data analysis to try to generate the forecasting method to predict the arrival of patients.

3 Extensive Data Analysis

In this chapter we perform an extensive data analysis of the data generated from the outpatient clinic and the diagnostics department. First we focus on the data of the outpatient clinic, using the number of consultations per specialty per week per consultation type (Section 3.1). Second we use the data of the diagnostics department to determine from which specialty and consultation type the MRI has been requested (Section **Fout! Verwijzingsbron niet gevonden.**). In Section 3.3 we will perform a correlation analysis to check if there is a correlation between the number of consultations and the number of MRI requests per specialty and consultation type. The explanatory factors will be discussed in the Section 3.4.

3.1 Outpatient Clinic

The outpatient clinic data is a collection of all consultations from all specialties in the period from January 1 2014 to December 16 2014 in the MST. We started by sorting the data according to specialty and consultation type per week. As discussed in Chapter 2 we directly combined the duplicate consultation types. Some consultation types are sparsely used by a specialty in comparison with the other consultation types. We used a trade-off to determine which data and consultation type we will take into account. The trade-off is calculated as follows: if the total number of a specific consultations type is more than 1% of the total consultations within a specialty, we will use the data. Figure 7 shows the results of the analysis of the outpatient clinic for Neurology.

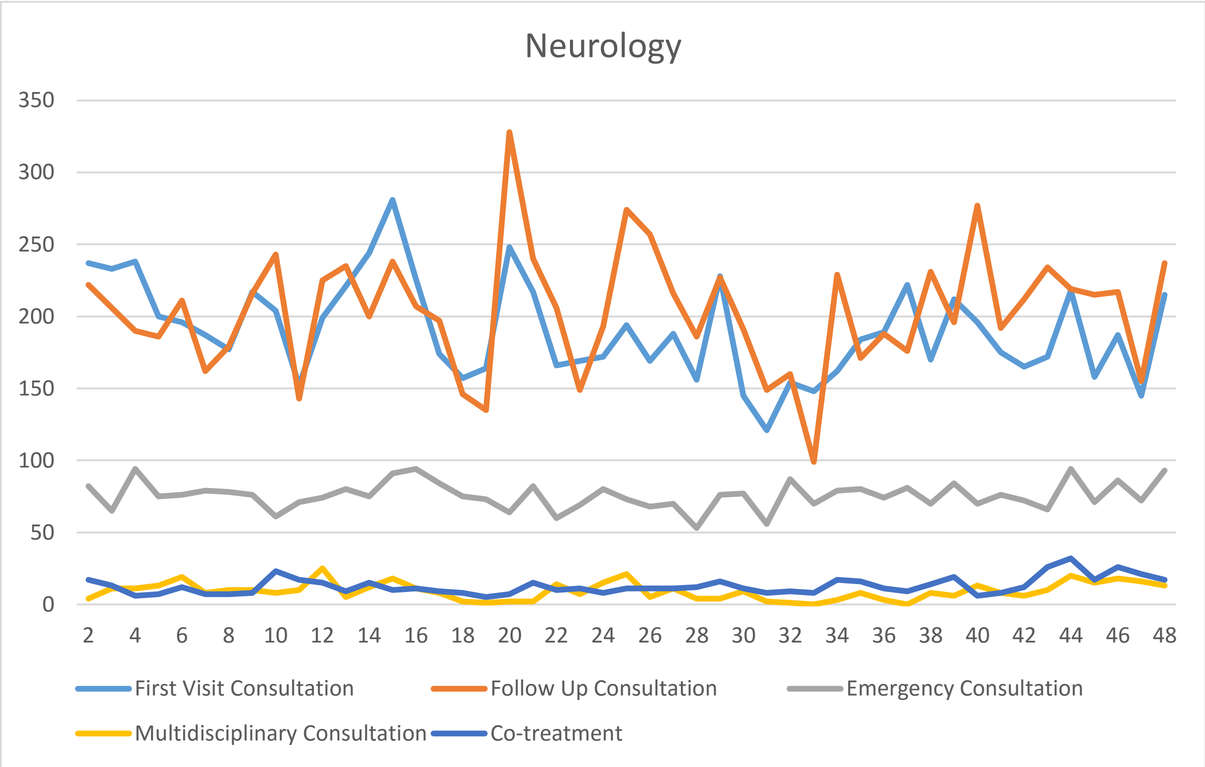


Figure 7 Number of consultations per week and consultation type of the Neurology Department (Jan-Dec 2014)

3.2 Diagnostics department

The dataset of the diagnostics department consists of all performed MRI in the period of January 1 2014 to December 1 2014. Included are the MRI type, execution date, patient number and the date the appointment has been made by the diagnostics department. In this time period a total of 10733 MRIs have been performed by the diagnostics department. The number of performed MRIs of the top 5 contributors of MRI requests per week can be seen in Figure 8. There is a lot of variance for each specialty over the weeks. The drop in week 30 to 33 is the summer holiday, here the number of total performed MRIs is lower than in other weeks. To analyze if there is a balance between the total numbers of MRIs and the performed MRIs per specialty and week, we calculated the percentage of these performed MRIs (Figure 9). The variance in Figure 9 is less than in Figure 8. There is however still a lot of variance.

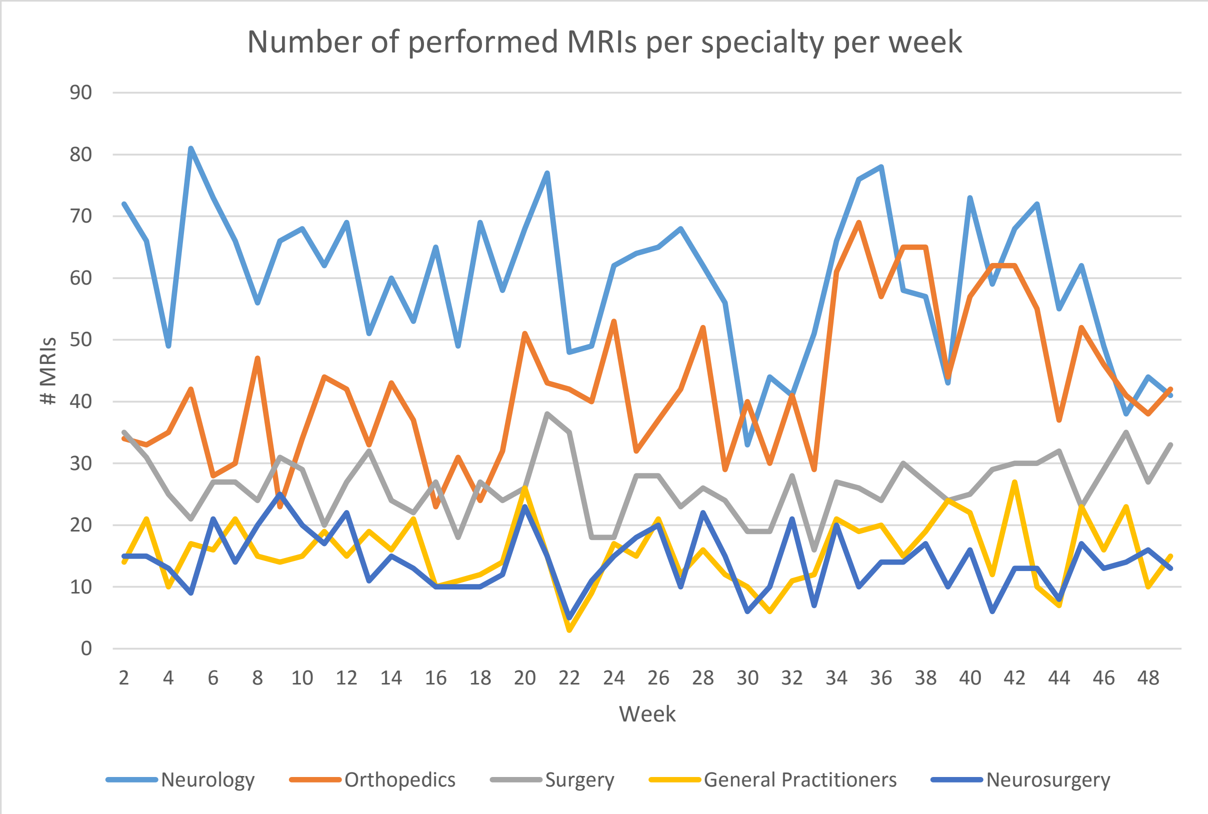


Figure 8 Number of performed MRIs per week for the Neurology, Orthopedics, Surgery, Neurosurgery Department and the General Practitioners (Jan-Dec 2014)

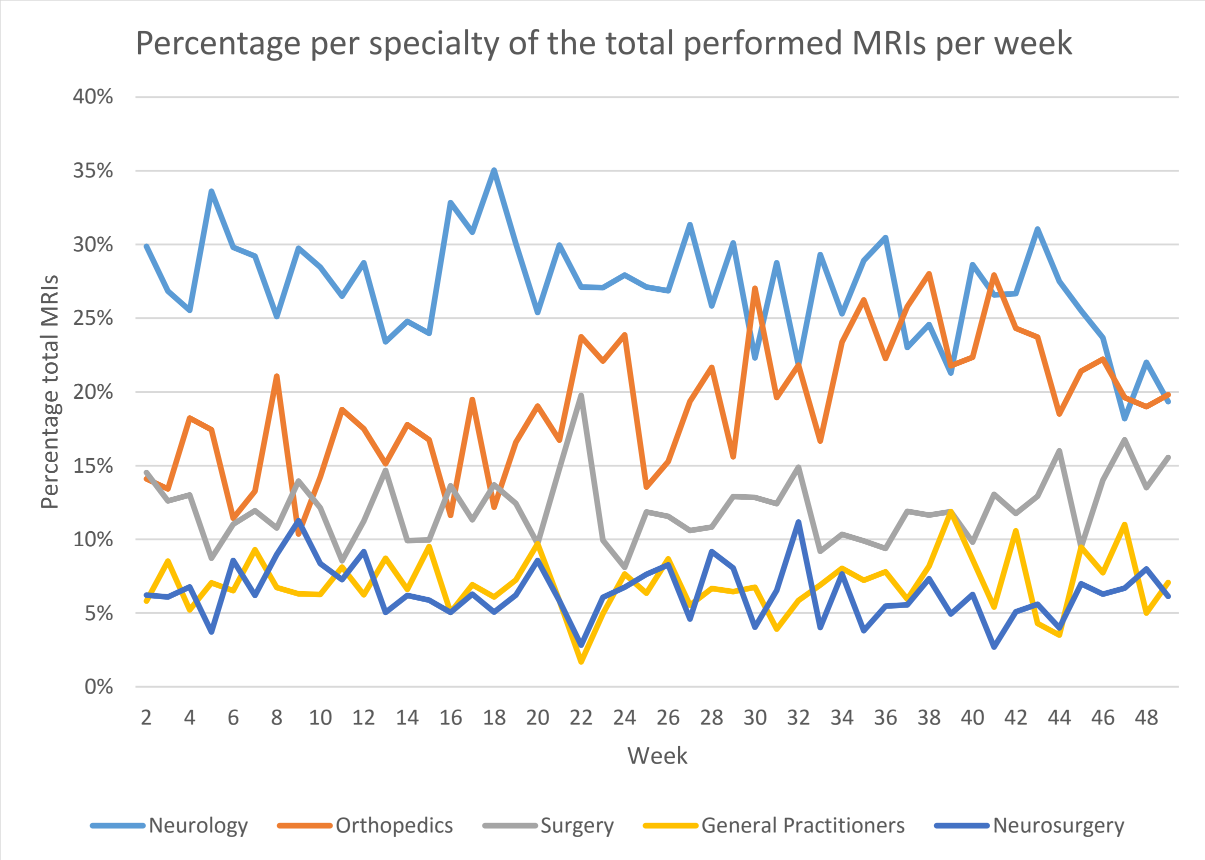


Figure 9 Percentage of performed MRIs per week for the Neurology, Orthopedics, Surgery, Neurosurgery Department and the General Practitioners (Jan-Dec 2014)

We can conclude from Figure 9 that the variance is partly but not completely caused by the total number of performed MRIs at the diagnostics department. This means that a lot of variance comes from the outpatient clinics, which we also saw in Figure 7.

3.3 Correlation Analysis

In Section **Fout! Verwijzingsbron niet gevonden.** we concluded that there might not be a pattern between the number of consultations and the amount of requested MRIs. A correlation analysis needs to be done to check if this conclusion is correct. To do a proper correlation analysis we have to make an overview of the requested MRIs per specialty and consultation type per week. Therefore we need to know which consultation led to an MRI request.

