**Resource allocation in an outpatient department**

**Part one**

**by**

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# Deventer Hospital

Resource allocation in an outpatient department

***A system for allocating generic rooms for the outpatient department in Deventer Hospital***

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# Preface

This report describes the results of our Master of Science thesis Industrial Engineering and Management at the department of Operational Methods for Production and Logistics (OMPL), University of Twente, Enschede, The Netherlands. This Department focuses on the optimisation of management and the organisation of business and healthcare processes, and participates in the Centre of expertise in Healthcare Operations Improvement and Research (CHOIR) of the University of Twente.

The Deventer Hospital (DZ) had, due to the newly built hospital, an interesting research topic concerning the allocation of rooms in the outpatient department (OD). The research within DZ gave us more insight into various hospital processes, but also into planning and logistics topics specific to the hospital environment. The open culture within DZ and the willingness to help and explain, gave us the possibility to gather a lot of extra knowledge next to the necessary information for this research. It pleases us that DZ partly uses the results of this report for the allocation and management of their new OD. The spatial distribution of the front office is implemented by the board of directors. In addition, DZ uses parts of the control plan for the evaluation of generic rooms.

We thank Theo van der Meer and Hermien ten Bolscher, both former managers at DZ, for supporting us at the start of our research. They introduced us in the hospital and gave us more insight into the hospital processes. The meetings resulted in interesting conversations about opportunities to improve healthcare. Unfortunately they left the hospital, to look for new challenges in healthcare logistics and management. We also thank Geert Kroes, our new supervisor at Deventer Hospital. His points of view and experience within the field gave new insights to our research, and helped evaluate the proposed allocation strategies for the OD. Outside the hospital we got support from W. Pustjens from Maasland Hospital in Sittard and J. Veldhuijzen from Antoni van Leeuwenhoek Hospital in Amsterdam. They gave useful information and new insights on the new concept of a separate front and back office. Finally we thank our supervisors from the University of Twente, Erwin Hans and Johann Hurink. We received a lot support and had many pleasant, useful and interesting discussions about our research and other (related) matters.

*Michel Kats,* *Jasper Quik*

*Enschede, June 2008*

# Samenvatting

Het Deventer Ziekenhuis (DZ) verhuist in augustus 2008 naar een nieuwe locatie in Deventer. Het is een algemeen opleidingsziekenhuis voor de regio Deventer. In 2006 zijn op de polikliniek 255.926 bezoeken geregistreerd, waarvan 94.964 eerste polikliniek bezoeken (EPB). In het nieuwe ziekenhuis wordt op de polikliniek een gescheiden front en back office geïntroduceerd. Meer dan 100 generieke consultatie kamers zijn centraal gesitueerd binnen de polikliniek. Deze kamers zijn gedeeltelijk uitwisselbaar tussen verschillende zorgverleners en specialismen.

De nieuwe opzet zorgt niet alleen voor een verandering van de werkprocessen, maar ook in het toewijzen en het beheren van de generieke kamers. Het beheer en toewijzen van de kamers moet zodanig worden georganiseerd dat deze in lijn is met de doelstellingen van het ziekenhuis.

Het doel van het onderzoek is als volgt geformuleerd:

*"Ontwikkel een systeem voor het beheren en toewijzen van gecentraliseerde generieke kamers op de polikliniek, met een gescheiden front en back office, om een efficiënt en flexibel gebruik van deze kamers te bevorderen"*

Hiervoor zijn volgende onderzoeksvragen opgesteld:

1. Hoe kan het aantal benodigde generieke kamers worden berekend, zodat aan de zorgbehoefte kan worden voldaan?
2. Hoe kunnen generieke kamers worden toegewezen aan de verschillende specialismen?
3. Hoe moet het beheer van generieke kamers (het regelmatig updaten) worden georganiseerd?
4. Hoe kan efficiënt gebruik van generieke kamers worden geëvalueerd en gemeten?

Het onderzoek is gebaseerd op de ontwikkelingen binnen het DZ. Naast een literatuurstudie en interviews met verschillende managers binnen het DZ, hebben wij een aantal interviews gehouden in andere ziekenhuizen. Deze ziekenhuizen hebben het concept van een gescheiden front en back office al geïntroduceerd of zijn bezig met het introduceren van dit concept.

Het raamwerk voor planning en beheer binnen ziekenhuizen maakt onderscheid tussen een strategisch, tactisch en operationeel niveau voor het beschrijven van de verschillende

toewijzingsbeslissingen gedurende het gehele proces. Voor deze toewijzingsbeslissingen op de verschillende niveaus moet een balans worden gevonden tussen en centraal of decentraal sturen / toewijzen. Verder moet het toewijzen op een transparante manier gebeuren, gebaseerd op eerlijkheid en gelijkheid. Toewijzingsmechanismen moeten echter waken voor situaties waarin suboptimalisaties worden gecreëerd. Het meten van het gebruik en de prestaties speelt een belangrijke rol bij het toewijzen van de generieke kamers. Het is een basis voor een succesvolle toekomstige implementatie van veranderingen om de vooraf opgestelde doelen te bereiken.

Het toewijzen en beheren van de generieke kamers is een continu proces. In het voorgestelde beheersplan beschrijven we de aspecten rondom een eerste berekening van de vraag naar generieke kamers vanuit de specialismen, het toewijzen van de generieke kamers en tot slot het evalueren van het gebruik van de toegewezen generieke kamers.

**Het aantal benodigde generieke kamers per specialisme**

Het aantal generieke kamers dat nodig is om aan de vraag naar zorg te kunnen voldoen, moet bij een eerste berekening worden bepaald op basis van duidelijk vooraf opgestelde regels. Dit maakt het mogelijk om de aangeleverde informatie vanuit de specialismen onderling te kunnen vergelijken:

- Gebruik alleen wekelijkse spreekuren voor het berekenen van het benodigde aantal generieke kamers;
- Ga uit van een gemiddelde aanwezigheid van de zorgverlener (houd rekening met afwezigheid);
- De spreekkamerfactor moet worden aangepast per specialisme (aantal kamers per zorgverlener);
- Maak duidelijk onderscheid in de verschillende typen generieke kamers die nodig zijn;
- Beschrijf de eventuele multidisciplinaire spreekuren;
- Geef aanvullende informatie over het aantal niet-wekelijkse spreekuren en het aantal generieke kamers die hiervoor nodig zijn.

Een analyse van de berekende capaciteitsvraag in 2006 en de gewenste capaciteit in 2007, laat zien dat de gewenste capaciteit significant hoger is gedurende de gehele week. Verder laat de gewenste capaciteit een toename in het gebruik van generieke kamers zien op woensdagmiddag en vrijdag, vergeleken met de berekende capaciteitsvraag in 2006. Desondanks zegt dit niets over het werkelijke gebruik van de aangevraagde kamers. Kijkend naar de wekelijks terugkerende spreekuren, dan is er voldoende kamer capaciteit in 2008. Rekeninghoudend met de niet-wekelijkse spreekuren, kan er op bepaalde dagdelen onvoldoende kamer capaciteit zijn in 2008. Dit hangt af van de frequentie en het tijdstip waarop deze niet-wekelijkse spreekuren worden gehouden. Een toename in de jaarlijkse productie op de polikliniek kan binnen een aantal jaren zorgen voor een capaciteitstekort aan generieke kamers.

**Het toewijzen van generieke kamers**

Gebaseerd op het aantal aangevraagde kamers door de specialismen en de berekeningen voor het benodigd aantal generieke kamers, kunnen de generieke kamers worden toegewezen aan de specialismen. Voor het toewijzen maken we onderscheid tussen basis, optionele en flexibele capaciteit.

De ruimtelijke toewijzing van de generieke kamers hangt af van drie factoren: de positie van het back office, de onderlinge afhankelijkheid tussen specialismen en de plek van de specialisme specifieke behandelkamers. Na het bepalen van de plek van elk specialisme kunnen de generieke kamers worden toegewezen.

**Het beheer van de generieke kamers**

Veranderingen zorgen ervoor dat de toewijzing van de generieke kamers met enige regelmaat moet worden bijgewerkt. Wij stellen voor om jaarlijks een herverdeling en evaluatie van de toegewezen generieke kamers te laten plaatsvinden. We adviseren om hier meteen mee te beginnen, ondanks dat er momenteel genoeg capaciteit voorhanden is. Dit om een cultuur te creëren die is voorbereid om te gaan met situaties waarbij er niet voldoende capaciteit voorhanden is en keuzes gemaakt moeten worden op basis van kamergebruik. Voor het toewijzen van generieke kamers speelt historisch gebruik en de lengte van de toegangstijd tot de polikliniek een belangrijke rol.

Door het jaar heen kunnen ook veranderingen plaatsvinden. Seizoensinvloeden en niet-wekelijkse spreekuren zorgen voor extra vraag naar flexibele capaciteit. Deze kamervraag is niet meegenomen in de basis en optionele capaciteit. Een beperkt aantal generieke kamers moet worden vrijgehouden voor deze piekvraag. Ook niet gebruikte generieke kamers van andere specialismen kunnen worden gebruikt. Wij beschrijven een systeem dat gedeeltelijk is gebaseerd op de OK planning, het historisch gebruik van de generieke kamers en eventueel de lengte van de toegangstijd tot de polikliniek. We adviseren om niet alle beschikbare capaciteit direct toe te wijzen tot een vooraf vastgestelde termijn. Op drie specifieke momenten kunnen er extra verzoeken voor generieke kamers worden verwacht. Elk moment heeft verschillende eigenschappen (verschillende criteria voor het toewijzen van de generieke kamers). Eén operationeel manager is verantwoordelijk voor het beheer van de generieke kamers en houdt de veranderingen bij.

**Meten van het kamergebruik**

Het is belangrijk een prestatie-meetsysteem te ontwikkelen, om flexibiliteit op tactisch niveau te creëren. Hierdoor kan worden gereageerd op veranderingen in vraag, kan efficiënt gebruik van generieke kamers worden gestimuleerd, en wordt er een werkbare situatie voor zorgverleners en ondersteunend personeel gecreëerd. Voor elk specialisme moet het gebruik van de generieke kamers worden gemeten. Wij adviseren het kamergebruik als volgt te bepalen:

$$\mathbf{UR} = \frac{\sum_{p}(N_p \times CT_p)}{RA \times DCH}$$

UR = Bezetting van de Kamers

RA = Aantal kamers Toegewezen

DCH = Duur van een Spreekuur

$N_P$ = Aantal patiënten van type p

$CT_p$ = Spreekuurtijd voor patiënttype p

**Aanbevelingen voor het DZ**

Wij adviseren in een vroeg stadium te focussen op efficiënt gebruik van de generieke kamers en het doel van het ziekenhuis om te groeien. Wij hebben de volgende aanbevelingen voor het DZ:

- Maak jaarlijks afspraken met elk specialisme rondom de toegewezen basis en optionele capaciteit die voor het specialisme beschikbaar is;

- Introduceer een duidelijke definitie van de berekenwijze voor de benodigde gewenste capaciteit;

- Zorg voor meer inzicht in de niet-wekelijkse spreekuren. Dit geeft een beter beeld van de extra benodigde flexibele capaciteit;

- Stimuleer de specialismen ongebruikte kamers in een vroeg stadium terug te geven. Dit geeft ander specialismen de mogelijkheid om de kamers te gebruiken;

- Focus op het gezamenlijke doel om het ziekenhuis te laten groeien. Op dit moment zien we dat elk specialisme op zichzelf werkt om haar doelen te bereiken wat kan leiden tot suboptimalisatie;

- Geef maandelijks, of elk kwartaal, inzicht in het gebruik van de generieke kamers per specialisme.

# Summary

Deventer Hospital (DZ) is moving to a new hospital in August 2008. DZ is a general teaching hospital, serving the region around Deventer. The hospital will introduce a separate front and back office in the outpatient department (OD). In 2006, there were 255.926 visits in the OD, 94.964 of which were first visits. More than 100 generic consultation rooms are centrally located in the new OD. The rooms in the OD are partly interchangeable between specialties and healthcare professionals.

The new set up does not only change the working process, but also the allocation and management of the centrally located generic rooms. The (management of) resource allocation in the OD should be arranged in such a way that it is in line with the hospital goals and restrictions.

The objective of this research is formulated as follows:

*"Propose a system for managing and allocating the centralised generic rooms of an outpatient department, with separate front and back office, to create an efficient and flexible use of those rooms"*

In order to attain the research objective above, we formulate a number of research questions:

1. How to calculate the number of generic rooms that are required to fulfil the demand for healthcare?
2. How can the generic rooms be allocated among different specialties?
3. How should management control (i.e. regularly update) the allocation of the generic rooms?
4. How can the efficient use of the generic rooms be evaluated and measured?

The study is based on the developments within DZ. Next to a literature study and interviews with different managers and healthcare professionals within DZ, we carried out a number of interviews in other hospitals. These hospitals are also introducing the concept of a separate front and back office, or have already done this.

The planning and control framework in hospitals distinguishes a strategic, tactical and operational level to describe the different allocation decisions made during the allocation process. For these allocation decisions a balance should be found between centralised and decentralised allocation. This takes place within different time frames. In addition, the allocation should be transparent and based on fairness and equity. However, allocation mechanisms should prevent situation where sub-optimisations can be created. Measuring performance takes an important role in the allocation of generic rooms and to reach objectives and targets.

The allocation of centralised generic rooms of the OD is an ongoing process. In our system for managing and allocating the centralised generic rooms of an OD, we describe the aspects linked to a first time calculation of demand for generic rooms by a specialty, the allocation of generic rooms and finally an evaluation of the allocated generic rooms.

**The number of generic rooms required by the specialties**

Clearly predefined assumptions should be used by the specialties for calculating the initial demand for rooms:

- Take only (regular) weekly consultation hours into consideration for the weekly demand for generic rooms;
- Use the average availability of the healthcare professional (take holidays into account);
- The consultation room factor should be adapted to each specialty (number of rooms per healthcare professional);
- Make a clear distinction in types of generic rooms required;
- Describe the presence of and need for multidisciplinary consultation hours;
- Give additional information on the number of rooms required for irregular consultation hours.

An analysis of the calculated capacity demand in 2006 and the desired capacity in 2007 shows that the desired capacity throughout the whole week is significantly higher. We conclude that the number of desired generic rooms is more spread throughout the week, although it does not give any insight in the actual use of the rooms. Only taking the regular hours into account, there are sufficient generic rooms in 2008. Taking into account a maximum demand for irregular hours, there can be insufficient generic rooms in 2008 on certain day-parts. This depends on the frequency and moment when these irregular hours take place. An increase in the yearly production by 3 to 5 % will create difficulties in the near future.

**The allocation of generic rooms**

To allocate the generic rooms to the different specialties, we make a distinction between the *base*, *optional*, and *flexible capacity*. The spatial allocation of rooms depends on three factors: the location of the back office, the mutual coherence of specialties, and the location of specialty specific treatment rooms.

**Management of the allocation of generic rooms**

The allocation of rooms should be regularly updated and evaluated, on an annual basis. The historic use of the allocated generic rooms and/or length of the access time to the OD plays an important role in the allocation of extra rooms to a specialty. We advise to start from the beginning with setting up a monitoring or evaluation system, although the need for it is limited on the short term. To prepare the organisation for a situation with a shortage of rooms and focus on efficient use of rooms, a culture should be created where the evaluation of (efficient) use of rooms is accepted.

Throughout the year the demand for generic rooms can change. Seasonal influences and irregular consultation hours ask for flexibility of the capacity, since these changes are not included in the base and optional capacity. A limited number of generic rooms should be kept free for flexible use. Changes in demand or increasing access times may cause the specialty to request extra rooms. Unused generic rooms of other specialties can also be used. We propose a system based on the OR planning, the historic use of allocated generic rooms by a specialty and/or length of the access time to the OD. We also advise not to allocate all of the available capacity until a predetermined period in time.

**Measurement of the use of generic rooms**

A performance measurement system is an important tool to create flexibility at a tactical level for responding to changes in demand, to create efficient use of the generic rooms, as well as a workable situation for healthcare professionals and supporting staff. We advise to measure the utilisation of the allocated generic rooms by each specialty. One operational manager of the OD keeps track of the changes. We advise to determine the utilisation of generic rooms as follows:

$$\mathbf{UR} = \frac{\sum_p (N_p \times CT_p)}{RA \times DCH}$$

UR = Utilisation of Rooms

RA = Number of rooms Assigned

DCH = Duration of a Consultation Hour

$N_P$ = Number of patients of type p

$CT_p$ = Consultation Time for patient type p

**Recommendations for DZ**

At an early stage the hospital should introduce a focus on proper use of the generic rooms and the aim of the hospital to increase production. We have the following recommendations for DZ:

- Make yearly appointments with each specialty about the base and optional capacity;
- Introduce clear definitions for the calculation of the desired capacity by a specialty;
- Get more insight into the irregular consultation hours. This gives more insight in the extra needed capacity;
- Stimulate specialties to return unused generic rooms at an early stage. This gives other specialties the possibility to use these rooms if necessary;
- Focus on the overall aim of the hospital to grow. Currently we see that each specialty is working on itself to reach their targets and  this can lead to sub-optimisation;
- Give monthly, or quarterly insight, into the utilisation of generic rooms by each specialty.

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# Chapter 1

# Introduction

In August 2008, Deventer Hospital (DZ) will move to a new location and will change the layout of their outpatient department (OD). A separate front and back office and generic rooms, centrally located within the hospital, are part of the new concept. The main focus of this concept lies on efficiency and patient-centred care. The new OD raises questions on how to manage and allocate the available generic rooms among the different specialties. In this report we propose a system to allocate the centralised generic rooms in an OD, and to create an efficient and flexible use of the rooms.

This report, the first out of two reports concerning capacity planning in DZ, focuses on the allocation and use of centralised and generic rooms in an OD. Report two focuses on capacity planning for Orthopaedics and the optimal throughput for Orthopaedic patients. Figure 1.1 is an overview of the two reports.

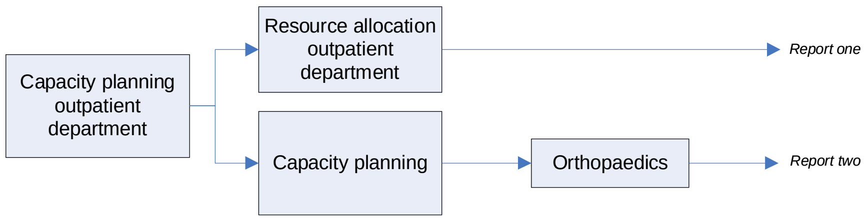


Figure 1.1: Overview of the report

This introductory chapter starts with a description of the situation in DZ (§1.2). In §1.3 we point out the problems concerning the new OD and the different goals of the hospital. §1.4 describes the research objective and questions. §1.5 describes the methodology of our research. We end this chapter with the outline of the report (§1.6).

## 1.2 Front and back office in the new Deventer Hospital

In 1985, the Sint Geertruiden Hospital (1472) and the Sint Jozef Hospital (1875) merged and became the Deventer Hospital (DZ). This hospital can be categorised as a general hospital where highly specialised medical care is provided for the region Salland (Overijssel) in the Netherlands. In

2006, there were 255.926 visits in the outpatient department (OD), 94.964 of which were first visits. In August 2008, both premises will move to a new building located at the Rielerenk in Deventer.

The new hospital at the Rielerenk is built to support the concept of a “multiple flow model” (Appendix I: Multiple flow model). A distinction is made between the different characteristics of patients (acute, urgent, elective, and chronic), supported by the layout of the hospital. The OD provides care to elective and chronic patients. In line with a focus on patient-centred care, part-time jobs and efficient and flexible use of available capacity, a new concept for the OD is introduced: a separate front and back office Other hospitals in the Netherlands have started or are also introducing this concept (Cbz, 2006; Oechsler, 2000; Bisschop, 2007; IOM, 2001). The separation of the front and back office is the biggest change for the OD.

There is a physical distinction between front and back office in the OD. In DZ, more than 100 consultation, consultation/examining (CE-rooms), and multifunctional rooms (MF-rooms) are clustered together in the front office, together with treatment rooms. Figure 1.2 shows a part of the consultation centre in DZ. Clustering rooms reduces the distance between the OD and other hospital departments for the patient, but also for the healthcare professional. Therefore, clustering rooms leads to more patient-centredness. The front office is where the interaction between the healthcare professional and the patient takes place.

Throughout the report, “generic rooms” refers to consultation rooms, CE-rooms and MF-rooms. “Non-generic rooms” refers to specialty-specific treatment rooms. The back office is located above the consultation centre, to create a working and learning area for healthcare professionals. Activities like administrative work or telephone consultation take place in the back office. *Appendix II: Outpatients work process* shows this separation of tasks in the OD.

The intended concept of the new DZ shows a set-up, in which the patient stays in ‘his’ room. This is also proposed by the Netherlands Board for Hospital Facilities (NBHF, 2006) describing the future of hospital care in the Netherlands. In situations where the patient needs to see several healthcare professionals during one consultation, the patient stays in the same room. This increases the patient-centeredness. In addition, there is a distinction in pathways for patients and medical specialists (MS).

In the old way of arranging the OD (referred as “old DZ”), each healthcare professional has its own room. This room can be considered as the specialist’s private working area and cannot be used by other healthcare professionals, also if the healthcare professional is neither present in the room nor in the hospital. In this room, the healthcare professional performs all the tasks that need to be done: seeing patients, doing administrative work, or making telephone consultations (Appendix II: Outpatients work process). The possibilities for specialties to get extra rooms are limited and the exchangeability of the rooms is difficult. But in the new way of arranging the OD (referred as “new DZ”), most of the rooms no longer belong to a single healthcare professional. The rooms are generic, which makes them exchangeable between healthcare professionals and specialties. This exchangeability leads to more flexibility within the OD, due to the possibility to use unused rooms of the neighbouring specialties in the consultation centre. Flexibility is required because of the tendency towards an increase in the number of part-time workers. In addition, the exchange of generic rooms leads to a higher utilisation of those rooms.

The number of CE-Rooms the healthcare professional may use during his consultation hour (consultation room factor) in the front office changes. A consultation hour is the time a specialist sees patients, which can by more than 60 minutes. Each MS can use more than one CE-Room in the front office at the same time during his consultation hour. This is done to use the MS time more efficiently. In this case, the MS does not have to wait for a free CE-Room to see the next patient. Depending on the nature of the consultation hour and the time the MS spends with the patient, the consultation room factor may differ. Although the number of rooms for the MS is variable, all other healthcare professionals (medical assistants or nurse practitioners) get one CE-room during their consultation hour.

For the planning and calculations of the use of generic rooms, the availability of the rooms is important. The rooms in the OD are currently available from Mondays until Fridays, from 08.00 until 12.30 and from 13.00 until 17.00. The time outside these slots is not taken into account within the planning and availability of the rooms.

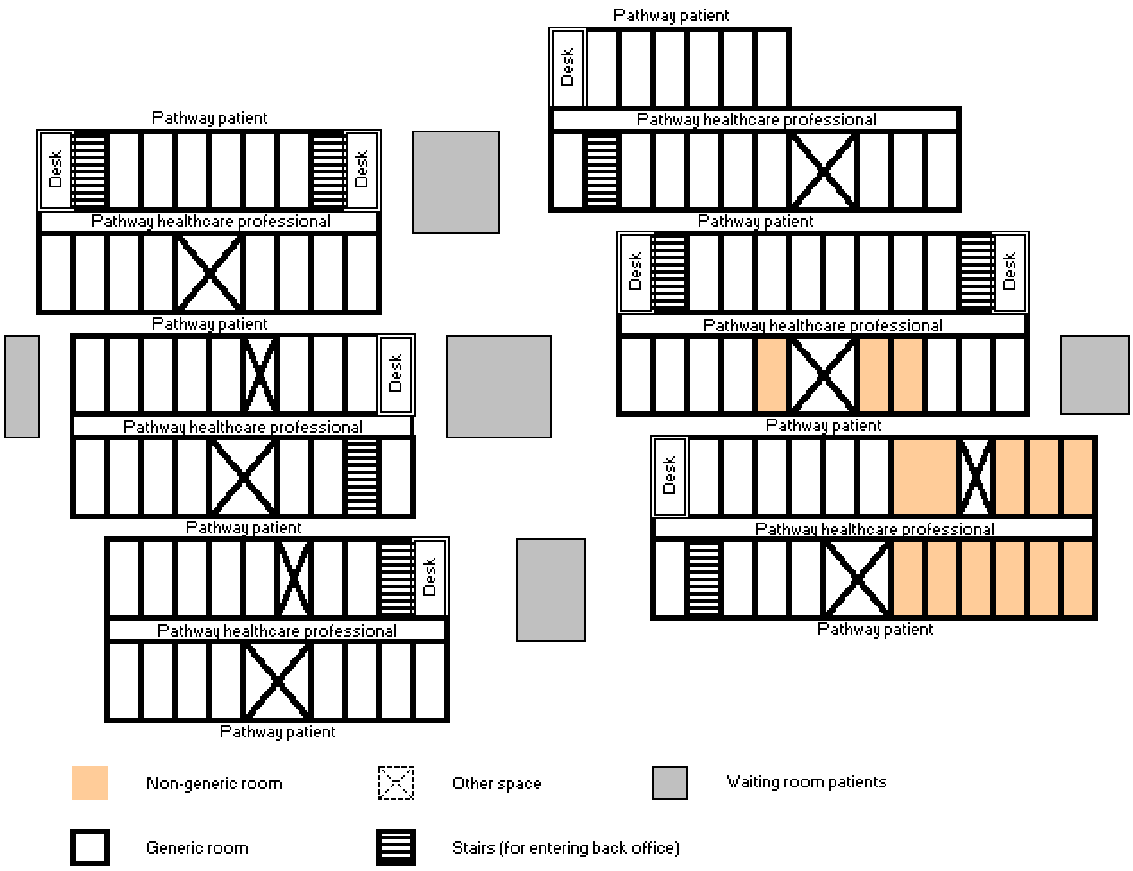


Figure 1.2: Front office outpatient department in the new DZ (ground floor)

Concluding, the most important alterations between the new and old OD in DZ are:

- A separate front and back office, located above each other;
- Contact with the patient takes place in the front office; all other tasks of the healthcare professional take place in the back office.
- The patient stays in the same room in the front office as much as possible;
- The rooms are generic and partly exchangeable between healthcare professionals and specialties;
- The MS can use more than one CE-room during a consultation hour. All other healthcare professionals use one room.

## 1.3 Problem description

The changes described in the previous section will not only affect the working procedures, but also the planning of generic rooms and staff within the outpatient department (OD). Generic rooms are introduced to create flexibility and more efficiency, but ask for coordination. The new Deventer Hospital (DZ) enables the exchange of generic rooms when there are fluctuations in demand. To facilitate this exchange, a new system has to be set up to manage the available generic rooms. At different moments in time extra demand for these rooms may arise. The question is how and when these rooms should be allocated to the different specialties. An important goal is to create sufficient flexibility at a tactical level and to maintain and stimulate an efficient use of these rooms.

In addition to efficient and flexible use of the (non-) generic rooms, DZ also has other goals within the organisation. Spurred by an ageing population (Appendix III: Aging), which triggers increased demand, and by increased market competition (due to the DTC-financed care), DZ wants to rise its production through the expansion of its market (share) and by organising their processes more efficiently. The OD should be able to respond to this trend. There is also a strong focus on access and waiting times. For an OD, the maximum access time is nationally defined within “Treeknormen”, which state that the access time should not be more than 3 weeks in 80% of the cases and 4 weeks maximum. Finally, DZ wants to allocate the resources of the OD in such a way that it does not hinder the healthcare process and healthcare professionals in doing their work.

Summarising, the (management of) resource allocation in the OD should be arranged in such a way that it is in line with the hospital goals and restrictions. Namely it should:

- Create flexibility at a tactical level;
- Create efficient use of the generic rooms;
- Create possibilities for growth;
- Create an optimal throughput of patients;
- Create a workable situation for healthcare professionals and supporting staff;
- Take into account the mutual coherence of specialties.

## 1.4 Research objective and questions

When changing over to the new philosophy of arranging an outpatient department (OD), the hospital should have guidelines on how to deal with resource allocation, management, and performance measurement. The objective of this report is as follows:

*"Propose a system for managing and allocating the centralised generic rooms of an outpatient department, with separate front and back office, to create an efficient and flexible use of those rooms"*

An efficient use focuses on the utilisation rate of the generic room, but also takes into consideration the utilisation of the healthcare professional's time. The use of the generic room can be maximised, but as a result the medical specialist may have to wait and treat fewer patients. For the hospital as a whole this leads to a decrease in the total number of patients seen, resulting in a lower production and in higher waiting lists or admission times. These two utilisation rates should be considered carefully.

Flexible use consists in generic rooms being exchangeable between specialties. When specialties do not need the allocated generic rooms, those rooms should become available for other specialties. Performance measurement should encourage this. Another aspect of flexible use is the location of available generic rooms. This means that available generic rooms should be closely positioned to other specialties, in order to facilitate the exchange and use of the free rooms.

Beside the efficient and flexible use, there are a number of restrictions an allocation system has to deal with. The proposed system should create a workable situation for the staff. The staff should be able to perform their jobs properly. In addition, there should be a potential for growth for the specialties and the hospital. Furthermore, the throughput of patients should not be hindered by the way the rooms are allocated. Patients should not have long waiting times to get a treatment. Finally, the system ought to take into account the mutual coherence of certain specialties, because some specialties should be located next to each other.

For attaining the research objective above, we formulate a number of research questions:

1. How to calculate the number of generic rooms that are required to fulfil the demand for healthcare?

2. How can the generic rooms be allocated among different specialties?

3. How should management control (i.e. regularly update) the allocation of the generic rooms?

4. How can the efficient use of the generic rooms be evaluated and measured?

Question 1 deals with the capacity needs of specialties that will work in a centralised consultation centre (§4.1 and §4.3). Question 2 deals with the aspects concerning the allocation of capacity (§4.2 and §4.6). Question 3 handles the issue of managing and coordinating the resource allocation in an outpatient department (§4.5). Question 4 concerns performance measurement by which the specialties and OD can be evaluated (§4.4).

In this report, the following definitions are used:

- **Demand for generic rooms**: the requested need for generic rooms posed by the specialty (desired capacity needs) or based on calculations (calculated capacity needs);

- **The use of generic rooms**; the time a generic room is used for consulting patients during operational time.

## 1.5 Methodology

First, we take a closer look at the new concept of centralised generic rooms with a separate front and back office. We analyse the consequences for the different specialties and discuss the advantages of introducing this new system in relation to the hospital goals. In order to do so we arrange meetings with managers within Deventer Hospital (DZ), but also outside the hospital. We consult The Maasland Hospital in Sittard and The Netherlands Cancer Institute - Antoni van Leeuwenhoek Hospital in Amsterdam, to get more insight into this new concept. These hospitals have already implemented this new concept or are intending to do so. In addition to these meetings, we also carry out a literature study on this concept. As a result we get a clear understanding of the philosophy behind the concept of a separate front and back office in an outpatient department (OD).

Second, we analyse the calculations and requests of the number of generic rooms needed per specialty in DZ. The research done by the NBHF is also an important input to get insight in the required number of rooms and the calculations. In addition, we use the different schedules provided by the specialties in the DZ for calculating their yearly capacity for generic rooms. This is done to get insight in the different characteristics of the specialties. These characteristics should be kept in mind when comparing the capacity needs of specialties. The result will be a way of calculating and comparing uniformly the capacity need for generic rooms of the different specialties involved in an OD.

For the allocation of generic rooms we perform a literature study to look for allocation mechanisms that can be used. We also indicate restrictions with respect to the spatial distribution of specialties by inquiring the concerned specialties. As a result we get an indication of how the OD should be arranged, keeping in mind the capacity requests from the specialties, the allocation principles, and restrictions for spatial distribution.

To be able to control and manage the generic rooms in an OD, performance is required. We compare various possibilities described in scientific journals. In addition, we take the OR planning in DZ into consideration, because the OR is for many specialties the bottleneck capacity in DZ. We carry out semi-structured open interviews with managers of hospitals applying the concept of a separate front and back office in their hospital. Furthermore we do a literature study in medical and management journals on how to manage the allocation of (generic) room capacity. This results in performance measurements for evaluating and steering the capacity needs of specialties in an OD.

## 1.6 Outline of the report

The remainder of this report is organised as follows. Chapter 2 presents the theoretical background concerning the research questions of §1.4. Chapter 3 describes the Deventer Hospital and the way of arranging the new outpatient department (OD). This chapter includes a description of the philosophy behind the front and back office. In Chapter 4 we propose our system for (management of) resource allocation in an OD with a separate front and back office. In Chapter 5 we summarise our results and give recommendations.

# Chapter 2

# Theoretical Framework

This chapter gives an overview of the relevant literature considering the (management of) resource allocation in an outpatient department. In §2.1 we propose a system to analyse on which levels of capacity planning and management the allocation of generic rooms occur. Furthermore, we take a closer look at resource allocation in healthcare (§2.2), the calculation of the demand for capacity need (§2.3), and aspects of managing and controlling centralised generic rooms (§2.4). §2.5 describes the importance and use of a performance measurement system. §2.6 gives an overview of the literature and links it to the research questions. The mentioned literature and concepts will form a basis for this report and will be referred to in the next chapters.

## 2.1 Framework for planning and control in hospitals

Problems regarding the allocation of generic rooms can be distinguished at different management or planning levels. Figure 2.1 describes a model with horizontally four categories of managerial areas: medical planning, capacity planning, material planning, and financial planning. *Medical planning* deals with the coordination and planning of medical activities by healthcare professionals. *Capacity planning* consists in the planning and control of resources like staff, beds, space, etcetera. *Material planning* is the coordination of materials. *Financial planning* is about the coordination of the financial processes. This research focuses on the capacity planning. In this section we define the different management levels where capacity planning occurs, and position the different levels of resource allocation in an outpatient department (OD) within this framework.

The managerial or planning activities can be distinguished in four hierarchical levels (Anthony, 1965): strategic planning, tactical planning, and operational control (offline and online). These hierarchical levels are presented on the vertical axis in Figure 2.1. *Strategic planning* focuses on the long-term (1-5 years). Decisions are made about the patient mix (case-mix), and the layout and location of the OD. At this level an aggregated capacity planning takes place. Changes in service area and demand are taken into consideration. The members of the board, management team, and medical staff participate in this. On a *tactical level* decisions concerning resource allocation to specialities in the OD are made for the mid-term (year-months). Seasonal influences on the number of patients are also taken into consideration and the patient flow of each specialty is analysed. The management and medical staff participate in this. The objective of this is to get a monthly allocation of available rooms (master planning). At the *operational level* decisions are made for the short-term (days-weeks). A distinction is made between *offline* and *online* decisions. Offline decisions concern the scheduling of patients and staff in the OD. Online decisions deal with the daily coordination of the healthcare process. The specialty, medical specialists, staff, and even the patient are involved in this. In this report we consider the capacity planning at all managerial levels, and also take into account the coordination between these hierarchical levels.

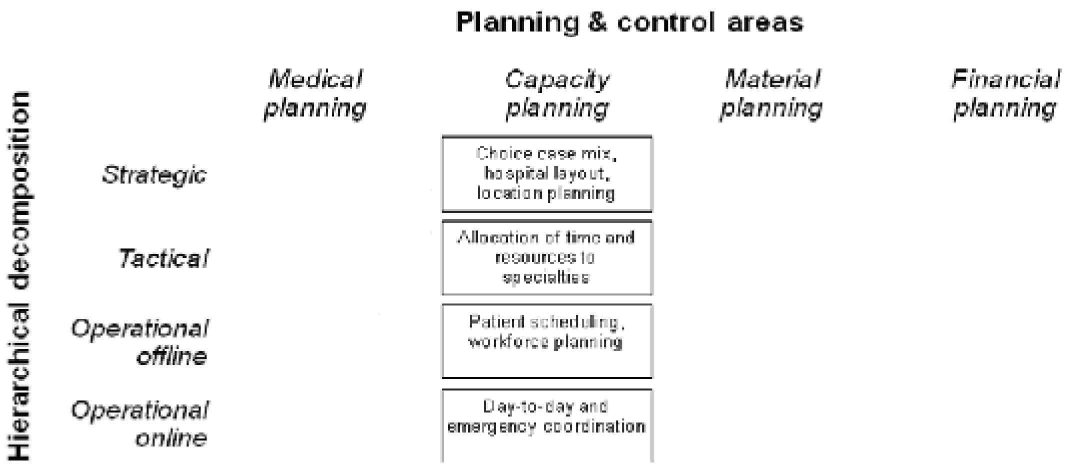


Figure 2.1: Framework for planning and control hospitals [Hans, 2006]

## 2.2 Resource allocation in healthcare

Resource allocation decisions deal with the use of available resources (Siggins & Miller, 2005). There are several approaches for resource allocation available in the literature, but they are specific to a particular context. All decisions are about identifying problems, and developing and choosing strategies to address. These decisions are guided by policies (Kramer, 1976). Decisions concerning resource allocation in general healthcare should be transparent, open to debate, and based on principles of fairness and equity (Siggins & Miller, 2005). In addition, the resource allocation should be based on need. Siggins and Miller (2005) describe that the process of resource allocation is not only guided by finite resources, but also by the arguments and assumptions of varying political persuasions, ethical considerations, pressure groups and research findings. This implies that resource allocation is not always about getting the best use out the available resources (efficiency).

## 2.3 Capacity measurement in an outpatient department

To determine the size of a consultation centre, the NBHF indicates two ways to calculate the number of rooms needed for the healthcare professional. The first method is based on the total production in the consultation centre and the average time of a consultation in the consultation room. This method is referred to as a 'calculation based on production'. The second method focuses on the working method of the medical specialist (MS). The time the MS spends with the patient in the consultation room compared to the total time the patient spends in the room determines the number of rooms needed. This method is referred to as 'calculation based on consultation time' and is based on a separate front and back office. This method means that in case the MS uses a small percentage of the total consultation time, a higher number of rooms is needed. Hereby the MS will not have to wait for a free consultation room. The consultation room factor can be different for each specialty and MS. A variable consultation room factor can lead to reduction of the number of rooms necessary by 10 to 30%, compared with the traditional way of organising a consultation centre. This reduction can be achieved if a centralised consultation centre with generic exchangeable consultation rooms is realised, because the consultation rooms are better used (Cbz, 2006).

To calculate the capacity needs for a specialty, an estimation of the average patient time is required. Vissers et al. (2000) describe that the average time required for one patient can be estimated on the basis of the length of an appointment slot for a first visit, the length of an appointment slot for repeat visits, and their relative occurrence.

## 2.4 Planning and control of the available capacity

Vissers and Beech (2005) describe different types of capacities within the hospital and their characteristics. They make a difference between bottleneck and non-bottleneck capacity. Huang (2002) describes that the throughput of the non-bottleneck capacity is always determined by the bottleneck capacity within the whole process. In the case of a hospital this is often the operating room (OR) (Jebali et al., 2004). The dependency between the main bottleneck (often the OR) and the outpatient department differs per specialty and becomes bigger when it concerns the surgical specialties.

The control of capacities takes place centrally or it is decentralised. A change can be seen in the way departments are managed (Monrad, 1998). A more decentralised management model is chosen to give more responsibilities to the departments. The decentralised model has many advantages, although still a balance has to be found between a centralised and decentralised management model (Boissoneau & Belton, 1991). A department should have sufficient possibilities to react to a fast changing environment. But there are also functions that can be better centrally organised, because of efficiency and a general covering importance (Boissoneau & Belton, 1991).

## 2.5 Performance management

When controlling the use of consultation rooms it the hospital should make use of performance management. Performance management creates the context for and the measures of performance. Performance is the potential for future successful implementation of actions in order to reach the objectives and targets (Lebas, 1995). Objectives are supported by measurement of key performance indicators (KPIs) and stems from the mission and strategy an organisation has. It aims to support the implementation and monitoring of strategic initiatives. At an operational level, input and output values of KPIs are compared with predefined goals. If there is a discrepancy, an appropriate action should take place with knowledge about the behaviour of the organisation. At a tactical or strategic level KPIs are evaluated and perhaps adapted, by changing goals if necessary. Performance management plays an important role at all managerial levels (Lohman et al., 2002).

The importance of measurement takes place along different dimensions. Examples of these dimensions and their importance are (Sinclair & Zairi, 1995):

- Planning, control, and evaluation: according to Euske (1984) “the measurement process is central to the operation of an effective and efficient planning, control, or evaluation system”;
- Measurement and improvement: according to Sink & Tuttle (1989) “perhaps the only really valid reason for measuring performance … is to support and enhance improvement”. Harrington (1991) adds that measurement is “the beginning of improvement, because if you cannot measure the activity, you cannot improve it”;
- Resource allocation: Thor (1991) announces that measurement “helps an organisation direct its scarce resources to the most attractive improvement activities … Measurement also provide a direct stimulus to action”;
- Measurement and motivation: Locke et al. (1981) and White & Flores (1987) state that performance improves if individuals are given targets, and is maximised if targets are seen as challenging but achievable. But it all depends on the organisational context of the measurement, the use made of measurements, the degree of agreement between measurements and organisational objectives, and the individual’s motivational response to measurement (Euske et al., 1993);
- Communication: as Juran (1992) mentioned, “vague terminology is unable to provide precise communication. It becomes necessary to say it in numbers”.

Terms that must be defined in performance management are performance measurement, performance measures, and performance measurement system (Sinclair & Zairi, 1995):

- Performance measurement: “the systematic assignment of numbers of entities” (Zairi, 1994; Churchmann, 1959). According to Churchmann (1959) the function of measurement is to “develop a method for generating a class of information that will be useful in a wide variety of problems and situations”;

- Performance measures: “characteristics of outputs that are identified for purposes of evaluation” (Euske, 1984). They are the vital signs of the organisation quantifying how well the activities within a process or outputs of a process achieve the specified goals (Hronec, 1993). According to Lohman et al. (2002) performance measures “quantify the efficiency and effectiveness of operations”. The authors also state that performance measures are based on characteristics of operations of an organisation and need to be reflected in the definitions of performance measures used;

- Performance measurement systems (PMSs): aim to “integrate organisational activities across various managerial levels and functions” (McNair et al., 1989). Hronec (1993) defines it as “a tool for balancing multiple measures (cost, quality, and time) across multiple levels (organisation, processes, and people)”. According to Edson (1988) and Talley (1991) performance measurement systems should focus on continuous improvement. An effective performance measurement system “should provide timely, accurate feedback on the efficiency and effectiveness of operation” (Kaplan, 1991). A PMS consists of several elements like strategy development and goal deployment, but also reward and recognition (Sinclair & Zairi, 1995).

Before measuring performance, the concept of performance measurement has to be operationalised (Lebas, 1995). In the literature there is a wide range of approaches to performance measurement. The most well known approach is the balanced scorecard (Kaplan & Norton, 1991). This is a useful tool in the performance management of small regional hospitals. It links strategy with performance and goes beyond the traditional financial metrics in determining whether or not an organisation has been successful. It translates the mission and the strategy into a set of performance measures that provides the framework for a strategic measurement and management system (Cutright & Edell, 2000). An example of a performance measure is the efficient use of the available capacity. Through measuring the use of generic rooms by each specialty, management can be supported in its task. For measuring the efficiency of the capacity use (or doing the right things with the minimum expenditure of resources) Reid and Sanders (2002) propose several measurement possibilities.

- Occupation = actual output rate / capacity $\leq$ 100%

- Occupation (effective) = actual output / effective capacity × 100%
- Occupation (design) = actual output / design capacity × 100%

The effective capacity is the maximum output rate, which can be reached under normal circumstances. Design capacity is the maximum output rate, which can be reached under ideal circumstances (Reid & Sanders, 2002).

According to Bourne et al. (2000) the development of a PMS can be separated into phases of design, implementation, and use. The design phase consists of identifying key objectives and designing measures. In the implementation phase, systems and procedures are put in place to collect and process the data that enable measurements to be made regularly. In the use phase the measurement results are reviewed for assessing the efficiency and effectiveness of operations and the successfulness of the implementation of the strategy. All phases should continuously be reviewed in where a measure may be deleted or replaced, the target may change, and the definition of measures may change. Figure 2.2 shows a development process of a PMS in which the processes are often iterative.

| Step | Action |
|---|---|
| 1 | Clearly define the firm's mission statement |
| 2 | Identify the firm's strategic objectives using the mission statement as a guide (profitability, market share, quality, cost, flexibility, dependability, and innovation) |
| 3 | Develop an understanding of each functional area's role in achieving the various strategic objectives |
| 4 | For each functional area, develop global performance measures capable of defining the firm's overall competitive position to top management |
| 5 | Communicate strategic objectives and performance goals to lower levels in the organization. Establish more specific performance criteria at each level |
| 6 | Assure consistency with strategic objectives among the performance criteria used at each level |
| 7 | Assure the compatibility of performance measures used in all functional areas |
| 8 | Use the PMS |
| 9 | Periodically re-evaluate the appropriateness of the established PMS in view of the current competitive environment |

Figure 2.2: Steps for developing a PMS [Lohman et al., 2002]

## 2.6 Summary of the literature

We use the planning and control framework in hospitals, which distinguishes a strategic, tactical and operational level, to describe the different allocation decisions made during the allocation process. For these allocation decisions a balance should be found between centralised and decentralised allocation. This takes place within different time frames. In addition, the allocation should be transparent and based on fairness and equity. Also the need is important. Allocation mechanisms should not always be based on getting the best use of the available resources. Measuring performance takes an important role in the allocation of generic rooms, because it is the potential for future successful implementation of actions in order to reach objectives and targets.

The literature on resource allocation in healthcare forms the basis for the questions mentioned in §1.4. We use the literature on capacity measurement for answering question 1. We use the literature on planning and control of available capacity for answering the questions 2 to 4. Furthermore, the literature on developing a PMS forms the basis for question 4.

# Chapter 3

## Resource allocation in the outpatient department of DZ

In this chapter we take a closer look at the new outpatient department (OD) of Deventer Hospital (DZ). The new consultation centre in DZ consists of several departments, here described as blocks, with (grouped) consultation rooms. The blocks differ in the number and sorts of specialty-specific rooms that are available beside the generic rooms. The following blocks can be distinguished in the new OD and are displayed in Figure 3.1:

- **K0- and L0-block**: consists of 116 generic rooms that are mainly exchangeable between specialties and specialists. These rooms are further divided into 102 CE-Rooms and 14 MF-Rooms. There are also specialty-specific treatment rooms (non-generic rooms). The rooms in the K0- and L0-block are divided into 9 smaller groups of rooms, each with its own desk where the patient notifies his presence;

- **A0-, C0-, H0-, and C1-block**: consists of specialty-specific rooms. For example Geriatrics and Ophthalmology are located in theses blocks. Beside specialty specific examination rooms, there are also consultation rooms. Although theses rooms are without an examination table, where only a consult can take place and no examination.

This report focuses on the K0- and L0 block. §3.1 describes the process to determine the capacity needs in the OD of DZ. §3.2 describes the differences in the determination of capacity needs by the different specialties. §3.3 describes the spatial distribution of the new OD in DZ. The results found in this chapter serve as input for Chapter 4, where we propose a system for resource allocation.

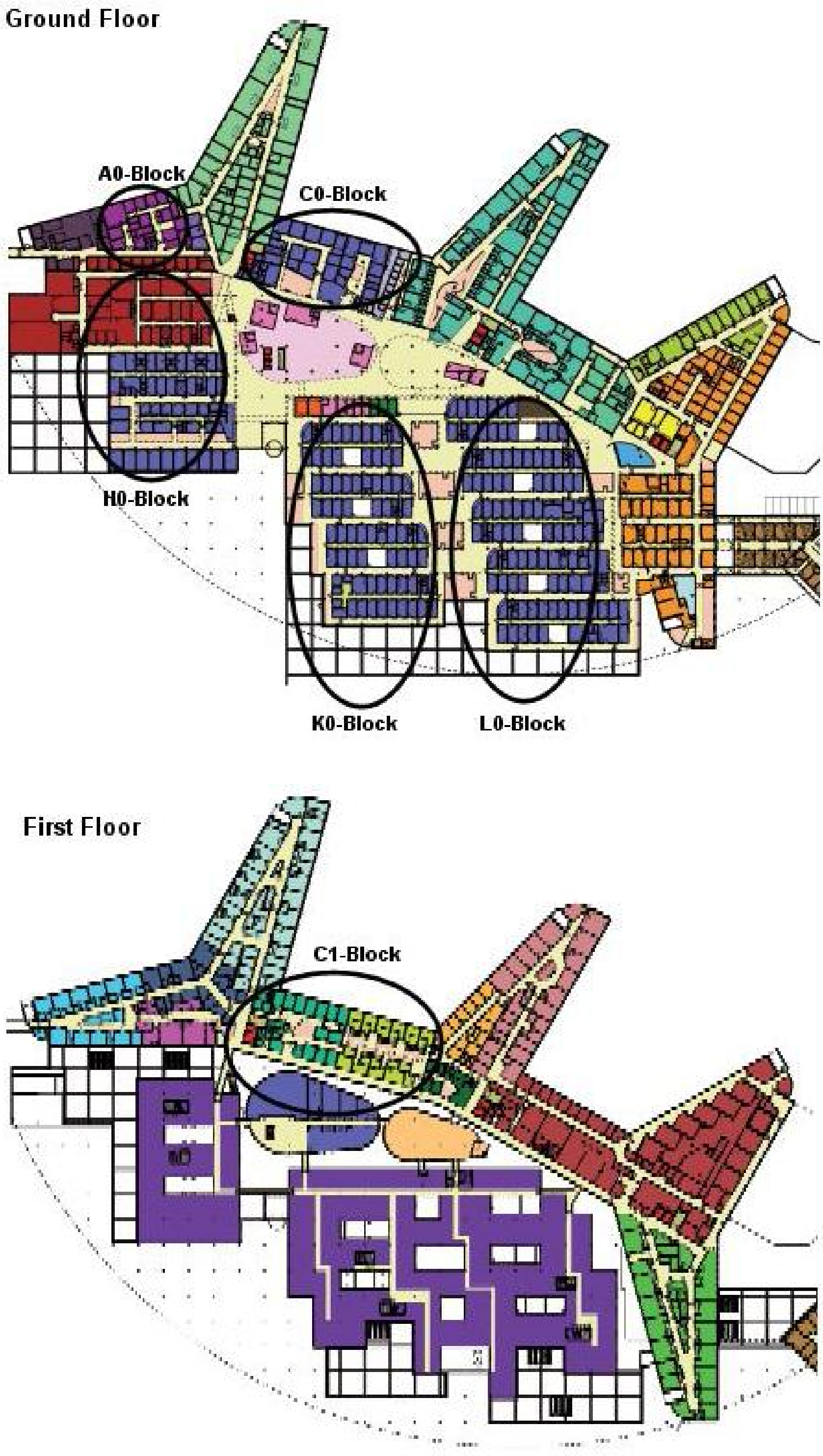


Figure 3.1: Ground and First Floor of the new DZ

## 3.1 Capacity needs of the outpatient department in DZ

This section describes the process in Deventer Hospital (DZ) to determine the capacity needs for the specialties in their outpatient department (OD). §3.1.1 describes the calculated capacity made in 2006. §3.1.2 shows the desired capacity by specialties determined in 2007. In §3.1.3 we describe the differences between these two capacity needs. These differences concern the regular consultation hours. Eventually, §3.1.4 describes the irregular consultation hours posed by the different specialties.

### *3.1.1 Calculated capacity for generic rooms*

In October 2006, DZ did a first inventory of the needed capacity in their new OD. They considered the months January until March 2006, which represent three busy months. The appointment system of the hospital was searched through per specialty for consultation hours that took place in the OD during that period. These consultation hours represent the presence of healthcare professionals and indicate the number of generic rooms needed per day-part: two CE-Rooms per medical specialist and one CE-Room for other healthcare professionals per consultation hour. This inventory was only done for the K0- and L0-block and gave an overview of the number of generic rooms required.

The inventory made in 2006 resulted in a spatial distribution of the specialties over the different blocks (see also §3.3). *Appendix IV: Spatial distribution of front office K0- and* L0-block displays this spatial distribution. It shows that there are 15 specialties that use the generic rooms in the K0- and L0-block. These rooms are furnished in such a way that all the specialties in these blocks can make use of generic rooms. Certain specialties already have a 'fixed' place within the new DZ, because of the presence of specialty-specific treatment rooms (for example Dermatology). Table 3.1 shows the number of generic rooms per day-part for each specialty that has consultation hours in the K0- and L0-block. The spatial distribution and the calculated capacity have formed the basis for the final transition to the new DZ.

### *3.1.2 Desired capacity for generic rooms*

Since October 2006, some changes occurred in the staff occupation within the specialties of DZ and the demand for and provision of care. These changes influenced the demand for (non-)generic rooms by the specialties. For that reason, in April 2007 the specialties in DZ were asked to determine their desired capacity of generic rooms in the OD. A guiding checklist was provided to the specialties to make a (realistic) prediction of the annual demand for the different kind of rooms for the front office in 2008 (Appendix V: Checklist planning consultation hours). Supported by this checklist, the specialties determined the number of generic rooms they need for each day-part in 2008. Table 3.1 shows the desired capacity for generic hours in the K0- and L0-block to perform the regular (weekly) consultation hours. *Appendix VI: Desired capacity for regular hours specialties* displays the desired capacity for generic rooms for all specialties in the OD in DZ to perform their regular consultation hours. Within this Appendix a distinction is made between the different generic rooms: CE-rooms, MF-rooms, and consultation rooms.

| | Monday | | | | Tuesday | | | | Wednesday | | | | Thursday | | | | Friday | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *AM* | | *PM* | | *AM* | | *PM* | | *AM* | | *PM* | | *AM* | | *PM* | | *AM* | | *PM* | | | | |
| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Rheumatology | 7 | 7 | 6 | 7 | 7 | 6 | 7 | 5 | 5 | 6 | 5 | 7 | 7 | 8 | 3 | 0 | 5 | 5 | 5 | 5 | 57 | 56 | -1,8% |
| Anaesthesiology (pain) | 5 | 2 | 5 | 4 | 5 | 2 | 6 | 4 | 5 | 2 | 6 | 4 | 5 | 2 | 6 | 4 | 5 | 2 | 6 | 4 | 54 | 30 | 48,1% |
| Anaesthesiology (preop) | - | 5 | - | 5 | - | 5 | - | 5 | - | 5 | - | 5 | - | 5 | - | 5 | - | 5 | - | 5 | - | 50 | - |
| Internal Medicine | 19 | 26 | 17 | 24 | 20 | 27 | 17 | 27 | 17 | 25 | 12 | 23 | 22 | 27 | 20 | 28 | 15 | 24 | 3 | 19 | 162 | 250 | 54,3% |
| Dermatology | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 100 | 100 | 0,0% |
| Orthopaedics | 6 | 4 | 7 | 5 | 6 | 6 | 7 | 6 | 0 | 4 | 5 | 5 | 6 | 3 | 6 | 2 | 6 | 5 | 6 | 5 | 55 | 45 | -18,2% |
| Plastic surgerty | 6 | 6 | 6 | 2 | 6 | 6 | 6 | 2 | 6 | 0 | 6 | 1 | 6 | 6 | 6 | 2 | 6 | 6 | 6 | 2 | 60 | 33 | -45,0% |
| Gastroenterology | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 2 | 4 | 2 | 40 | 28 | -30,0% |
| Cardiology | 10 | 10 | 8 | 12 | 13 | 12 | 10 | 12 | 12 | 9 | 7 | 8 | 11 | 10 | 9 | 12 | 4 | 6 | 2 | 7 | 86 | 98 | 14,0% |
| Surgery | 14 | 14 | 14 | 13 | 9 | 10 | 9 | 9 | 14 | 15 | 0 | 14 | 0 | 15 | 0 | 15 | 0 | 15 | 0 | 0 | 60 | 120 | 100,0% |
| Neurology | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 3 | 40 | 42 | 5,0% |
| Pneumology | 7 | 12 | 7 | 12 | 7 | 12 | 7 | 11 | 7 | 12 | 5 | 11 | 7 | 12 | 7 | 12 | 7 | 11 | 7 | 10 | 68 | 115 | 69,1% |
| Clinical neurophysiology | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | - | 10 | - |
| Medical psychology | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | - | 10 | - |
| SMA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 1 | - |
| *Total* | 92 | 105 | 88 | 104 | 91 | 105 | 87 | 101 | 84 | 97 | 64 | 98 | 82 | 107 | 75 | 99 | 66 | 98 | 53 | 74 | 782 | 988 | 26,34 |
| *Utilisation (%)* | 79 | 91 | 76 | 90 | 78 | 91 | 75 | 87 | 72 | 84 | 55 | 84 | 71 | 92 | 65 | 85 | 57 | 84 | 46 | 64 | 67 | 85,17 | 26,34 |

Table 3.1: Calculated and desired capacity of specialties in the K0- and L0-block

### *3.1.3 Differences between calculated and desired capacity*

Comparing the calculated capacity (of 2006) and desired capacity (of 2007) (Table 3.1), we can conclude that the total desired capacity for the K0- and L0-block is 26% higher for a whole week. Especially Anaesthesiology (Pain and Preoperative), Surgery, and Internal Medicine request more rooms. Plastic Surgery, Orthopaedics, Gastroenterology, and Pneumology show a decrease.

Looking at the number of the available generic rooms requested per day-part, we see for the calculated capacity a low utilisation on Wednesday afternoon (55%) and Friday (57% morning and 46% afternoon). But the desired capacity shows an increase in the utilisation on Wednesday afternoon (84%) and Friday (84% morning and 64% PM). Looking at the whole week, the utilisation of the available generic rooms for the calculated capacity is 67%. The desired capacity shows an 85% utilisation, an increase of 26%. Overall, we can conclude that the utilisation of available generic rooms on all days increased, although it does not tell us if the requested room are really used. In addition, we can conclude that the demand for generic rooms is more spread during a week, although the actual use remains unknown.

The number of available generic rooms is sufficient to fulfil the number of demanded rooms of the specialties. Although in 2008 there are sufficient generic rooms, a yearly production increase of 4 to

5% creates difficulties in the near future. Figure 3.3 shows the utilisation of generic rooms per week in near future in case of a 3, 4, and 5% growth in healthcare demand. In Figure 3.3 the irregular consultation hours are not included and a 100% utilisation of the OD rooms is not realistic. The maximum utilisation of the rooms depends on the variation of room demand throughout the year. High fluctuations result in a lower maximum utilisation and vice versa. The tendency to treat more patients in the OD instead of the clinic, and the ageing of the population creates an even higher increase in demand for generic rooms.

| desired capacity | 3% growth | 4% growth | 5% growth |
|---|---|---|---|
| | | | |
| 2008 | 85,17% | 85,17% | 85,17% |
| | | | |
| 2009 | 87,73% | 88,58% | 89,43% |
| 2010 | 90,36% | 92,12% | 93,90% |
| 2011 | 93,07% | 95,81% | 98,60% |
| 2012 | 95,86% | 99,64% | 103,53% |

Figure 3.2: Impact of growth for available generic rooms

### *3.1.4 Irregular consultation hours*

Aside from the regular hours taking place every week, there are also irregular consultation hours that do not take place every week. These hours affect the available capacity, but are not yet taken into consideration in the desired capacity posed by the specialties as shown in Table 3.1. Directly assigning capacity for these hours leads to a low utilisation of generic rooms, because the rooms are not used every week. *Appendix VII: Desired capacity for irregular hours specialties* shows these hours for all specialties. This appendix shows an average demand of 30 rooms per week in the K0- and L0-block. When taking these extra hours into account, the utilisation increases to 88% during a whole week (30% higher than the calculated capacity). Furthermore, the appendix shows that not all the specialties indicate when these irregular hours take place. If these hours take place in the same week, a maximum of 44 generic rooms is necessary. This will lead to an 89% utilisation of all generic rooms a week during that specific week. The irregular hours can cause a considerable extra peek demand, which makes it important to have more insight into the frequency and moment these hours takes place.

We use the desired and calculated capacity (regular and irregular hours) for the allocation of the available capacity in the OD (§3.3).

## 3.2 Differences in the determination of the desired capacity

The desired capacity, which each specialty made based on the checklist, resulted in a diverse overview regarding to the information provided. With respect to the calculation of the desired capacity by the specialties themselves, we encountered a number of differences. These differences are important for the comparison of capacity between specialties on the one hand and important for a realistic capacity demand on the other hand. Aspects to take into consideration:

- **The level of detail**: the level of detail in which the calculations and processes are described shows huge differences. Some specialties give insight into the calculations that have been made. Other specialties indicate that the calculated capacity is still sufficient to deliver care in 2008. Overall, no uniform used calculation method can be found among all specialties;

- **52-week presence of employees**: the desired capacity is often based on a fulltime yearly presence of the healthcare professionals. Each healthcare professional is scheduled every week during 52 weeks a year. No attention is paid to the fact that the healthcare professional may have activities somewhere else, or is on holiday. This absence results in unused rooms, which is not always mentioned or deducted from the desired capacity. Most of the specialties made an operational schedule for one week and apply that schedule for the whole year. An average week schedule, adjusted for the absence of healthcare professionals, is more appropriate;

- **Number of irregular hours**: not all of the consultation hours take place every week. Reserving a room for these activities during the irregular hours results in a low utilisation of the room, if this room is allocated to a specialty every week. A limited number of specialties describe these consultation hours apart from the master plan, and for other specialties it is not clear whether and how those hours are scheduled. There is no insight in the frequency and moment these hours takes place;

- **The number of rooms per medical specialist (MS)**: the number of rooms an MS uses at the same time is not always two. For the determination of the calculated capacity, this number of rooms is set to two. Because of practical considerations the number of rooms can be also one or three. This consultation room factor does not have to be the same for each specialty;

- **Multidisciplinary consultation hours**: some consultation hours need the presence of more than one specialty. The required generic rooms should be requested by one specialty, although it happens that both specialties extra demand rooms, or none at all. In addition, the description of the same multidisciplinary consultation hour and the frequency are sometimes described different. This makes it difficult to compare the number of consultation hours and to make an inventory of the multidisciplinary consultation hours;

- **A focus on an above average demand**: overall, the total desired capacity by the specialties is based on calculations that consider an above average demand during each day-part. The annual peak demand is often taken as the desired capacity for a specific day-part. Figure 3.3 shows an example of this. The specialty poses a desired capacity of 10 rooms (horizontal line at 10) for day-part X during week 1 to 10. Only at day-part 5 this number of generic rooms is actually needed. The number of generic rooms needed for that specialty is most of the time lower than 10 (Area C). This demand only consists of the weekly consultation hours. This means that a number of rooms are not used during the week. Area B shows this number of unused rooms during week 1 to 10.

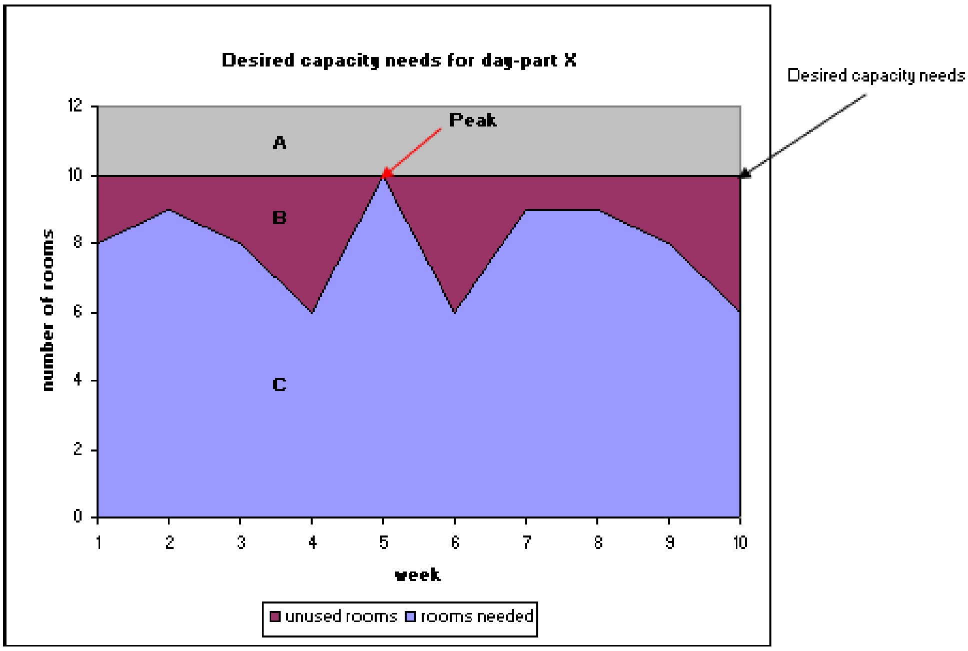


Figure 3.3: Focussing on an above average demand

Concluding, specialties use different calculation methods in determining their desired capacity for the outpatient department (OD). This makes it difficult to compare the desired capacity between specialties. In §4.3 more attention is paid to the calculation of the desired (generic) rooms for the OD.

## 3.3 Spatial distribution of the outpatient department in DZ

This section describes the spatial distribution of the K0- and L0-block within DZ proposed in 2006 and 2007. The spatial distribution of the other blocks, located outside the centrally located consultation centre K0 and L0, are not further described. The layout of these rooms is specific and the rooms are not exchangeable.

After the determination of the calculated capacity in 2006, Deventer Hospital (DZ) started with the spatial distribution of the K0- and L0-block. For the spatial distribution of the outpatient department (OD), DZ identified a number of important constraints. These constraints are:

- **The location of the back office**: the location of the back office should be close to the rooms the specialty has in the front office. This saves time, especially when a colleague drops by during a consultation hour;
- **The mutual coherence of specialties**: an example of mutual coherence of specialties in DZ is Gastroenterology and Surgery, and the Pain and Preoperative department (Anaesthesiology). The specialties should be close to each other;
- **The location of specialty-specific treatment rooms**: there are also specialty-specific treatment rooms leading to a fixed position of certain specialties in the OD. Examples are Dermatology, Neurology, Pneumology and Cardiology.

Figure 3.4 shows the initial spatial distribution. The figure shows the ground floor of the OD in the new DZ. Some specialties overlap, indicating that some specialties have to take place in neighbouring groups of consultation rooms during certain day-parts of the week.

For more background information on this spatial distribution see *Appendix IV: Spatial distribution of front office K0- and* L0-block.

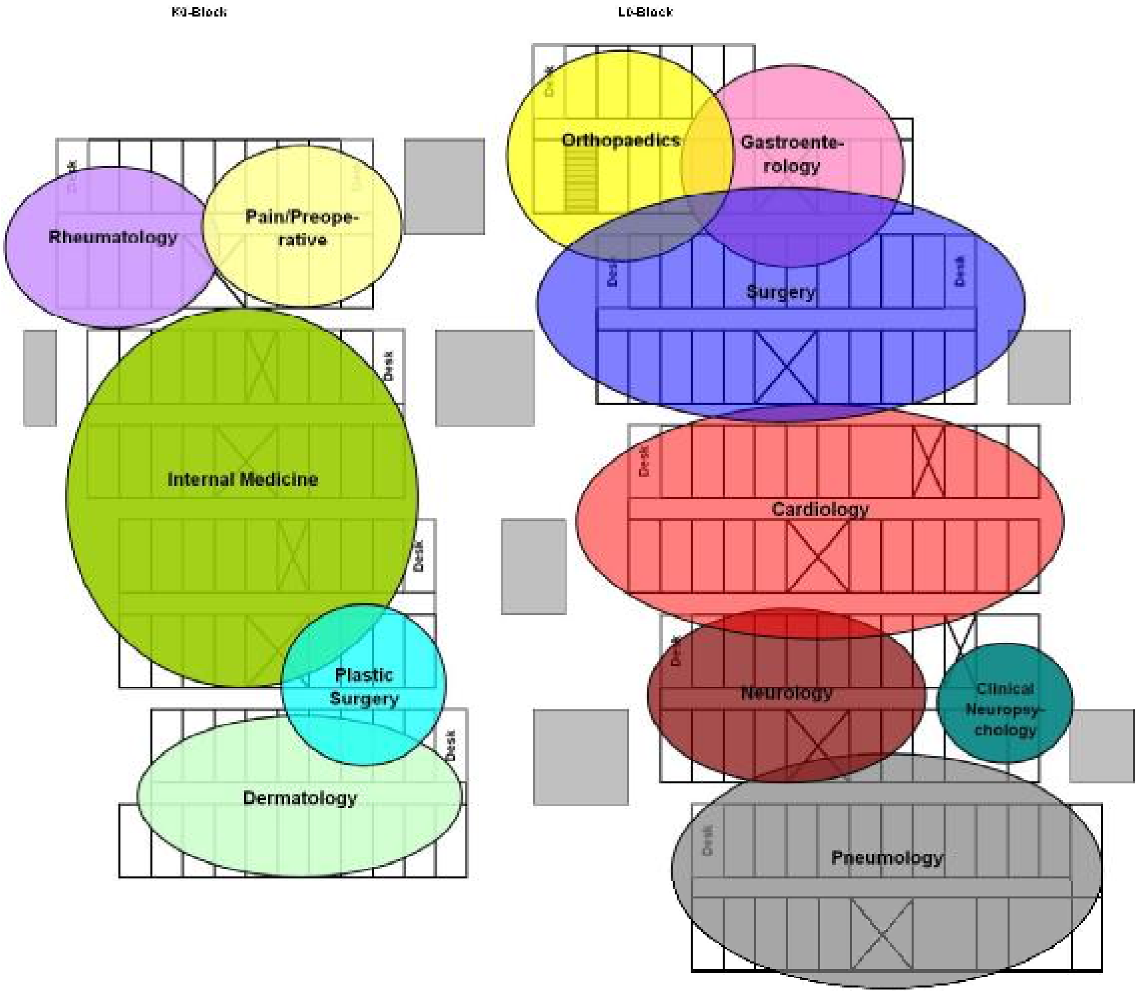


Figure 3.4: Spatial distribution of the front office for the K0- and L0-block 2006

Due to a number of changes within the specialties, the specialties were asked to determine their desired capacity in 2007 (§3.1). This influences the initial spatial distribution made in 2006. Plastic Surgery moves next to Orthopaedics, because Internal Medicine has a much higher desired capacity than the calculated capacity. The other specialties are located at the same position as determined in 2006. In addition, a number of other specialties are now also located within these blocks. This holds for Clinical Neuropsychology, Medical Psychology, and SMA. Figure 3.5 shows this spatial distribution. *Appendix VIII: Spatial distribution outpatient department DZ 2007* shows a day-part with the desired capacity and the new proposed spatial distribution in the new DZ.