The datasets cannot be compared with each other since they use different internal operation codes. For example, the dataset from the diagnostics department shows patient 00030609 with code M3-86, while the data from the outpatient clinic uses for the same appointment three CTG-codes: 81092, 83190, and 83290. This results in duplicates (Table 4) which we will have to delete. To do this we used the data of the outpatient clinic and added the column "Appointment made by diagnostics department". From the data from the diagnostics department we could fill in the date and time the appointment was scheduled by the diagnostics department. Subsequently, we sorted the dataset by patient number. All appointments which have the same patient number and planning date have to be duplicates and were deleted. A total of 2646 "duplicates" have been removed and 10536 MRI appointments remain in the dataset.

Interne Ve	Interne Ve	Maand	Uitvoerdatum	Verr Interr	Verr Interr	Verr Patier	Week	Weekdag	Hoeveelhe	afspraak gemaakt door radiologie	SLEUTEL	DUBBELCOI
081092	MRI herser	5	1-5-2014	Neurologie	Radiologie	00021243	18	4	1	7-4-2014	0002124341760	0
081093	MRI herser	2	2-2-2014	Neurologie	Radiologie	00024714	5	7	1	29-1-2014	0002471441672	0
081092	MRI herser	4	28-4-2014	Neurologie	Radiologie	00024963	18	1	1		0002496341757	0
089090	MRI heup(	9	16-9-2014	Orthopedi	Radiologie	00027579	38	2	1	4-9-2014	0002757941898	0
087090	MRI abdor	10	17-10-2014	Radiothera	Radiologie	00027648	42	5	1	10-10-2014	0002764841929	0
089090	MRI heup(	11	16-11-2014	Orthopedi	Radiologie	00028525	46	7	1	11-11-2014	0002852541959	0
089090	MRI heup(	2	11-2-2014	Orthopedi	Radiologie	00028616	7	2	1	20-1-2014	0002861641681	0
089090	MRI heup(	7	28-7-2014	Huisartsen	Radiologie	00029309	31	1	1	23-6-2014	0002930941848	0
085190	MRI-hart.	10	15-10-2014	Cardiologi	Radiologie	00029651	42	3	1	3-9-2014	0002965141927	0
081093	MRI herser	7	18-7-2014	Neurologie	Radiologie	00030131	29	5	1	16-7-2014	0003013141838	0
081092	MRI herser	1	7-1-2014	Neurologie	Radiologie	00030609	2	2	1	20-11-2013	0003060941646	0
083190	MRI cervic	1	7-1-2014	Neurologie	Radiologie	00030609	2	2	1	20-11-2013	0003060941646	1
083290	MRI thora	1	7-1-2014	Neurologie	Radiologie	00030609	2	2	1	20-11-2013	0003060941646	1
081093	MRI herser	10	7-10-2014	Neurologie	Radiologie	00031882	41	2	1	26-9-2014	0003188241919	0
083190	MRI cervic	10	7-10-2014	Neurologie	Radiologie	00031882	41	2	1	26-9-2014	0003188241919	1
081093	MRI herser	2	24-2-2014	Neurologie	Radiologie	00033817	9	1	1	21-2-2014	0003381741694	0
089090	MRI heup(	9	21-9-2014	Orthopedi	Radiologie	00035409	38	7	1	4-9-2014	0003540941903	0

Table 4 Screen of a duplicate appointment for patient 00030609 with CTG-codes 081092, 083190 and 083290 but only one MRI on 20-11-2013

Now that the duplicates have been removed, we have to find the consultation which led to the performed MRI. Once we know which consultation was the predecessor of an MRI scan, we also know what type the consultation was. This is needed to make a forecasting model.

In the period of January 1 2014 to December 1 2014, the MST held 475.000 consultations and had 120.000 unique patients, so every patients had on average 4 consultations in a year. In Section 2.3.1 we discussed that the access time cannot be known for certain, so we cannot use access time as a method to determine the correct consultation. Since most patients have more than one consultation, it is not sufficient to take the first consultation before an MRI. It is a good indicator, but some MRI appointments are made long in advance. To be more certain which consultation led to the MRI request, we used the dataset of the diagnostics department including the date and time of the planning of the appointment. This is often not the same date as the actual consultation date, because the communication in the MST still goes via paper forms and not every request will be scheduled as soon as possible, so there can be some days between those two dates. If the date of a consultation is before the MRI, but after the date when the appointment was scheduled, it most probably is the consultation which led to the MRI request. For these cases (N=1338), we took the last consultation before the date of scheduling.

For 365 inpatient clinic consultations, there was not a planning date for the diagnostics department. This would result in a loss of data, therefore we used an access time based on practice of 2 days. This is a common access time for MRI requests coming from the inpatient clinic.

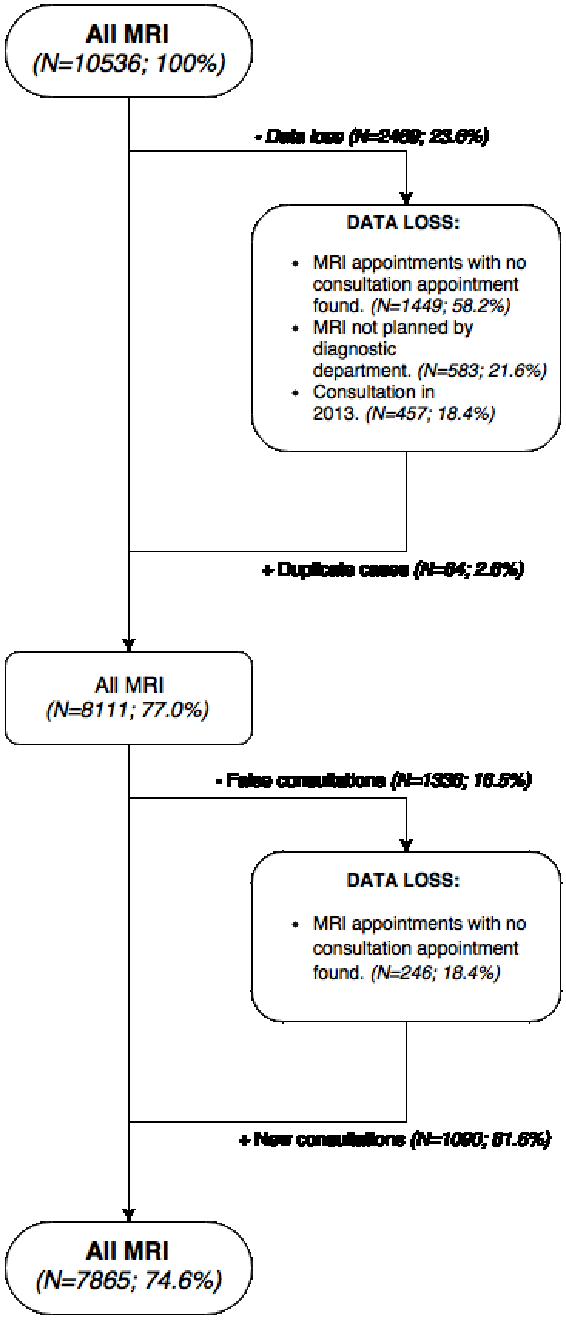


Figure 10 Overview of the number of appointments that could be linked

It was not possible to link all the appointments (Figure 10). Out of the 10536 MRI appointments 1449 (13.8%) found no consultation date before the execution date and 457 (4.3%) were MRI requests from 2013. These had to be deleted as well since we did not have those data. 583 appointments were for some reason not planned by the diagnostics department, these might have been emergency cases. 64

appointments had more than one factor, which leads to a total loss of 1449 + 457 + 583 – 64 = 2425 MRIs where we could not say with a certainty which consultation led to those particular MRI requests.

Using the planning date the diagnostics department used (as discussed previously) as a check, resulted in 1338 cases which had to be recalculated. These cases were all appointments of consultations which were held later than the date the diagnostics department planned the MRI, which is not possible. That is why we used the first consultation before the planning date. This resulted in another 246 items of data loss, due to not enough information about the appointments (consultations which were held in 2013). At the end of the process of cleaning up the 10536 available appointments, we can use 7865 (74.6%) of them for further analyses.

The diagnostics department sometimes combines different MRIs appointments. The 7865 MRI appointments correspond to 8030 MRI scans. Based on these 8030 MRIs we could calculate the number of requested MRIs per specialty, per consult type per week. If we focus for example on Orthopedics we see that in week 4 26 consultations required an MRI (Figure 11). We have to keep in mind that due to the aforementioned data loss of 25% this probably should be somewhat higher than 26 consultations. Figure 11 shows clearly that there is a high variance in the number of requested MRIs for Orthopedics, especially for the requests that came from first visit consultation. The variance in follow up consultations is smaller. This trend is also visible in the other specialties.

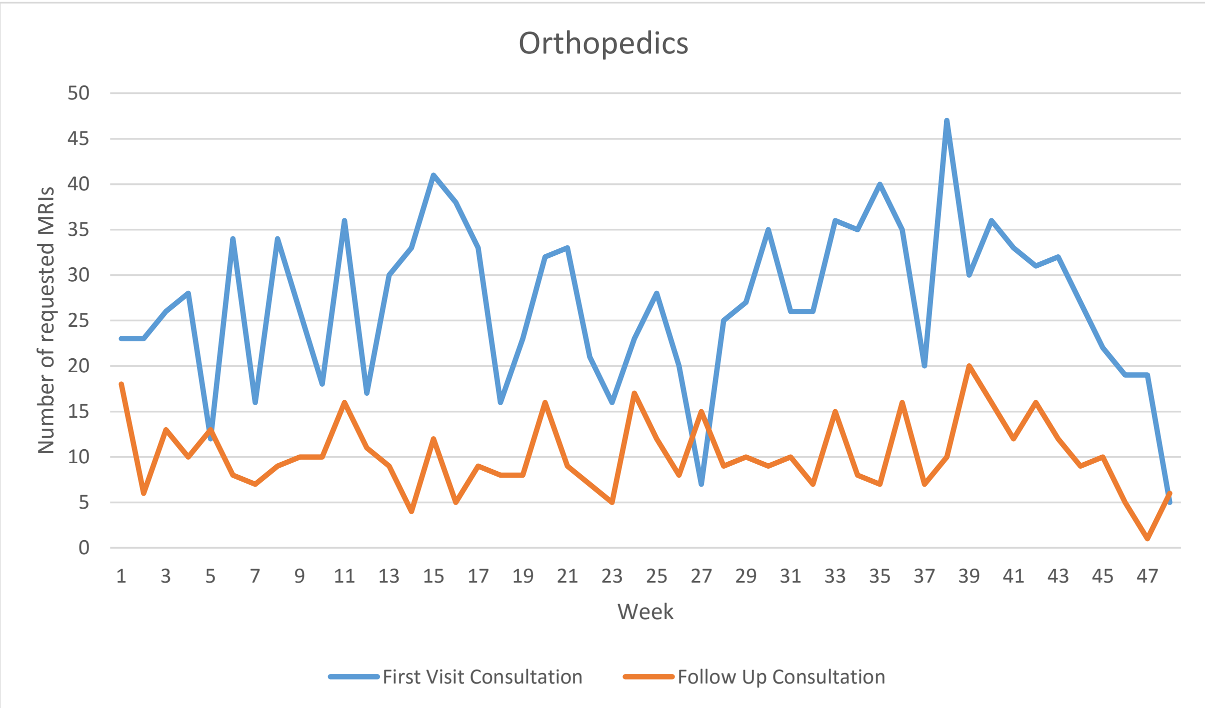


Figure 11 Number of requested MRIs coming from the first visit and follow up consultations of the Orthopedics Department (Jan-Dec 2014)

Since we now know all the consultations per consultation type per specliaty per week as well as how much of these consultations requested an MRI, we can do the correlation analysis. We assume that there is a positive correlation between the consultations and the number of requested MRIs. This means that when a specialty decides to have more consultations in one week, the number of requested MRI from that specialty also increase for that week. Table 5 shows the different correlation types we use.

Value of the Correlation Coefficient	Strength of Correlation
1	Perfect
0.7 - 0.9	Strong
0.4 - 0.6	Moderate
0.1 - 0.3	Weak
0	Zero

Table 5 The correlation coefficient and the strength of the correlation we used divided in 5 categories

Table 6 shows the strength of the correlation of all specialties combined, for each consultation type and overall. The correlation analysis shows a strong correlation for First Visit Consultation and a Follow Up Consultations. Emergency and Peer Consultation show a positive weak correlation, this is probably due to the low number of consultations and resulted MRI requests from these types. The total of all specialties and consultation types shows a correlation of 0.8. This high number is the result of combining all consultations and correlate this with all MRI requests. This reduces the variances and therefore increases the correlation.

Total		
	First Visit Consultation	0.7
	Follow Up Consultation	0.7
	Emergency Consultation	0.3
	Peer Consultation	0.2
	Multidisciplinary Consultation	0.0
	Outside Office Consultation	0.2
	Co-treatment	0.0
	Other Consultation	0.1
	Total	0.8

Table 6 Correlation values of the different consultation types of all specialties combined

When focusing at the individual specialties (for example Orthopedics and Neurology (Table 7)) we see that the first visit consultation of the Neurology department has a strong correlation (0.8) and the follow up consultation a moderate correlation (0.5). The results for Orthopedics are a bit lower, first visit consultation has a moderate correlation (0.6), and follow up consultation a weak correlation (0.3). There is no correlation for emergency consultation for the specialty Orthopedics.