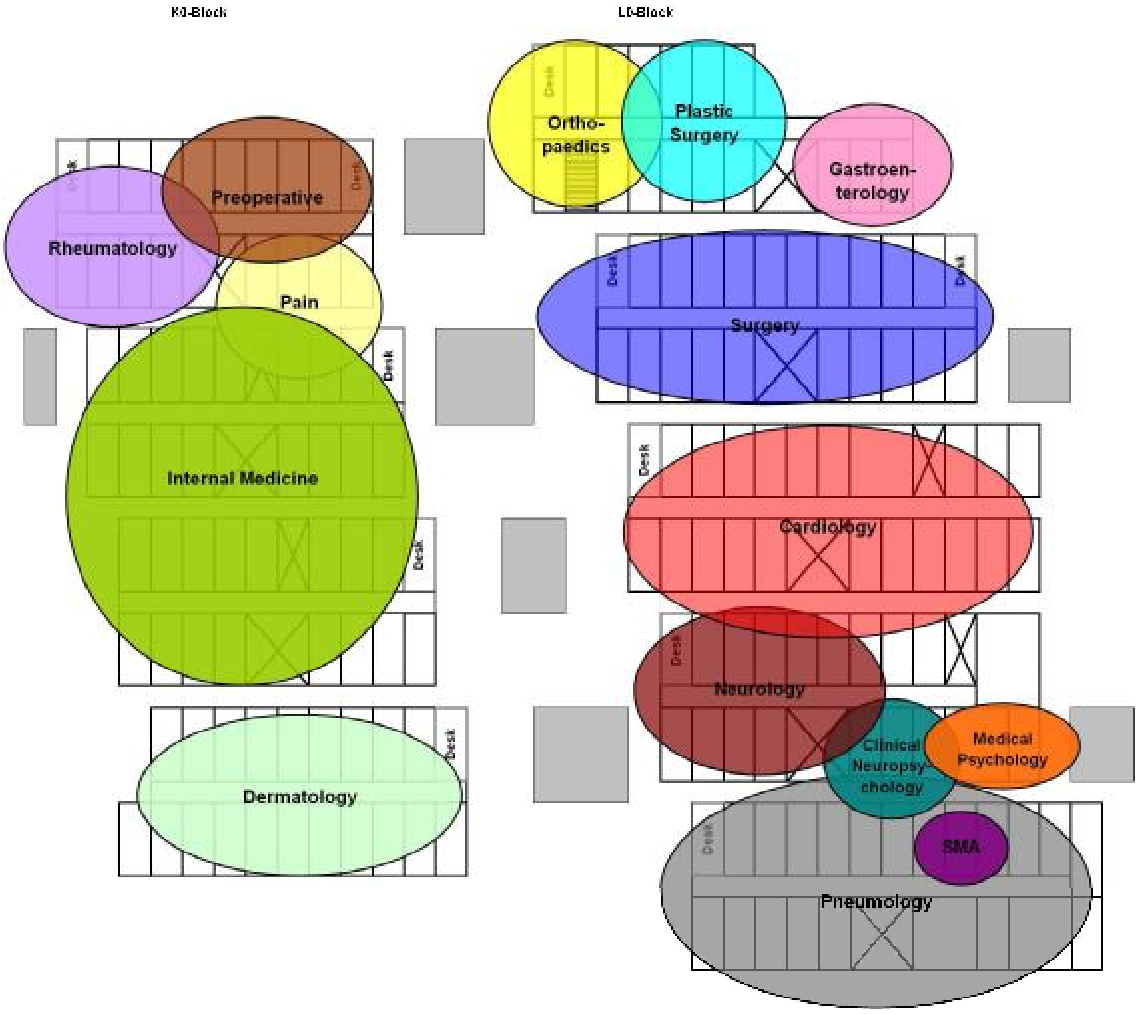


Figure 3.5: Spatial distribution of the front office for the K0- and L0-block 2007

# Chapter 4

# A system for resource allocation in an outpatient department

This chapter describes a general system for capacity allocation in the outpatient department (OD). The capacity allocation concerns an OD with a separate front and back office. The historic use of the allocated generic rooms plays an important role in the allocation. §4.1 presents factors which influence the number of generic rooms demanded by the specialties. §4.2 proposes a categorisation of the capacity allocated to the specialties. §4.3 describes the allocation of generic rooms in an initial phase when there is no information available on historic use of rooms. §4.4 describes the necessity to regularly monitor the use of the generic rooms. §4.5 deals with the regular updating and adjusting the allocation of rooms. Finally, §4.6 describes spatial allocation principles for the generic rooms.

## 4.1 Factors that influence the demand for generic rooms

For the allocation of generic rooms in the OD, it is required to use comparable data. Unclear and ill-defined requirements and assumptions cause differences in the way the specialties in Deventer Hospital (DZ) calculate the desired capacity for generic rooms. The different calculation methods are caused by differences in healthcare processes, insights, and specialty characteristics.

Based on the inadequacies observed in DZ, we propose to use a uniform calculation method adaptable to each specialty. A number of assumptions should be taken into account. These assumptions should lead to a proper, more viable and uniform comparison between specialties with respect to their capacity need. The generic rooms will also be distributed more fairly, when keeping these assumptions in mind. The assumptions are:

- **Availability of the healthcare professional**: the capacity demand should be based on an average availability of the healthcare professional. No more rooms than necessary should be demanded. Each specialty has to take absence into account into their calculations (holidays, education, congress, etc.);

- **Consultation room factor**: the number of rooms necessary per healthcare professional during a consultation hour can vary between and within specialties. The consultation room factor should be determined for each specialty in advance. One consultation factor for all specialties does not fit;

- **Distinction in types of rooms**: the consultation centre has different types of consultation rooms (consultation examining, multifunctional, and specialty specific rooms). Each specialty should make a distinction in the capacity needs for these rooms, as they are equipped differently. Ill-defined demand can cause an inappropriate allocation of the rooms;

- **Need for multidisciplinary consultation hours**: it has to be clear which specialties have multidisciplinary hours, with whom, and how many times these hours take place. Also should be stated clearly which specialty accounts for these hours to prevent a double reservation of these hours;

- **Rooms for irregular consultation hours**: consultation hours that do not take place every week have to be mentioned distinctly, to get more detailed insight in frequency and moment these demand for rooms takes place. In addition, the hospital is able to use empty rooms and prevent unnecessary claiming of rooms.

The information required should be clearly stated. Not doing so gives back information that is difficult to compare. It requires a lot of effort to get sufficient extra necessary information from the specialties afterwards.

## 4.2 Categorisation of different capacity demands

The demand for generic rooms differs for each specialty. The differences depend on healthcare processes and patient characteristics. The need for and use of allocated rooms for a specialty differs over time. We make a distinction in the room capacity demand: *base capacity*, *optional capacity* and *flexible capacity*. The main aim is to distribute the rooms fairly between the different specialties and to stimulate efficient use of generic rooms.

The distinction between the three different capacities represents the chance the capacity is needed. The allocated base capacity of generic rooms will always be used by the specialty. The optional capacity represents the difference between the base capacity and demanded capacity. It is difficult to get proper insight into the calculations for this optional capacity, because it is influenced by uncertainties and inefficiencies. Finally, the flexible capacity for irregular or extra consultation hours is described.

- **Base capacity**: the minimum number of required generic rooms, based on the total number of patients seen and the time spend per patient with a 100% occupation of the generic rooms. This assumes an average demand and presence of healthcare professionals throughout the year to see the patients. This capacity is always guaranteed and will not be assigned to other specialties. The base capacity gives the specialties a starting point for the planning of the consultation hours;

- **Optional capacity**: this capacity is reserved for a specific specialty to be able to respond to ‘normal’ peaks in demand for healthcare. In the initial stage this is the total number of generic rooms demanded by the specialty (desired capacity) minus the base capacity. The specialty does not have to use these rooms and can make them available for other specialties. When these rooms are given back on time, this influences the utilisation rate of the rooms positively. The optional capacity gives the specialties the certainty and flexibility they need to be able to plan all the required consultation hours in, within certain limits, throughout the year;

- **Flexible capacity**: the capacity demand that is higher than the optional capacity that is available for the specialty. This allows specialties to react to changes or fluctuations in the demand for healthcare. Historic occupation of the base and optional capacity is taken into account when allocating extra capacity. The number of flexible generic rooms is limited by a predetermined number of the available generic rooms. This number also depends on the number of optional generic rooms given back by the specialties. To be able to allocate the available capacity in a fair manner, a distinction is made between flexible capacity on a long term and on a short term. Flexible capacity on the long term means that specialties can ask for a certain capacity (depending on the amount of base and optional capacity) at any moment. Flexible capacity on the short term means that x% of capacity stays unallocated until a certain moment in time to be able to react on short term changes. It gives specialties the ability to get extra capacity at any time in case they cannot indicate the need for extra rooms at an early stage.

Dividing the demanded capacity of the specialty into base and optional makes it possible to give security on the number of available generic rooms to the specialty. But it also stresses the focus on efficient use of generic rooms. The focus on efficient use and on returning unused rooms supports the aim to use the capacity in a flexible way. It also enables growth, because unused rooms create possibilities for other specialties. Extra flexible capacity that is available for temporary demand gives the specialties the possibility to get extra generic rooms. This set-up gives more possibilities to respond to changes in demand compared to a situation where each specialty has its ‘own’ rooms and no sharing of available capacity takes place. Moreover, there is insight in the availability of free rooms.

**Example 1: Interaction different types of capacities**

The graph in Figure 4.1 represents the interaction between the different capacities for one specialty on day-part X for 10 weeks. Each week 6 base generic rooms, 4 optional generic rooms and no flexible generic rooms are assigned. Figure 4.1 shows that the base capacity is used each week. The optional capacity on the other hand is partly used. The unused optional capacity can be made available for other specialties. During the weeks shown, no flexible capacity was required, because the specialty could use its own optional rooms for irregular consultation hours. An evaluation of the use of the rooms eventually can lead to a reduction of the number of base and optional rooms which will be offered to the specialty in the next months or years. In the example a reduction of the total optional rooms for day-part X to 3 will cause a problem only once if all the rooms are properly used. Bringing down the total number of rooms to 9 rooms per day-part can be compensated by extra flexible capacity, or by better spreading the capacity each week.

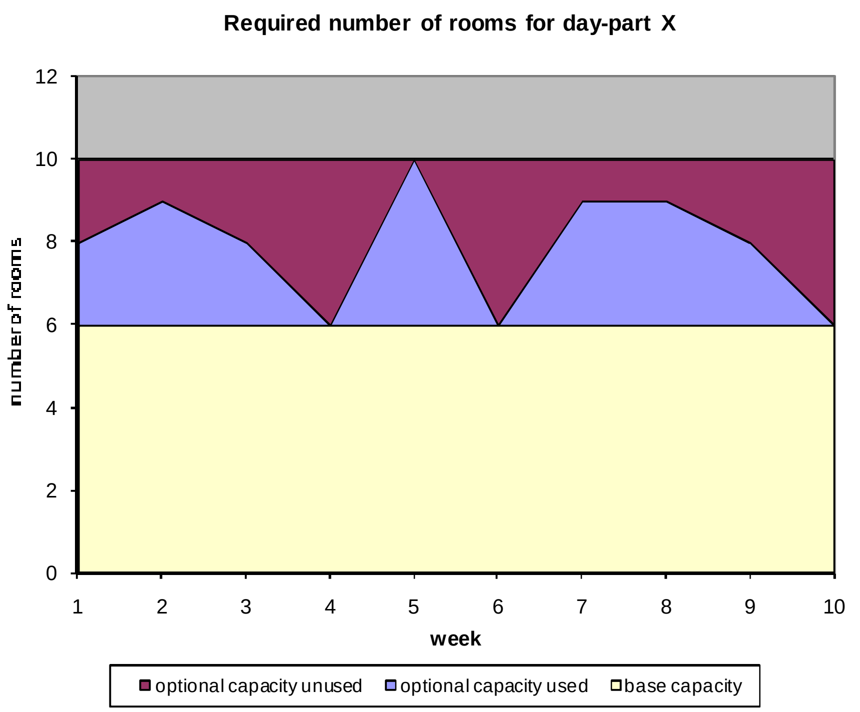


Figure 4.1: Example different types of capacities

# 4.3 Initial calculation of the demand for generic rooms

To be able to allocate the generic rooms, a proper and comparable calculation of the capacity needs of the specialties should be realised. If there is no historic information available on the use and demand for rooms, an initial calculation of the required capacity should be performed. §4.3.1 up to §4.3.3 describe respectively the calculation of the base capacity, optional capacity, and flexible capacity.

In the calculations of demand for rooms we assume that the specialties are asked to indicate the number of generic rooms needed. For a good comparison of the capacity needs demanded by specialties we propose a system to use the same presumptions for the calculations as stated in §4.2. Measuring and evaluating the utilisation of the generic rooms per specialty should eventually lead to a more realistic capacity need (§4.6).

## 4.3.1 Calculation of the base capacity

The calculation of the base capacity is based on production figures. It does not take inefficiencies into account like visiting of patients in the clinic. It leads to a minimum number of generic rooms necessary to provide healthcare to the patients of the specific specialty. The base capacity depends on:

- **Number of patients per year**: this is defined by the production arrangements made with the healthcare insurance, or is based on historic production;
- **Time spend per patient**: this can be estimated based on the length of an appointment slot for that type of consultation (Vissers et al., 2000). Inefficiencies are not taken into account;
- **Consultation room factor**: this is calculated by dividing the total consultation time of the patient by the time the medical specialist (MS) uses to see the patient. The consultation room factor can differ per patient type or consultation hour and depends on the time per consult and the time the healthcare professional spends with the patient during that consultation. The consultation room factor for patient type *p* is determined as follows:

$$\mathbf{CRF_p} = \frac{\mathrm{TC}}{\mathrm{TSP}}$$

CRF = Consultation Room Factor

TC=Time per Consultation

TSP = Time Spend per Patient

p = Patient type

Example: if an MS spends 30 minutes with a patient and the consultation takes 40 minutes due to preparation time, the consultation room factor is 40/30=1,33.

The base capacity for a year is calculated by multiplying the number of day-parts to see all the patients with the consultation room factor:

$$\mathbf{BC} = \frac{\sum_{p}(N_p \times CT_p \times CRF_p)}{DCH}$$

BC = Base Capacity

$N_P$ = Number of patients of type p

$CT_p$ = Consultation Time for patient type p

$CRF_p$ = Consultation Room Factor for patient type p

DCH = Duration of a Consultation Hour

For a weekly base capacity, the annual total is divided by 52. *Appendix IX: Calculating base capacity* shows this calculation schematically. This method partly corresponds to the method 'calculation based on the production' described by the NBHF (Cbz, 2006). Finally, this weekly base capacity has to be divided for the different day-parts. This should be decided in dialogue with the specialty, because specialties can have consultation hours on a specific day-part.

### *4.3.2 Calculation of the optional capacity*

In the initial state, when there is no historic data available on the use of generic rooms, it is not possible to calculate the optional capacity based on objective production figures. The number of generic rooms needed on top of the base capacity partly depends on:

- **Availability of the healthcare professionals**: some healthcare professionals have tasks outside the outpatient department (OD) like the surgery, or visiting patients in the clinic;
- **Characteristics of the healthcare process**: each specialty has different healthcare processes and also a different availability of healthcare professionals in the OD;
- **Planning of the consultation hours**: specialties often have fixed and irregular consultation hours during the week.

Each specialty has to calculate the desired capacity needs based on factors mentioned in §4.1. The difference between the desired capacity needs based on a weekly schedule and the base capacity defines the optional capacity for the specialty:

$$\mathbf{OC} = \mathrm{DCN} \quad \mathrm{BC}$$

OC = Optional Capacity

DCN = Desired Capacity Needs

BC = Base Capacity

A check to prevent extreme requests for the optional capacity by a specialty is to have an upper bound of the optional capacity. This upper bound depends on the number of healthcare professional a specialty has and the mean consultation room factor concerning that specialty:

$$\mathbf{UB} = \mathrm{HP} \times \overline{\mathrm{CRF}}$$

UB = Upper Bound optional capacity

HP = number of Healthcare Professionals

$\overline{\mathrm{CRF}}$ = Mean Consultation Room Factor

One disadvantage of this method is that specialties often tend to ask more generic rooms than the average rooms needed. Another disadvantage is that its inefficiencies are taken into account in the calculation by the specialty. A good performance measure and evaluation program should reduce the effect of these disadvantages (§4.4). For example, a low utilisation of the optional capacity can lead to an adjustment of the number of rooms throughout the year. As a result, undesirable claiming of too many rooms can be prevented and adjusted.

To maintain flexibility at a later stage, a limited number of rooms should be kept free. It is possible that the demand for rooms is higher than the number of rooms available. This can be at two levels, during a specific day-part, or overall during the week. In case it considers a specific day-part, alternative day-parts should be proposed and evaluated with the different specialties. A shortage throughout the week can only be solved by building extra rooms, or by reducing the capacity demand of the rooms.

### *4.3.3 Calculation of the flexible capacity*

Due to irregular consultation hours and unforeseen circumstances, like a reduction in available OR-time, a specialty may want to get temporary extra generic rooms. To be able to respond to these requests, a fixed number of flexible rooms are free per day-part. Also extra generic rooms can become available when specialties return a part of their optional capacity. At a certain point in time the available flexible capacity is assigned based on a minimum utilisation of the rooms. The length of the access time to the OD is also an important factor when there are more requests than capacity available. By providing these rooms the flexibility is provided for the specialty.

By clearly defining the assumptions that should be used in the calculations for the room demand, a more uniform calculation method is realised. A limited insight into the healthcare processes of the specialties, and changes and choices that are made within the specialty make it difficult to evaluate the demand posed by the specialty. By dividing the capacity into a base, optional and flexible capacity, the specialty is stimulated to make efficient use of the generic rooms.

## 4.4 Performance management for control and use of generic rooms

To control the use and allocation of the generic rooms properly, the hospital should make use of performance management. Measuring performance enables to act en respond better to reach the set objectives. These objectives are supported by the measurement of KPIs (key performance indicators) stemming from the mission and strategy of the organisation. Performance management takes place at all managerial levels. Below we assume the situation at Deventer Hospital (DZ) and use the steps for developing a performance measurement system (PMS) (Figure 2.2). We describe only the most relevant steps.

### *4.4.1 Developing a performance measurement system*

The first step in developing a performance measurement system is to clearly define the mission statement of the organisation. The new DZ wants to be a hospital that reacts in a flexible way to patient demands and maintain or increase its market share (Internal document A, 2003). These points of the mission statement of DZ are leading to the following objectives and goals for the consultation centre as stated in §1.3:

- Create flexibility at a tactical level for responding to changes in demand;
- Create efficient use of the generic rooms;
- Create possibilities for growth;
- Create a workable situation for healthcare professionals and supporting personnel;
- Have insight in the unused generic rooms of specialties to be able to use them for other specialties.

The next step is to find one or more KPI(s) that support these objectives and that can be used to for making decisions on the allocation of the generic rooms. The differences between healthcare processes and patient characteristics make it difficult to compare specialties. Unequal allocation of generic rooms causes frustration between specialists. To be able to make a fair allocation of the generic rooms the use of the rooms has to be registered and used during the allocation process. An important and recurring KPI in performance measurement is the rate of utilisation, meaning [1]:

*"The state of having been made use of"*

This describes the proportion of the available capacity that is actually being used. The available capacities in an outpatient department (OD) in the context of this research are generic rooms and the healthcare professional's time.

Before actually using the PMS it also has to keep in mind the kind of data that is needed. This research looks at the utilisation of the generic rooms in an OD (§4.4.2), and how to control the measurement (§4.5).

### 4.4.2 Utilisation measurement of generic rooms

The utilisation of the generic rooms for a certain specialty during a period depends on the total time the generic rooms are assigned to that specialty and the total time that patients are seen in that period. The utilisation of the allocated generic rooms for a specialty in a certain period is as follows:

$$\mathbf{UR} = \frac{\sum_{p}(N_p \times CT_p)}{RA \times DCH}$$

UR = Utilisation of Rooms

RA = Number of rooms Assigned

DCH = Duration of a Consultation Hour

$N_P$ = Number of patients of type p

$CT_p$ = Consultation Time for patient type p

The total time of generic rooms is determined by the number of generic rooms assigned to that specialty multiplied by the time that can be planned with patients. This takes into account the visiting activities a specialty has in the clinic. The total time the generic rooms are allocated has to be registered *centrally*. Monthly changes can easily be registered. At a weekly and daily level, the registration will be more work. These changes should be notified to one manager of the OD. The total time that patients are seen is determined by the actual time the patients spend in the generic room. Appointment slots can be used for the consultation time of the type of patients treated. A more precise approach for the determination of the consultation time is registering the exact time the healthcare professional spends with the patient. This requires a detailed registration system, which will not be discussed and goes beyond the scope of this research. When "no shows" are low, they should not be taken along in the total time that patients are seen, because specialties cannot be blamed for this. But in case a specialty has a lot of "no shows", a hospital can react on this by assigning fewer rooms to the specialty.

A disadvantage of using only the occupation of the consultation room is that by increasing the consultation time per patient, the occupation of the rooms can be increased on paper. Although this is theoretically possible, we expect that this tendency will be limited. The processes are arranged in such a way that the specialist time is used efficiently. An increase in patient time will hinder the specialty to reach production targets. We expect that registering the occupation of rooms will increase the focus on efficient use of rooms to enable future growth.

## 4.5 Regularly updating the assignment of consultation rooms

After an initial allocation of the generic rooms, changes in the room allocation may become necessary. Changes in the number of patients seen, staff, or new working methods may require an alteration in the number of the rooms allocated. These changes can be temporary or structural. We make a distinction between regularly updating of the room assignment on the long term (§4.5.1) and on the short term (§4.5.2).

In the proposed planning scheme for allocating the rooms in the outpatient department (OD), the link with the OR planning is used. If the demanded OR capacity is not provided to a (surgical) specialty, the specialty wants more consultation hours in the OD. This enables to use the healthcare professionals efficiently. Linking the OR planning and the allocation of the capacity in the OD concerns the three managerial levels. Figure 4.2 shows the timeline of the allocation of generic rooms.

### *4.5.1 A yearly update of the assignment of generic rooms*

Each year the specialty makes arrangements with the central hospital management about the production for the next year. The number of patients treated, time needed in the OR, number of staff employed are part of this. We propose to also evaluate and make arrangements about the allocated number of consultation rooms that are available for the specialty throughout the year. We advise to do this at an early stage, even when there is still sufficient capacity. The organisation has to be prepared for a shortage of rooms and a situation in which rooms have to be redistributed and choices are made between specialties. Providing insight into this process and introducing it at an early stage prevents problems in the future. The hospital creates a culture that is prepared to a situation in which there is not sufficient capacity, and focuses on efficient use and growth of the hospital production.

The allocation of generic rooms on a strategic level takes place on a yearly basis. The goals at this level are:

- An overview of the allocation and utilisation of generic rooms;
- An allocation based on production agreements and utilisation of generic rooms over the past 12 months.

Corrections for growth or changes in the staff should be taken into account. The base and optional capacity allocation gives the possibility for each specialty to plan the consultation hours throughout the year. It gives securities to the specialty on which a standard planning can be made. Changes in the production, or the number of patients seen, do affect the time necessary in the OR, but also in the OD. Historic use of the rooms takes an important role in adjusting the base and optional capacity of a specialty. The hospital management and the operational manager of the specialty are involved in this yearly decision. Based on interviews with managers in Deventer Hospital (DZ) and The Maasland Hospital, we recommend using the utilisation of the total number of generic rooms in the past (§4.4.2).

For each day-part the specialty gets a fixed number of base and optional rooms, which is the same throughout the year. In a later stage, already during the yearly arrangements, also seasonal adjustments in the allocated capacity can be made.

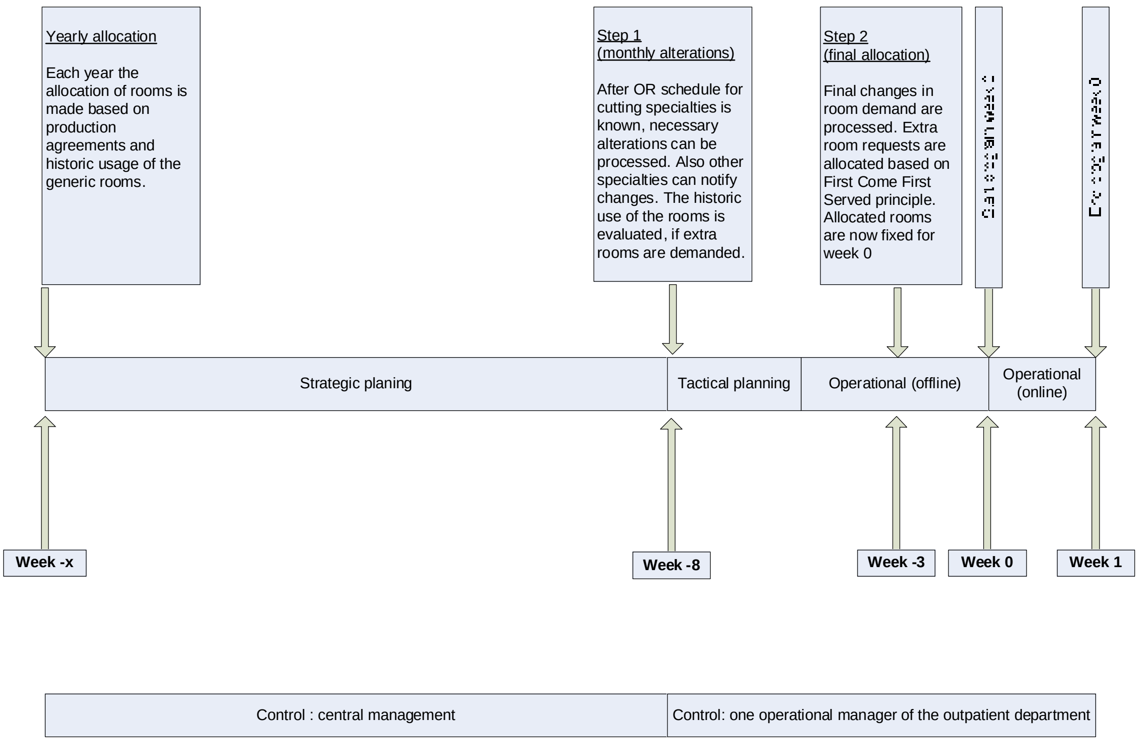


Figure 4.2: Timeline for the allocation of generic rooms

### *4.5.2 Monthly and weekly alterations in the assignment of generic rooms*

On a tactical level, a regular monthly adjustment of the allocation of generic rooms is provided for dividing and redistributing need for extra capacity. Main goals at this level are:

- To handle the temporary alterations in the demand for generic rooms due to seasonal influences or irregular hours. For surgical specialties the availability of the medical specialist is determined by the time available in the OR. Changes in OR-time can cause changes in demanded consultation rooms;
- To create flexibility, by making an inventory of all unused rooms and make them available for other specialties which demand for extra rooms;
- To have a control plan that restricts with a limited administrative workload. The control system must be user-friendly, as well as for the specialties as for the manager of the control plan.

The first two goals are encouraged by making use of historic utilisation of generic rooms of a specialty (over the past 3 months). In this way, not only the possibility to get extra rooms is in the interest of the specialty. Also returning unused rooms will have a positive effect on the utilisation rate of the allocated rooms. Publishing the use of rooms gives insight in the own use of rooms, but also in other specialties room use. This puts pressure on the specialties to return unused rooms if other specialties need them. Figure 4.3 shows the timeline of the monthly / weekly adjustment of requested changes of generic rooms and is closely relation to the OR planning. It is based on the situation in DZ, but is generable applicable.

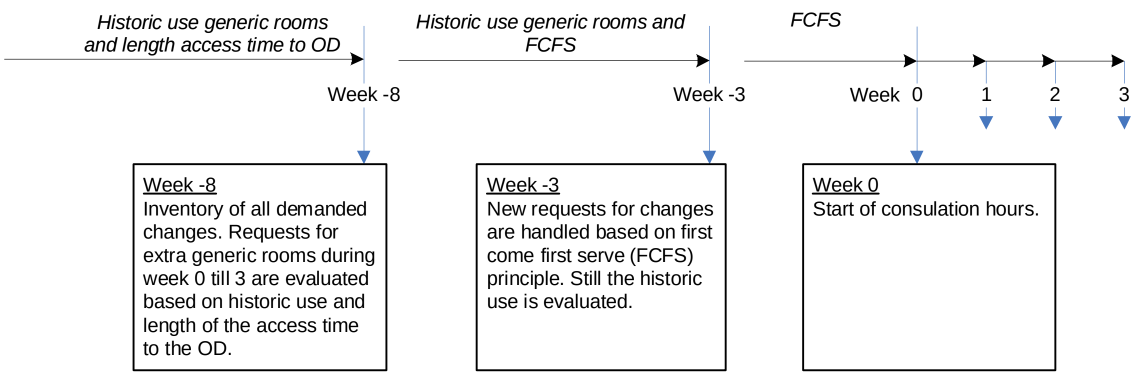


Figure 4.3: Monthly planning of capacity in an outpatient department

Alterations in the demand for generic rooms can occur throughout the year. There are three specific moments in time when more requests for generic rooms can be expected, or have to be expressed by the specialties:

- 8 Weeks before the start of a consultation month (week 0 till 3);
- Until 3 weeks before the start of a consultation week;
- Within 3 weeks before the start of a consultation week.

Surgical specialties know their OR week schedule for a specific month (week 0 till 3) at least 8 weeks in advance. Changes in the assigned number of ORs can result in more or less demand for generic rooms in the outpatient department (OD). Non-surgical specialties can also notify the OD manager if they require more generic rooms or want to return generic rooms. At week -8, the manager evaluates the changes demanded. Important at this point is that the requests are evaluated at the same time based on a minimum utilisation rate of generic rooms in the past and the length of the access time to the OD. The evaluation based on the minimum utilisation rate is *specialty dependent*, because specialties differ in reaching a high utilisation rate. For some specialties it can be difficult to maintain a high utilisation rate, because of variations in demand, In addition, it is wise to assign a maximum of x% of the available generic rooms. It brings flexibility at a later stage in the allocation of rooms. The requests that are not fulfilled and that satisfy the criteria will be placed on a waiting list. They will be taken along in allocating the last x% of the capacity or will be fulfilled when more capacity is given back during the following weeks. In case there is enough capacity there is no problem in fulfilling the requests. The reallocation concerns weeks 0 till 3 and is done each month.

Until three weeks before the start of a consultation week, each specialty can still notify their alterations for the demand for generic rooms to the manager in charge. Until this moment, there is still enough time to schedule patients for extra consultation hours (see ”Treeknormen”). A shorter period will reduce the usability of free generic rooms by specialties. This stems from the planning of patients and specialist that is more difficult to arrange after that moment. A request will be evaluated on a First Come First Serve (FCFS) principle and on a minimum utilisation rate of generic rooms in the past (specialty dependent). The length of the access time to the OD can also be a criterion. If a request fulfils the criteria and if there are generic room available, a request can be fulfilled immediately. Otherwise, the request will be put on a waiting list and fulfilled when generic rooms are given back. At week -3, the last x% of available generic rooms is allocated. This is based on utilisation of the generic rooms in the past (specialty dependent) and/or length of the access time to the OD. In the end, the manager publishes a final schedule.

After week -3, *central coordination* of the reallocation of generic rooms does *not* pay-off. If there are requests for generic rooms and if there is still capacity left, the principle of FCFS counts and is not based on utilisation of the generic rooms in the past (specialty dependent) and/or length of the access time to the OD. If a specialty does not need the allocated generic rooms after week -3, that specialty has to find another specialty that can and will use the room. *Central management* should be notified of these changes, for the track of historical utilisation of the generic rooms.

By aligning the planning of the flexible generic rooms and *centrally coordinating* this on a strategic and tactical level the hospital goals as stated in §1.3 are supported. Giving insight in the available generic rooms per period creates flexibility at a tactical level. Furthermore specialties can indicate if they need extra generic rooms on top of their base and optional room demand. These rooms can also be made available to other specialties. This, together with the performance measurement, enhances efficient use and flexibility especially when there is a shortage of rooms. Growth is also made possible, because the generic rooms are used efficiently and are subjected to performance measurement leading to more available free generic rooms.

Specialties should have a drive to return unused capacity. They will not return unused capacity if they do not have the certainty to get extra capacity when needed. By measuring and publishing the utilisation rates of generic rooms by specialties, specialties are stimulated to return unused capacity. A specialty with a high utilisation of rooms that wants extra capacity will look at other specialties with a low utilisation of rooms and puts pressure on those specialties to get extra rooms. Measuring and giving insight into the utilisation of rooms stimulates the (future) efficient use of rooms.

## 4.6 Spatial allocation principles for generic rooms

This section describes how to control the spatial allocation of generic rooms. Before assigning the generic rooms to the specialties, more insight is needed into the location of each specialty within the outpatient department (OD). To do this properly, the restrictions of each specialty are determined regarding the surrounding facilities and positioning within the OD. The following constraints / factors are important:

- **Location of the back office**: the location of the back office puts limitations on the location where a specialty should have its consultation hours in the front office. On the contrary, the position in the front office can also determine the place in the back office. Our research is based on a situation where the position in the back office is pre-determined. The front and back office of a specialty should be closely positioned, if a healthcare professional needs consultation of a colleague from the same specialty sitting in the back office during a consultation hour. The distance between the front and back office should be as short as possible;

- **Mutual coherence of specialties**: dependencies between specialties need to be carefully analysed. Positioning specialties together, which are closely related to each other, creates more efficient logistics of patient and healthcare professionals. It reduces the distances between dependent specialties and facilitates the communication between the specialties;

- **Location of specialty specific treatment rooms**: the layout of the OD and its specific treatment rooms bounds a speciality to a location within the consultation centre. When treatment rooms are specific for a specialty, the possibilities to have consultation rooms on the other side of the consultation centre are limited.

The way the generic rooms are spatially allocated to the specialties influences the exchangeability and flexible use of these rooms. We discuss two possibilities to assign the rooms. Figure 4.4 shows these two concepts of allocation, based on the layout of the OD in Deventer Hospital.

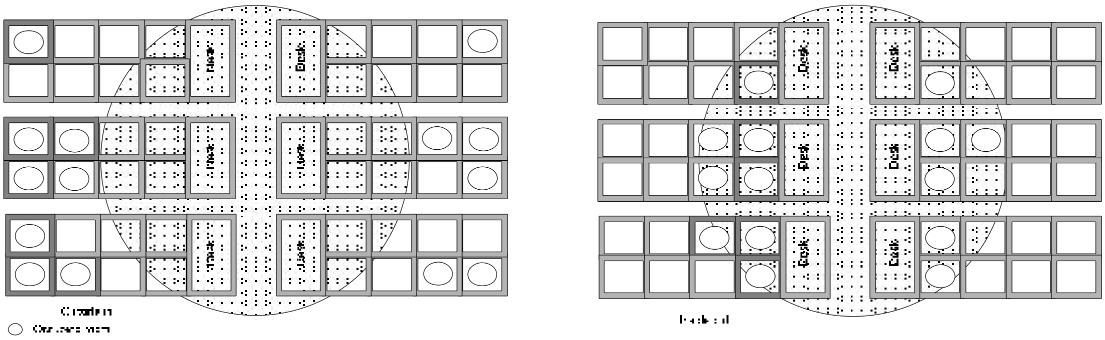


Figure 4.4: Allocating inside out and outside in

The first possibility is assigning rooms by starting behind the desk (inside) to the outside reducing for each specialty the distances to each consultation room for the patient. Also the distance for the healthcare professional is minimised. The second possibility, to improve the flexible use of free generic rooms, is the allocation of these rooms starting from the outside to the inside. When another specialty has to use a generic room in another block, the distance travelled for that specialty is minimised in that way. The healthcare professionals of the different specialties pass each other less, because of the location of the back office. Healthcare professionals of the specialty that move to the other block needs to be in the back office or needs consultation from a colleague, that healthcare professional does not have to walk from the end to the beginning of the consultation block. The specialty already present in the consultation room block has its back office above the front office. They can walk through the back office. On average, there is no difference for the patient when all the rooms are used. This set-up eventually increases the overall flexibility because the flow of different specialties is better divided leading to a workable situation for healthcare professionals and supporting staff.

To score different spatial distributions, ranking tools are useful tools to make a decision. *Appendix X: Ranking techniques* describes a number of these techniques.

# Chapter 5

# Conclusions and recommendations

The allocation of the centralised generic rooms of the outpatient department (OD) is an ongoing process, rather than a one-time event. In our study to propose a system for managing and allocating the centralised generic rooms of an OD, we describe the aspects concerning a first time calculation of demand for generic rooms by a specialty, the allocation of generic rooms and finally an evaluation of the allocated generic rooms.

**The number of generic rooms required by the specialties**

The number of rooms that are required to fulfil the demand for healthcare should be calculated on the basis of clearly predefined assumptions. This is especially important in the initial phase when there is no historic information available on the use of the generic rooms. Calculations will be primarily based on information provided by specialties. To compare the supplied information, the calculation methods should be based on the same assumptions:

- Take only (regular) weekly consultation hours into consideration for the weekly demand for generic rooms;
- Use the average availability of the healthcare professional (take holidays into account);
- The consultation room factor should be adapted to each specialty (number of rooms per healthcare professional);
- Make a clear distinction in types of generic rooms required;
- Describe the presence of and need for multidisciplinary consultation hours;
- Give additional information on the frequency and moment at which rooms are required for irregular consultation hours.

An analysis of the calculated capacity demand in 2006 compared with the desired capacity in 2007, shows that the desired capacity in 2006 is 26% higher for a whole week than in 2007. Furthermore, the desired capacity shows an increase in the utilisation of generic rooms on Wednesday afternoons (84%) and Fridays (84% Friday mornings and 64% Friday afternoons) compared to the calculated capacity. Looking at the whole week, the desired capacity shows a 85% utilisation. The utilisation of generic rooms, based on the requested rooms, has increased on all days, although it does not give information on whether the requested room are actually used. In addition, we conclude that the number of requested generic rooms is more equally spread throughout the week. Including a maximum demand for irregular hours, a utilisation of 89% a week can be reached. For 2008 there are enough generic rooms for regular consultation hours. However, taking into account a maximum demand for irregular hours, in 2008 there can be insufficient generic rooms on certain day-parts. This depends on the frequency and moment when these irregular hours take place. Although there are sufficient generic rooms in 2008, a yearly production increase by 3 to 5% will create difficulties in the near future.

**The allocation of generic rooms**

Based on the number of rooms demanded by the specialty and the calculations for generic rooms, the generic rooms can be allocated. To allocate the generic rooms to the different specialties, we make a distinction between the capacities allocated that give insight in the use of the rooms:

- *Base capacity*: the minimum number of required generic rooms, based on the total number of patients seen and the time spend per patient with a 100% occupation of the generic rooms;
- *Optional capacity*: this capacity is reserved for a specific specialty to be able to respond to 'normal' peaks in demand for healthcare. The optional capacity can remain unused, and should be made available for other specialties;
- *Flexible capacity*: the demanded capacity that is higher than the optional capacity that is available for the specialty.

The spatial allocation of generic rooms to each specialty depends on three factors: the location of the back office, the mutual coherence of specialties, and the location of specialty's specific treatment rooms. After defining the position of each specialty, the allocation of generic rooms can be arranged in two different strategies:

- *Inside out*: starting to use generic rooms closely located to the desk of each specialty. This reduces the distances for the specialty itself, but decreases the usability of rooms in the back for other specialties;
- *Outside in*: allocating first the generic rooms far away from the desk. This will improve the flexible use of free generic rooms by other specialties.

**Management of the allocation of generic rooms**

The allocation of generic rooms should be updated on a regular basis. We propose an annual redistribution and evaluation of the allocated generic rooms. The annual negotiations about the production targets between *central management* with each specialty will also include the number of generic rooms required. The historic use of the allocated generic rooms plays an important role in the allocation of more or less generic rooms to a specialty. Also, adjustments in staff occupation or an expected increase in patients are evaluated during the negotiations. We advise to start from the beginning with setting up an evaluation and monitoring system, although the need for it is limited. The organisation has to be prepared for a shortage of rooms and a situation in which rooms have to be redistributed and choices are made between specialties. Providing insight into this process and introducing it at an early stage can prevent problems in the future.

Throughout the year the demand for generic rooms can change. Seasonal influences and irregular consultation hours ask for flexibility of the capacity, since these changes are not included in the base and optional capacity. A limited number of generic rooms are kept free for these purposes. Also, unused generic rooms of other specialties can be used. We propose a system based on the OR planning and historic use of generic rooms by a specialty and/or length of the access time to the outpatient department (OD). We also advise not to allocate all of the available capacity until a predetermined period in time. At three specific moments in time more requests for generic rooms can be expected, or have to be expressed by the specialties:

- *8 Weeks before the start of a consultation month (week 0 till 3)*: the specialties passes on alterations in the number of generic rooms needed for a certain period when they know the OR schedule of that period. This step takes place on a tactical level. A minimum utilisation of generic rooms in the past (specialty depended) and/or length of the access time to the OD should be used in the evaluation of requests for extra generic rooms;

- *Until 3 weeks before the start of a consultation week*: specialties passes on alterations in the number of generic rooms needed. In addition to the utilisation and/or access time criterion, we maintain a First Come First Served (FCFS) principle when not all of the available capacity is allocated. Three weeks maximum before the start of a consultation hour week, each specialty should indicate if it has unused generic rooms. This makes it possible for other specialties to use extra generic rooms if necessary. Generic rooms that are given back, have a positive influence on the occupation rate of the allocated generic rooms of that specialty. In week -3, also the last x% of available generic rooms is allocated;

- *Within 3 weeks before the start of a consultation week*: within three weeks before the consultation hour week, the utilisation and/or access time criterion drops for the requests. The principle of FCFS still holds. If a specialty does not need the allocated generic rooms, that specialty has to find another specialty that can and will use the room. Changes should be passed on to the manager in charge. This step takes place on an operational level.

One operational manager of the OD keeps track of the changes.

**Measurement of the use of generic rooms**

A performance measurement system should be developed, in order to create flexibility at a tactical level for responding to changes in demand, to create efficient use of the generic rooms, and to create a workable situation for healthcare professionals and supporting staff.

We propose to measure the utilisation of the generic rooms by each specialty. This concern the time the generic rooms are used compared to the allocated time of the generic rooms. This indicator does not evaluate what is actually happening within the generic room, but assumes that it is necessarily used. Differences in consultation time between specialties are taken into account, which makes the information comparable. The utilisation is determined as follows:

$$\mathbf{UR} = \frac{\sum_{p}(N_p \times CT_p)}{RA \times DCH}$$

UR = Utilisation of Rooms

RA = Number of rooms Assigned

DCH = Duration of a Consultation Hour

$N_P$ = Number of patients of type p

$CT_p$ = Consultation Time for patient type p

**Recommendations for DZ**

We expect that in the end of 2008, Deventer Hospital (DZ) will not have an overall shortage of available generic rooms. The number of allocated generic rooms for the specialties is sufficient. It is based on the desired capacity demanded by the specialties. There are still generic rooms available. We advise at an early stage to introduce a focus on proper use of the generic rooms and the aim of the hospital to grow. We have the following recommendations for DZ:

- Make yearly appointments with each specialty about the base and optional capacity. Also get more insight into the extra flexible capacity needed for irregular hours;
- Introduce clear definitions for the calculation of the desired capacity by a specialty. Take for example the average presence of healthcare professionals into account;
- Get more insight into the irregular consultation hours. This gives more insight in the extra needed flexible capacity;

- Stimulate specialties to return unused generic rooms at an early stage. This gives other specialties the possibility to use these rooms if necessary;
- Focus on the overall aim of the hospital to grow. Currently we see that each specialty is working on itself to reach their targets;
- Monitor the use of allocated rooms and give quarterly or monthly insight into the utilisation of generic rooms by each specialty;
- Give insight in the average availability of generic rooms for each day-part. Specialties can anticipate on this by spreading their demand to low demand day-parts.

Monitoring the use of the consultation rooms, offers more insight in the use of the rooms and the growth possibilities of the separate specialities and the hospital. If there is not yet a shortage of rooms, the hospital can chose not to actively re-allocate the empty rooms. Taking back unused rooms from specialties without having a new purpose of the rooms, will create a negative atmosphere. In case of a shortage reducing the number of allocated rooms to a specialty can be justified.

**Discussion**

The proposed system for allocation is mainly based on the situation in DZ. Although slight adjustments might be necessary, the system is widely applicable. Interviews with managers in other hospitals and the analysis of comparable set-ups of the OD support this.

Although the proposed system is widely applicable, we observed big differences within different hospitals. One of them is the culture within the hospital. This is an important factor, both for the introduction of a separate front and back office, but also for the flexible exchange of generic rooms within and between specialties. Some hospitals started a couple of years earlier than DZ with introducing the ‘new’ culture. They have done this, because the principle of not having an own room in the front office will not be ‘accepted’ on a short term by a specialty or healthcare professional. This acceptation takes a long time. Another difference is the difference in applying the new concept of a separate front and back office. In DZ, the desk in the front office belongs to one or two specialties. In other hospitals, the desks are also exchangeable and depending on the specialty having a consultation hour at that time. In addition, medical specialists in DZ can use more than one generic room at the same time during a consultation hour. Other hospitals go even further in the use of flexible rooms and share the room between specialties during consultation hours. They cluster the rooms of a specialty or some specialties, where the healthcare professionals use a free room, which can be a different room each time.

**Limitations**

The proposed system is based on an in depth analysis of one hospital and interview with a couple of other hospitals. The concept of a separate front and back office is not yet widely introduced in hospitals in the Netherlands. Literature on this topic is limited.

**Further research**

In this report we look at the allocation of generic rooms and the utilisation of generic rooms as important indicator for the allocation of these rooms. We do not propose methods to increase the utilisation. It would be interesting to take a closer look at possibilities to increase the utilisation of generic room by looking at strategies to share generic rooms with a group of healthcare professionals. By sharing the rooms, the total utilisation of the rooms can be increased and fewer rooms are necessary.

In addition, more research can be done on the effects of introducing financial incentives for the efficient use of generic rooms. This will stimulate the specialty to look critically at the necessity of the number of generic rooms demanded.

The allocated rooms for each specialty are clustered together on either the K0- or L0- block. Further research can be done on the effect of spreading one big specialty over the two blocks. This might increase flexibility and offers opportunities to look for extra generic rooms in both blocks when necessary.

# Terminology & Abbreviations

| | |
|---|---|
| *Access time* | Time between the moment a patient makes an appointment and the moment the patient is actually seen by the medical specialist. |
| *Acute care* | Care to patients being in a life-threatening situation. |
| *Aging* | Proportional over-representation of elderly people (increase in over 65- and 80-year olds). |
| *Service area* | The extent to which a population makes use of clinical care, and outpatient treatment of a hospital. |
| *Case-mix* | Number of different patients and categories within the patient population. |
| *CE-room* | Consultation/examining room (in Dutch “spreek/onderzoekkamer”). Room in the OD where the healthcare professional treats his or her patient. |
| *Consultation room* | In Dutch “spreekkamer”. Room without an examination table, where only a consultation takes place and no examination. |
| *Consultation room factor* | A variable taking into account the percentage of the time the healthcare professional is seeing his or her patient during a consultation in relation to the total duration of a consultation. The less the consultation time, the higher the number of parallel consultation rooms a healthcare professional needs. With other words: the higher the factor, the higher the number of CE-rooms a medical specialist needs. |
| *Consultation hour* | In Dutch “spreekuur”. Time available for seeing and treating patients in the OD. |
| *Chronic care* | Care that is provided on a long-term basis. Often a longstanding personal relationship with the patient is developed. |
| *Day-part* | Day period in which certain treatments are performed. A distinction is made in a morning (AM) and an afternoon (PM) shift. A week has ten day-parts. The morning shift takes place from 08.00 till 12.30-13.00 and the afternoon shift from 13:00-13.30 till 16.00-17.00. |
| *Dejuvenation* | Proportional under-representation of younger generation (decline in the number of people which are under 35-year old). |

*DTC* — Diagnosis Treatment Combination (in Dutch “Diagnose Behandel Combinatie” or “DBC”). Codes the healthcare professional uses in a hospital to administratively handle the care process. A cost price will be available for each code, which can be used during negotiations and during benchmarking with other hospitals. The DTC-system consists of:

- *A-segment*: determined prices and covers 90% of the DTCs. Covers hospital care in which (at this moment) the financing is based on parameters like admissions, days of hospitalisations, outpatient treatments and FOVs (90% of the hospital budget). Producing more will not lead to extra revenue.

- *B-segment*: consists of negotiable prices in which insurance companies, hospitals and medical specialists negotiate. Covers the other 10% of the DTCs. Within this segment there is market competition.

- *C-segment*: not part of the Health Insurance Law (in Dutch “Zorgverzekeringswet”) and represents the rest of the hospital care.

A DTC consist of a care process for a certain patient having a certain disease. A DTC can cover a maximum period of twelve months. After that the DTC will be closed automatically. A new initial DTC will be opened / started if a patient has a first visit at a gate specialty with a new disease. At the same time an FOV will be registered if there has not been a DTC opened in the last twelve months for that specialty. Otherwise a RV will be registered. Opening a DTC not leading to an FOV has not influence on the hospital budget. If a patient visits a specialty within twelve months with the same disease and the initial DTC has already been closed, a follow up DTC will be opened. After twelve months a new initial DTC will be opened. A DTC does not have to be in parallel with an FOV.

*DZ* — Deventer Ziekenhuis (in English “Deventer Hospital”).

*Elective care* — Refers to care that is pre-arranged. Elective care is care that, in the opinion of the treating clinician, is necessary and admission for which can be delayed for at least 24 hours.

*FOV* — First outpatient visit (in Dutch “eerste polikliniekbezoek” or “EPB”). In the case of an FOV a patient visits a medical specialist of a certain gate specialty in the hospital for the first time that year. An FOV may be registered and declared if in the twelve months preceding this visit no FOV has already been registered at that gate specialty. In case of an FOV, the following aspects must been met:

- Face-to-face contact between patient and medical specialist or medical assistant.

- "Help by, or due to the hospital", the location (OD inside or outside the hospital, or a nursery home) will be taken along.

Medical checks, inter-collegial consultations, co-treatment of clinical patients and handing over of clinical patients are not seen as FOV.

*Gate specialty* (in Dutch “Poortspecialisme”). In hospitals a distinction is made in gate specialties and supporting specialties. Gate specialties are specialties that the patient visits first (‘at the gate’) after being referred by a general practitioner. They are specialties that generate the hospitalisation, days of hospitalisation, etcetera. By this they influence the external budget that is determined by production parameters. Examples of gate specialties are Internal Medicine, Cardiology, Obstetrics, Orthopaedics, Paediatrics, Surgery, etcetera. Examples of supporting specialties are Radiology, Anaesthesiology, Medical Microbiology, etcetera.

*MF-room* Multifunctional room. A MF-room is a room that does not always need an examining table. These rooms can be used for counselling, training and consultation between healthcare professionals.

*NBHF* Netherlands Board for Hospital Facilities (in Dutch “College bouw zorginstellingen” or “Cbz”). Institution that makes decisions about building licences and that provides building permissions.

*OD* Outpatient department. Area in a hospital with grouped consultation rooms and a front office desk.

*OR* Operating Room.

*Production agreements* Agreements between hospitals (medical specialist, specialty, and management) and health insurances about the production that has to be realised in a year for a certain category of patients.

*RV* Revisit (in Dutch “herhaalconsult” or ”HC”). In case of a RV a patient visits a medical specialist of a certain gate specialty and an FOV has already been registered. If an RV takes place after twelve months a new DTC will be opened and the RV will be converted into that DTC.

*Secondary needs* Capacity needs of a specialty outside its own specialty.

*Specialty* Science part that is separately practised.

*Treeknorm* Defines the maximum acceptable access time for a treatment and a FOV. Within “Treeknormen”, a distinction is made in:

- Access time FOV: the maximum access time for an outpatient consultation should not be more than 3 weeks in 80% of the cases and 4 weeks maximum;

- Waiting time clinical treatment: the maximum waiting time for a clinical treatment should not be more than 5 weeks in 80% of the cases and 7 weeks maximum;
- Waiting time outpatient treatment: the maximum waiting time for an outpatient treatment should not be more than 4 weeks in 80% of the cases and 6 weeks maximum;
- Waiting time day treatment: the maximum waiting time for a day treatment should not be more than 4 weeks in 80% of the cases and 6 weeks maximum.

*Urgent care* Care to patients in which a couple of hours between admission and treatment do not lead to any problems.

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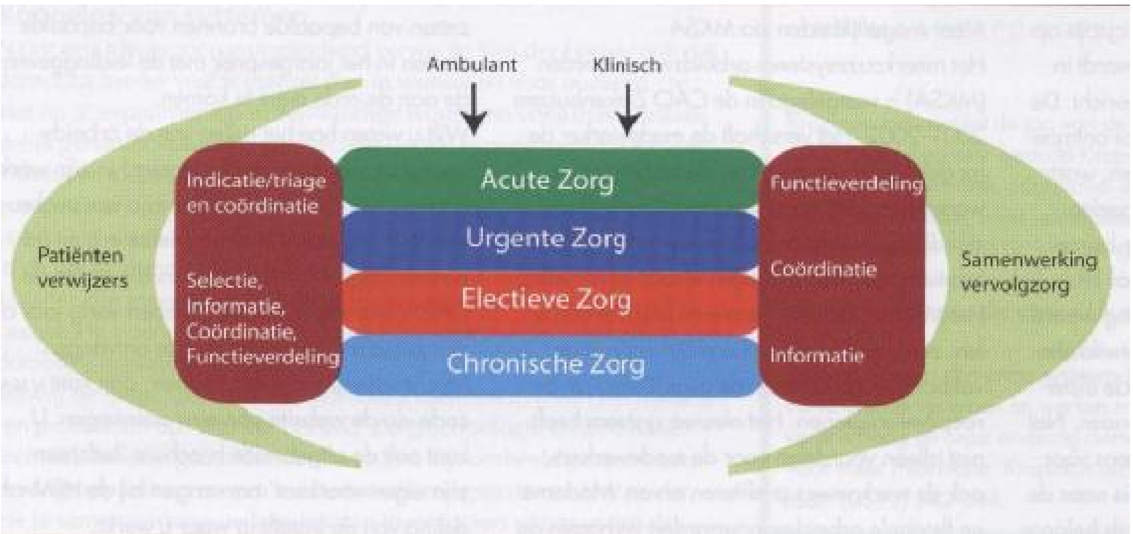
## Appendix I: Multiple flow model




Appendix I - Figure 1: Multiple flow model [Internal document B, 1999]

Starting-point for the multiple flow model is the translation of differences between the categories of patients into the construction and organisation without the appearance of unwanted effects of suppression. The flows represent the different ‘environments’, each having their own distinctive ‘ambiance’. The four flows in Deventer Hospital are acute, urgent, elective, and chronic care. There are further explained below.

*Elective care* is care to patients in which there is time between the announcement and the visit in a hospital. This care is mostly predictable.

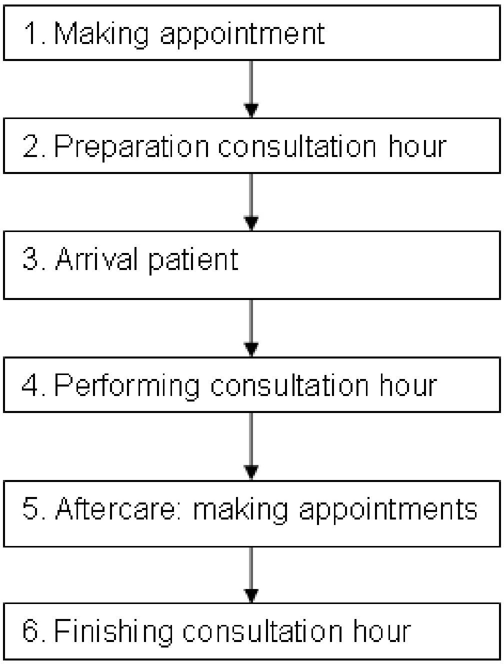
*Acute care* is care to patients being in a life-threatening situation.

*Urgent care is c*are to patients in which a couple of hours between admission and treatment does not lead to any problems.

*Chronic care* is care to patients for which a long-standing relation and contact with the patient is required. This care is mostly not elective.

# Appendix II: Outpatients work process

Figure 1 below shows the steps within the outpatients work process.

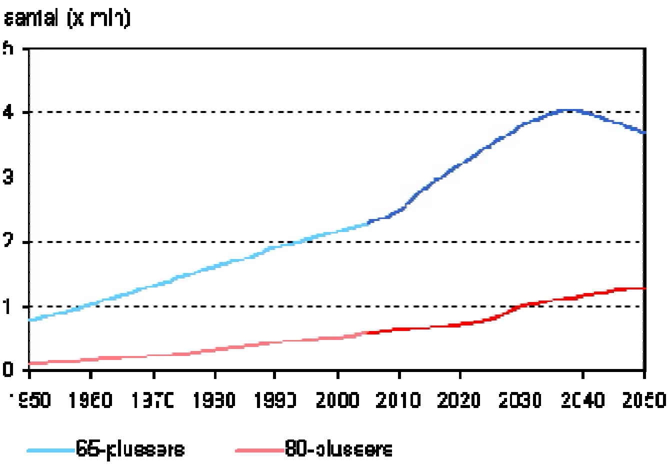



Appendix II - Figure 1: Outpatients work process [Internal document C, 2007]

Step 1 and 2 take place in the back office. The remaining steps take place in the front office. A remark in this is that step 1 can also take place in the back office (making an appointment by telephone). Besides, step 6 can take place partially in the back office when it consists of making a report of the observations.

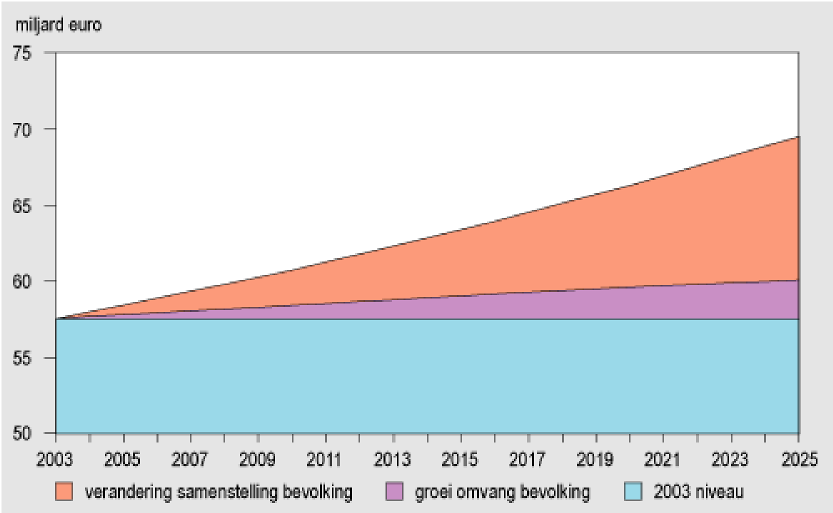
# Appendix III: Aging

The baby boom after World War II will result in an increase in the proportion of people of 65 years and older from 2010 with respect to the total population. It results in a maximum of 24% of the total population in 2040. At the moment this size is 14%. After 2025 the proportion of people of 80 years and older will increase to nearly 8% in 2050; at the moment this percentage is 3% (De Jong, 2005). Appendix III - Figure 1 shows this aging. The life expectancy also increases. In 2005 at birth the life expectancy for men was 77,2 years and 81,6 years for women. In the period 2006-2050 this life expectancy will further increase to 81,5 years for men and 84,2 years for women (CBS, 2006).



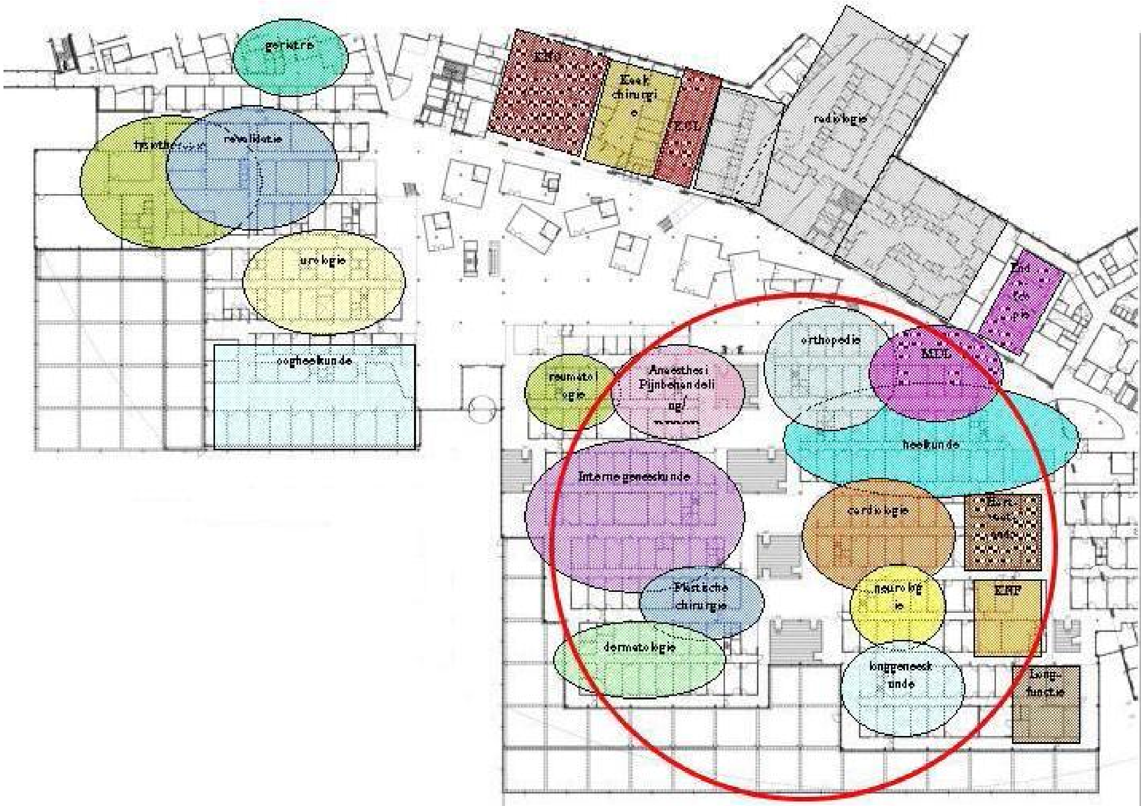

Appendix III - Figure 1: Number of 65+ and 80+  [De Beer en Verweij, 2005]

This means that the elderly, generally needing more healthcare demand, put a higher pressure on healthcare (Van den Berg Jeths et al., 2004). In the next 20 years this, but also because of the current lifestyle and obesity, leads to more (40%) chronic diseases. Statistics Netherlands (in Dutch “Centraal Bureau voor de Statistiek” or “CBS”) expects an enormously increase in the number of elderly diseases in the upcoming years based op prevalence for important chronic disorders and population prognoses. This leads to aging. Because of the relative dejuvenation of the population disorders like asthma will decrease. This leads also to an increase of healthcare expenditure of 57 billion in 2003 to nearly 70 billion in 2025 as can be seen in Appendix III - Figure 2 (De Jong, 2005).




Appendix III - Figure 2: Development of healthcare expenditure based on demography [De Jong, 2005]

# Appendix IV: Spatial distribution of front office K0- and L0-block




Appendix IV - Figure 1: Spatial distribution front office K0- and L0-block 2006 [Internal document D, 2006]

Starting-points for the spatial distribution are:

- A separate front and back office;
- Foreseen production growth;
- Distribution of area based on planning production;
- The working process in the outpatient department;
- The recognition of the specialty for the patients has to be guaranteed.

The figure above shows the ground floor of the outpatient department in the new Deventer Hospital. In the upper left there is the H0- and A0-block, in the upper right and a part of the upper left there is the C0-block. These blocks have specialty-specific areas. The part of the figure enclosed by the red circle is the K0- and L0-block and mainly consists of generic rooms. A couple specialties are located at the first floor (Paediatrics and Obstetrics).

In the figure some specialties overlap, indicating that some specialties have to take place at their neighbours at certain day-parts for their consultation hours.

Some specialties have a fixed position because of the specialty specific treatment rooms located there. This applies for Cardiology, Neurology, and Pneumology. Beside that Dermatology needs daily light for diagnosis. This means that the specialty is located at the outside of the outpatient department.

The position of the specialty at the front office is connected as much as possible with the position of that specialty at the back office. For the K0- and L0-block this is certainly the case, but for the H-block not. Walking distance will be kept as short as possible by this.

The specialties having the ability to use the generic rooms are:

- Rheumatology;
- Internal Medicine;
- Anaesthesiology (Pain and Preoperative);
- Dermatology;
- Plastic Surgery;
- Orthopaedics;
- Gastroenterology;
- Surgery;
- Cardiology;
- Neurology;
- Clinical Neurophysiology;
- Medical Psychology;
- SMA;
- Pneumology.

# Appendix V: Checklist planning consultation hours

**Explanation**

This checklist is a first version based on the experiences of the specialty cardiology. Also an example is worked out based on experiences with the project “Working without Waiting List” (in Dutch: “werken zonder wachtlijst”). The checklist is at first meant as a tool for the calculation of our own planning for the consultation hours. It is of course a dynamic process that needs appositions in practise.

Later on departments can use this information for making agreements about the coordination of the planning and capacity of consultation hours.

The Project group Outpatients Care gives support for carrying out this checklist.

## 1. Description specialty

Give a short description of the specialty.

## 2. Organisation

- Number of FTEs and number of persons (medical specialists (MS), medical assistants (AIOS), support staff).
- Describe the activities the MS performs during a week:
  - Consultation hour outpatient department (OD);
  - Clinic;
  - emergency shifts;
  - Operations;
  - Education;
  - Etcetera.
- Describe the activities the AIOS performs during a week:

- Clinic;
- etcetera.

- Describe the activities the supporting staff performs during a week:
    - Supporting consultation hour;
    - Examination;
    - Etcetera.
- Describe also the competencies of the persons (especially if supervision medical specialist is a requirement).
- Describe the culture in the OD:
    - Cooperation specialty and management;
    - Agreements department (for example absence);
    - etcetera.

**3. Schedule**

- Making agreements about the absence of all staff working in the OD;
- MS: notifies ….. weeks in advance absence for next year. Disturbances maximum … weeks;
- Employees must make absence clear in the same way (yearly agreements);
- Planning examination and treatment (for example OR schedule, clinical support) also depends on well planned absence.

**4. Week schedule**

There are other activities that are important in making a week schedule beside activities OD:

- Shift clinic;
- Shift emergency;
- OR program;

- Supervision / education;
- Multidisciplinary consultation.

These things should be taken into account for your program. A starting point could be to schedule first the established things and the rest next.

You can also allocate the consultation hours and schedule the remaining hours afterwards (pay attention to multidisciplinary consultations).

## 5. Performances

- Determine the maximum access time first outpatient visit (FOV);
- Determine the maximum waiting time between the agreed time and the time the patient is actually helped (waiting time waiting room);
- Discuss the throughput time at care programs, as well as waiting times between treatments taking place on the same day (utilisation waiting room) as the time required for giving results (repeat visit) or starting treatment (reserve treatment room).

## 6. Agenda

- Determine where absence medical specialist, medical assistant, and other employees is reported;
- Who makes shift for staff;
- MS is leading;
- How are the agreements with respect to clinical patients: each MS his/her own patient; supervision by one MS;
- Is there education to AIOS.

How are agreements achieved with other departments: OR schedule, secondary needs etcetera. How fast can you make appointments with these departments? Can you make a schedule for a year in the OD when there are also surgeries by MS?