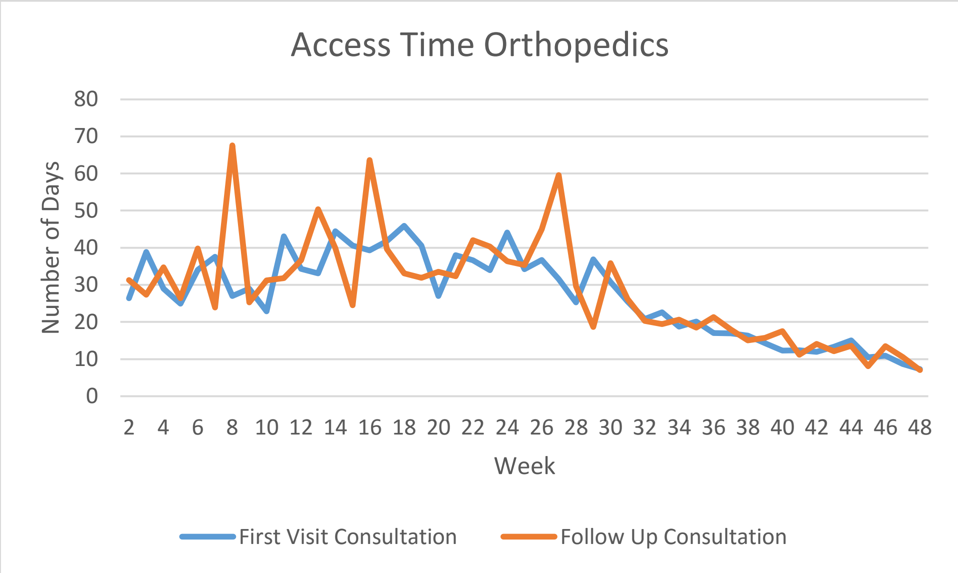
Neurology		
	First Visit Consultation	0.8
	Follow Up Consultation	0.5
	Emergency Consultation	0.3
	Peer Consultation	0.1
	Multidisciplinary Consultation	0.2
	Outside Office Consultation	
	Co-treatment	0.3
	Other Consultation	
	Total	0.6
Orthopedics		
	First Visit Consultation	0.6
	Follow Up Consultation	0.3
	Emergency Consultation	0.0
	Peer Consultation	
	Multidisciplinary Consultation	
	Outside Office Consultation	
	Co-treatment	
	Other Consultation	
	Total	0.5

Table 7 Correlation values between the number of consultations and the number of subsequent MRI requests for the different consultation types of the Neurology and the Orthopedics Department

There is also a strong correlation for Neurosurgery (0.7), a moderate correlation for Surgery (0.6) and Otorhinolaryngology (0.6) and a weak correlation for Cardiology (0.3).

3.4 Explanatory Factors

We now know that there is a correlation between the number of consultations and the requested MRIs, but there is still a lot of variance and there is a great difference between first visit consultation and the follow up consultation with relation to the access time. One would expect that the access time for follow up consultations is longer than that of first visit consultations. With the current datasets we can determine what these access times are. We used the number of days between the time the MRI has been requested and the time the MRI has been performed. The access times are based on average access time in days and are determined for each week (Figure 12)



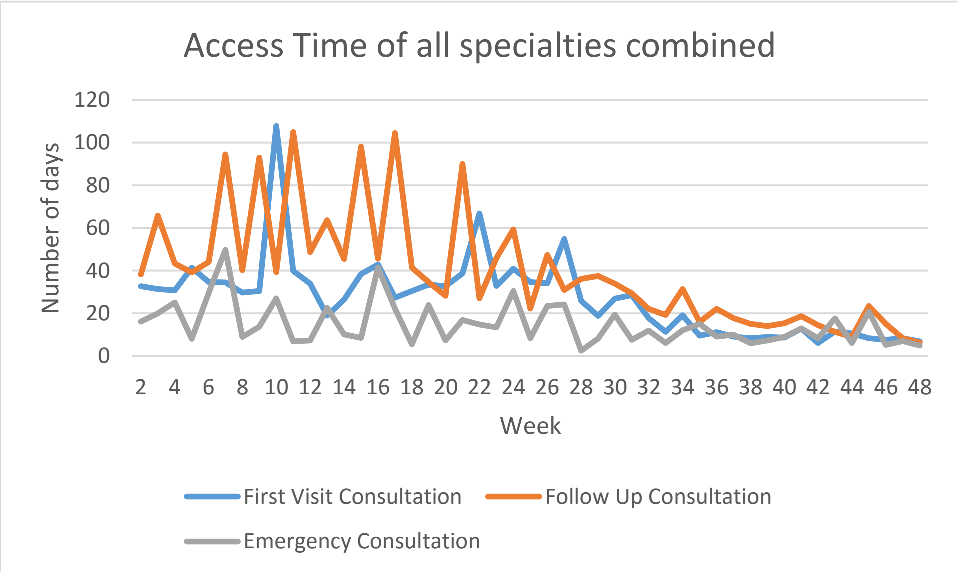


Figure 12 Access Time in number of days per week for each consultation type of the Orthopedics Department and all specialties combined (Jan-Dec 2014)

There are great differences in the access times over the weeks. These could be explained by the phenomenon that when the waiting time of the operation room is high, more surgeons will come to operate to reduce this waiting time. These surgeons are also the people who take the consultations, therefore the waiting list for outpatient clinic will grow. This leads to less consultations and, due to the correlation between them, less MRI requests and lower access times. When the waiting time for the outpatient clinic is too high, or the waiting time for the OR too small, more specialists will help to reduce the outpatient clinic waiting list. This will result in more consultations, so more MRI requests and a higher access time for an MRI.

This effect should be highest with first visit consultations, because most MRI appointments will be planned as soon as possible. However Figure 12 shows that the variation for the follow up consultations and not first visit consultation is higher. This is due to another cause: the access time is much more variable because of the fact that some of the MRI appointments are being made far in advance. These outliers cause for a lot of variance. The effect of the bullwhip effect of the specialist is still higher in first visit consultations, but less visible because of the outliers from follow up consultations.

Remarkable is the almost linear decrease from week 30 onwards (Figure 12), which is visible in the specialty Orthopedics and in all specialties combined. In our research we only use coupled appointments, so all appointments contain an outpatient clinic consultation and the appointment of the performed MRI. Our data runs to Dec 2014, which means that at the end of the period only appointments with a lower access time can occur. It could be that there are consultations with an MRI appointments in Dec 2014 and beyond, but we do not have these data and therefore cannot calculate these longer access times.

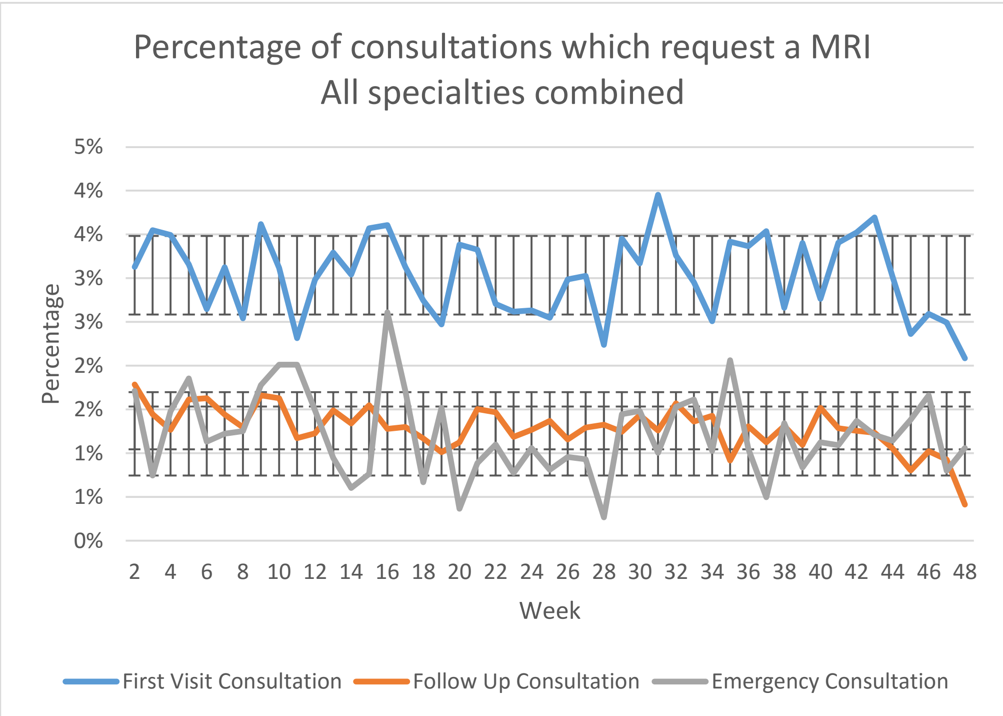


Figure 13 Percentage of the number of consultations which led to an MRI request per week and consultation type for all specialties combined (Jan-Dec 2014)

Since we know that there is a correlation between the consultations and the requested MRIs from these consultations, we can analyze if it is possible to use the percentage of the consultations requesting an MRI as a forecasting value. Figure 13 shows us this percentage for all specialties. This percentage is very stable over time with a small standard deviation (0.4%). The number of data points is very high, since all the specialties are combined, and therefore the standard deviation is low. Focusing on a single specialty, for example Orthopedics, is showing not only a higher percentage, but also a higher standard deviation (3.9% for First Visit Consultation and 1.2% for Follow up Consultation) (Figure 14).

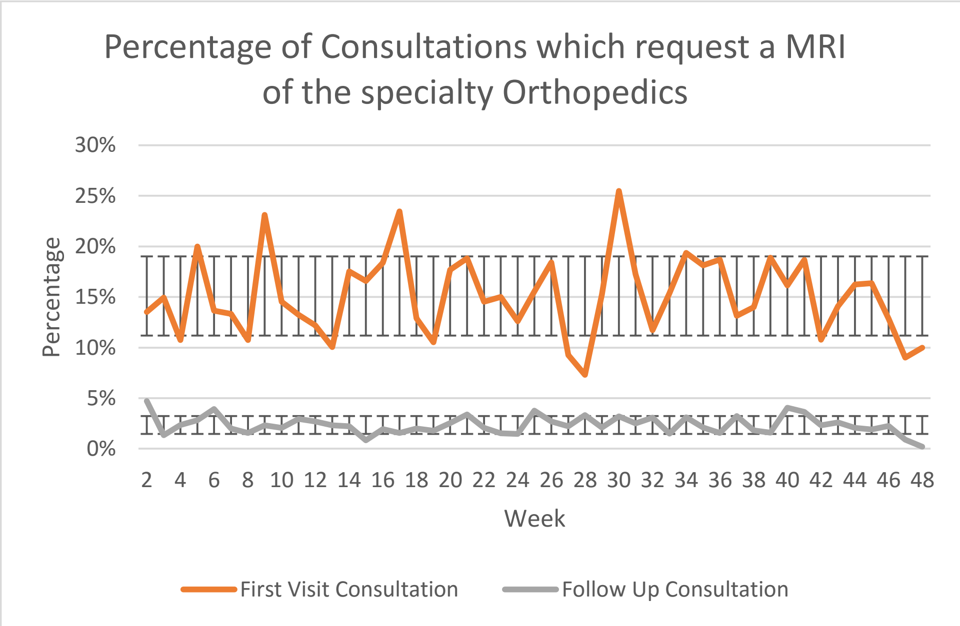


Figure 14 Percentage of the number of consultations which led to an MRI request per week and consultation type for the specialty Orthopedics (Jan-Dec 2014)

3.5 Conclusions

Extensive data analysis shows us that we can use the number of consultations as an input variable for the model. There is a strong correlation between the number of consultations and the amount of MRI requests coming from these consultations. With the use of the ratio of these consultations we could predict the number of arrivals. Not every specialty has a strong correlation and some specialties have a higher standard deviation in percentages of consultations requesting an MRI. This has to be kept in mind when building the model in Chapter 4.

4 Forecast Model MRI Demand

In this chapter we build the forecasting model. We start with determining the input values (Section 4.1) of the model. In Section 4.2 we describe the method we used to determine the outcomes and explain how the model works. The outcomes themselves are discussed in Section 4.3. The validation of the model will be done in Section 4.4. In Section 4.5 we focus at commonly used forecasting methods such as the moving average and exponential smoothing method. Finally we end this chapter with a conclusion in Section 0. A manual of the model can be found in Appendix B – Manual Forecasting ModelAppendix B – Manual Forecasting Model.