# Appendix VI: Desired capacity for regular hours specialties

| K0- and L0-block | Monday AM CE-Rooms | Monday AM MF-Rooms | Monday AM Consultation Rooms | Monday AM Total Rooms | Monday PM CE-Rooms | Monday PM MF-Rooms | Monday PM Consultation Rooms | Monday PM Total Rooms | Tuesday AM CE-Rooms | Tuesday AM MF-Rooms | Tuesday AM Consultation Rooms | Tuesday AM Total Rooms | Tuesday PM CE-Rooms | Tuesday PM MF-Rooms | Tuesday PM Consultation Rooms | Tuesday PM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rheumatology | 6 | 0 | 1 | 7 | 6 | 0 | 1 | 7 | 5 | 0 | 1 | 6 | 4 | 0 | 1 | 5 |
| Anaesthesiology (preop) | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 |
| Anaesthesiology (pain) | 1 | 1 | 0 | 2 | 3 | 1 | 0 | 4 | 1 | 1 | 0 | 2 | 3 | 1 | 0 | 4 |
| Internal Medicine | 21 | 5 | 0 | 26 | 20 | 4 | 0 | 24 | 22 | 5 | 0 | 27 | 23 | 4 | 0 | 27 |
| Dermatology | 9 | 1 | 0 | 10 | 9 | | 0 | 10 | 9 | 1 | 0 | 10 | 9 | | 0 | 10 |
| Orthopaedics | 4 | 0 | 0 | 4 | 5 | 0 | 0 | 5 | 5 | 1 | 0 | 6 | 6 | 0 | 0 | 6 |
| Plastic Surgery | 8 | 0 | 0 | 8 | 7 | 0 | 0 | 7 | 8 | 0 | 0 | 8 | 7 | 0 | 0 | 7 |
| Gastroenterology | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 3 |
| Cardiology | 9 | 1 | 0 | 10 | 1 | | 0 | 12 | 11 | 1 | 0 | 12 | 1 | | 0 | 12 |
| Surgery | 10 | 1 | 0 | 11 | 12 | 1 | 0 | 13 | 9 | 1 | 0 | 10 | 8 | 1 | 0 | 8 |
| Neurology | 4 | 0 | 0 | 4 | 5 | 0 | 0 | 5 | 4 | 0 | 0 | 4 | 4 | 0 | 0 | 4 |
| Pneumology | 9 | 1 | 2 | 12 | 9 | | 2 | 12 | 9 | 1 | 2 | 12 | 9 | | 2 | 11 |
| Clinical Neurophysiology | | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| Medical Psychology | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| SMA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Total | 33 | 10 | 4 | 105 | 36 | 6 | 4 | 104 | 38 | 11 | 4 | 105 | 36 | 6 | 4 | 101 |
| Utilisation (%) | | | | 91 | | | | 90 | | | | 9 | | | | 87 |

| K0- and L0-block | Wednesday AM CE-Rooms | Wednesday AM MF-Rooms | Wednesday AM Consultation Rooms | Wednesday AM Total Rooms | Wednesday PM CE-Rooms | Wednesday PM MF-Rooms | Wednesday PM Consultation Rooms | Wednesday PM Total Rooms | Thursday AM CE-Rooms | Thursday AM MF-Rooms | Thursday AM Consultation Rooms | Thursday AM Total Rooms | Thursday PM CE-Rooms | Thursday PM MF-Rooms | Thursday PM Consultation Rooms | Thursday PM Total Rooms | Friday AM CE-Rooms | Friday AM MF-Rooms | Friday AM Consultation Rooms | Friday AM Total Rooms | Friday PM CE-Rooms | Friday PM MF-Rooms | Friday PM Consultation Rooms | Friday PM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rheumatology | 5 | 0 | 1 | 6 | 6 | 0 | 1 | 7 | 7 | 0 | 1 | 8 | 6 | 0 | 0 | 6 | 4 | 0 | 1 | 5 | 4 | 0 | 1 | 5 |
| Anaesthesiology (preop) | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 |
| Anaesthesiology (pain) | 1 | 1 | 0 | 2 | 3 | 1 | 0 | 4 | 1 | 1 | 0 | 2 | 3 | 1 | 0 | 4 | 1 | 1 | 0 | 2 | 3 | 1 | 0 | 4 |
| Internal Medicine | 21 | 4 | 0 | 25 | 19 | 4 | 0 | 23 | 22 | 5 | 0 | 27 | 23 | 5 | 0 | 28 | 20 | 4 | 0 | 24 | 14 | 5 | 0 | 19 |
| Dermatology | 9 | 1 | 0 | 10 | 9 | | 0 | 10 | 9 | 1 | 0 | 10 | 9 | | 0 | 10 | 9 | 1 | 0 | 10 | 9 | | 0 | 10 |
| Orthopaedics | 4 | 0 | 0 | 4 | 5 | 0 | 0 | 5 | 3 | 0 | 0 | 3 | 7 | 0 | 0 | 7 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 |
| Plastic Surgery | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 8 | 0 | 0 | 8 | 7 | 0 | 0 | 7 | 8 | 0 | 0 | 8 | 7 | 0 | 0 | 7 |
| Gastroenterology | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 3 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 2 |
| Cardiology | 8 | 1 | 0 | 9 | 7 | | 0 | 8 | 9 | 1 | 0 | 10 | 1 | | 0 | 12 | 5 | 1 | 0 | 6 | 6 | | 0 | 7 |
| Surgery | 14 | 1 | 0 | 15 | 12 | 1 | 0 | 11 | 14 | 1 | 0 | 15 | 14 | 1 | 0 | 15 | 14 | 1 | 0 | 15 | 0 | 0 | 0 | 0 |
| Neurology | 4 | 0 | 0 | 4 | 4 | 1 | 0 | 5 | 4 | 0 | 0 | 4 | 4 | 0 | 0 | 4 | 5 | 0 | 0 | 5 | 2 | 1 | 0 | 3 |
| Pneumology | 11 | 1 | 0 | 12 | 9 | | 2 | 11 | 9 | 1 | 2 | 12 | 10 | | 1 | 12 | 8 | 1 | 2 | 11 | 9 | | 1 | 10 |
| Clinical Neurophysiology | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| Medical Psychology | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| SMA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 34 | 8 | 2 | 97 | 37 | 10 | 4 | 98 | 21 | 10 | 4 | 107 | 35 | 10 | 5 | 99 | 33 | 8 | 4 | 98 | 56 | 10 | 8 | 74 |
| Utilisation (%) | | | | 84 | | | | 84 | | | | 92 | | | | 93 | | | | 84 | | | | 54 |

Appendix VI - Figure 1: Desired capacity for regular hours specialties K0- and L0-block

**A0- and H0-block**

| A0- and H0-block | Monday AM CE-Rooms | Monday AM MF-Rooms | Monday AM Consultation Rooms | Monday AM Total Rooms | Monday PM CE-Rooms | Monday PM MF-Rooms | Monday PM Consultation Rooms | Monday PM Total Rooms | Tuesday AM CE-Rooms | Tuesday AM MF-Rooms | Tuesday AM Consultation Rooms | Tuesday AM Total Rooms | Tuesday PM CE-Rooms | Tuesday PM MF-Rooms | Tuesday PM Consultation Rooms | Tuesday PM Total Rooms | Wednesday AM CE-Rooms | Wednesday AM MF-Rooms | Wednesday AM Consultation Rooms | Wednesday AM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ophthalmology | 13 | 0 | 0 | 13 | 12 | 0 | 0 | 13 | 12 | 0 | 0 | 13 | 12 | 0 | 0 | 13 | 12 | 0 | 0 | 13 |
| Urology | 9 | 0 | 0 | [illegible] | [illegible] | 0 | 0 | [illegible] | [illegible] | 0 | 0 | [illegible] | 10 | 0 | 0 | 10 | 11 | 0 | 0 | 11 |
| [illegible] | 3 | 2 | 6 | 11 | 2 | 2 | 6 | 10 | 3 | 2 | 6 | 11 | 3 | 2 | 5 | 10 | 3 | 2 | 6 | 11 |
| Paramedics | Minimal 3 room for rehabilitation doctors | | | | | | | | | | | | | | | | | | | |
| Medical Psychology | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 |

| A0- and H0-block | Wednesday PM CE-Rooms | Wednesday PM MF-Rooms | Wednesday PM Consultation Rooms | Wednesday PM Total Rooms | Thursday AM CE-Rooms | Thursday AM MF-Rooms | Thursday AM Consultation Rooms | Thursday AM Total Rooms | Thursday PM CE-Rooms | Thursday PM MF-Rooms | Thursday PM Consultation Rooms | Thursday PM Total Rooms | Friday AM CE-Rooms | Friday AM MF-Rooms | Friday AM Consultation Rooms | Friday AM Total Rooms | Friday PM CE-Rooms | Friday PM MF-Rooms | Friday PM Consultation Rooms | Friday PM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ophthalmology | 12 | 0 | 0 | 13 | 13 | 0 | 0 | 13 | 12 | 0 | 0 | 13 | 12 | 0 | 0 | 13 | 12 | 0 | 0 | 13 |
| Urology | 10 | 0 | 0 | 10 | [illegible] | 0 | 0 | [illegible] | [illegible] | 0 | 0 | [illegible] | 11 | 0 | 0 | 11 | 11 | 0 | 0 | 11 |
| [illegible] | 3 | 2 | 5 | 10 | 0 | 2 | 2 | 4 | 2 | 2 | 5 | 9 | 2 | 2 | 3 | 7 | 2 | 2 | 3 | 7 |
| Paramedics | | | | | | | | | | | | | | | | | | | | |
| Medical Psychology | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 |

**C0-block**

| C0-block | Monday AM CE-Rooms | Monday AM MF-Rooms | Monday AM Consultation Rooms | Monday AM Total Rooms | Monday PM CE-Rooms | Monday PM MF-Rooms | Monday PM Consultation Rooms | Monday PM Total Rooms | Tuesday AM CE-Rooms | Tuesday AM MF-Rooms | Tuesday AM Consultation Rooms | Tuesday AM Total Rooms | Tuesday PM CE-Rooms | Tuesday PM MF-Rooms | Tuesday PM Consultation Rooms | Tuesday PM Total Rooms | Wednesday AM CE-Rooms | Wednesday AM MF-Rooms | Wednesday AM Consultation Rooms | Wednesday AM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |
| Dental Surgery | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 |

| C0-block | Wednesday PM CE-Rooms | Wednesday PM MF-Rooms | Wednesday PM Consultation Rooms | Wednesday PM Total Rooms | Thursday AM CE-Rooms | Thursday AM MF-Rooms | Thursday AM Consultation Rooms | Thursday AM Total Rooms | Thursday PM CE-Rooms | Thursday PM MF-Rooms | Thursday PM Consultation Rooms | Thursday PM Total Rooms | Friday AM CE-Rooms | Friday AM MF-Rooms | Friday AM Consultation Rooms | Friday AM Total Rooms | Friday PM CE-Rooms | Friday PM MF-Rooms | Friday PM Consultation Rooms | Friday PM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dental Surgery | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 | 3 |

**C1**

| C1 | Monday AM CE-Rooms | Monday AM MF-Rooms | Monday AM Consultation Rooms | Monday AM Total Rooms | Monday PM CE-Rooms | Monday PM MF-Rooms | Monday PM Consultation Rooms | Monday PM Total Rooms | Tuesday AM CE-Rooms | Tuesday AM MF-Rooms | Tuesday AM Consultation Rooms | Tuesday AM Total Rooms | Tuesday PM CE-Rooms | Tuesday PM MF-Rooms | Tuesday PM Consultation Rooms | Tuesday PM Total Rooms | Wednesday AM CE-Rooms | Wednesday AM MF-Rooms | Wednesday AM Consultation Rooms | Wednesday AM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paediatrics | 11 | 1 | 0 | 12 | 12 | 0 | 0 | 12 | 11 | 2 | 0 | 13 | [illegible] | 0 | 0 | [illegible] | 11 | 2 | 0 | 13 |
| Obstetrics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |

| C1 | Wednesday PM CE-Rooms | Wednesday PM MF-Rooms | Wednesday PM Consultation Rooms | Wednesday PM Total Rooms | Thursday AM CE-Rooms | Thursday AM MF-Rooms | Thursday AM Consultation Rooms | Thursday AM Total Rooms | Thursday PM CE-Rooms | Thursday PM MF-Rooms | Thursday PM Consultation Rooms | Thursday PM Total Rooms | Friday AM CE-Rooms | Friday AM MF-Rooms | Friday AM Consultation Rooms | Friday AM Total Rooms | Friday PM CE-Rooms | Friday PM MF-Rooms | Friday PM Consultation Rooms | Friday PM Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paediatrics | 11 | 0 | 0 | 11 | 12 | 1 | 0 | 13 | 12 | 0 | 0 | 12 | [illegible] | 1 | 0 | [illegible] | 0 | 0 | 0 | 0 |
| Obstetrics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

* Needs an additional 10 day-parts in the week for dietetics and social work (consultation room)
[illegible]

Appendix VI - Figure 2: Desired capacity for regular hours specialties A0-, HO-, C0- and C1-block

# Appendix VII: Desired capacity for irregular hours specialties

| Speciality | Frequency | Description | | Day | Room | # rooms needed | #/year |
|---|---|---|---|---|---|---|---|
| K0- and L0-block | | | | | | simultaneously | |
| Rheumatology | 365 day-parts/year | Information to patients | | AM or PM | Information Room | 1 | 36 |
| | 1x per [illegible] | Rheumatology [illegible] consultation hour | | | OS-Room | 2 | 24 |
| Internal Medicine | 1x per 4 wks | Multidisc primary consultation hour [illegible] (diabetic foot [illegible]) | | | OS-Room | 2 | 26 |
| Plastic Surgery | 1x per mth | Mammacare 3 medical specialties, 10 hours monthly, multidisciplinary | | | OS-Room | 2 | 72 |
| | 1x per 6 wks | Consultation hands, 60 minutes multidisciplinary, max 10 [illegible] unscheduled patients | | | OS-Room | 2 | 17 1/3 |
| | 1x wk | Extra room [illegible] | | Wednesday AM and PM | OS-Room | 1 | 104 |
| | | Sometimes extra consultation hour [illegible] over 5 days, 2 rooms needed | | | OS-Room | 2 | |
| | 1x per mth | Dermatography 1 hour | | | OS-Room | 2 | 24 |
| Orthopaedics | 2 day parts | Physio [illegible] screening shoulders | | Monday and Thursday AM | OS-Room | 2 | 208 |
| Cardiology | 20 hours per wk | Consultation hour [illegible] | | | OS-Room | 1 | 208 |
| | 1 day-part | Dietetics | Asked by Paramedics | | Consultation room | 1 | 52 |
| | 2 day-part | Social Work | Asked by Paramedics | | Consultation room | 1 | 104 |
| | 2x 2 hours | Physio ([illegible] for rehabilitation) | Asked by Paramedics | | Consultation room | 1 | 104 |
| Surgery | 3 day parts | Social Work | Asked by Paramedics | | Consultation room | 1 | 156 |
| Pneumology | 1x per 6 wks | Multidisciplinary consult COPD | | Thursday AM 09.30-10.30 | OS-Room | 2 | 17 1/3 |
| | 1x per 6 wks | Multidisciplinary consult OSAS | | Friday AM 12.00-13.00 | OS-Room | 2 | 17 1/3 |
| | 8 day-parts | Expectation [illegible] in 2008 | | | OS-Room | 1 | 416 |
| | | | | | | Total | 1556 |
| | | | | | | Avg. Week | 29,91 |

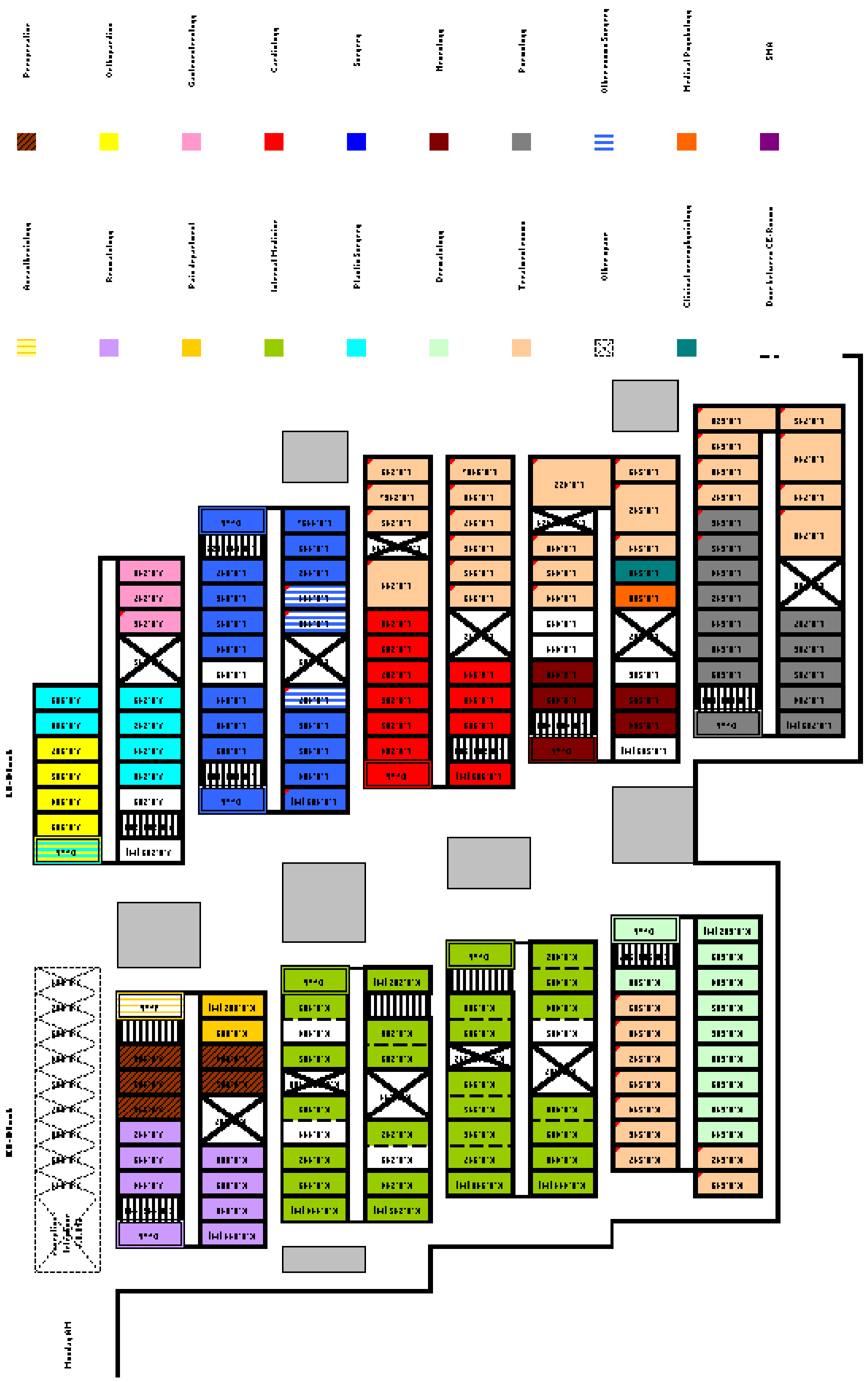
* Information room [illegible]

Appendix VII - Figure 1: Desired capacity for irregular hours specialties K0- and L0-block

| Speciality | Frequency | Description | | Day | Room | # rooms needed simultaneously |
|---|---|---|---|---|---|---|
| Other blocks | | | | | | |
| Ophthalmology | 1x per 2 wks | Consultation hours in evening, 2 medical specialists and optometrist | | Evening | C0-Room | 1 |
| Paramedics | Weekly | Consultation hour shoes | | Monday AM 09.00-10.00 | C1-Room | 1 |
| | Weekly | Consultation hour orthesis | | Monday AM 10.00-11.00 | C0-Room | 1 |
| | Weekly | Consultation hour shoes | | Thursday AM 10.00-12.00 | C1-Room | 1 |
| | 1x per mth | - | | Monday AM 11.00-12.00 | C0-Room | 1 |
| | 1x per 2 wks | Consultation hour shoes | | Monday PM 13.00-16.00 | C1-Room | 1 |
| | 1x per 6 wks | Consultation hour hand rehabilitation | *Asked by Rheumatology* | Monday PM 16.15-17.00 | C0-Room | 2 |
| ENT | 2 day-parts | Speech therapy | *Asked by Paramedics* | Wednesday PM and Friday AM | Audio space | 1 |
| Paediatrics | 6 day-parts/year | Consultation hour external specialists | | Tuesday or Friday PM | C0-Room | 3 |
| | Whole week | Physiotherap./ther./speech ther. | *Asked by Paramedics* | | C1-Room | 1 |
| | 3 day-parts | Dietetics | *Asked by Paramedics* | | Consultation room | 1 |
| | 3 day-parts | Social Work | *Asked by Paramedics* | | Consultation room | 1 |

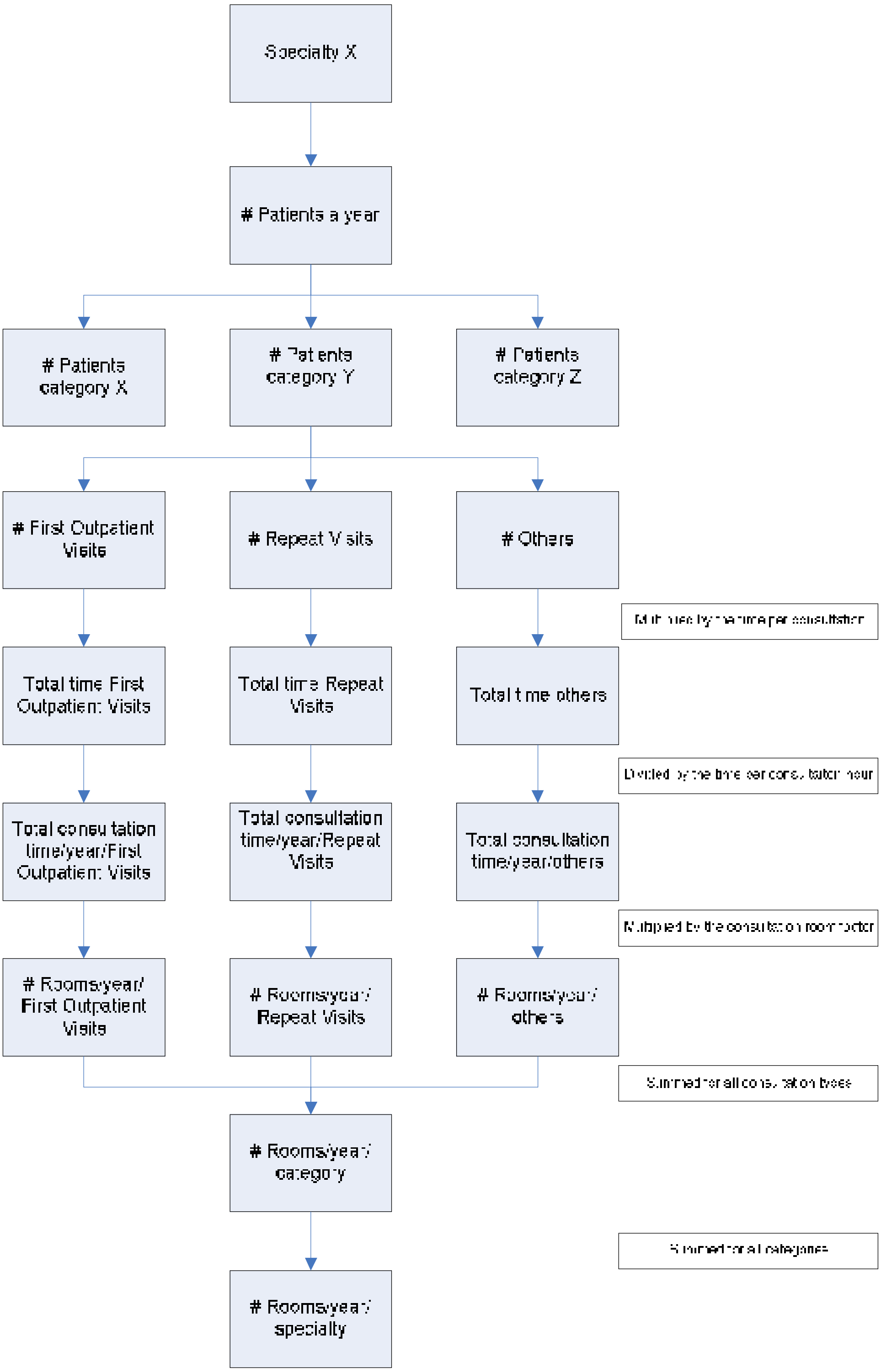
Appendix VII - Figure 2: Desired capacity for irregular hours specialties A0-, HO-, C0- and C1-block

# Appendix VIII: Spatial distribution outpatient department DZ 2007



Appendix VIII - Figure 1: Monday morning at the K0- and L0-Block

# Appendix IX: Calculating base capacity




Appendix IX - Figure 1: Determining the capacity need per type of healthcare professional of a specialty

# Appendix X: Ranking techniques

When there are several alternatives / scenarios, a choice must be made between the most suitable alternatives. A decision can be made, based on different criteria (Goodwin & Wright, 1991). By assigning weighing factors to the different criteria a choice can be made base on predetermined objectives. Before a choice can be made, the alternatives / scenarios must be evaluated on criteria. The criteria have to be placed in order of importance, and alternatives / scenarios had to be placed in order of suitability.

The choice of an alternative / scenario is based on a number of criteria. There are attributes t can not be represented by quantifiable variables (e.g. the attribute ‘image’). A method that can be useful for these variables is direct rating. Here each alternative is given a value between 0 and 100, in which 100 should be assigned to the best alternative. The space between the values of the alternatives represents the strength of preference for one alternative over another (e.g. difference between 0 and 100 means that 100 is ten times more preferable) (Goodwin & Wright, 1991). Also the four point scale (real bad, bad, good, real good) of Harris and the five point scale (where you can chose a neutral value) of Miller can be used (Eekels et al., 1995). Value functions can be used for attributes that can be represented by quantified variables. The best alternative gets a score of 100 and the least preferable a score of 0. Alternatives in between can be valued by a method named bisection. Here the midpoint value is determined which has a score of 50 (Goodwin & Wright, 1991).

For ranking the criteria in order of importance the following techniques are useful. One way is to attach weights to each of the attributes that reflects their importance to the decision makers. But this does not take into account how large the range is between the most preferred and least preferred alternative of each attribute. A way to avoid this problem is by using *swing weights*. Here the decision makers are asked to compare a change (or swing) from the least preferred to the most preferred value on one attribute to a similar change in another attribute. The best attribute gets a score of 100 and all the others a score below that. By normalisation a weighting factor is determined (Goodwin & Wright, 1991). Another method is the use of the *cross-impact matrix*. Here the criteria are two by two compared with each other. The one that wins the most is putting at top of the list (so is the most important criteria) (Eekels et al., 1995).

In cases the alternatives / scenarios are evaluated on one criterion this choice is rather easy. It becomes more difficult when there are more criteria to evaluate alternatives. The scores of the alternatives / scenarios for the different criteria must than be evaluated against each other. In literature such a problem is known as a multiple criteria decision making (MSDM) (Hwang & Yoon, 1981). Here a distinction is made between compensatory and non-compensatory techniques.

Besides, there are easy and more difficult techniques to use. It depends on the situation which technique to use. In a pre-selection phase with a lot of criteria and alternatives a simple method is preferable. Non-compensatory techniques are more suitable in situations where only the best alternative is good enough, in a pre-selection, or in situation of a lot of alternatives. In a pre-selection this results namely in less ‘shortcomings’ of the selected alternatives in latter phases. In these latter phases a more sophisticated technique can be used. Below a number of (non)-compensatory techniques are shown.

| **Method** | **Proponents** | **Methodology** |
|---|---|---|
| *Lexicographic ordering* | Van der Wegen et al. (2004), Massam (1980) | Criteria are ranked from most to least important. The alternatives that satisfy the first criterion are evaluated with respect to the second criterion. Non-compensatory. |
| *Maximin* | Cheng & Hwang (1991) | The overall performance of an alternative is determined by its lowest score on any of the criteria. The alternative with the highest of these scores is chosen. Non-compensatory. |
| *Pareto preference ordering* | Van der Wegen et al. (2004), | Method that can lead to incomparability of decision options. |
| *Average value options* | Van der Wegen et al. (2004), | Does not take into account that some criteria are more important than others. |
| *Conjunctive decision model* | Hwang & Yoon (1981) | Applies the principle of rejecting an alternative if this alternative does not equal or exceed a minimum score for each criterion. Non-compensatory |
| *Disjunctive decision model* | Hwang & Yoon (1981) | An alternative is selected if at least one of its criterion-scores exceeds a specified minimum value. Non-compensatory. |
| *Linear assignment model* | Cheng & Hwang (1991) | A rank to each alternative is assigned such that the summation of the scores for that assignment is maximal. Quasi-compensatory. |

Appendix X -Table 1: Simple ranking techniques

| Method | Proponents | Methodology |
|---|---|---|
| *Electre III* | Buchanan et al. (1999), Vincke (1992), van der Wegen et al. (2004) | Outranking method that uses indifference and preference thresholds (assigned after consultation with decision makers). Separates objective and subjective components of the ranking problem. Non–compensatory. |
| *Analytical Hierarchy Process (AHP)* | Harker (1989), van der Wegen et al. (2004) | Copes with a finite number of discrete alternatives. Starts with the construction of a value tree. Uses pair wise comparisons to find the relative priority of the criteria. Uses also consistency ratio. This ratio is a comparison of the matrix and a purely random answering of questions. Compensatory. |
| *Multiattribute Rating Technique (SMART)* | Van der Wegen et al. (2004), | Copes with a finite number of discrete alternatives. Starts with a value tree. The difference with AHP is that in AHP the alternatives are put on the lowest level of the value tree, while this is not the case in SMART. Uses swing weights, direct ranking and value functions. |
| *Multiattribute utility theory (MAUT)* | Belton & Stewart (2002), van der Wegen et al. (2004) | Copes with uncertainties by using the utility theory. Handles multi criteria problems that include risks. Compensatory. |

Appendix X -Table 2: Complex ranking techniques

**Planning at Orthopaedics based on DTC-codes**

**Part two**

**by**

**M.M. Kats**
**J.H. Quik**

# Deventer Hospital

Planning at Orthopaedics based on DTC-codes

***Capacity planning Orthopaedics in Deventer Hospital***

Enschede

June 11 2008


| | | |
|---|---|---|
| *University of Twente* | | *Deventer Hospital* |
| *Faculty*: | School of Management and Governance | |
| *Study*: | Industrial Engineering & Management | |
| *Specialisation*: | Health Care Technology and Management | |
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# Management samenvatting

De toegangstijden voor Orthopedie binnen het Deventer Ziekenhuis zijn hoger dan de landelijk afgesproken “Treeknormen” en wisselen maandelijks. Daarnaast neemt jaarlijks de vraag naar zorg toe en heeft het specialisme een beperkte capaciteit beschikbaar voor het leveren van zorg. Het aantal spreekuren en OK sessies per week schommelt en er is sprake van overboekte spreekuren. In dit kader is gekeken naar de mogelijkheden voor Orthopedie voor het spreiden van de spreekuren en OK sessies en naar de mogelijkheden om meer grip te krijgen op de toegangstijden en wachttijden voor de OK en polikliniek.

**Aanbevolen wordt**

- Het inroosteren van optionele spreekuren en deze inzetten bij:
    - Het reduceren van de toegangstijd tot de polikliniek voor (2 jaarlijkse) herhaalpatiënten, om vertraging van het zorgproces te beperken of te voorkomen;
    - Het reduceren van de toegangstijd tot de polikliniek voor nieuwe patiënten. Hierbij moet rekening worden gehouden met benodigde OK en polikliniek capaciteit in de toekomst;
    - Een verwacht tekort aan OK patiënten, met als doel de OK bezetting te verhogen. Er worden nieuwe patiënten gezien met een korte toegangstijd tot de OK;
- Een planning te maken voor een periode van minimaal 6 maanden, waarbij de productie doelstellingen leidend zijn voor de aan- en afwezigheid van de zorgverleners;
- Het eenduidiger maken van de protocollen rondom de planning van operaties en eerder overleggen en afstemmen van het OK programma met het Opnamebureau en de OK;
- Het nauwkeuriger registeren van DBC’s, wanneer deze voor de planning wordt gebruikt;
- Voor of tijdens de gedeeltelijke OK zomersluiting een grotere wachtlijst opbouwen met OK patiënten die behandeld willen worden na de zomerperiode;
- Het registreren van het moment waarop nieuwe patiënten een afspraak willen maken, om meer inzicht te krijgen in het daadwerkelijke aankomstproces van patiënten;

- Het hanteren van een ‘niet vervuilde’ wachtlijst om beter inzicht te hebben in de daadwerkelijke wachtlijst met patiënten.

**Motivatie**

Door middel van een analyse van de huidige capaciteit en een modellering van de zorgvraag per patiëntengroep is inzicht verkregen in de relatie tussen de polikliniek en de OK. Uit het onderzoek is gebleken dat de hoge toegangstijden voor de polikliniek zorgen voor overboekingen van spreekuren en een vertraging van de behandeltrajecten. Niet alle beschikbare dagdelen van de medisch specialist (MS) worden op de polikliniek gebruikt. Dit geeft mogelijkheden om extra spreekuren te draaien en een productietoename van maximaal 11% te realiseren.

De lange termijn waarover het aantal OK tafels vaststaat, maakt het moeilijk deze op de korte termijn aan te passen aan de vraag naar zorg. Om de OK voldoende te vullen is het belangrijk om het aantal spreekuren af te stemmen op de beschikbare OK-tijd, met als doelstelling een hogere bezettingsgraad van de OK te realiseren. Door een lange termijn planning te maken van minimaal 6 maanden gebaseerd op vooraf opgestelde productie doelstellingen, kan de aanwezigheid van de zorgverlener en de vraag naar zorg beter worden afgestemd.

Het eenduidiger maken van de protocollen rondom de planning van patiënten voor de OK, zorgt voor meer flexibiliteit bij het vullen van OK programma’s. Vroegtijdige afstemming met het Opnamebureau over de vulling van het OK programma biedt mogelijkheden om de patiëntenstroom beter te sturen.

Wanneer het specialisme het zorgaanbod beter wil afstemmen op de zorgvraag (patiëntgerichte zorg), is het belangrijk dat hier meer inzicht in komt en onderzoek wordt gedaan naar de aankomst van nieuwe patiënten en wanneer deze een behandeling *willen* starten.