4.1 Input values

The model was developed in Excel because of the high availability of this program in the MST. The people who have to work with the model (MR-planners) already know how to work with Excel. The model should be built foolproof. We will use the scheduled number of consultations as input variables, since we prefer a causal forecast model. The advantage of a causal forecast model is that you can predict the change in demand in advance, whether a time series forecast method uses previous data and will therefore lack behind.

The model will be based on six different specialties: Neurology, Orthopedics, Surgery, Neurosurgery, Cardiology and EMT. These six specialties have the most MRI referrals in the hospital. Together with the General Practitioners they use 80% of all MRIs. The General Practitioners are excluded of the input screen (Figure 15) because there is no data available on the number of consultations. The number of MRI referrals the general practitioners send weekly are known and we use an average of these numbers as input. This holds as well for the other specialties. The number of generated MRI requests by the general practitioners are 16 and 44 for the other specialties (the renaming 20%) combined each week. These values can be found in the "Data" worksheet of the model, which will be explained more in Section 4.2.

	Specialisme:	Neurologie		Orthopedie		Chirurgie		Neurochirurgie		Cardiologie		KNO	
		Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal
Aantal Consulten	Week 1:	237	222	170	383	476	1267	81	82	197	356	304	630
	Week 2:	233	206	154	444	421	1178	72	60	257	541	327	615
	Week 3:	238	190	242	551	403	1176	71	72	182	475	292	550
	Week 4:	200	186	140	356	459	1076	77	78	194	387	288	524
	Week 5:	196	211	88	332	469	1014	66	60	181	466	287	567
	Week 6:	187	162	255	400	386	1174	75	95	136	533	273	592

Nieuwe week **Bereken!**

Figure 15 Input screen of our forecasting model

The specialties are divided in two different input variables: First visit consultation and follow up consultation. This is done because we found different percentages of MRI referrals coming from both consultation types in our research. There is also a clear distinction of these consultations in the data, so this will result in better forecasting. Every week the new number of consultations has to be entered.

For six weeks the number of consultations for each consultation type and specialty will have to be noted, whereby week 1 is the current week. These data must be send by the specialties themselves since the diagnostics department has no access to these data yet. Subsequently the diagnostics department can fill in all the data and run the model. There are two buttons on the input page: New Week and Calculate. New Week will shift all weeks one week to the front, so the new values can be added in for the new week 6. The button Calculate will result in the calculation of the model. Both buttons will be explained in more detail in Section 4.2. It should not be much work to keep this field updated, once every week (preferably Monday mornings) the values have to be added. Every specialty should know the number of consultations for each consultation type.

4.2 Black box

The black box is the working of the model. It calculates with the help of the "Data" worksheet the number of consultations to the number of expected MRI requests. As discussed in Section 4.1, there are two buttons on the input page, New Week and Calculate (Figure 15). The button New Week should be pressed when a new week starts and the diagnostics department wants to add a new week. All weeks shift up one week which will clear a space for the new data. Besides convenience to fill in the model, it also stores the last week in the worksheet "Historical Data". It saves the input of last week and the corresponding calculated output, as well as the week number (Figure 16).

	Specialisme:	Neurologie		Orthopedie		Chirurgie		Neurochirurgie		Cardiologie		KNO	
		Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal
Aantal Consulten	Week 1:	237	222	170	383	476	1267	81	82	197	356	304	630
	Week 2:	233	206	154	444	421	1178	72	60	257	541	327	615
	Week 3:	238	190	242	551	403	1176	71	72	182	475	292	550
	Week 4:	200	186	140	356	459	1076	77	78	194	387	288	524
	Week 5:	196	211	88	332	469	1014	66	60	181	466	287	567
	Week 6:												

WEEKNUMMER	INPUT: AANTAL CONSULTEN												VOORSPELLING: AANTAL MRI'S									
	Neurologie		Orthopedie		Chirurgie		Neurochirurgie		Cardiologie		KNO		Neurologie	Orthopedie	Chirurgie	Neurochirurgie	Cardiologie	KNO		Huisartsen	Overigen	**Totaal**
	Eerste poli	*Herhaal*	*Eerste poli*	*Herhaal*	*Eerste poli*	*Herhaal*	*Eerste poli*	*Herhaal*	*Eerste poli*	*Herhaal*	*Eerste poli*	*Herhaal*										
Week 2	237	222	170	383	476	1267	81	82	197	356	304	630	50	33	34	9	6	11		16	44	203

Figure 16 The input and historical data screen of our forecasting model after pushing the New Week button

			Percentage MRI's		
	Specialisme		Eerste poli	Herhaal	Spoed
1	Neurologie		14.6%	4.5%	6%
2	Orthopedie		15.0%	2.0%	0%
3	Chirurgie		1.0%	2.0%	1%
4	Neurochirurgie		6.5%	5.1%	3%
5	Cardiologie		1.1%	0.9%	1%
6	KNO		0.6%	1.4%	0%
8	Huisartsen		16		
9	Overigen		44		

Figure 17 The data screen of our forecasting model

The Calculate button triggers the actual calculation of the model. It uses the input values and uses with the help of the data analyzed in Chapter 3 to forecast the number of MRI requests for each specialty, see Eq. 1. 1Our forecasting model consists of three parts:

1. The number of MRI requests from the General Practitioners and other specialties

2. The number of MRI requests coming from FVC and FUC for each specialty

3. The number of MRI requests coming from EC for each specialty

For part 1 we only have constant C, which is the constant of MRI requests of the General Practitioners and the other specialties. For part 2 we summarize over the different consultation types j and specialty n (so in our case $n = 6$). α_{ij} is the percentage of consultations which will request an MRI for specialty i and consultation type j and $X_{ij}t$ is the number of consultation of specialty i and consultation type j in week t. Part 3 is the most difficult because we do not know exactly the number of emergency consultations. However we do know the percentage of the emergency consultation out of the total consultations: γ_i. We estimate the total consultations with $\left(\frac{X_{i1t}+X_{i2t}}{1-\gamma_i}\right)$ and by multiplying this with γ_i we have an estimation of the number of emergency consultations. β_i is the percentage of consultation which will request a MRI for specialty i. Adding these 3 parts you get Y_t which is the forecasting of the number of MRI request in week t.

$$Y_t = C + \sum_{i=1}^{n} \sum_{j=1}^{2} (\alpha_{ij} * X_{ijt}) + \sum_{i=1}^{n} \beta_i * \gamma_i * \left(\frac{X_{i1t} + X_{i2t}}{1 - \gamma_i}\right) \qquad 1$$

The calculation process consists of five steps.

Step 1: Clear the Previous Forecasting.

First the “Output” worksheet will be cleared of the previous prediction. The first week has been copied to the “Historical Data” worksheet by the New Week button. The whole outcome will be cleared, since it might be possible that more input values have been updated.

Step 2: Add the number of MRIs for the general practitioners and the other specialties (part 1).

The constant values C are defined in the “Data” worksheet (Figure 17) and are being added to the “Output” worksheet for each week. These values can be changed when necessary in the “Data” worksheet.

Step 3: Calculate the number of requested MRI for first visit consultation and follow up consultation (part 2).

We can calculate the number of requested MRIs by using part 2 of Equation 11. The percentages α_{ij} are the average percentages taken over 46 weeks of our historical data (Jan-Dec 2014) of specialty i and can be found in the “Data” worksheet (Figure 17). Multiplying these values with the number of consultations X_{ijt} for each consultation type j results is a good estimation of the number of requested MRIs.

Step 4: Estimate the number of Emergency MRI requests (part 3).

Using part 3 of Equation 1 will give us the number of MRI requests coming from emergency consultations. The percentages β_i and γ_i are the average percentages taken over 46 weeks of our historical data (Jan-Dec 2014) of specialty i and can be found in the “Data” worksheet (Figure 17).

Step 5: Calculate the total amount of estimated MRI requests.

The values of the estimated first visit, follow up and emergency consultation are added as the total estimated MRI requests per specialty per week in the “Output” worksheet. The total amount of estimated MRI request per week are all these values from every specialty as well as the values of the general practitioner and the remained specialties. See Section 4.3 for more information about the Output values and what they mean.

4.3 Output

The “Output” worksheet is the summery of the forecasting (Figure 18) made by the model. The total amount per each specialty per week can be seen as well as the overall predicted amount of MRI requests. The forecasting is done for the next six weeks and the diagnostics department can use this information for the allocation of personnel and patients. Every week new input values will be added.

This will change the multiplying factor which is used to transform the number of consultation hours to consultations. As a result all output values can slightly change. The difference between weeks however remains.

		Aantal MRI's									
		Neurologie	Orthopedie	Chirurgie	Neurochirurg	Cardiologie	KNO		Huisartsen	Overigen	**Totaal**
Forecasting	Week 1:	50	33	34	9	6	11		16	44	203
	Week 2:	47	32	32	8	10	11		16	44	200
	Week 3:	47	47	32	8	8	9		16	44	211
	Week 4:	42	28	30	9	7	9		16	44	185
	Week 5:	42	20	28	7	8	10		16	44	175
	Week 6:	39	46	31	10	8	10		16	44	204

Figure 18 Output screen of our forecasting model with the forecasted MRI requests per week

4.4 Validation of the model

We used the number of first visit and follow up consultations from January 2014 to December 2014 (week 2 to week 47) from the specialties Neurology, Orthopedics, Surgery, Neurosurgery, Cardiology and Otorhinolaryngology as input values. We let the model run and validated the model by comparing the outcome of the model with the number of MRIs the diagnostics department scheduled in the same week. Preferable you want to validate the model with the actual MRI requests per week and per specialty, unfortunately there is no such historical data available. Using the number of MRI requests the diagnostics department scheduled per week and specialty is a good alternative. It is possible that there is a delay of 1 or 2 days between the MRI requests and the actual scheduling of these requests, which can be result in scheduling in a new week, but the most requests will be done mostly in the same week.

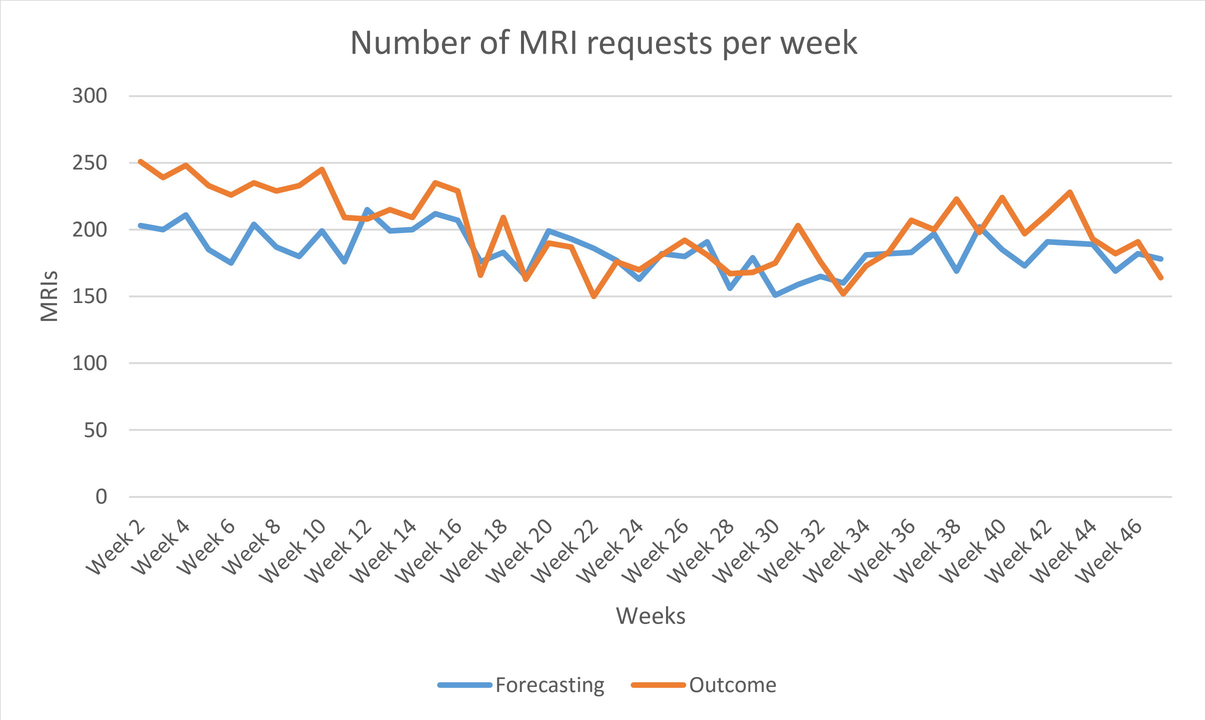


Figure 19 Number of forecasted and real MRI requests per week for 45 weeks (Jan-Dec 2014)

The results of the forecasting and the real outcomes are plotted in Figure 19. We calculated the Mean Absolute Percentage Error (MAPE) (see Eq. 22) and did a correlation analysis and found a MAPE of 10.2% and a correlation of 0.6. The MAPE gives insight in the forecasting power and is the average percentage of the difference between the forecasting and the real outcomes. All calculations and comparison are done on the total outcome of MRIs and not per individual specialty. This is done because the diagnostics department is only interested in these values. A MAPE of 10.2% means that our model has on average 10.2% error compared to the real outcomes.

$$MAPE = \left[\left(\frac{1}{n}\right) \sum_{i=1}^{n} |e_i / D_i| \right] * 100 \qquad 2$$

Focusing on the individual specialties shows us that we underrate and overrate some of the specialties. Table 8 shows us the error between the average forecasted value and the average real outcomes as well as the correction we would need to improve the model. Especially Neurology, Neurosurgery and Cardiology are underrated. The reason for this behavior could be found in the 25% data loss we found in our data, apparently these specialties had some consultations in the data we lost. Another explanation could be that these specialties generate MRIs from other consultations than first visit, follow up or emergency. Our research indicates that this would be unlikely though.