**Consequenties**

- Van de MS wordt meer flexibiliteit verwacht. Optionele spreekuren kunnen tot 2 weken van tevoren onzeker zijn. Het aantal dagdelen dat totaal wordt gewerkt op de polikliniek en OK kan enkele weken hoger liggen dan 4 dagen per week, maar wordt in andere weken gecompenseerd en ligt niet hoger dan de jaarlijks afgesproken aanwezigheid;

- De aan- en afwezigheid van zorgverleners staat langer van tevoren vast en moet vroegtijdig worden doorgegeven;

- Voor het vooruitkijken naar de benodigde capaciteit op de polikliniek en OK dient er wekelijks gemonitord te worden naar deze capaciteiten.

# Management Summary


The access and waiting times for Orthopaedics in Deventer Hospital are higher than the national agreed maximum access times (“Treeknormen”), and change every month. The yearly demand for care increases, although there is a limited available capacity to provide care. The number of consultation hours and OR sessions in a week varies and we see overbooked consultation hours. Within this context we looked at the possibilities for Orthopaedics to spread the consultation hours and OR sessions and the possibilities to get better grip on the access and waiting times for the OR and outpatient department (OD).

**We recommend to**

- Schedule optional consultation hours and use these to:
    - See more (2-yearly) revisit patients, to reduce the access time and to prevent or reduce a further delay of the treatment;
    - See more new patients, to reduce the access time to the OD. Enough future capacity should be available to see these patients in the OR and OD;
    - See more new potential OR patients, to prevent a shortage of OR patients, with the aim to increase OR utilisation. Patients are seen with a short access time to the OR. The specialty has to keep in mind that this can lead to extra OD capacity in the future;
- Make a planning for a period of at least 6 months, for which the production targets are leading for making the monthly working schedules for the healthcare professionals;
- Make a more uniform protocol for the planning of surgeries of each medical specialist (MS) and communicate in an early stage with the admission planning about the OR program and the problems encountered during the planning of OR sessions;
- Register more accurately the DTCs, if they are used for planning purposes;
- Build up larger waiting lists before or during the partial OR closure in the summer, with patients that want to be treated after the holiday period;

- Register the moment at which a patient asks for an appointment, to get more insight into the arrival of new patients through time;
- Use a waiting list with patients that want to be treated immediately instead of the current registration, to get insight into the real number of patients waiting.

**Motivation**

Through an analysis of the current capacity and by making a linear programming model of the healthcare demand for each patient group, more insight is obtained in the relation between the OD and the OR. Our study shows that the high access time of the outpatient department results in overbooking of consultation hours and delayed patient treatments. We also see that not all available day-parts of the MS are used in the OD. This gives possibilities to schedule extra consultation hours to prevent or reduce a delay of the revisits or surgery and to increase production by 11%.

The long period for which the OR capacity is already fixed makes it difficult to adapt the capacity to the actual healthcare demand on a short-term basis. To be able to use the allocated OR-time to a maximum, the number of consultation hours should be adapted to the available OR-time. Insight into the number of planned surgeries and remaining time available in the OR is necessary. Active exchange of information between the admission planning and the speciality creates possibilities to influence the patient flow to the OR and finally the utilisation of the available OR-time.

If the specialty wants to align the supply of care with the demand of care (patient-centred care), more insight is needed in the arrival of new patients and when patients want to receive care and start a treatment.

**Consequences**

- More flexibility is expected from the MS. Extra optional consultation hours can remain uncertain until 2 weeks in advance. The total number of day-parts the MS works in the OD or in the OR can be higher than 4 day-parts during a limited number of weeks, although this is compensated in other weeks, and the total number of day-parts a year is not more than the yearly agreed presence;
- The absence and presence of the healthcare professional is decided in an earlier stage and has to be notified longer in advance than before;
- Weekly monitoring of the OD and OR is necessary to anticipate changes in access or waiting times.

# Preface

This report describes the results of our Master of Science project Industrial Engineering and Management for the department of Operational Methods for Production and Logistics (OMPL), University of Twente, Enschede, The Netherlands. OMPL focuses on the optimisation of management and the organisation of business and healthcare processes, and participates in the Centre of expertise in Healthcare Operations Improvement and Research (CHOIR) of the University of Twente.

After doing a study in Deventer Hospital (DZ) on the allocation of rooms for the outpatient department we carried out a study for Orthopaedics. That study gave us more insight in the primary task of the hospital: delivering care to patients. We learned a lot about the planning of patients, but also about the problems encountered by healthcare professionals. We saw within the hospital that there are many ideas to improve healthcare. We were also pleased to be able to bring new ideas to Orthopaedics concerning planning and making more efficient use of their resources.

We thank Hanny van der Werff, operational manager for Orthopaedics, for the time she took to explain us the working processes and helping us to get the information we needed. In particular we thank dr. R.H.G.P van Erve, who took a lot of time to help us collect more information about the clinical pathways of Orthopaedic patients and to validate our model. This did not only provide the required information, the interesting discussions also brought up new ideas to improve healthcare. Furthermore we were always able to ask our questions to the staff of Orthopaedics, which made working with the specialty pleasant. We appreciated a lot the conversations we had with Wies Lemstra, responsible for the hospital admission planning. She gave us more insight in to the planning of patients, but also gave us an external view on the planning of Orthopaedic patients. Furthermore we thank Geert Kroes, our supervisor within DZ, for helping us with this second report.

Finally, we thank Erwin Hans and Johann Hurink. We were always able to pose our questions and working together with them was even more pleasant than for our first report. We had many pleasant, useful and interesting discussions about our research and other (related) matters.

*Michel Kats,* *Jasper Quik*

*Enschede, June 2008*

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# Chapter 1

# Introduction

Due to an ageing population, the demand for healthcare is increasing. In addition, healthcare in The Netherlands is subject to a market-based competition. This spurs specialties to organise their processes more efficiently, while still delivering patient-centred care. Patient-centred care does not only consist of delivering high quality care, but also means short access time to the outpatient department (OD) and short waiting lists for a treatment. Specialties are looking for possibilities to manage the waiting lists and access times and respond to it. One way to reduce access times is increasing the available capacity, but the possibilities are limited and costs will increase. This report describes how capacity planning of Orthopaedics can help to improve patient-centred care and efficiency. We look at the possibilities to control access and waiting times and to make efficient use of the available capacities for Orthopaedics.

This report, the second out of two reports concerning  capacity planning in DZ, focuses on the capacity planning for Orthopaedics. The first report ‘Resource allocation in an outpatient department’, deals with the allocation and use of centralised and standardised rooms in an outpatient department. Figure 1.1 shows an overview of the relation between the two reports.

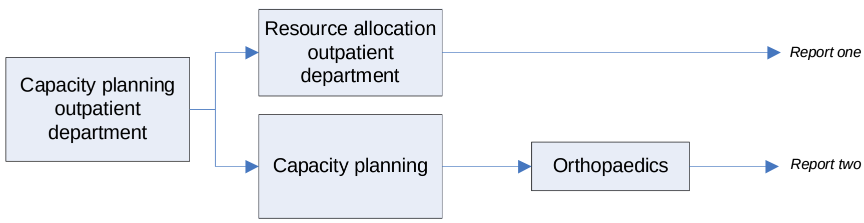


Figure 1.1: Overview of the report

This introductory chapter starts with a description of Orthopaedics in Deventer Hospital (DZ) (§1.1). §1.2 describes the problem analysis around Orthopaedics in DZ. §1.3 describes the research objective and questions.  We conclude this chapter with the methodology of our research (§1.4).

## 1.1 Orthopaedics in DZ

Orthopaedics mainly provides elective care, which is care that is pre-arranged. This can be an appointment in the outpatient department (OD) or a surgery in the operating room (OR). In addition, Orthopaedics provides to a limited extent emergency (non-planned) care. This section briefly describes the situation at Orthopaedics in Deventer Hospital (DZ) and the patient flow.

New patients entering the OD, are referred by a general practitioner or by another hospital department and get a consult with one of the 5 medical specialists (MS). Waiting times and access times determine the time at which a patient gets its treatment. The access time is the time needed to get a first appointment in the OD. The waiting time is the time between two consultations or between a consult and a (surgery) treatment. After a first appointment the patient may either need no further treatment, need a revisit in the OD, or need surgery in the OR. In the OD, 3 medical assistants (AIOS) and 1 nurse practitioner also provide care to patients. In the OR only the MS performs surgery, sometimes accompanied by an AIOS.

In 2006, Orthopaedics registered 10.821 Diagnosis Treatment Combinations (DTCs) that describes a complete treatment to a patient. This covered 18.949 outpatient consultations and 2.389 surgeries. §3.1 goes into further detail on the patient flow and §4.1 describes DTCs.

## 1.2 Problem description

The increasing age of the population causes an increase in the demand for Orthopaedic care. More new patients arrive in the outpatient department (OD) and need surgery, but patients also come back more often for yearly revisits. This causes a yearly increase of demand by at least 3% (Hollander et al., 2006). Reducing the time needed per patient and increasing the efficiency of the available capacities enables the specialty to increase the delivered care with a limited available capacity.

Orthopaedics has difficulties keeping the access and waiting times below the ”Treeknormen”. “Treeknormen” [1] are nationally defined maximum access and waiting times. In the OD in the Deventer Hospital the patients do not always get their appointment within 3 weeks, which is the defined maximum access time for the OD. Throughout the year, the access time may rise up to 7 weeks, which is one of the highest access times in The Netherlands. In comparison, Orthopaedics of Alysis Zorggroep in Arnhem has an access time of 1 week [2]. Too high access times stimulate new patients to defer to other hospitals with shorter access times. For revisit patients a high access time results in an unnecessary delay of the treatment and blocks the patient flow to the OR.

Before a patient can enter the OR, a visit in the OD is required. The number of patients seen in the OD directly influences the number of OR patients waiting for surgery several weeks later. Although there are waiting lists for the OR, that vary throughout the year, there are not always enough patients available for a treatment in the OR. For example, at the beginning of September (week 36) Orthopaedics starts full production after a holiday period (week 30-35) where the OR and OD availability was reduced (see Figure 1.2). After working away a backlog due to the holiday period, a shortage of patients for treatment in the OR is encountered in October. As a result, a lot of effort is made to fill the available OR-time. Although there are still a limited number of patients on the waiting list, many of them prefer not to be operated at that time of the year. In addition, unambiguous protocols for the planning of OR patients limit the possibilities to fill the available OR-time. As a result OR and specialist time remain unused, resulting in a loss of capacity and a reduced number of patients that can be seen. This results in a decreased utilisation of the available OR-time. In 2006, Orthopaedics used 88,6% of the available OR-time. For standardised procedures, or elective care, an utilisation of 95% is possible (De Vries, 2007).

Figure 1.2 illustrates the number of consultation hours and the time scheduled in the OR per week in 2006. A *consultation hour* consists in a shift with patient appointments in the OD. The duration can be more than 60 minutes. Figure 1.2 shows that the workload in the OD and OR is fluctuating over the weeks. Figure 1.3 illustrates the same weekly OR capacity as in Figure 1.2, but the consultation hours are shown from 6 weeks before the OR session. Normally the number of consultation hours is expected to be equal to the number of OR sessions needed 6 weeks later. Figure 1.3 shows there is a gap between the expected OR capacity needed and the actual available OR capacity (for examples, see the red circles). Figure 1.3 also shows that during the summer holiday an increased OR demand is expected, although there is a reduced OR capacity available. We can conclude that there is a mismatch in the number of consultations hours and the number of OR sessions several weeks later.

Summarising, Orthopaedics experiences a high external pressure to increase production and provide patient-centred care. In addition, Orthopaedics wants more insight in the patient flow between the OD and OR, wants to improve the control on access and waiting times and possibilities to react to it. Orthopaedics seeks ways to match the workload in the OD and the workload in the OR over the weeks.

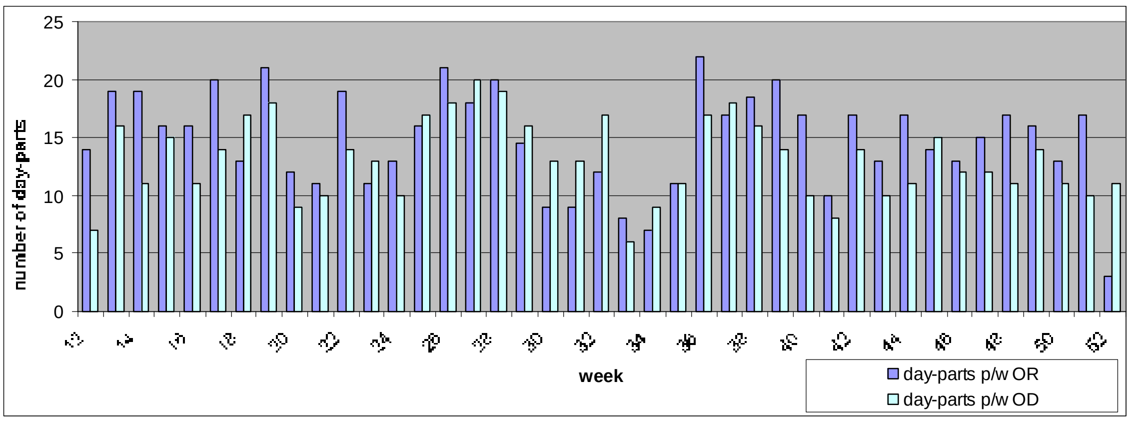


Figure 1.2: Number of OR-shifts and consultation hours for Orthopaedics (2006)

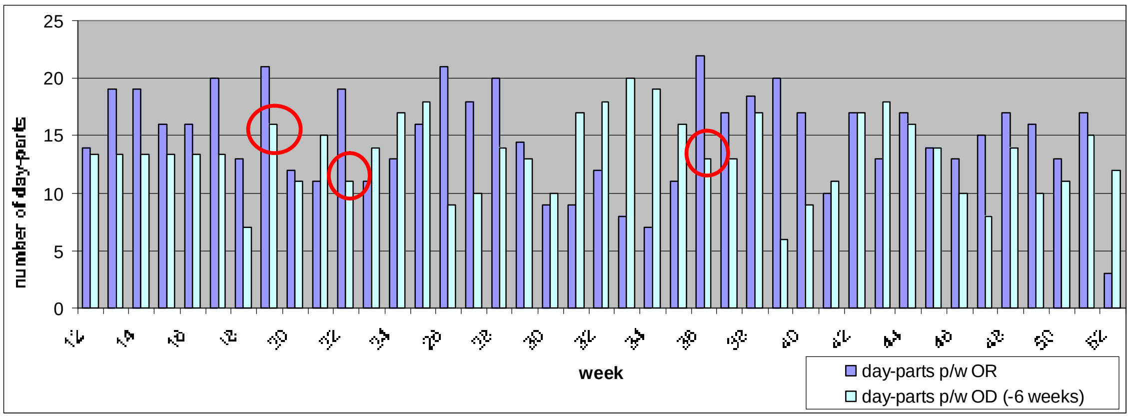


Figure 1.3: Number of OR-shifts and consultation hours for Orthopaedics (2006)

## 1.3 Research objective and questions

Based on the problems seen for Orthopaedics in Deventer Hospital (DZ) the objective of this report is as follows:

*"To get more insight into the relation between outpatient department and OR demand, propose methods to control the target access and waiting time, and propose methods to balance the workload of the outpatient department and operating room"*

We focus on the outpatient department (OD) and OR of Orthopaedics and do not take into account other departments or diagnostic activities related to a treatment. For the target access and waiting times we use the nationally set maximum access and waiting times ("Treeknormen").

The objective implies the following sub-goals:

- To create an optimal throughput of patients;
- To create efficient use of available resources;
- To take the "Treeknormen" into account;
- To respond to variations in demand (i.e. summer holidays);
- To prevent fluctuations in the number of consultation hours and OR-blocks.

For attaining the research objective we formulate a number of research questions:

1. *What influences the access and waiting times for the OD and OR*? We take a closer look at the patient routing between the OD and OR. This gives insight in the interaction of the demand for healthcare and the supply of healthcare (*Chapter 3*).

2. *What determines the weekly capacity required for Orthopaedic patients?* In order to determine the capacity required we define distinct groups to categorise Orthopaedic patients. We use this categorisation and the available information on patient routing to get more insight into the weekly capacity required for Orthopaedic patients. (*Chapter 4*).

3. *What are the possibilities for Orthopaedics to influence waiting lists?* We use the results of question 1 and 2 and the current situation of Orthopaedics in DZ to evaluate the possibilities on how to influence or control the waiting lists and access time (*Chapter 5*).

## 1.4 Methodology

To start, we take a more detailed look at the planning of patients and capacity scheduling. This consists in a literature study. We also study the patient flows within the hospital, between the Outpatient Department and OR. We evaluate the available capacities and use of capacities for Orthopaedics, based on the production figures of 2006.

Through interviews and DTC information, the routing and planning of patients throughout the hospital is examined. This takes into account the planning of patients in the outpatient department (OD) of Orthopaedics for a (re)visit and the admission of a patient for surgery. We have chosen to describe, for a limited number of patient groups, the patient pathways in more detail, in order to get more insight in the weekly capacity needed. These groups have been selected according to size and time needed during consultation and surgery. This is done in dialogue with a medical specialist. Also the clinical pathways for the selected patient groups are evaluated. We use historical data to determine the healthcare demand for these patients. This information is obtained from the management information system “Proclarity” in DZ and concerns the year 2006.

Using clinical pathways as a basis, we make a mathematical model to determine the weekly capacity needed and to evaluate the consequences of changes in capacity use. With the model we try to establish a levelled workload in the OD and OR. In addition, the mathematical model gives information on the production Orthopaedics can handle with the current available capacity.

The model also gives insight in the capacity demand per week in terms of time required for consultation hours, the number of patients to be seen, and the time required in the OR. The time dependencies between the consultation hours and OR for each group of patients are based on clinical pathways. This information is useful to schedule the healthcare professionals, consultation hours, and to request ORs throughout the year. As a result, Orthopaedics has possibilities to control the access and waiting times.

# Chapter 2

# Theoretical Framework

This chapter gives an overview of the relevant literature concerning the planning of Orthopaedic patients. In §2.1 we propose a system to analyse on which levels of capacity planning and management the planning of Orthopaedic patients occur. §2.2 gives an overview of combinatorial optimisation problems. §2.3 deals with the capacity planning of specialists. §2.4 describes ways for improving the scheduling of patients in the outpatient department. §2.5 gives an overview of the literature and links it to the research questions. The mentioned literature and concepts will form a basis for this report and will be referred to in the next chapters. The reader familiar with the literature regarding capacity planning in healthcare may skip this chapter.

## 2.1 Framework for planning and control in hospitals

Problems regarding the planning of Orthopaedic patients can be distinguished at different management or planning levels. Figure 2.1 describes a model with horizontally four categories of managerial areas: medical planning, capacity planning, material planning, and financial planning. *Medical planning* concerns the coordination and planning of medical activities by healthcare professionals. *Capacity planning* consists in the planning and control of resources like staff, beds, space, etcetera. *Material planning* is the coordination of materials. *Financial planning* concerns the coordination of the financial processes. This research focuses on capacity planning. In this section we define the different management levels where capacity planning occurs, and position the different levels of planning Orthopaedic patients within this framework.

The managerial or planning activities can be distinguished into four hierarchical levels (Anthony, 1965): strategic planning, tactical planning, and operational control (offline and online). These hierarchical levels are presented on vertical axis in Figure 2.1. *Strategic planning* focuses on the long-term (1-5 years). Decisions are made about the patient mix (case-mix), and the layout and location of the outpatient department. At this level an aggregated capacity planning takes place. Changes in service area and demand are taken into consideration. The members of the board, management team, and medical staff participate in this. At a *tactical level* decisions are made for the mid-term (year-months). Seasonal variations of the number of patients are also taken into consideration and the patient flow is analysed. The management and medical staff participate in this. The objective at this level is to get a master planning for Orthopaedics. At the *operational level* decisions are made shortly in advance. A distinction is made between *offline* and *online* decisions.

Offline decisions concern the scheduling of patients and staff in the outpatient clinic. Online decisions deal with the daily coordination of the healthcare process. The specialty, medical specialists, staff, and even the patient are involved in this.

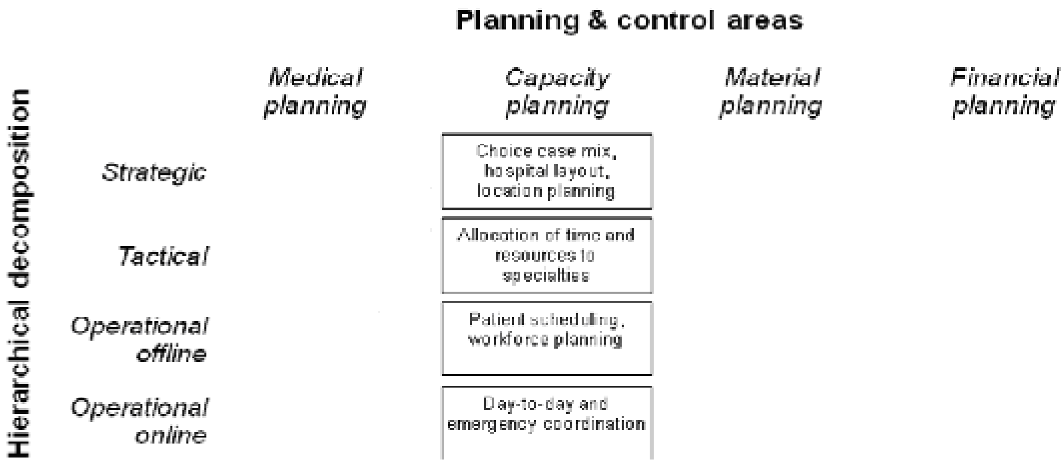


Figure 2.1: Framework for planning and control hospitals [Hans, 2006]

## 2.2 Integer linear programming

A *combinatorial optimization* problem or *integer programming* problem is an optimisation problem that has a finite number of feasible solutions (Winston, 1993). Integer programming also consists in the efficient allocation of limited resources to meet an objective function (minimisation or maximisation). The selection of the best solution is based on altering predefined decision variables. The feasible solution is determined by restrictions or constraints, and parameters (input data) (Hans, 2005). Combinatorial optimization is the process of finding one of more solutions in a well defined discrete problem space (Vossen et al., 2000). There are several combinatorial optimization techniques like Lagrangian relaxation or branch-and-bound. For more optimisation techniques we refer to e.g., Winston (1993); Wolsey (1998); Johson et al. (1998); Nemhauser and Wolsey (1988).

A tool for solving a wide range of optimisation problems is linear programming (LP). However, many practical optimisation problems require integer variables and are often hard to solve. *Mixed integer linear programming* (MILP) is a linear program of which some of the variables are integers. A *pure integer linear program* (PILP) is a linear program of which all of the variables are integer. In addition, when the integer variables are restricted to values 0 or 1, we speak of a (mixed) *binary integer linear program* (MBILP or BILP) (Winston, 2003).

*Integer linear programming* (ILP) refers to the process of formulating and solving ILPs. There are many combinatorial optimization techniques for solving ILPs. However, there is always a trade-off between the computational effort (running time) and quality of the obtained solution. ILPs can be solved by an *exact algorithm* to optimality, or by a *heuristic* (*approximation*) *algorithm*. An exact algorithm determines an optimal solution, but uses a lot of computation time. A heuristic algorithm determines a feasible solution that is as good as possible in as little time as possible (Johnson et al., 1998).

A problem can be classified by its complexity (Garey & Johnson, 1979). This complexity is measured in the number of elementary calculations (addition, subtraction, multiplication, division) that is necessary to solve the problem to optimality, expressed as a function of the input size. The input size is defined as the number of symbols used to represent it. If the input is measured by *n*, then the running time of an algorithm is expressed as *O(f (n))*. For example: when there are *n* cities in a Travelling Salesmen Problem (TSP), there are *(N-1)!* feasible solutions. This means that the number of elementary calculations is bounded from above by an exponential in *n* and that the problem can be solved in "*exponential time*" *(e.g. O (n!))*. When the running time is bounded by a polynomial function *f (n)*, the problem can be solved in "*polynomial time*" *(O (n))*. A particular class is the *NP-hard* problems, which are unlikely to be solved in polynomial time. They are generally solved by heuristics (Garey & Johnson, 1979).

## 2.3 Capacity planning of medical specialist time

In literature capacity planning of specialist time has received little attention. Vissers (1994) addressed specialist time planning by making a spreadsheet type of model to describe master schedules for specialists. In that model Vissers analyses the effects of specialist master schedules on resource utilisation within the hospital. Klaasen (1996) and Vissers (1996) followed this research by making a decision support tool (Schedule Optimisation Model). A disadvantage of this model is that it cannot handle a bi-weekly and four-weekly pattern. De Kreuk et al. (2004) overcome this shortcoming by translating the scheduling problem into a mathematical model in the form of an *integer quadratic program* (IQP). The model is implemented in the software tool MediPlan. The models also make use of a *Local Search* technique (*simulated annealing*) for generating an alternative schedule.

## 2.4 Patient scheduling

Patient scheduling within the hospital has drawn the attention of many researchers. The analysis of patient arrivals and the control of waiting lists has resulted in new patient scheduling techniques. The main aims are reducing patients' waiting times and use the specialist's time efficiently.

Queueing theory is often used in healthcare organisations. "Any system in which arrivals place demands upon a finite capacity resource may be termed as a queueing system". This can be found wherever patients demand for healthcare services (OR, outpatient department (OD), etcetera). Goal of queueing analysis is to minimise (in)tangible costs like waiting costs or capacity costs (Singh, 2006). 30% of the patients in England go to other hospitals when waiting times are shorter there (Mahon et al., 1993). This percentage is supposed to increase due to the increasing patient control (e.g. better informed due to the internet).

In The Netherlands there are “Working Without Waiting List” projects (In Dutch “Werken Zonder Wachtlijst”) introduced by CBO, a quality institute for healthcare. They investigate possibilities to reduce the access time to outpatient care, as well as possibilities for organising outpatient care (CBO, 2005; CBO, 2006).

In their research Ho & Lau (1992) consider various rules for scheduling patients in an outpatient department. Ho & Lau (1992) investigated the ability to minimise a weighted sum of the idle costs of both the patients and the medical staff. The idle times incurred by any given rule are affected by three environmental factors, namely the probability of no-show, the coefficient of variation of service times, and the number of patients per consultation hour. Ho & Lau (1992) also state that an appropriate scheduling rule can be identified only if one knows the values of these parameters and the ratio between the medical staff and patients' idle-time costs.

Advanced access (or “open access”), originally developed by Murray & Tantau (1999), refers to the practice of providing patients with access to health care when they want it; i.e. an appointment the same day or the next day, regardless of the reason for the visit. The advanced access model differs from a walk-in approach in that patients call in ahead and are assigned an appointment slot. Benefits are improvements in patient, provider and staff satisfaction, increased physician productivity, reduced appointment no-show rates and wait times for appointments, improved continuity of care, and increased revenues (Singer & Regenstein, 2003). O’Hare & Corlett (2004) give guidelines in their article for implementing the open access principle.

In literature it is shown that the fundamental problem of outpatient appointment systems is the case where patients are given appointments for a consult with one or more healthcare professionals. Appointment systems are often designed in favour of reducing the idle time of the healthcare professional at the expense of increasing the waiting time of the patient. In literature this is often examined using queueing theory and simulation (Bailey, 1952; Jackson et al., 1964; Vissers & Wijngaard, 1979; Brahimi & Worthington, 1991). Bailey & Welch (1952) first tackled the problem. They name punctuality and consulting time as the two main factors affecting the design of an appointment system. They found that most of the patients are early and only some are late, but that the healthcare professionals in general do not arrive on time. In order to balance the practitioners’ and patients’ waiting times they propose to schedule $n$ patients at the start of the clinic and then schedule patients at intervals equal to the average consulting time (a so called mixed block-individual appointment rule). They recommend beginning the session with 2 present patients with the purpose of preventing excessive waiting for the patients. This appointment rule is identified as one of the basic scheduling principles in literature. Hutzschenreuter (2004) found that this Bailey-Welch rule outperforms the other rules for all combinations of mean service times and their variability. The utilisation under this scheduling rule is higher due to the fact that “inventory” is built at the start of the session. The author also found that the Bailey-Welch rule leads to the highest utilisation for the doctor and that this individual scheduling method improves its performance for low variability of service time.

## 2.5 Conclusion of the literature

The planning and control framework in hospitals, which distinguishes a strategic, tactical and operational level, is used to describe the different planning and scheduling decisions. Literature on integer linear programming is used for the formulation of the model for planning Orthopaedic patients. Literature on specialist capacity planning and scheduling patients is useful to look for possibilities to increase the production for Orthopaedics.

# Chapter 3

# Providing care to Orthopaedic patients

In this chapter we describe the patient routing of Orthopaedic patients and the related demand for care (§3.1). For Orthopaedic patients the waiting times and access times are influenced by the available capacity in the outpatient department (OD) and operating room (OR) and are influenced by the demand for care by patients (§3.2). We describe and analyse the use and the availability of the different capacities. We also discuss the possibilities to influence and control the access time and waiting lists (§3.3).

## 3.1 Patient routing and demand for care

The demand for care is determined by new patients and revisit patients arriving in the outpatient department (OD). We describe the steps in the arrival of a new patient within the Orthopaedics department, which is also displayed in Figure 3.1.

New patients can only take a first consult in the OD after a referral has been obtained from a general practitioner (GP) or a medical specialist (MS) within the hospital. The time it takes to get a first consult depends on the access time to the OD. In the year 2000, maximum access times for non-emergency care were nationally defined by ”Treeknormen” [1]. Together with hospitals, GP, MS, healthcare insurers and the government, the “Treeknormen” were agreed to be the target access and waiting times. The agreement includes that 80% of the patients should get an appointment for a first consult within 3 weeks, with a maximum of 4 weeks. After contacting the OD for a first consult, the patient can chose to accept the appointment given by the OD, or he can look for a shorter access time in another hospital. Thus the number of new patients that ask for a first consult at Orthopaedics is also influenced by the access time to the OD and the waiting time for a treatment. In case the admission time is shorter than in neighbouring hospitals, the number of patients may rise. Too high admission times may result in the contrary.

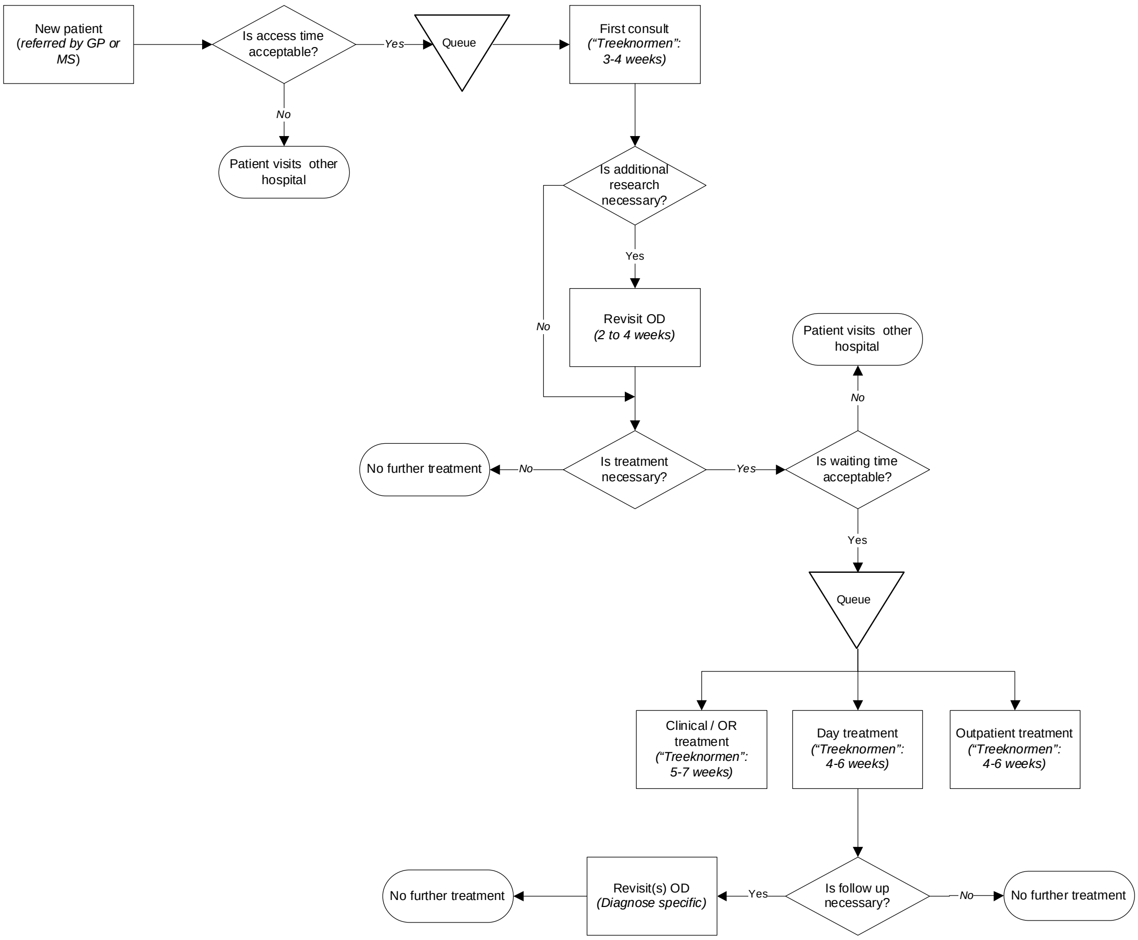


Figure 3.1: Arrival of a new patient within the Orthopaedic department

During the first consult the MS determines the patient's diagnosis. For each diagnosis there is a treatment program. In the Netherlands, the combination of the diagnosis and treatment is described by a Diagnosis Treatment Combination (DTC) [3, 4]. A DTC is a predetermined healthcare product, which consists of all the activities in the hospital that are related to the diagnosis and treatment of the patient. Each patient gets only one DTC for a primary diagnosis, but more patients can have the same DTC. This means that they have the same disease and undergo the same treatment. After a first consult, the patients can either:

- **Revisit the OD**: a revisit in the OD can be necessary to discuss additional research that has been done (e.g. MRI or X-Ray). After this revisit, the patient either needs a treatment, or ends the DTC;

- **Follow a treatment**: for Orthopaedics there are 3 types of treatment: clinical / OR treatment, outpatient treatment, or day treatment. Each type of treatment is subject to

“Treeknormen”. After the treatment there can be a follow up trajectory in the OD (e.g. for removing stitches or evaluation). The number of revisits necessary in the OD depends on the diagnosis and the related treatment (DTC-code);

- **End DTC**: the patient does not need any further treatment or additional research.

If the patient needs surgery he can decide to accept the offered appointment and the corresponding waiting time, or he tries to find another hospital with a shorter waiting time. Patients with ‘easy to treat’ problems that include an OR session, easily defer to other hospitals. After a surgery the patient has to come back for one or more revisits in the OD or needs no further treatment.