	Average Forecasted Value	Average Real Outcome	Difference	Correction in Percentage
Neurology	41	54	13	33%
Orthopedics	37	39	2	6%
Surgery	25	24	-1	-5%
Neurosurgery	7	13	6	90%
Cardiology	7	9	2	36%
Otorhinolaryngology	8	8	-1	-7%

Table 8 Difference of the average forecasted and the real MRI requests, including the correction needed to improve the model (Jan-Dec 2014)

After running the model with the new corrected percentages, we found a MAPE of 9.9%, this is slightly better than our previous configuration. The last step we can use to improve the model is to check what the number of MRI requests is of the other remaining specialties. At this moment this value is still 44. By decreasing this value to 34 MRIs per week, we can improve the model to a MAPE of 9.2% while keeping the correlation at 0.6. Figure 20 is a representation of our improved forecasting model and the real outcome of the requested MRIs per week.

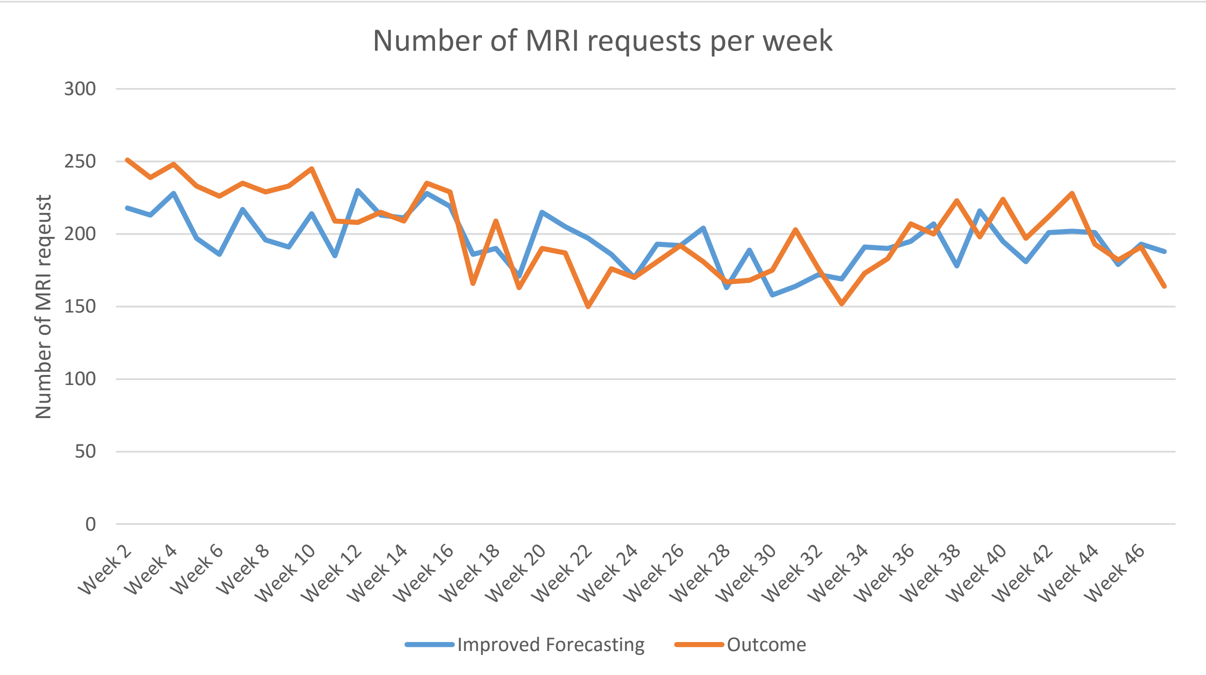


Figure 20 Number of forecasted and real MRI requests per week for 45 weeks using the improved forecasting model (Jan-Dec 2014)

4.5 Other Forecasting Methods

The forecasting model we use is based on scheduled future data, there are however also other forecasting methods who use historical data. This section will compare our forecasting model with other forecasting methods such as the Moving Average (Section 4.5.1) and Exponential Smoothing

(Section 4.5.2) (Simchi-Levi, Kaminsky, & Simchi-Levi, 2009). These methods are Time Series Methods; they require no information other than the past values of the variable being predicted (Nahmias, 1997). The data we use is from Jan-Dec 2014 (week 2 to week 47) and for each method we will determine the MAPE and the Correlation. We compare these methods with our own model in Section 0 and based on these comparison we improve our model in Section 4.5.4.

4.5.1 Moving Average

The moving average method is a forecasting method that uses the average of the last N weeks as a forecasting (Eq. 3). The simplest moving average method is using a N of 1, this is also called Naïve Forecasting (Nahmias, 1997) (Eq. 4). We calculated the forecast error and correlation of the moving average method using a N of 1 to 10, see Table 9. The moving average of the previous 3 weeks is the best forecast method (Figure 21), with a MAPE of 8.1% and a correlation of 0.67. Forecasting with a small N follows the demand best, the downside of the moving average is that you can only forecast over week $t > N$.

$$F_t = \left(\frac{1}{N}\right) \sum_{i=t-N}^{t-1} D_i \qquad 3$$

$$F_t = D_{t-1} \qquad 4$$

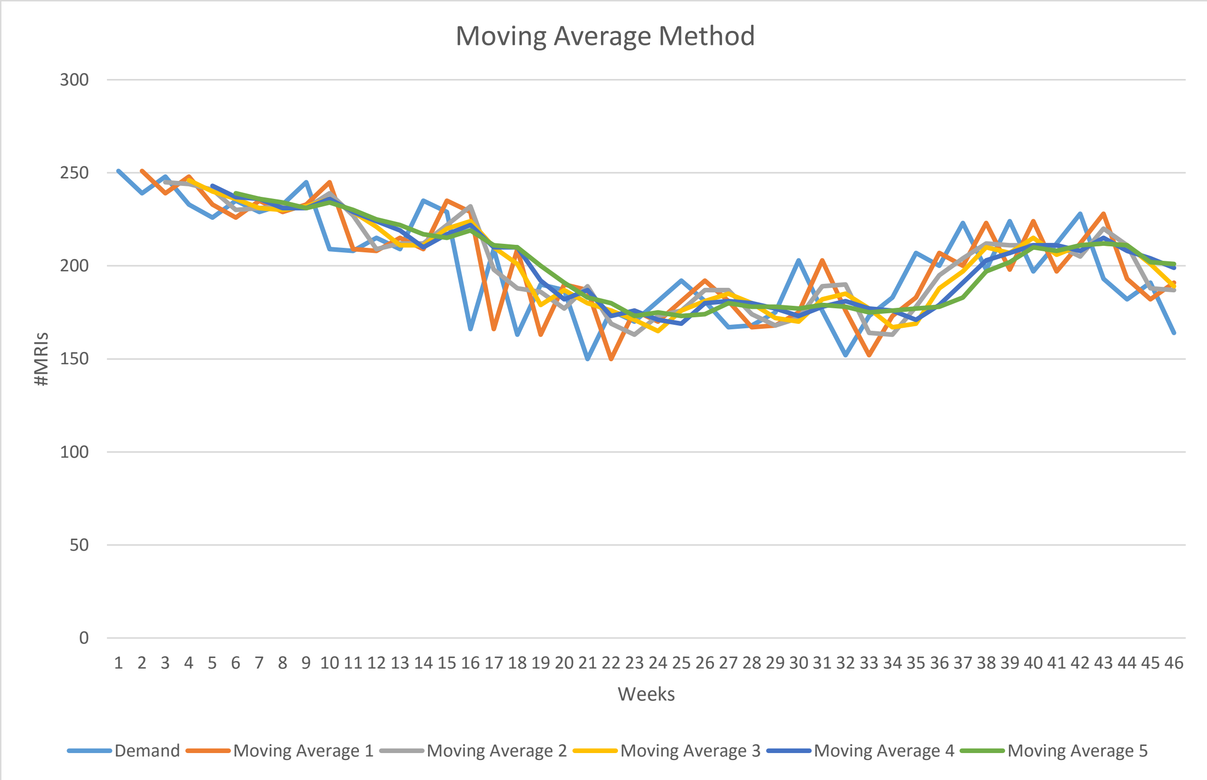


Figure 21 Number of forecasted MRI requests using the Moving Average Method (N = 1, 2, 3, 4 and 5) and the actual Demand (Jan-Dec 2014)

	MA 1	MA 2	MA 3	MA 4	MA 5	MA 6	MA 7	MA 8	MA 9	MA 10
MAPE	9,6%	8,3%	8,1%	8,6%	8,4%	8,9%	9,4%	10,0%	10,6%	10,8%
Correlation	0,65	0,69	0,67	0,62	0,63	0,59	0,53	0,46	0,35	0,30

Table 9 Mean Average Percentage Error and Correlation of the Moving Average method with an N of 1 to 10 (Jan-Dec 2014)

4.5.2 Exponential Smoothing

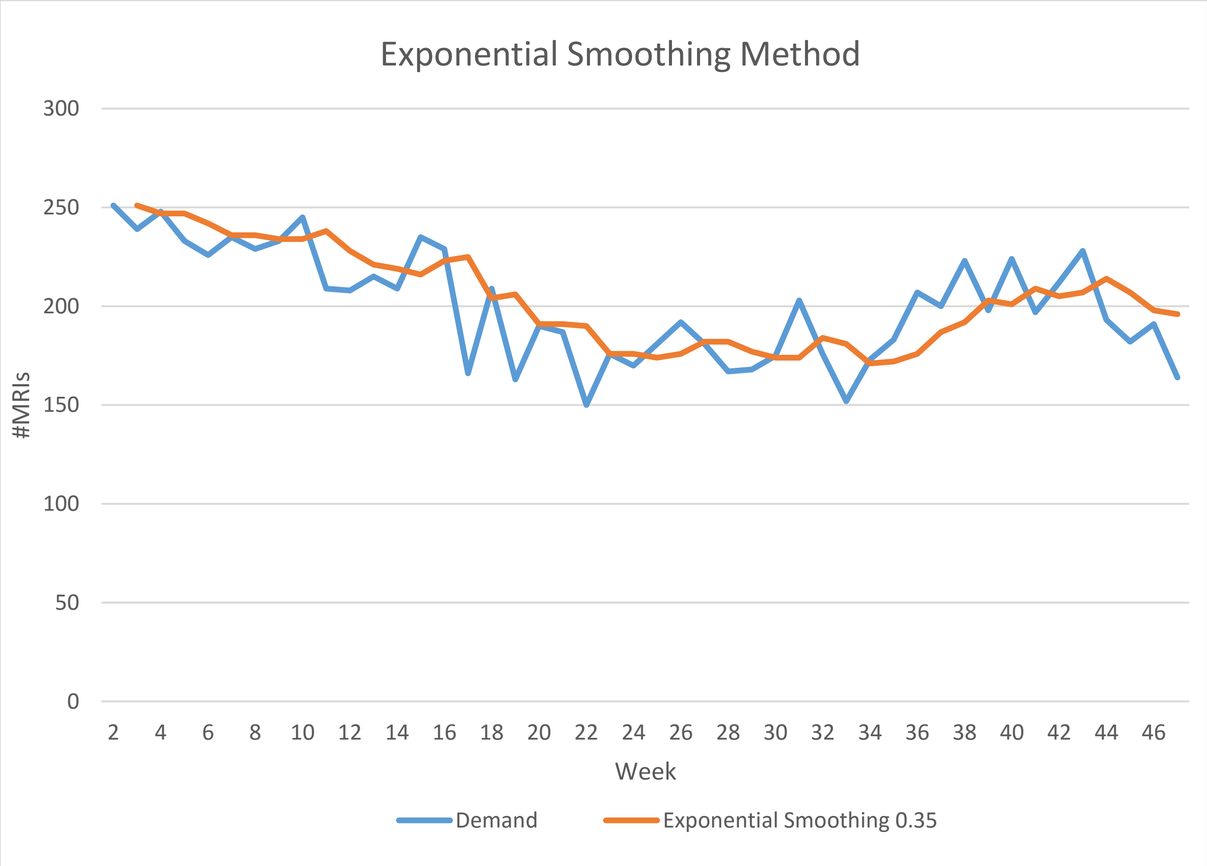


Figure 22 Number of forecasted MRI requests using the Exponential Smoothing Method (alpha 0.35) and the actual Demand (Jan-Dec 2014)

The second forecasting method we use is the exponential smoothing method. This method can be defined as: The forecast in any period t is the forecast in period $t-1$ minus some fraction of the observed forecast error in period $t-1$, Eq. 5 (Nahmias, 1997). We calculated the forecast error and correlation of the exponential smoothing method, using an alpha of 0.1 to 1.0, see Table 10. We used the solver in Excel to find an even better alpha by minimizing the MAPE. The best alpha for forecasting the MRI requests is $\alpha = 0.35$ (Figure 22), it has a MAPE of 7.8% and a correlation of 0.72.

$$F_t = F_{t-1} - \alpha(F_{t-1} - D_{t-1}), \qquad 0 < \alpha \leq 1 \tag{5}$$

	EXP 0.1	EXP 0.2	EXP 0.3	EXP 0.4	EXP 0.5	EXP 0.6	EXP 0.7	EXP 0.8	EXP 0.9	EXP 1.0
MAPE	11,2%	8,9%	8,1%	7,9%	8,0%	8,2%	8,5%	8,8%	9,1%	9,6%
Correlation	0,60	0,68	0,71	0,72	0,72	0,71	0,70	0,69	0,67	0,65

Table 10 Mean Average Percentage Error and Correlation of the Exponential Smoothing method with an alpha of 0.1 to 1.0 (Jan-Dec 2014)

4.5.3 Comparison

The Exponential Smoothing Method with an alpha of 0.35 has the best results of all Time Series Methods we analyzed. It preforms much better than our forecasting method which has a forecast error of 9.2% instead of 7.8% and a correlation of 0.6 instead of 0.7 instead. The difference of the two forecasting methods is the data the forecasting method use. For the exponential smoothing method it is the previous demand and forecast, for our own model it is the scheduled number of consultations. This can also be seen in Figure 23, the exponential smoothing method is smoother and follows the demand better than our own model and resulting in a better forecasting error and correlation.

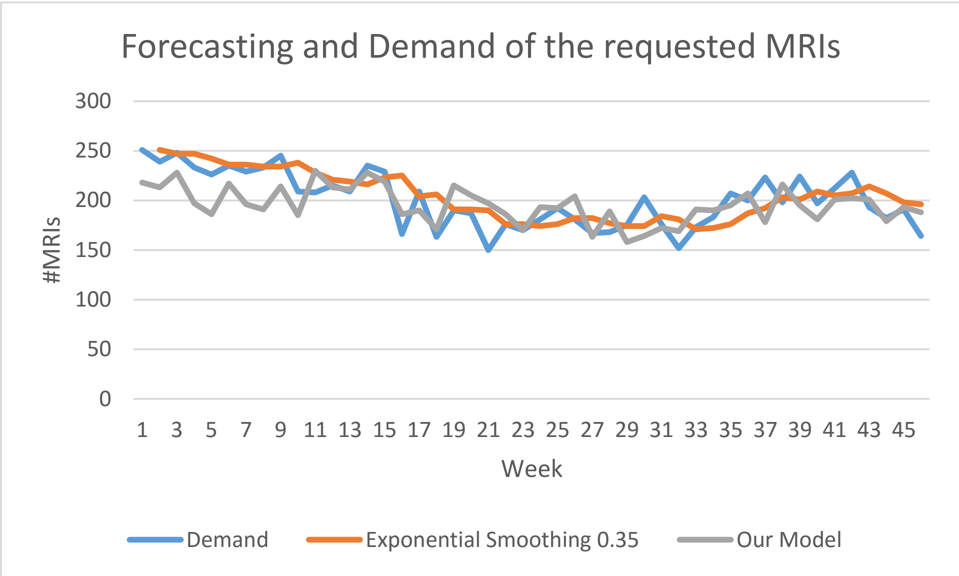


Figure 23 Comparison the requested MRIs for the Exponential Smoothing (alpha 0.35) and our Forecasting Model with the Demand (Jan-Dec 2014)

4.5.4 Improving current model

The Exponential Smoothing method forecasts better than our own model, therefore we will combine the time series methods with our current causal forecasting method to see if this combination will improve its forecasting ability (Carpenter et al., 2011), see Eq. 7. The best qualities of our causal forecasting method is the ability to predict an incremental in- or decrease of the number of requested MRIs. Therefore part 1 of the equation will be the forecast of the causal model, Y_t. For strong qualities of the time series methods is the ability to correct the forecast when the demand is higher of lower than predicted. The second part of the equation is a combination of the exponential smoothing and the moving average. For the exponential smoothing we used the difference of the previous forecast by the causal forecast model and the actual demand, see Figure 24. With this model we found an optimal alpha of 0.35, a MAPE of 8.8% and a correlation of 0.66.

$$F_t = Y_t + \alpha * (Y_i - D_i) \qquad 6$$

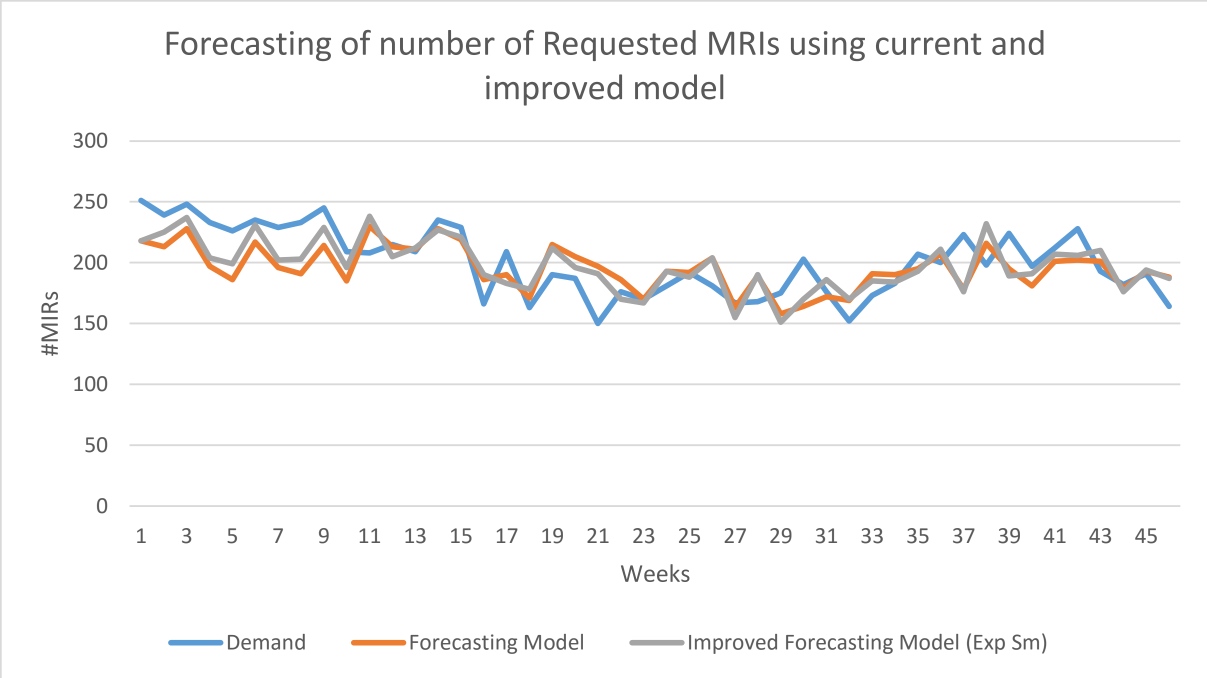


Figure 24 Demand and Forecasting of requested MRIs per week using the previous and its improved forecasting method (exponential smoothing) (Jan-Dec 2014)

This could be even better improved if we also used a moving average part (N in Eq. 7), because of the high variation in the forecast. Using an average will reduce this variation. Figure 25 is an overview of the possible MAPE when using a different N and α. Remarkable is the shape of the figure, for each moving average the shape is what you would expect. Starting with a MAPE that will decrease when alpha increases till it reaches its optimum, which then increases again. You would also expect this behavior when increasing N while using the same alpha. Figure 25 however shows us that the moving average 4 has an higher MAPE that $N = 3$ or $N = 5$. Apparently using the average difference in the previous demand and the forecast of the last 4 periods differs more with the actual demand than when using the last 3 or 5 periods.

Using a Moving Average of N of 5 proved to have the best results in combination with an alpha of 0.717. With this combination of both our causal forecast model, the exponential smoothing part and the moving average part we found an optimal a MAPE of 8.0% and a correlation of 0.717, see Figure 26.

$$F_t = Y_t + \alpha * \left(\left(\frac{1}{N}\right) \sum_{i=t-N}^{t-1} (Y_i - D_i) \right) \qquad 7$$

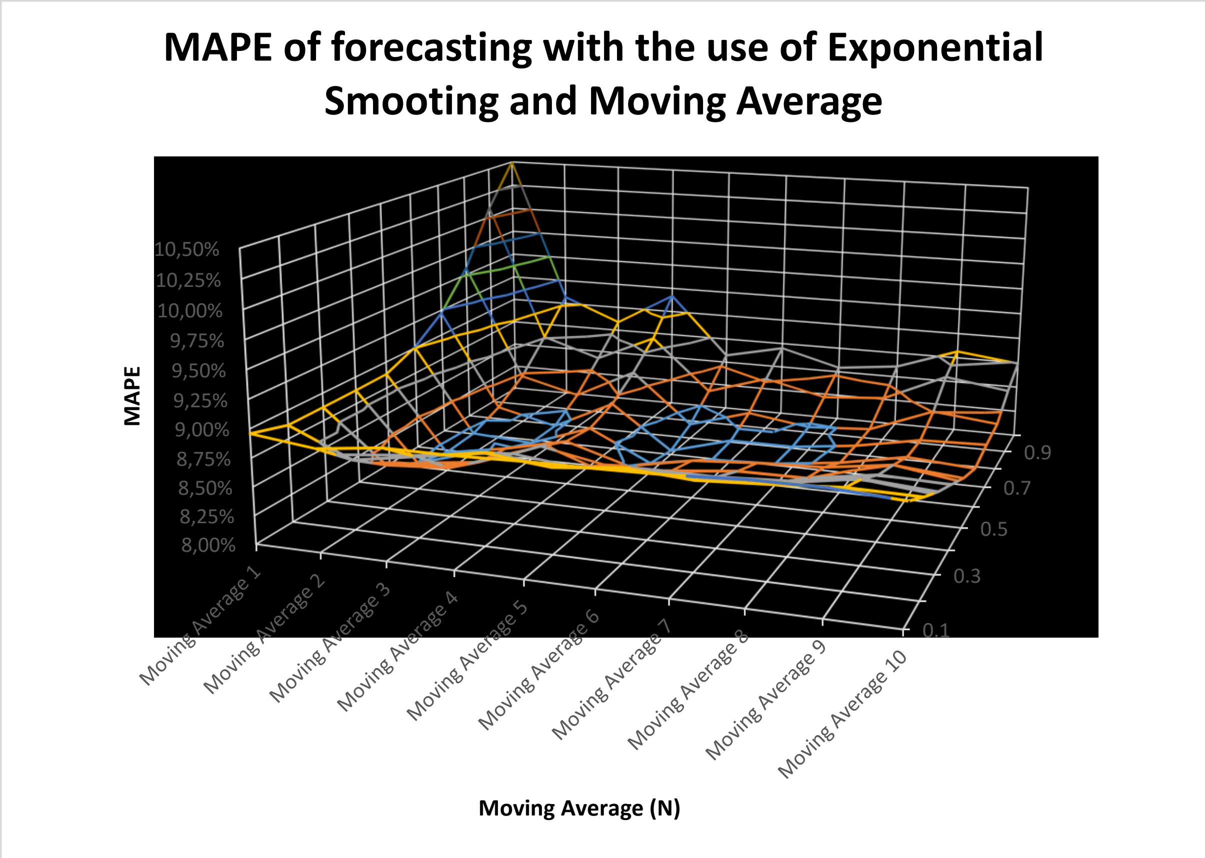


Figure 25 Summary of the Mean Average Percentage Error of the improved forecasting method using alpha 0.1 to 1 and the moving average of 1 to 10 (Jan-Dec 2014)