## 3.2 Care provided by healthcare professionals

Care provided by Orthopaedic healthcare professionals consists of consultations in the outpatient department (OD) and treatments in the OD and OR. The Orthopaedic healthcare professionals in DZ consist of 5 medical specialists (MS), 3 medical assistants (AIOS) and 1 nurse practitioner. Currently during one week, the MS works 2 days in the OR and 2 days in the OD. A nurse practitioner works 1½ day in the OD and an AIOS works 1 day. New patients are only seen by an MS or AIOS. Revisit patients are also seen by the nurse practitioner. In the OR, patients are seen by the MS, or by an AIOS under the supervision of an MS. The OR capacity is controlled centrally in the hospital and each speciality has to request its OR capacity 3 months in advance. The allocated capacity is known at least 2 months in advance and the possibility to get extra OR capacity on short-term notice is limited. In the OD, the available capacity is limited by the number of healthcare professionals and available consultation rooms. There are 9 consultation rooms daily available, of which an MS uses 2 rooms in parallel.

## 3.3 How to influence the access and waiting times

The access and waiting times to the outpatient department (OD) and OR are influenced by the availability of healthcare professionals and the demand for care by patients. The number of patients seen in the OD influences the demand for OR capacity. A patient first visits the OD and afterwards a visit in the OR can take place (Figure 3.1). The availability of the medical specialist, OR and consultation rooms are important for supplying enough care at the moment the patients need care. This section describes the possibilities to control and steer the patient flow, which depend on the planning horizon and timeframe within the adjustments are necessary.

A certain percentage of all new patients in the OD is expected to need surgery in the OR. The time between the consult in the OD and surgery in the OR is on average 6 weeks. For Orthopaedics in Deventer Hospital (DZ), on average 1 hour in the OD leads to approximately 1 hour needed in the OR. This relation results from the current patient mix in the OD and it should be noted that a change in patient mix can lead to a different fraction between the two demands. In addition, it should be noted that increasing the number of consultation hours directly influences the future OR capacity needed.

To influence the patient flow or waiting times between OD and OR, the speciality has a number of options. These options are based on the situation in DZ and depend on the timeframe (short and long term) during which changes are necessary. First, on the long term the number of OD and OR sessions can be altered. Orthopaedics in DZ requests ORs 3 months in advance and the ORs are allocated 2½ months in advance. The work schedule of the healthcare professionals is determined about 2 to 3 months in advance. When admission times get too high for the OR, extra ORs can be asked. Furthermore, seasonal effects that are foreseen can be taken into account during the request for ORs. Currently the number of allocated consultation rooms is fixed throughout the year. Holidays of healthcare professional can also be adapted to peaks in care demand if known in advance, although at this moment the availability of the MS determines the production.

On the short term the number of ORs *cannot* be changed. The OR capacity cannot be adapted to the actual demand from the patients seen in the OD after the ORs are allocated 2 months in advance. However, the number of consultation hours *can* be altered. Extra consultation hours can be added in case a shortage of new patients in the OR is expected or when the admission times for the OD creates problems for new and revisit patients. An alternative to prevent unused OR-time is selecting a specific type of patient for OD consultations that can be seen in the OR on a short term basis to fill the available OR capacity. By providing extra consultation hours, the specialty prevents that new patients decide to defer to other hospitals. However, attention should be paid to not overload the system (OD and OR) in the future by assigning extra consultation hours in which new patients are planned.

Summarising, the OR capacity can mainly be altered on the long term, while the OD capacity is better adjustable on the short term. By adjusting the OD capacity to the available OR capacity, the throughput time of the patients can be controlled on the short term. For a balanced workload we look at the long-term possibilities in the next sections.

# Chapter 4

# Model for planning Orthopaedic patients

In this chapter we formulate a model for planning Orthopaedic patients over a predetermined period. It is based on the situation in Deventer Hospital (DZ), but it remains generally applicable. In §4.1 we give a categorisation of Orthopaedic patients based on DTC registration. This categorisation is not specific to DZ and can be used for all Orthopaedic departments in the Netherlands. The categorisation forms the basis of the proposed model in the next sections. §4.2 concerns the assumptions and notations of the model. It describes the entities, parameters, and (auxiliary) variables used. §4.3 and §4.4 describe the modelling of the capacity restrictions and the objective function of the linear programming model. There are several optimisation criteria that can be used in healthcare, which can be distinguished into hospital-driven and patient-driven optimisation criteria.

## 4.1 The categorisation of patient groups

Since 2005, healthcare organisations in the Netherlands use DTC-registration. This registration is mainly introduced and used for administrative purposes. However, in this report we show that DTC-registration is also useful for logistical and planning purposes.

A DTC characterises the healthcare demand of a patient and reflects activities and treatments that take place within the hospital. It consists of a diagnosis linked to a clinical pathway and its related average costs. Each DTC is bounded by a start and end date with a maximum duration of 52 weeks. DTCs are only started / opened by gate specialties (in Dutch “Poortspecialismen”). This are specialties which the patient visits first (‘at the gate’) after being referred by a general practitioner. The supporting specialties (like Anaesthesiology or secondary needs like MRI or X-Ray) are also indicated in the DTC registration.

We first describe the structure of a DTC-code and explain the coding, next we look at the information the DTC registration offers.

### The structure of a DTC-code

A DTC-code consists of five different elements (Folpmers & De Bruijn, 2005; Van der Haagen, 2004):

- *Specialty*: the specialty which provides the care;
- *Type of care*: there is a distinction between regular / initial care, emergency care, and revisit / follow-up care;
- *Demand of care*: this is an optional code in the DTC registration. It describes the type of problem or complaint which the patient expresses to medical specialist;
- *Diagnosis*: characterises the syndrome of the patient or type of disease which the medical specialist sees after research;
- *Treatment*: the type of treatment given to a patient. It describes the setting of the complete treatment, like outpatient treatment, one-day clinic, or treatment with clinical episode.

Each of these elements has a different code. This means that each diagnosis that is linked to a treatment results in a unique DTC-code. Patients with the same diagnosis and same treatment have an identical DTC-code. For Orthopaedics the DTC-codes are displayed in *Appendix II: DTC-codes for Orthopaedics*. Table 4.1 shows an example of an Orthopaedics patient with a hernia that needs surgery and a clinical episode.

| Specialty | Type of care | Demand of care | Diagnosis | Treatment |
|---|---|---|---|---|
| **05.** | **11.** | **X.** | **1360.** | **213** |
| Orthopaedics | Regular care | N/A | Hernia patient | Surgical clinical episode |

Table 4.1: DTC-code for a hernia patient of Orthopaedics

*Appendix II: DTC-codes for Orthopaedics* shows that type of care can be divided in initial and follow-up DTCs. An initial DTC (regular care, code 11) will be opened or started at the moment a patient, having a new disease (primary diagnosis), has a first visit in a healthcare organisation at a gate speciality and no DTC is opened for the same diagnosis in the past 52 weeks. If the primary diagnosis and treatment is continued with a long-term or follow-up treatment, this initial DTC is transferred to one or more follow-up DTCs (code 21). There are two possibilities to start a follow-up DTC:

- If the treatment takes more than 52 weeks: the initial DTC has to be closed after 52 weeks, and a follow-up DTC is opened at the moment the next revisit takes place;

- If the initial DTC is closed within 52 weeks and the patient still needs a treatment for the same primary diagnosis. A follow-up DTC is opened because the initial DTC cannot be reopened, but also 2 DTCs cannot be opened for the same diagnosis within 52 weeks. If the patient needs the same treatment 52 weeks after the first diagnosis, an (other) initial DTC will be opened.

A follow-up DTC can only be opened if the initial DTC is closed. In case of another primary diagnosis, a new initial DTC is opened. This means that a patient can have more than one initial DTC with a maximum of 3 DTCs that are open at the same time. *Appendix III: Open and closure of an initial DTC* and *Appendix IV: Open and close of a follow-up DTC* display schematically when an initial and follow-up is opened and closed.

**Information extracted from DTC registration**

Each DTC represents the total healthcare demand of patients with a specific DTC. All activities are registered during the treatment in the hospital. If a patient has finished the treatment (or after 52 weeks), the DTC is closed. All registered DTCs that are closed provide us information about:

- *The number of patients having a specific DTC*: this only described the number of closed DTCs;

- *The number of outpatient visits*: this includes first outpatient visits (FOVs) and revisits (RVs);

- *The number of diagnostic activities*: this includes evaluating diagnostic imaging, laboratory tests, etcetera;

- *The number of diagnostic imaging*: this includes MRIs, CT-scans, X-rays, etcetera;

- *The number of surgical procedures*: this includes all treatments that are done in the OR. This means that one operation can have more than one surgical procedure;

- *The number of hospitalisation days*: number of days the patients stayed in the hospital;

- Extra information: the available extra information depends on the registration within the hospital (e.g. age, gender, etc).

To get more insight in the total expected time needed in the OD and OR, we need information on the patient mix and average time needed per capacity. We use the information extracted from the DTCs to get insight in the weekly healthcare demand. The available information extracted from the

DTCs is *not deterministic*, because there are no unambiguous causal relations between them. The numbers are averages for a specific DTC. A DTC gives information about the *probability* of getting one or two outpatient visits when having a specific DTC (*stochastic*). The exact time for each visit, the time between two visits and the treating healthcare professional were not available. For all closed DTCs the *demand* for healthcare is known for a *group* of patients. This can be translated into an average demand for healthcare per type of patient. Also the case-mix of patients (or the probability that a patient is a certain type of patient) can be determined.

Summarising, the DTC-codes are useful in categorising patient groups and in determining the average healthcare demand of a type of patient. In this report we use diagnosis and treatment in categorising patient groups.

To estimate the duration of each consult or surgery and the time between each consult or surgery, we use different sources within the hospital:

- **Time in the OR**: as mentioned earlier, a DTC-code describes the number of surgical procedures. Each type of surgical procedure in the Netherlands has a CTG-code. This code is used by the Healthcare Tariff Board / Healthcare Authority. The information system of the OR provides the following information per CTG-code: the number of procedures, the average time per procedure as well as the total OR-time. We assume that the average surgery duration per DTC is *deterministic*;

- **Time in the outpatient department**: we use the appointment slots for the time needed for a FOV and revisit (RV), because the actual time used is not registered. According to Vissers et al. (2000) using the appointment slot is a good estimation for the time needed for a FOV and RV. The time for a FOV or RV has only small variations and therefore we consider them as *deterministic*;

- **Time between each consultation or surgery**: due to unavailable historic information on the time between two hospital visits, we used interviews with the healthcare professional to obtain the information. The time between each healthcare visit is considered to be *deterministic*.

Based on the previously stated information, we can determine the clinical pathways of each patient group. Patient groups are based on diagnosis and *initial* treatment, which means that each clinical pathway consists of an initial and a possible follow-up DTC. A clinical pathway in our model may consist of two DTCs with a maximum length of 104 weeks (52 weeks for each DTC). An example is shown in Table 4.2. The example shows a hernia patient that needs surgery and a clinical episode. For these patients there are two DTCs (initial and follow-up). This means that the clinical pathway for these patients also consists of two DTCs, where the follow-up DTC follows the initial DTC. We use these clinical pathways further on for logistical purposes (e.g. planning of patients).

| Specialty | Type of care | Demand of care | Diagnosis | Treatment |
|---|---|---|---|---|
| 05. | *11.* | X. | 1360. | 213 |
| 05. | *21.* | X. | 1360. | 111 |

Table 4.2: Example of a patient group

## 4.2 Model assumptions and notations

This section describes the assumptions and the notations used in the proposed model. We assume a cyclic model (2 years) where all the variables are considered to be modulo 104. In this section we make a distinction between: healthcare professionals working in the hospital department, patients entering a hospital department, and healthcare demand for a hospital department.

**Healthcare professionals working in the hospital department**

We consider the Orthopaedics specialty, where $H$ healthcare professionals (index $h$ = 1,…, $H$), perform a number of medical activities (treat patients) over a discretized time horizon. We discretize the planning horizon $T$ into time periods of one week (index $t$ = 0,…, $T$); $T = T_1 \cup T_2$ with $T_1$ = {0,…, 51} and $T_2$ = {52,…, 103}. The unit of time is one *minute*, and the time periods have a length of one *week*. In addition, we introduce $Q$ to indicate the quartile (index $q = 0\ldots,\ T/_{12}$ ) used for planning yearly revisit patients. The total number of yearly patient per quartile is fixed to guarantee that the total number of patients are seen, but offers possibilities to alter the number of yearly revisit patients per week and balance the workload of healthcare professionals. Each healthcare professional is part of a certain type of healthcare professional that performs different kind of tasks. There are healthcare professionals that operate and healthcare professionals only doing consultation hours. We consider $H_1,\ldots,H_z$ disjunct sets of healthcare professionals; $H = \bigcup_{i=1}^{z} H_i$ where $H_i$ is the set of healthcare professionals of type $i$: medical specialist (MS) ($i = 1$), medical assistant (AIOS) ($i = 2$) and nurse practitioner ($i = 3$). Each type of healthcare professional has a limited time available in the hospital:

- $v_i$: number of weeks per year a healthcare professional of type $i$ is available;
- $w_i$: minutes per week a healthcare professional of type $i$ is available;
- $vp_i$: minutes per week a healthcare professionals of type $i$ have visiting activities in the clinic. This time is at the expense of the availability in the OR and outpatient department (OD);

- $f_i$: the ratio that indicates the relative difference in number of patients that can be seen by a healthcare professional during a consultation hour, compared to the medical specialist (MS).

**Patients entering a hospital department**

From §4.1 we can conclude that a categorisation of patients can be made based on diagnosis and type of treatment. We consider *S* types of diagnoses (index $s = 1,\dots, S$) and *B* types of treatments (index $b = 1,\dots, B$).

Patients entering a hospital department can be treated either in the *OR department* or in the *outpatient department (OD)*. Within these departments the patient can have different healthcare demands. We consider *C* healthcare demands (index $c = 1,\dots, C$): a surgical procedure ($c = 1$), an outpatient visit with a MS or AIOS ($c = 2$), or an outpatient visit with a nurse practitioner ($c = 3$). Secondary needs like hospital stay or MRI scans are not taken into account in the proposed model. In all cases we assume that the patients follow their clinical pathways in the same hospital.

We assume that there is no difference of surgical durations (including setup times) between the different healthcare professionals. Furthermore, we make no distinction between surgery duration dependant on the type of healthcare professional doing the surgery. Patients with the same treatment and diagnosis are referred to a patient group. For each patient group an average surgery duration is used.

For the OD we assume that patients that have a first outpatient visit (FOV), starting an initial DTC, are only seen by an MS or AIOS.

Patients arriving at Orthopaedics can be divided in two types of patients: *new patients* and *yearly revisit patients*. The number of yearly revisit patients and new patients per week are the *decision variables* in our model:

- **Yearly revisit patients** ($YP_{ct}$): patients that visit the OD for 2-yearly checkups and had a last visit more than 52 weeks before the start of the planning period ($t = 0$). These are patients that had a surgical procedure in the past (e.g. prosthesis) and need follow-ups for a life time. They visit the OD once every 2 years;

- **New patients** ($NP_t$): all other patients. These patients either enter the OD for the first time in the current planning ($t > 0$) and start a new (initial) DTC, or are patients that finish their clinical pathways (they constitute the work in process (WIP) of the hospital department).

New patients result in a future capacity demand in the OR and OD. Based on the historic information on the case-mix of patients and the time spent in the OD and OR, we can obtain insight into the expected future capacity demand of new patients. They have the following characteristics based on DTC-codes:

- $hd_{sbct}$: probability that a patient of type *s* and treatment *b* has a healthcare demand *c* after *t* weeks. This follows from the figures of a DTC-code;
- $d_{sbct}$: expected duration (minutes) for healthcare demand *c* in week *t* for patient type *s* with treatment *b*;
- $np_{sb}$: part of the case-mix that has diagnosis *s* and treatment *b* $\left(\sum_{s,b} np_{sb} = 1\right)$;
- $NP_{sbt}$: *auxiliary variable* that indicates the number of new patients of patient type *s* with treatment *b* in week *t* $\left(NP_{sbt} \quad NP_t \cdot np_{sb}\right)$.

*Yearly revisit patients* come back for one visit in the outpatient department. They have the following characteristics based on DTC-codes:

- $rd_c$: expected duration (minutes) for healthcare demand *c*;
- $\varepsilon$: mortality factor. 2 year revisit patients do not revisit the OD forever;
- $TOR_q$: expected number of yearly revisit patients that visits the OD in quartile *q* $\left(\sum_{c,t:\,q} YP_{ct} = TOR_q\right)$.

**Healthcare demand for a hospital department**

As mentioned earlier, patients have various healthcare demands. For each healthcare demand a subset of healthcare professionals is able to fulfil this demand and we assume that each healthcare professional of this subset can treat every type of patient. We ignore the fact that when a patient is treated by a specific healthcare professional, the patient of this type should be treated by the same healthcare professional the next time. For each healthcare demand we introduce the following notations:

- $W_{sbct}$: *auxiliary variable* that indicates the workload (minutes) for new patients of patient *s* with treatment *b* that need healthcare demand *c* in week *t*;
- $TW_{ct}$: total healthcare demand *c* (in minutes) in week *t*;
- $CH_{ct}$: needed consultation hours in week *t* to provide healthcare demand *c* in the OD ($c \neq 1$);

- *dch*: duration (minutes) of a consultation hour. This can be more than 60 minutes. We assume no distinction in duration for a morning and afternoon consultation hour;
- *bch*: buffer (minutes) during a consultation hour for taking care of any delay during consultations with patients;
- $npc_c$: maximum number of new patients during a consultation hour for healthcare demand *c*, because a high number of new patients leads to a high workload due to the related extra work for new patients;
- *dos*: duration (minutes) of an OR-block;
- *eor*: OR-time (minutes) that should be reserved per week for emergency patients. This time is at the expense of the availability of the MS and the available OR-time;
- $mos_t$: maximum number of OR-blocks in week *t*. The specialty is limited by the available capacity in the OR;
- *orc*: maximum OR-time (minutes) available per year.

Some hospital departments have seasonal patterns in patient demand. This is also the case for Orthopaedics, where the healthcare demand of patients is lower during summer holidays and during Christmas. In addition, hospitals may close the OR partly during summer holidays. The parameters for this can be adjusted in the model.

The goal is to make use of the available resources in such a way that an objective function is optimised and the constraints are satisfied. The objective function and constraints are further explained in the next sections.

*Appendix V: Overview model notations* gives an overview of the notations used in the proposed model.

## 4.3 Modelling resource capacity restrictions

The resource capacity restrictions in this model can be modelled by linear constraints. The resource capacity restrictions are divided in different categories: healthcare professionals, healthcare demand, OR department, and outpatient department (OD).

**Healthcare professionals**

The availability of healthcare professional *h* is restricted by the maximum time he can work during a week ($w_i$) and the maximum number of weeks he works a year ($v_i$). The medical specialist (MS) works in the OR and OD. The total working time during week *t* per type of healthcare professional is determined by the time the healthcare professionals spend in the OD and the OR ($TW_{ct}$). The following factors are taken into account:

- Only the MS (*i = 1*) performs surgical procedures (*c = 1*);
- New patients in the OD having a first outpatient visits (FOV) are seen by an MS (*i = 1*) or medical assistant (AIOS) (*i = 2*);
- The productivity factor $f_i$. An MS can see more patients during one hour than a medical assistant;
- The weekly availability of the type of healthcare professionals *i* is restricted by the time needed for visiting of patients ($vp_i$).

Constraint (4.1) shows the capacity restriction on a weekly basis for healthcare professionals.

$$\begin{aligned} &\sum_c TW_{ct} + \sum_i vp_i \le \sum_i \left(|H_i| \cdot w_i \times f_i\right) \quad (\forall_{i,c \in \{1,2\},t}), \\ &TW_{3t} + vp_3 \le |H_3| \times w_3 \quad (\forall_t), \end{aligned} \tag{4.1}$$

As indicated by constraint (4.2), on a yearly basis the total healthcare demand ($TW_{ct}$) and visiting in the clinic ($v_i$) should not exceed the available time of each type of healthcare professional:

$$\begin{aligned} &\sum_{c,t \in T_k} TW_{ct} + \sum_i \left(vp_i \times 52\right) \le \sum_i \left(|H_i| \times w_i \times v_i \times f_i\right) \quad (\forall_{i,c \in \{1,2\},k}), \\ &\sum_{t \in T_k} TW_{3t} + vp_3 \times 52 \le |H_3| \times w_3 \times v_3 \quad (\forall_k), \end{aligned} \tag{4.2}$$

**Healthcare demand**

The time needed to provide healthcare demand *c* in a week *t* ($TW_{ct}$) depends on the number of *new patients* and *yearly revisit patients* seen in the OD.

The number of new patients seen in the OD in week *t* is represented by $NP_t$. With a probability of $np_{sb}$ a new patient has type *s* and treatment *b*. As indicated by constraint (4.3), multiplying $NP_t$ and $np_{sb}$ determines the number of patients with type *s* and treatment *b* in week *t* ($NP_{sbt}$):

$$NP_{sbt} = NP_t \times np_{sb} \quad (\forall_{s,b,t}), \tag{4.3}$$

These patients have a probability of $hd_{sbct}$ that they need healthcare demand *c* after *t* weeks. In the model we assume that the number of patients in week *t* is the same as the number of patients 1 planning period earlier (*t - 103*). We consider the model to be cyclic. To determine the expected workload for patients that need a certain healthcare demand in a certain week ($W_{sbct}$), we have to do a summation over all new patients in the OD from week *t* until week *t - 103* (maximum length of a clinical pathway) that need healthcare demand *c* in week *t* with a duration of $d_{sbct}$ minutes. This is expressed by constraint (4.4):

$$W_{sbct} = \sum_{j=0}^{j=103} \left( NP_{sb(t-j)} \cdot hd_{sbcj} \cdot d_{sbcj} \right) \quad (\forall_{s,b,c,t}), \tag{4.4}$$

*An example*: for week *5* we determine the time needed for new patients (time needed this week for first visits and first visits of previous weeks that come back for revisits) of type *s* and treatment *b* for capacity *c*. The summation goes from *0* to *103,* new patients of the current week 5 and 103 weeks back. In the summation this means a multiplication of new patients of type *s* and treatment *b* in week *-98* to *5* that have healthcare demand *c* over *0* to *103* weeks. This results in the total time needed for all patients with a healthcare demand *c* in week *5*.

The number of yearly revisit patients seen in the OD that need healthcare demand *c* in a week *t* is represented by $Y_{ct}$. These patients have an expected duration of $rd_c$ minutes for healthcare demand *c*. Multiplying these parameters with the variables determines the time needed to deliver healthcare demand *c* in week *t*. The total workload for healthcare demand *c* in week *t* ($TW_{ct}$) is the sum of the time needed for each patient group and the time needed for yearly revisit patients. For the OR, time has to be reserved for emergency patients (*eor*). Constraint (4.5) shows this:

$$\begin{aligned} TW_{1t} &= \sum_{s,b} W_{sb1t} + eor \quad (\forall_t), \\ TW_{ct} &= \sum_{s,b} W_{sbct} + \left( YP_{ct} \cdot rd_c \right) \quad (\forall_{t,c \neq 1}), \end{aligned} \tag{4.5}$$

The total number of yearly revisit patients that need follow-ups for a life time (once every 2 years) is determined per quartile. During a quartile the number of yearly revisit patients per week can vary to level the workload. This means that they are used in a *flexible* way. This flexibility means that the amount per quartile (represented by $TOR_q$) should be met, but that the amount per week may fluctuate. Yearly revisit patients are only seen in the OD and only consists of patients having a prosthesis (*b = 10*). Because the model is cyclic (2 years), the variables are modulo 103, and yearly revisit patients need follow-up once every 2 years. The number of yearly revisit patients in quartile *q* depends on:

- The number of new patients in the past needing a prosthesis (*b = 10*). This is represented by $NP_{s10t}$;

- A mortality factor $\varepsilon$ ($0 \leq \varepsilon \leq 1$). Yearly revisit patients cannot revisit the hospital department for a life time. This means that in a week *t* , $NP_{s10t}$ has to be multiplied by:

$$\sum_{i=1}^{\infty} \varepsilon^i = \frac{\varepsilon}{1-\varepsilon}$$

*Proof:*

$$\sum_{i=1}^{n} \varepsilon^i = \frac{\varepsilon - \varepsilon^{n+1}}{1-\varepsilon}$$

$$\lim_{n\to\infty} \frac{\varepsilon - \varepsilon^{n+1}}{1-\varepsilon} = \frac{\varepsilon}{1-\varepsilon} - \lim_{n\to\infty} \frac{\varepsilon^{n+1}}{1-\varepsilon} \overset{(0<\varepsilon<1)}{=} \frac{\varepsilon}{1-\varepsilon}$$

Constraints (4.6) and (4.7) represent $TOR_q$:

$$TOR_q = \sum_{c=1, t\in q} YP_{ct} \quad (\forall q), \tag{4.6}$$

$$TOR_q \geq \sum_{s,t\in q} NP_{s10t} \times \left(\frac{\varepsilon}{1-\varepsilon}\right) \quad (\forall q), \tag{4.7}$$

**OR department**

The OR-time needed in week *t* is determined by the total time needed for pre-planned patients ($TW_{1t}$) plus time that is reserved for emergency patients (*eor*) each week. In addition, each week a specialty has a maximum availability of ORs, indicated by OR-blocks ($mos_t$). An OR-block takes *dos* minutes. As indicated by constraint (4.8), the time needed in the OR in week *t* may not exceed the maximum time available:

$$TW_{1t} \leq mos_t \times dos \quad (\forall t), \tag{4.8}$$

On a yearly basis a specialty has limited OR capacity, indicated by *orc*. Constraint (4.9) guarantees that the OR-time needed in a year does not exceed the maximum availability of OR-time in a year:

$$\sum_{t} TW_{1t} \leq orc, \tag{4.9}$$

Because only the MS (*i = 1*) can operate, the OR-time needed is also restricted by the availability of the MS during a week and year. This is represented by constraint (4.10) and (4.11):

$$TW_{1t} - vp_1 \leq |H_1| \times w_1 \quad (\forall t), \tag{4.10}$$

$$\sum_{t} TW_{1t} - vp_1 \times 52 \leq |H_1| \times w_1 \times v_1, \tag{4.11}$$

**Outpatient department**

The workload in the OD ($TW_{2t}$ and $TW_{3t}$) constitutes a number of consultation hours ($CH_{ct}$) for each type of healthcare demand. Each consultation hour has a duration of *dch* minutes and a buffer of *bch* minutes. This means that the workload in the OD is determined by the time needed to see all patients in the OD multiplied by a factor (1+ (*bch / dch)*). This results in a modification of constraint (4.5) for $c \neq 1$ as displayed in constraint (4.12):

$$c \neq 1: \quad TW_{ct} = \left(\sum_{s,b} W_{sbct} \cdot YP_{ct} \cdot rd_c\right) \cdot \left(1 + \frac{bch}{dch}\right) \; (\forall_t), \tag{4.12}$$

The needed number of consultation hours in a week *t* for healthcare demand $c \neq 1$ can be determined based on the weekly workload:

$$c \neq 1: \quad CH_{ct} \cdot dch = TW_{ct} \; (\forall_t), \tag{4.13}$$

During a consultation hour a healthcare professional has a maximum number of new patients that can be seen ($npc_c$). This only holds for an MS and an AIOS ($c = 2$), because new patients are only seen by an MS or AIOS. Constraint (4.14) guarantees that the number of new patients during a consultation hour does not exceed its maximum for respectively MS and AIOS:

$$CH_{2t} \cdot npc_2 \geq NP_t \; (\forall_t), \tag{4.14}$$

Constraint (4.15) ensures that all variables are positive.

$$\text{all variables} \geq 0, \tag{4.15}$$

Constraint (4.16) ensures that number of new patients are an integer.

$$NP_t \; \text{integer}. \tag{4.16}$$

## 4.4 Objective function

Due to the market based competition, a hospital department tries to maximise the number of new patients seen during a year. The more patients seen the more profit a hospital department is expected to make. In this model new patients are given by $NP_t$.

The hospital department also tries to achieve a high utilisation of specialist time and OR-time. For practical reasons, it is also important that the workload in a hospital department per week is equally spread. The hospital department can guarantee a levelled availability of healthcare professionals to provide patient care. We describe 3 steps for the objective function, to take the maximisation of new patients and levelling of workload into account.

- **Step 1**: we maximise the total number of new patients, indicated by *mnp*. The objective function is:

$$mnp = \max \sum_{t} NP_t \tag{4.17}$$

- **Step 2**: the second step consists of 4 runs with 4 separate objective functions. We maximise respectively the minimum values of $NP_t$, $TW_{1t}$, $TW_{2t}$, $TW_{3t}$, given the restriction that the sum of all new patients ($NP_t$) should be greater or equal to $\zeta * mnp$. The parameter $\zeta$ indicates the percentage of *mnp* that the specialty wants to see. A lower percentage can result in more possibilities to level workload. The 4 objective functions for step 2 are:

  - $\text{Max}\left(\min_t \{NP_t\}\right) \Leftrightarrow \text{Max } Z, \text{ where } Z \le NP_t \ (\forall_t);$
  - $\text{Max}\left(\min_t \{TW_{1t}\}\right) \Leftrightarrow \text{Max } Z, \text{ where } Z \le TW_{1t} \ (\forall_t);$
  - $\text{Max}\left(\min_t \{TW_{2t}\}\right) \Leftrightarrow \text{Max } Z, \text{ where } Z \le TW_{2t} \ (\forall_t);$
  - $\text{Max}\left(\min_t \{TW_{3t}\}\right) \Leftrightarrow \text{Max } Z, \text{ where } Z \le TW_{3t} \ (\forall_t).$

This results in the values shown in Table 4.3, which serves as input for step 3;

| ***Objective*** | $\underset{t}{\text{Min}}\{NP_t\}$ | $\underset{t}{\text{Min}}\{TW_{1t}\}$ | $\underset{t}{\text{Min}}\{TW_{2t}\}$ | $\underset{t}{\text{Min}}\{TW_{3t}\}$ |
|---|---|---|---|---|
| $\text{Max}(\underset{t}{\text{Min}}\{NP_t\})$ | | | | |
| $\text{Max}(\underset{t}{\text{Min}}\{TW_{1t}\})$ | | | | |
| $\text{Max}(\underset{t}{\text{Min}}\{TW_{2t}\})$ | | | | |
| $\text{Max}(\underset{t}{\text{Min}}\{TW_{3t}\})$ | | | | |
| ***Minimum*** | $\underline{\text{Min}\{NP_t\}}$ | $\underline{\text{Min}\{TW_{1t}\}}$ | $\underline{\text{Min}\{TWP_{2t}\}}$ | $\underline{\text{Min}\{TW_{3t}\}}$ |
| ***Maximum*** | $\overline{\text{Min}\{NP_t\}}$ | $\overline{\text{Min}\{TW_{1t}\}}$ | $\overline{\text{Min}\{TW_{2t}\}}$ | $\overline{\text{Min}\{TW_{3t}\}}$ |

Table 4.3: Results after step 2

- **Step 3**: the third step takes all the variables of step 2 together in one objective function after rescaling. We rescale by taking the highest and lowest minimum value of each variable which results in a range for each variable. Rescaling is then based on the range of each variable (see Table 4.4):

| ***Objective*** | ***Range*** | ***Parameter*** | ***Value parameter*** |
|---|---|---|---|
| $\text{Max}(\underset{t}{\text{Min}}\{NP_t\})$ | $\overline{\text{Min}\{NP_t\}} \quad \underline{\text{Min}\{NP_t\}}$ | $\alpha$ | $1/(\overline{\text{Min}\{NP_t\}} \quad \underline{\text{Min}\{NP_t\}})$ |
| $\text{Max}(\underset{t}{\text{Min}}\{TW_{1t}\})$ | $\overline{\text{Min}\{TW_{1t}\}} \quad \underline{\text{Min}\{TW_{1t}\}}$ | $\beta$ | $1/(\overline{\text{Min}\{TW_{1t}\}} - \underline{\text{Min}\{TW_{1t}\}})$ |
| $\text{Max}(\underset{t}{\text{Min}}\{TW_{2t}\})$ | $\overline{\text{Min}\{TW_{2t}\}} - \underline{\text{Min}\{TW_{2t}\}}$ | $\gamma$ | $1/(\overline{\text{Min}\{TW_{2t}\}} - \underline{\text{Min}\{TW_{2t}\}})$ |
| $\text{Max}(\underset{t}{\text{Min}}\{TW_{3t}\})$ | $\overline{\text{Min}\{TW_{3t}\}} - \underline{\text{Min}\{TW_{3t}\}}$ | $\delta$ | $1/(\overline{\text{Min}\{TW_{3t}\}} - \underline{\text{Min}\{TW_{3t}\}})$ |

Table 4.4: Rescaling variables in step 3 to have an equal importance

Now all the variables have an equal importance in the objective function. To maintain this equal importance of variables, *Min{NP$_t$}, Min{TW$_{1t}$}, Min{TW$_{2t}$}, Min{TW$_3$}$_t$* should be equal or higher than the minimum values obtained in step 2.

This leads to the objective function as illustrated by (4.18) with the related constraints as illustrated by (4.19)-(4.27):

$$\max\left(\alpha \times \min\{NP_t\} - \beta \times \min\{TW_{1t}\} - \gamma \times \min\{TW_{2t}\} + \delta \times \min\{TW_{3t}\}\right) \quad (4.18)$$

$$\sum_t NP_t \geq \zeta \times mnp, \quad (4.19)$$

$$NP_t - Min\{NP_t\} \geq 0 \ (\forall_t), \quad (4.20)$$

$$Min\{NP_t\} \geq Min\left(Min\{NP_t\}^{step2}\right) \ (\forall_t), \quad (4.21)$$

$$TW_{1t} - Min\{TW_{1t}\} \geq 0 \ (\forall_t), \quad (4.22)$$

$$Min\{TW_{1t}\} \geq Min\left(Min\{TW_{1t}\}^{step2}\right) \ (\forall_t), \quad (4.23)$$

$$TW_{2t} - Min\{TW_{2t}\} \geq 0 \ (\forall_t), \quad (4.24)$$

$$Min\{TW_{2t}\} \geq Min\left(Min\{TW_{2t}\}^{step2}\right) \ (\forall_t), \quad (4.25)$$

$$TW_{3t} - Min\{TW_{3t}\} \geq 0 \ (\forall_t), \quad (4.26)$$

$$Min\{TW_{3t}\} \geq Min\left(Min\{TW_{3t}\}^{step2}\right) \ (\forall_t), \quad (4.27)$$

*Appendix VI: Synthesis of the proposed model* gives the synthesis of the integer linear programming (*ILP*) formulation.