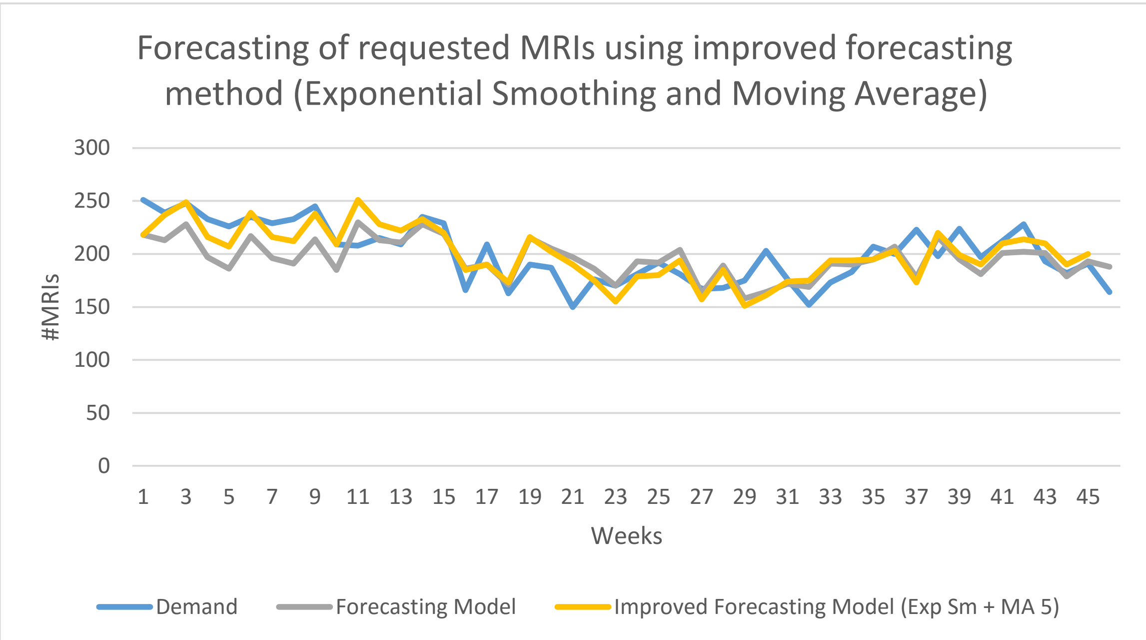


Figure 26 Demand and Forecasting of requested MRIs per week using the previous and its improved forecasting method (exponential smoothing and moving average (N=5)) (Jan-Dec 2014)

4.6 Conclusion

The Exponential smoothing method preforms slightly better than our improved model (Table 11), but we still recommend the diagnostic department of the MST to use our own model. The most valuable information for the diagnostic department is not the actual number of MRIs, but to see if there will be a change in demand. When using only the exponential smoothing model, you will detect this change after it happens, since it uses historical data. With our improved model you can see this coming on forehand.

	Our Model	EXP 0.35	MA 3	Model + EXP 0.35	Model + EXP 0.72 + MA 5
MAPE	9,1%	7,8%	8,1%	8,8%	8,0%
Correlation	0,60	0,72	0,67	0,66	0,72

Table 11 Overview of the MAPE and Correlation of all forecasting methods we used

We performed a correlation analysis of the demand $D_t - D_{t-1}$ and the forecast $F_t - F_{t-1}$, for the exponential smoothing and our improved forecasting model and found out that there is negative moderate correlation for the exponential smoothing (-0.5) and a weak correlation for our model (0.3). In fact for 69% of the cases our model will forecast correct whether it will be a positive or negative change compared to the previous week, while the exponential smoothing method only forecasts correctly for 27% of the times, see Figure 27.

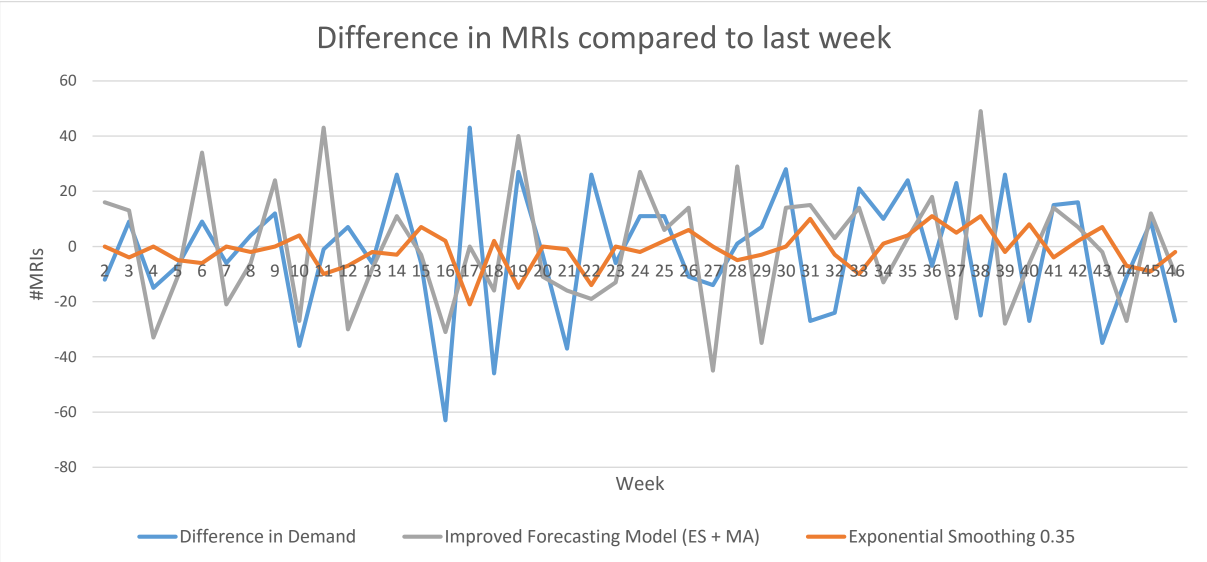


Figure 27 The difference in MRI requests for each week t and week t-1 for the Demand and our Forecasting Model (Jan-Dec 2014)

The forecasting model will be used by the diagnostic department to predict the number of MRI requests per week and specialty. The diagnostics department will use this to see on forehand how much referrals they can expect for the coming six weeks. This information can be used to decide to open the MRI in evenings or weekends when more MRIs requests are to be expected. The planning of personnel and patients can be changed. On quiet weeks the diagnostic department can decide to have less personnel on duty. This will lead to a more stable access time for the radiology, which is beneficial for all departments that rely on diagnostics.

Another possibility to use the model is to reserve certain blocks for specialties. The scheduling of patients at the diagnostic department is done in blocks as discussed in Section 2.2.2. With this information the radiology department can decide to have an extra MRI block for the neurology department, when demand for this specialty is higher.

Finally the model can also function as a feedback tool to the different departments by showing the departments the effect of their way of scheduling their consultations. It can be used as a bargaining position to prevent much variation in the arrival pattern of the patients, which is preferable by the diagnostic department by adding or removing MRI blocks and by the department in question.

5 Conclusion

In our problem formulation we explained the current situation of the diagnostics department. There is no insight in the arrival of patients from the outpatient clinics to the diagnostics department who need an MRI. In addition, there is great variation in the number of patients that arrive from each specialty. This leads to high access times for the diagnostics department and therefore high throughput times for patients. This led to our following research questions:

1 What does the current care pathway for patients who arrive at the outpatient clinic and need an MRI at the diagnostics department look like?

In the MST there is a total of 43 different specialties (69 including subspecialties). Most specialties have outpatient clinics and in these outpatient clinics patients arrive for a consultation. There are eight different consultations types: First visit consultation, follow up consultation, emergency consultation, peer consultation, multidisciplinary consultation, outside office consultations, co-treatment, and other consultations. First visit consultation and follow up consultations are the consultations mainly used in the outpatient clinic. All consultation types can result in an MRI request.

The seven biggest MRI contributors are Neurology, Orthopedics, General Practitioner, Surgery, Neurosurgery, Cardiology and Otorhinolaryngology. Together they request 80% of all MRIs. The referral for an MRI arrives to the radiology department via a paper form, possibly a few days after the consultation of the patient. The radiology department has divided MRI slots per specialty. Based on urgency and convenience of the patient, an MRI appointment will be made. This results in certain an access time for the diagnostics department that varies over the time, exceeding the *'treeknorm'* of 4 weeks 25% of the time (in the time July 2013 to May 2014). This results in a longer throughput time for the patient. So far, there has been no relation found between the number of consultations and the number of performed MRIs.

2 Is there a correlation between the different consultations and the requested MRIs?

A strong correlation (0.9) is found between the consultations and the requested MRIs, though not every consultation type has a strong correlation. Emergency consultation and peer consultation have a moderate correlation with the number of requested MRIs and multidisciplinary consultation, outside office consultations, co-treatment, and other consultations have a weak correlation.

Focusing on the individual specialties results in lower values for consultations. The highest MRI-request contributors still have a strong correlation to the number of requested MRIs: Neurology (0.8), Orthopedics (0.7), Surgery (0.8) and Neurosurgery (0.7). Cardiology (0.5) and Otorhinolaryngology (0.7) have a moderate correlation. The correlation for other specialties is lower, these are however not interesting for the model since they do not contribute much to the total number of MRIs requested. The diagnostics department is mainly interested in the variation of the patient arrival from the specialties that contribute highly to MRI referrals. This means that we can use the number of consultations as an input variable to calculate the requested MRIs.

3 What input, calculations and output do we need to make a model to forecast the arrival of patients at the diagnostics department who need an MRI.

As input values we would want to use number of consultations, though this is not possible since it is too difficult to obtain these data from the specialties. That is why we use consultation hours as input; these values are simpler to obtain. This means that we have to convert these values to the number of consultations. We do this by making use of a factor we defined, which uses the average number of consultations per week to convert the consultation hours to number of consultations. Subsequently we can use these values to predict the number of MRI requests. The advantage of the model is the adaptability of the model. With the use of the historical data and the correct data, one can see the effectiveness of the model and when necessary easily adapt the model to get a better prediction.

4 What configuration and recommendations would be most beneficial for the diagnostics department?

With the use of extended data analysis we found that there was a correlation between the number of consultations and the number of MRI requests. We used the average ratio between number of consultations and MRI requests per specialty and consultation type to predict the number of MRIs. The model shows an increase in MRI requests when the number of consultations is higher. To improve the forecasting model we used a combination with time series methods such as exponential smoothing and moving average. The improved model is a good representation of the reality with a Forecast Error of 8.0% and a correlation of 0.72.

6 Discussion and Recommendations

This chapter will be the discussion of our research and some recommendation for the diagnostics department to use the model.

We used the historical data from January 2014 to December 2014, which is not a very wide range. Our extended data analysis shows that there is a correlation between the number of consultations and the number of MRI requests. The correlation is based on linked appointments. 25% of the data could not be linked to an appointment and therefore could not be used. The main reason for this data loss is because of the small data range. Consultations in 2013 and MRI requests for December 2014 and beyond resulted in data loss. This probably effects follow up consultations the most, since they have a large amount of MRI requests over a longer period of time. Validating the model showed the same results; the percentages for neurology, neurosurgery and cardiology were too low and had to be adjusted to get better results. This correction is however affecting the total number of consultations and not the individual consultation type.

There are thirteen different types of consultations that are based on the Internal Operation Codes the MST uses. For convenience we combined these consultations into eight different consultation types. In the model we only use first visit, follow up and emergency consultation. These are the most important and most used consultation types, but there are also some MRI requests coming from the other consultation types. It could therefore mean that we underestimate the number of requested MRIs. Systematic underestimation will be corrected by the exponential smoothing and moving average part of the method, but changing the base values is still recommended.

It is not known where the MRI requests come from and when they were requested. For the validation of the model we used the date the diagnostics department scheduled the MRI. This is however not accurate, it is possible that there is a delay of one or two days between the MRI request and the scheduling of this MRI. We recommend the MST to keep track of these data and use it as input values for our model. The model can still function without these data, but it will decrease its forecasting power. Furthermore we recommend to validate the model after a period of time with the real MRI historical request data.

At this moment it is not possible for the diagnostics department to get an overview of the number of consultations per consultation type for the six specialties we used in our model. This means that the diagnostics department is depending on the willingness of the specialties to provide accurate data for the model. We highly recommend the diagnostics department to get access to these data to provide the model with accurate data.

The model we built is a good estimator of the expected MRI requests, however due to the above mentioned issues it has to be tested before it can be used as a functional tool for the diagnostics department. Therefore we recommend the MST not to implement this model immediately, but assess its forecasting strength during a 6 month shadow run. An implementation manual can be found in Appendix A – Implementation of the forecasting ModelAppendix A – Implementation of the forecasting Model.

The MST has indicated that when this model is a success, it is interested in using the same method to forecast the CT requests and other applications. Our model and research is highly adaptable and can be used when implementing a forecasting model for these other applications. The data of the number of consultations remain the same, so the only thing the MST needs to do is link the appointments to the CT requests, following the same steps we used in our research. The values they find can be used in the same model.

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Appendix A – Implementation of the forecasting Model

The following steps are designed for the diagnostics department to use this model efficiently into the daily use. We recommend to use this model in a shadow run first.

Step 1: Involve the different specialties which are going to deliver the input values.

The six specialties have to be involved into the beginning of the process. It is important to let them understand the value of this model to their department: shorter access times for patients in need of an MRI. This can be achieved with minimal effort, they only have to provide data to the diagnostics department once a week. (If the diagnostics department can get direct access to these data, the effort for the specialties will become nonexistent.)

Step 2: Acquire the input data for six weeks in advance.

In order to start the model, the diagnostics department needs to have 6 weeks of input values. This is the "warm up period" of the model. You can start with only one specialty involved, but more are preferable since this indicates the working of the whole model instead of the prediction of one specialty.

Step 3: Run the model for the first time.

Once you have the data for the first six weeks, the model can be used. You now have a forecast for the number of MRI requests for the first upcoming week. When using the model for the first time, you will get a warning. This is because there is no historical MRI request data available.

Step 4: Acquire real MRI requests.

In order to check the forecasting of the model, you need to know the real number of MRI requests as well as where they came from. The output of the model can be found in the "Historical Data" worksheet. It is recommended to compare the forecasting values with the real MRI requests. This information is also needed when pushing the Next Week button.

Step 5: Adjust constant values and percentages when necessary.

After the six months of comparing the forecasting values with the MRI requests, you can say something about the forecasting strength of the model. It might be necessary to adjust some constant values when it the forecasting proves to be under or overrated. When this is done you can start using the model as a daily tool and react on the model with personnel allocation and patient scheduling as well as using it as a communication tool to the other specialties.

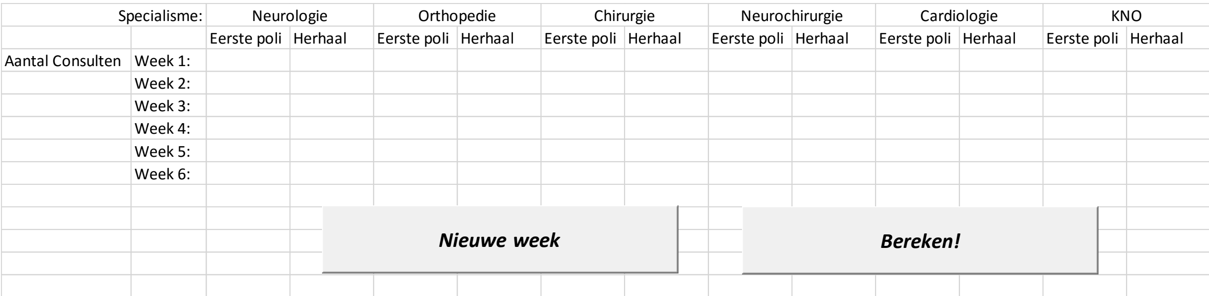
Following these steps will result in a good forecasting model that can be used as a tool to forecast the MRI requests which can help the diagnostics department with the allocation of personal and scheduling of patients to reduce the variation in access time. Furthermore it can be used as a negotiation and communication method to the other specialties to give insight in there variation and to allocate different MRI slots to specialties.

Appendix B – Manual Forecasting Model

This is a manual for the MST for how to use the forecasting model. The Excel file Forecasting Model MRI Requests MST consists of 4 Worksheets: Input, Output, *Historische Gegevens* and Data. The only worksheet you will use to fill in data will be the Input worksheet.

Step 1: Fill in the number of consultations

**The pictures are made in Excel 2013 and Windows 10, it could be that the model looks slightly different in other versions but the working of the model remains the same.*



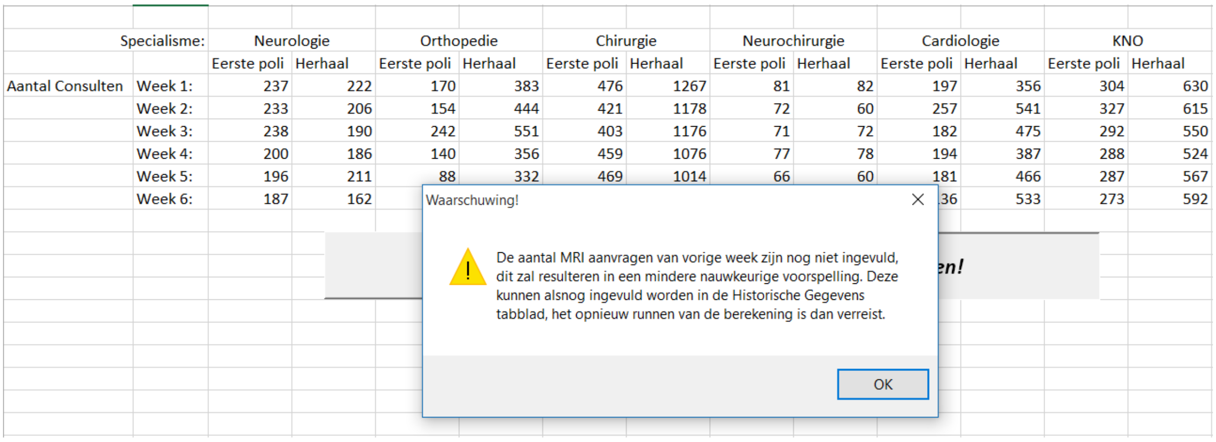
	Specialisme:	Neurologie		Orthopedie		Chirurgie		Neurochirurgie		Cardiologie		KNO	
		Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal
Aantal Consulten	Week 1:												
	Week 2:												
	Week 3:												
	Week 4:												
	Week 5:												
	Week 6:												

Figure 28 The Input worksheet when using the model for the first time

The Input worksheet will be empty when using the model for the first time (see Figure 28). So the first thing you want to do is filling the worksheet with data. The 6 specialties are divided into *Eerste poli* and *Herhaal consulten*. For the coming week (week 1) you have to fill in the number of consultations for each specialty and consultation type. These can be found in Business Objectives or will be provided to you via email. The model is now ready to forecast the number MRI requests for the coming week. It is possible to fill in the data for up to 6 weeks.

Step 2: Push the "*Bereken!*" button.

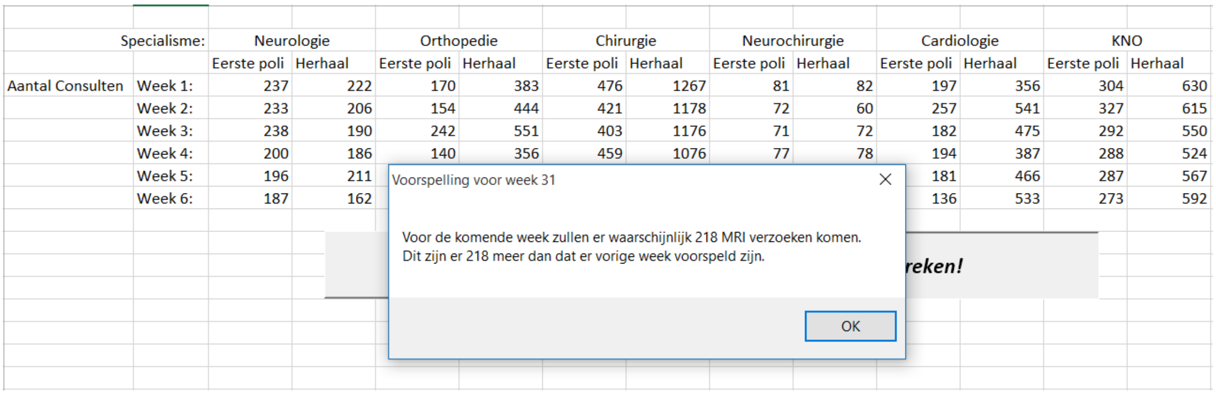
When you have filled in the first or more weeks you can push the button "*Bereken!*", the model will then forecast the requested MRIs for coming up to six weeks. When running the model for the first time, a warning appears see Figure 29.



	Specialisme:	Neurologie		Orthopedie		Chirurgie		Neurochirurgie		Cardiologie		KNO	
		Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal
Aantal Consulten	Week 1:	237	222	170	383	476	1267	81	82	197	356	304	630
	Week 2:	233	206	154	444	421	1178	72	60	257	541	327	615
	Week 3:	238	190	242	551	403	1176	71	72	182	475	292	550
	Week 4:	200	186	140	356	459	1076	77	78	194	387	288	524
	Week 5:	196	211	88	332	469	1014	66	60	181	466	287	567
	Week 6:	187	162							36	533	273	592

Figure 29 Warning Pop-up after pushing the *Bereken!* button for the first time because of the missing MRI request data of last week

This warning appears because the number of requested MRIs of last week is not available, since it is the first time you run the model you can ignore this warning and push *OK*.



	Specialisme:	Neurologie		Orthopedie		Chirurgie		Neurochirurgie		Cardiologie		KNO	
		Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal	Eerste poli	Herhaal
Aantal Consulten	Week 1:	237	222	170	383	476	1267	81	82	197	356	304	630
	Week 2:	233	206	154	444	421	1178	72	60	257	541	327	615
	Week 3:	238	190	242	551	403	1176	71	72	182	475	292	550
	Week 4:	200	186	140	356	459	1076	77	78	194	387	288	524
	Week 5:	196	211							181	466	287	567
	Week 6:	187	162							136	533	273	592

Figure 30 Pop-up and Input worksheet after pushing the *Bereken!* button for the first time with the forecasted MRI request

After pushing the button another pop-up will appear, this pop-up will give you information about the forecasted MRI requests and the difference of this forecasting and the previous forecasting, see Figure 30. In this case the difference has the same value as the current MRI requests, this is because it is the first time the model has run. The pop-up will only show the forecast of the current week. If you want to see the forecast of the coming 6 six you can go to the Output Worksheet, see Figure 31. You are now done, the next step will be done when a new week has begun.

		Aantal MRI's										
		Neurologie	Orthopedie	Chirurgie	Neurochirurg	Cardiologie	KNO	Huisartsen	Overigen	**Totaal Voorspelling**	**Incl Exp. Smoothing**	*Verschil*
Forecasting	Week 1:	64	35	33	18	8	10	16	34	218	218	*218*
	Week 2:	62	34	30	15	12	10	16	34	213	213	*-5*
	Week 3:	62	50	30	16	11	9	16	34	228	228	*15*
	Week 4:	54	30	29	17	9	8	16	34	197	197	*-31*
	Week 5:	55	21	27	14	10	9	16	34	186	186	*-11*
	Week 6:	50	49	30	18	11	9	16	34	217	217	*31*

Figure 31 Output worksheet after pushing the *Bereken!* button for the first time

Step 3: Using the model for the second time.

After a week you will have to update the model, you can do this by pressing the "*Nieuwe Week*" button. A pop-up window will appear which asks you to fill in the MRI requests of last week, see Figure 32. The model will still run without this information, but the forecasting power of the model will be lower. It is possible to fill in number of MRI requests on a later moment in the *Historische Gegevens* worksheet in Cell "X4", see Figure 33. Pressing the *Nieuwe Week* button will copy Week 1 and its forecast automatically to the *Historische Gegevens* worksheet and it will shift all weeks one week ahead.

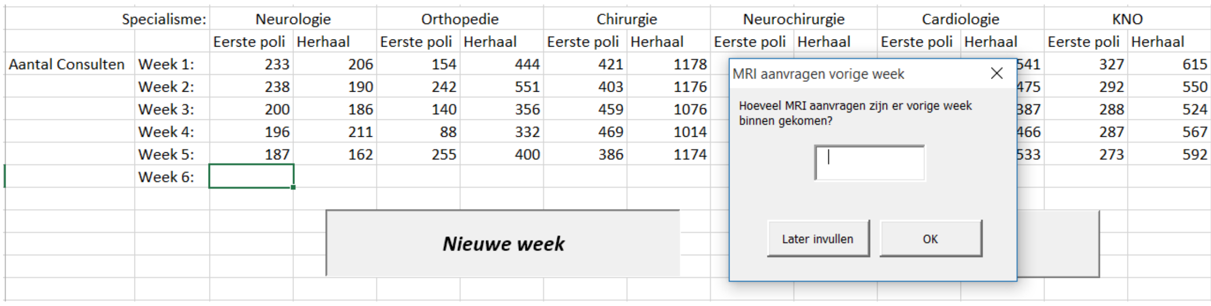


Figure 32 Input worksheet after pushing the *Nieuwe week* button

	A	N	O	P	Q	R	S	T	U	V	W	X
1	**WEEKNUMMER**	**VOORSPELLING: AANTAL MRI'S**										**UITKOMST**
2-3		Neurologie	Orthopedie	Chirurgie	Neurochirurgie	Cardiologie	KNO	Huisartsen	Overigen	**Totaal**	**Totaal Exp**	**Totaal**
4	Week 30	64	35	33	18	8	10	16	34	218	218	

Figure 33 *Historische Gegevens* worksheet after pushing the *Nieuwe week* button

You can now fill in the new values for week 6, just as in step 1.

If there are any questions you can always contact me via email.