# Chapter 5

# Model implementation for Orthopaedics in DZ

This chapter looks at the implementation of the proposed model, presented in Chapter 4, for Orthopaedics within Deventer Hospital (DZ). The demand for healthcare and the availability of the resources are taken into account. We try to get more insight into the relation between the consultation hours in the outpatient department (OD) and the time needed in the operating room (OR).

To make better-founded decisions on the use of the available capacities we try to get more insight into the time needed in the OD and OR. Based on clinical pathways of patients and availability of healthcare professionals we determine the workload each week. This will be the weekly production target for the OD and OR. Based on this information and the actual weekly demand for healthcare, the specialty can make decisions on the number of healthcare professional that should work in the OD and OR throughout the year.

This chapter starts with the categorisation of Orthopaedic patients (§5.1). §5.2 describes the parameters used in the proposed model and the way how they are determined. §5.3 shows the results of the model. This chapter ends with a validation of the model (5.4).

## 5.1 Categorisation of Orthopaedic patients

The categorisation of Orthopaedic patients is based on DTC-codes as explained in §4.1. The patients are categorised by diagnosis *s* and treatment *b*. For Orthopaedics there are 216 types of diagnosis and 11 types of treatments (Appendix II: DTC-codes for Orthopaedics). Based on the outpatient visits and surgery duration in 2006, we select 14 diagnoses including 1 remaining group ($S = 14; B = 11$). Table 5.1 shows the characteristics of the selected groups. It shows that they cover more than 50% of the registered DTCs and outpatient visits and more than 65% of the OR-time. Table 5.2 and Table 5.3 show the selected patient groups and types of treatment for each patient group.

| ***Description*** | ***13 groups (#)*** | ***13 groups (%)*** | ***Remaining group (#)*** | ***Remaining group (%)*** |
|---|---|---|---|---|
| *DTCs* | 5.710 | 52,83 | 5.099 | 47,17 |
| *OR-time (min.)* | 106.593 | 66,46 | 53.787 | 33,54 |
| *Outpatient visits* | 9.765 | 51,53 | 9.184 | 48,47 |

Table 5.1: Characteristics of the selected patient groups

| ***s*** | ***Code*** | ***Diagnosis*** |
|---|---|---|
| *1* | 1360 | Hernia |
| *2* | 1401 | Shoulder prosthesis |
| *3* | 1450 | Shoulder scopy |
| *4* | 1460 | Shoulder (stitching muscles) |
| *5* | 1630 | Carpal tunnel release |
| *6* | 1701 | Hip prosthesis |
| *7* | 1750 | Congenital hipdysplasia |
| *8* | 1801 | Knee prosthesis |
| *9* | 1801 | Posture correction lower leg |
| *10* | 1805 | Knee scopy |
| *11* | 1820 | Anterior cruciate ligament |
| *12* | 1850 | Patellofemoral pain syndrome |
| *13* | 2050 | Hallux valgus |
| *14* | - | Remaining group |

Table 5.2: Selected diagnoses within DZ

| ***b*** | ***Code*** | ***Treatment*** |
|---|---|---|
| *1* | 111 | Conservative outpatient |
| *2* | 112 | Conservative with one day(s) clinic |
| *3* | 113 | Conservative with clinical episode(s) |
| *4* | 114 | Singular outpatient conservative |
| *5* | 211 | Surgical outpatient |
| *6* | 212 | Surgical one day clinic |
| *7* | 213 | Surgical clinical episode(s) |
| *8* | 214 | Singular outpatient with treatment |
| *9* | 216 | Clinical without days (in Dutch “KZD”) surgical with clinical episode(s) |
| *10* | 223 | Surgical with clinical episode(s) with prosthesis |
| *11* | 226 | Clinical without days (in Dutch “KZD”) surgical with clinical episode(s) with prosthesis |

Table 5.3: Selected treatments within DZ

Each patient group has a distinct clinical pathway as shown in *Appendix VII: Clinical pathways of Orthopaedic patient groups in DZ*. This appendix displays the duration of each visit in the OD or in the OR ($d_{sbct}$) as well as the number of weeks between each healthcare demand ($hd_{sbct}$). In addition, the percentage each patient group represents is given ($np_{sb}$). These figures are based on DTC information of 2006 and have been extracted from the hospital information system "Proclarity" and are based on dialogues with a medical specialist (MS). Furthermore, follow-up DTCs (code 21) are taken together with a new initial DTC, to describe the complete clinical pathway.

For the remaining group ($s = 14$) we assume that the probability of needing healthcare demand $c$ after $t$ weeks ($hd_{sbct}$) is equally spread over the weeks. The only exception is that every patient within the remaining group has a first outpatient visit (FOV) in week 0 and that they cannot be operated in week 0. This means that if the DTC information for the remaining group shows 10 outpatient visits per patient, the patient has 1 outpatient visit in week 0 and 9/51 outpatient visits during the other weeks.

## 5.2 Model parameters for Orthopaedics

Orthopaedics has 9 healthcare professionals ($H = 9$). Each healthcare professional belongs to a type $i$ of healthcare professional. There are 3 types of healthcare professionals for Orthopaedics ($I = 3$): medical specialist (MS), medical assistant (AIOS), and nurse practitioner. Each type of healthcare professional has a limited availability per week ($w_i$) and year ($v_i$) for treating patients in the OD and OR. In addition, they perform visiting activities ($vp_i$) at the expense of their availability in the OD. During the holidays (week 30-35 and 51-52), the availability of the healthcare professionals is reduced to 60%. Table 5.4 shows the availability of each type of healthcare professional:

| $i$ | $\|H_i\|$ | *Description* | $v_i$ *(weeks)* | $w_i$ *(minutes)* | $vp_i$ *(minutes)* |
|---|---|---|---|---|---|
| *1* | 5 | Medical specialist (MS) | 42 | 1920 | 120 |
| *2* | 3 | Medical assistant (AIOS) | 48 | 420 | 0 |
| *3* | 1 | Nurse practitioner | 47 | 630 | 0 |

Table 5.4: Availability of healthcare professionals of Orthopaedics in DZ

Each type of healthcare professional performs different kinds of tasks. *Appendix VII: Clinical pathways of Orthopaedic patient groups in DZ* shows that patients can be either treated in the OD or in the OR. We distinguish 3 types of healthcare demand by patients ($C = 3$):

- $c = 1$: the patient needs a treatment in the OR. We assume that only an MS operate;
- $c = 2$: the patient needs a consult in the OD with an MS or AIOS. We assume that patients starting a new DTC are first seen by an MS or AIOS. Furthermore, the factor $f_i$ is used, because MS treat patients faster than AIOS. The MS is used as a reference, since the consultation time is given for the MS. In DZ, the MS treats patients approximately 1½ times faster than an AIOS. This means that $f_1 = 1{,}00$ and $f_2 = 0{,}67$;
- $c = 3$: the patient needs a consult in the OD with a nurse practitioner.

Consultation hours (shifts) in the OD have an average duration (*dch*) of 210 minutes. We make no distinction between consultation hours in the morning or afternoon. During the consultation hours, the specialty keeps a free buffer time of 15 minutes (*bch*) to cope with delay. In addition, during a consultation hour the MS and AIOS have a maximum number of 8 new patients that can be seen ($npc_2 = 8$).

In the OR, the duration of a working day is limited by the duration of an OR-block of 480 minutes (*dos*). Each week, 60 minutes of OR capacity has to be reserved for emergency patients (*eor*). The number of OR blocks ($mos_t$) per week $t$ outside the summer period is set to 10. During the summer period (week 29-34 of a year) $mos_t$ is set to 6. The maximum OR-time a year (*orc*) is 2.673 hours (160.380 minutes) and is based on the data of 2006.

Two yearly revisit patients (YP) are seen by an MS or AIOS ($c = 2$) or by the nurse practitioner ($c = 3$). The expected duration of the treatments are respectively 10 minutes ($rd_2$) and 15 minutes ($rd_3$). The yearly revisit patients are ageing and the number of times they come back for a revisit is limited. We introduce a mortality factor to describe the reduction of the current yearly revisit patients. Due to an ageing population the mortality factor can increase in the near future. This factor is based on the figures of 2006. In 2006, Orthopaedics registered 645 patients that needed prosthesis ($NP_{s10}$), and there were 928 outpatient visits for yearly revisit patients. This leads to the following mortality factor:

$$\xi = \frac{928/645}{1\ (928/645)} = 0{,}5900$$

## 5.3 Computational results of the model for Orthopaedics

This section describes the results of the model for Orthopaedics. First, we describe general results with respect to the clinical pathways of an Orthopaedic patient. Second, we describe the possibilities to see more Orthopaedic patients with the current capacity (step 1 model). Third, we describe the effects of the different workload balancing objectives (step 2 and 3 model). Finally, we end this section with an evaluation of different scenarios of the available capacity.

**Results clinical pathways**

A new Orthopaedic patient needs on average 38,20 minutes treatment to complete the clinical pathway. 20,07 minutes are needed in the OD and 18,13 minutes in the OR. Table 5.5 shows the average expected time needed for a new Orthopaedic patient for each healthcare demand *c*. Figure 5.1 shows for one new Orthopaedic patient the average time needed per week for each healthcare demand week starting from the first visit in the outpatient department. Figure 5.1 illustrates that in the first 12 weeks a new Orthopaedic patient spends most of his time within Orthopaedics, with a peek in the OD in the first week and in the OR after 6 weeks.

| ***Per new patient (NP)*** | ***Minutes*** |
|---|---|
| OR-time (c = 1) | 18,13 |
| OD-time MS and AIOS (c = 2) | 18,55 |
| OD-time nurse practitioner (c = 3) | 1,52 |
| OD-time (c ≠ 1) | 20,07 |
| *Total* | *38,20* |

Table 5.5: Average time for a new Orthopaedic patient in DZ

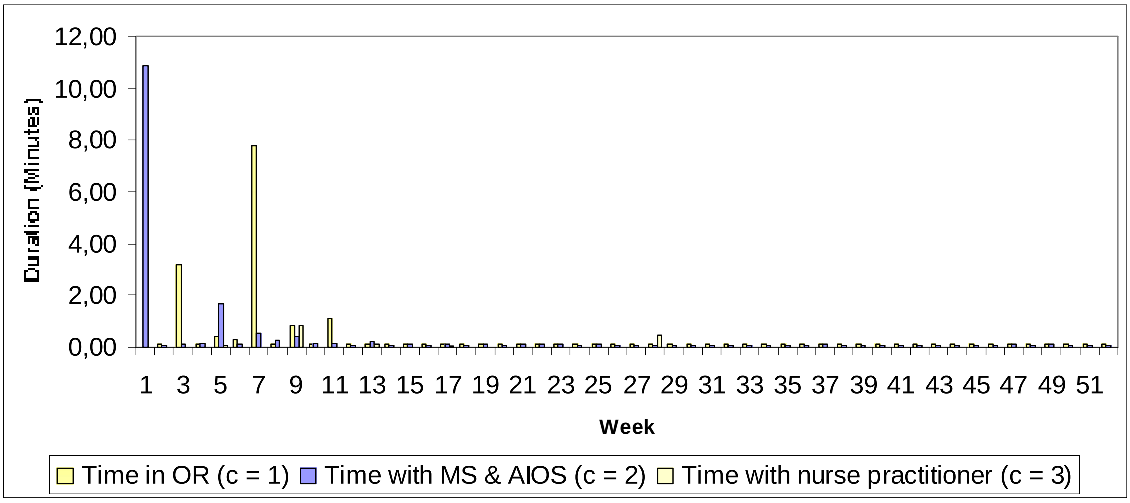


Figure 5.1: Average time for a new Orthopaedic patient in DZ per week

**Maximising number of new patients (step 1 model)**

To evaluate the possibilities for Orthopaedics to see more patients with the current available capacity, the objective function of the LP model is maximising the number of new patients that can be seen during a year (step 1 in §4.4). Table 5.6 shows the results and illustrates that the OR capacity limits the number of new patients that can be seen. The MS and the AIOS and nurse practitioner time still remain available throughout the year. With the available resources Orthopaedics can see a maximum of 9.818 new patients during a year, an increase of more than 10% compared to 2006.

| ***Variable*** | ***Model (minutes)*** | ***Available (minutes)*** | ***Utilisation (%)*** |
|---|---|---|---|
| OR-time ($TW_1$) | 181.080 | 181.080 | 100,00 |
| OD and OR-time MS and AIOS ($TW_1$+$TW_2$) | 414.773 | 443.520 | 93,51 |
| OD-time nurse practitioner ($TW_3$) | 16.694 | 29.610 | 56,38 |
| | | | |
| ***Variable*** | ***Model*** | ***2006*** | ***Difference (%)*** |
| Number of new patients (*NP*) | 9.818 | 8.860 | 10,81 |
| Number of patients (*NP* and *YP*) | 10.831 | 9.944 | 9,70 |
| Number of DTCs (initial and follow-up) | 11.687 | 10.716 | 9,79 |

Table 5.6: Results step 1 of the model for Orthopaedics

*Appendix VIII: Results step 1 of the model for Orthopaedics in DZ* shows the figures for the workload in the OD and OR for the different healthcare professionals per week as well as the number of new and yearly revisit patients per week. The appendix shows that the workload is not well levelled over the weeks as the number of yearly revisit and new patients seen.

Sensitivity analysis of the LP constraints indicates that an increase of the yearly available OR-time (*orc*) by 60 minutes results in 3,3 extra new patients that can be seen. This is possible until the other capacities become limited, specifically the MS time.

**Balancing workload (step 2 and 3 model)**

The second step is to spread the capacity demand throughout the year to prevent peaks in capacity demand. This is done by maximising the minimum values of $NP_t$, $TW_{1t}$, $TW_{2t}$, $TW_{3t}$ separately with $\zeta = 1{,}00$ as stated in §4.4. Each time the number of new patients is fixed on its maximum ($mnp = 9.818$), as a result of step 1. *Appendix IX: Results step 2 of the model for Orthopaedics in DZ* illustrates the results obtained from our model with the four separate optimisation criteria. This appendix shows that the workload is still not well levelled. The one optimised is levelled quite well, but the other variables not.

The difference between minimum and maximum value of each optimisation criterion is used as a rescaling factor in step 3 of the model (see Table 5.7).

| ***Objective*** | ***Range*** | ***Parameter*** | ***Value parameter*** |
|---|---|---|---|
| $\text{Max}(\min_t\{NP_t\})$ | 1.319,3 | $\alpha$ | 0,00728 |
| $\text{Max}(\min_t\{TW_{1t}\})$ | 1.654,7 | $\beta$ | 0,00076 |
| $\text{Max}(\min_t\{TW_{2t}\})$ | 265,69 | $\gamma$ | 0,00060 |
| $\text{Max}(\min_t\{TW_{3t}\})$ | 137,4 | $\delta$ | 0,00452 |

Table 5.7: Rescaling the minimum values for Orthopaedics

Taking the rescaled optimisation criteria together to plan new and yearly revisit patients, results in a weekly capacity demand per week as shown in Figure 5.2 until Figure 5.5. Variation in the demand for the different capacities is still seen. This is caused by the reduced OR capacity during the holiday and the healthcare professionals. Also the deterministic character of the patient's weekly capacity demand, used in the model, results in a rigid capacity requirement. Although levelling over the weeks might be possible with the use of increased waiting times between appointments, this is not taken into account in the model.

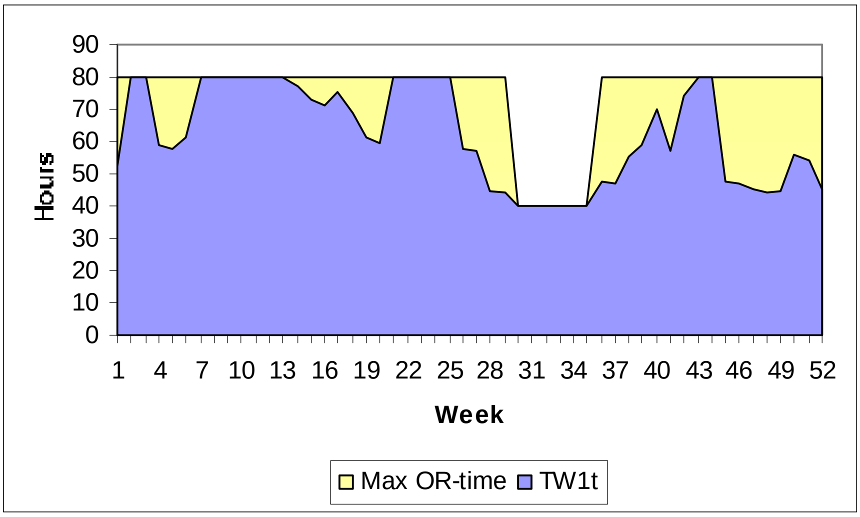


Figure 5.2: $TW_{1t}$ with respect to its maximum after step 3

Figure 5.2 clearly shows that several weeks before the summer holiday closure of the OR (week 29-34), the total OR-time gradually decreases and increases gradually after the holiday. Although the difference between the maximum available OR-time per week and the actual time used ($TW_{1t}$) shows room for extra working hours, the total yearly availability limits the extra use of OR capacity.

The total working time of the MS and the AIOS shows a variation over the weeks (Figure 5.3). Before the start of summer holiday the working time is reduced, as well as the number of new patients (Figure 5.5). Before the end of the holiday period we see an increase in the total time worked by MS and AIOS (Figure 5.3) and an increase in new patients (Figure 5.5).

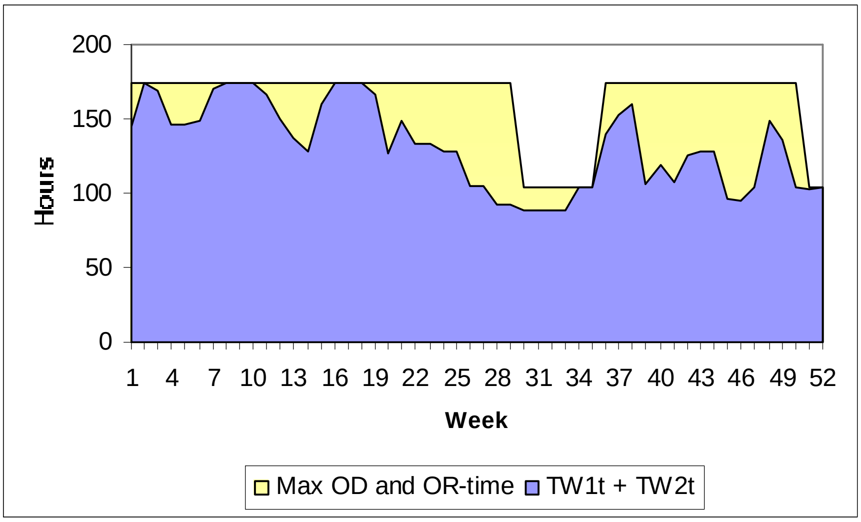


Figure 5.3: $TW_{1t}$ and $TW_{2t}$ with respect to its maximum after step 3

The total working time per week of the nurse practitioner ($TW_{3t}$) shows a limited variation as shown in Figure 5.4. The remaining time available illustrated in Figure 5.4 consists in free time of the nurse practitioner that cannot be used for seeing more patients. The time at which the free time is scheduled can be changed.

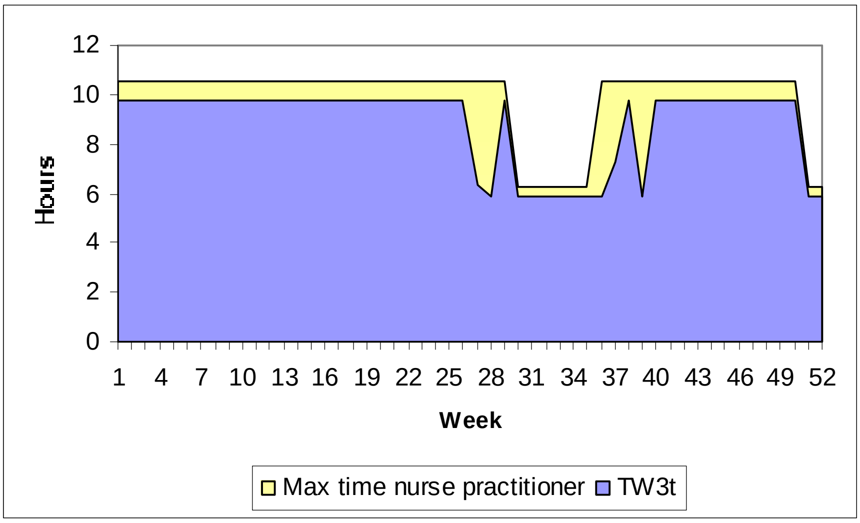


Figure 5.4: $TW_{3t}$ with respect to its maximum after step 3

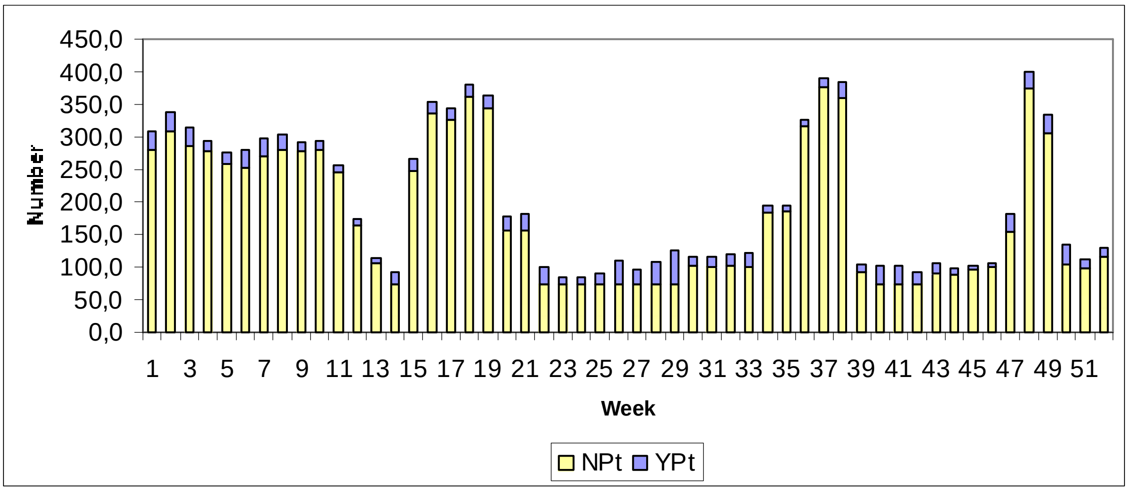


Figure 5.5: $NP_t$ and $YP_t$ after step 3

We see a difference between the results of the model and the current situation at Orthopaedics. Especially before and after the holiday period an increase of new patients in the OD is seen. Although the capacity to see all new patients in the OR during the holiday period is not sufficient, waiting lists are partly used to see the patients at a later moment. The utilisation rate of the MS time shows that there is still time to plan extra consultation hours (see Figure 5.2). The proposed solution of our model shows a feasible solution. Although changes can be made in the number of patients in each specific week, it is the maximum number of patients that can be seen with the available capacity.

**Expanding the available healthcare professionals or OR capacity**

The specialty is looking for the possibilities to expand the production. Based on this, we look at a number of capacities that the specialty could expand in order to increase the number of patients seen. We consider the following scenarios:

- Increase the OR-capacity;
- Increase the number of nurse practitioners;
- Increase the number of MS and AIOS;
- Alter the case-mix.

*Extra OR-capacity*

In case an unlimited yearly OR capacity is available, an OR use of 3.297 hours a year is possible. This results in a possible increase of new patients by 21%. The available capacity of healthcare professionals for the OD limits a further increase of the production. The nurse practitioner sees most of the two yearly patients, although some patients are still seen by the MS. Table 5.8 shows the results.

| ***Variable*** | ***Model (minutes)*** | ***Available (minutes)*** | ***Utilisation (%)*** |
|---|---|---|---|
| OR-time ($TW_1$) | 197.820 | - | - |
| OD and OR-time MS and AIOS ($TW_1+TW_2$) | 443.520 | 443.520 | 100,00 |
| OD-time nurse practitioner ($TW_3$) | 29.610 | 29.610 | 100,00 |
| | | | |
| ***Variable*** | ***Model*** | ***2006*** | ***Difference (%)*** |
| Number of new patients (*NP*) | 10.743 | 8.860 | 21,26 |
| Number of patients (*NP* and *YP*) | 11.756 | 9.944 | 19,08 |
| Number of DTCs (initial and follow-up) | 12.692 | 10.716 | 19,23 |

Table 5.8: Results when the OR-capacity increases

*Extra nurse practitioner*

By increasing the nurse practitioners time to 2 working days (840 minutes), the number of yearly patients seen by the nurse practitioner ($YP_{3t}$) is increased although this is not enough to see all 2-yearly revisit patients. 23 yearly revisit patients are still seen by the MS or the AIOS. The MS has more available time for new patients, but the limited availability of the OR does not result in more new patients that can be seen.

*Extra MS*

An extra MS does not result in more new patients that can be seen, because a lack of available OR-time. Theoretically an extra MS results in 20% extra capacity. This also means 20% more new patients can be seen, assuming that there is enough OR capacity and that there are enough new patients. It is not likely that the case-mix of patients stays the same if the number of new patients increases with 20%.

*Case-mix*

Alterations in the patients' case-mix of results in a change in the maximum number of new patients or DTCs per year, if the average OR-time per new patient changes. A reduction in the average OR-time per new patients leads to a production increase. 10% reduction (2 minutes) of the average OR-time leads to a possibility to increase number of new patients by 10%.

## 5.4 Validation of the model

We performed a theoretical validation of clinical pathways with an MS. Also the assumptions used are discussed with an MS, and lead to a good representation of the actual situation for Orthopaedics in DZ. The data that is used for the clinical pathways is extracted from the management information system, and is based on completely finished (closed) DTCs. The information has been used for billing the DTCs. This assures that the information of 2006 is complete, although mistakes in registration are not excluded. The total number of outpatient visits and surgeries is correct, only the number of visits for each type of DTC or patient group may differ due to wrong registration. The effects on the results are limited, because this considers mainly DTCs with only OD visits. Running the model with the information of 2006 results in a difference of 1% with respect to the real OR-time used in 2006. The number of outpatient visits was the same.

## 5.5 Limitations model

The model is based on a deterministic arrival of patients and a deterministic pathway of patients throughout the healthcare process. In reality this is stochastic. Changes in the number of provided consultation hours results in a more gradually change in future OR demand. In addition, no waiting lists are modelled. The use of waiting lists can postpone future capacity demand and offers more possibilities to balance the workload of the healthcare professionals.

Due to the extensive number of patient groups, a selection of 13 groups (out of 216) was made. Based on figures of 2006, this selection accounts for 52% of the outpatient visits and 64% of the OR-time. All other patient groups are taken together as one remaining group. Although in our model homogeneity is assumed, this is not realistic. The timeframe of the revisits may differ, but the number of visits stays the same.

On a strategic / tactical level, the healthcare professionals are expected to be able to treat all kinds of patients. In reality each medical specialist (MS) has his specialisation. At this planning level the specialisation of the MS has a limited effect.

We use a mortality factor for 2-yearly revisit patients, but not for new patients. One can consider taking this into account. The total number of visits can be lower due to mortality during treatment, although we expect the influence of this effect is limited.

## 5.6 Conclusions based on the implementation of the model

Using our mathematical model for the situation of Orthopaedics in Deventer Hospital gives good insight in the demand for the different capacities and to level the workload of the healthcare professionals. By adjusting the number of patients per week (new and yearly revisit patients) we try to level the workload. A change in the number of patients seen per week does not have to affect the total number of patients that can be seen per year. There is flexibility within the available capacities for Orthopaedics to level the workload throughout the year.

Comparing the number of day-parts consultation hours and OR sessions in 2006 with the results of the model, we see that the fluctuations in the day-parts (and also the workload) per week are reduced. There are still several peeks in the number of consultation hours and OR sessions. These are mainly the result of the deterministic character of the patient pathways in our model and limited availability of the OR and nurse practitioner. The deterministic patient pathways allow no changes in duration between two visits. In reality the possibility to increase the waiting time increases the possibility to level workload.

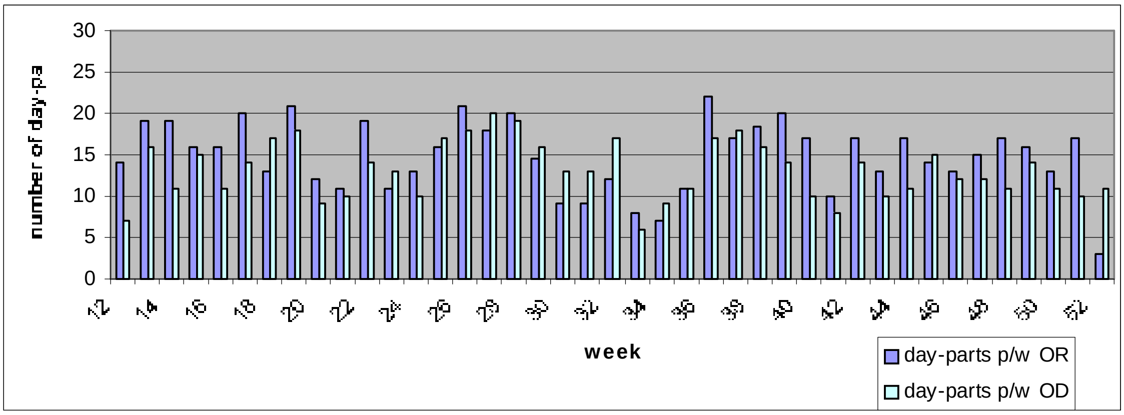


Figure 5.6: Number of OR-shifts and consultation hours for Orthopaedics (2006)

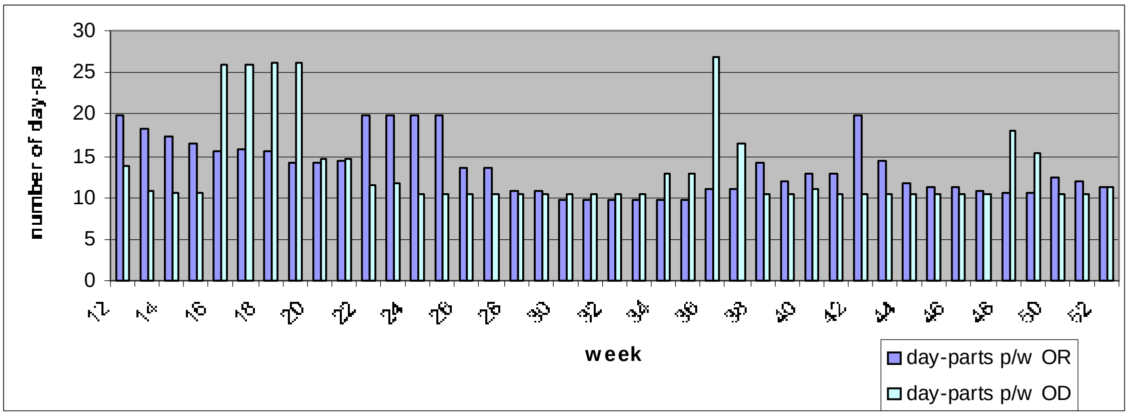


Figure 5.7: Number of OR-shifts and consultation hours for Orthopaedics (2006) after step 3

Around the summer holiday period we see a difference between the results of our model and the real situation for Orthopaedics in 2006. Before the holiday period our model shows a reduction of the number of new patients (Figure 5.7), due to a reduced availability of the OR and medical specialist (MS) during the summer holiday. Before the end of the holiday extra new patients are seen, and we see a gradually increase of OR use. Mainly because of patient demand and MS preferences, the production of 2006 shows that Orthopaedics sees a higher number of new patients before the holiday period compared to our model. After the holiday we see immediately a maximum OR and outpatient department (OD) capacity. Seeing more new patients before the holiday and use extra OR capacity after the holiday is mainly possible through the use of waiting lists. The OR demand is delayed. We conclude that this is not problematic if extra OR capacity is available after the holiday to see these patients and to prevent an increasing waiting list for the OR.

The described clinical pathways used for the model offer detailed information on the effects on workload when there are changes in the number of new patients a week. The planning of the MS can be adapted to expected fluctuations in patient demand on the long term. It is necessary to make a planning of 6 months to take the effects of holidays into account and due to the duration of the patients' clinical pathways and the long term in advance OR rooms have to be requested.

A production increase of 11% is possible with the available capacity. The OR capacity can be increased and there still remains MS time available. The current situation with 2 days working in the OD and 2 days in the OR is sufficient. The model shows the same relation, although throughout the year this can change to get grip on the waiting times or to level the workload.

The yearly revisit patients are mainly seen by the nurse practitioner, although during the holiday period the MS is also seeing yearly revisit patients. The weekly number of revisit patients is fluctuating throughout the year to level the workload.

By increasing the OR-time, Orthopaedics can increase the production by 20%. If no extra OR-time is available, extra MS time is not useful considering the current working methods. A reduction of the time per patient or a change in case-mix can increase the number of patients seen.

# Chapter 6

## Conclusions and recommendations

In this report we described a mathematical model for the planning of Orthopaedic patients and balancing the workload in the outpatient department (OD) and operating room (OR) throughout the year. We applied the model for Orthopaedics in Deventer Hospital (DZ) to get more insight into the possibility to level workload and the maximum production that can be realised. Our model provides a basis to test and set production targets throughout the year. Based on the findings within Orthopaedics and the outcomes of the applied model we describe measures that can be taken to get better grip on the access time and waiting lists.

We found that the patients DTC-code offers a good basis to describe logistically the patient healthcare process. The weekly average demand for healthcare of each clinical pathway is specified per DTC-code. For Orthopaedics in DZ we selected 13 diagnoses that offer detailed insight into the weekly demand for healthcare for 52% of the OD time and more than 64% of the OR-time. We used an approximation of the weekly demand for the remaining group. The average time used by a new patient is 18,13 minutes OR-time and 18,46 minutes OD-time. Table 5.5 describes into more detail the average time per patient for each healthcare demand $c$. By expanding the number of diagnoses described into detail, we can further increase the accuracy of the model.

The use of and availability of the OR capacity limits the possibilities for Orthopaedics to see more patients. There remains available MS time, that is not directly used for consultation hours or for OR sessions. This makes the continuous availability of patients for the OR important, in order to use the OR capacity to its maximum.

A better-balanced workload throughout the year can be realised by setting weekly production targets and adapt the working schedule of the healthcare professionals to the production targets. The weekly production targets and presence of healthcare professionals should be set and determined for a period of 6 months to 1 year to be able to level workload and adjust the planning to the patient demand. As a result, the speciality has more control over the access and waiting times by planning forward. In addition, the specialty prevents peak demands throughout the year.

To influence the patient flow or waiting times between OD and OR, Orthopaedics has a number of options. On the long term (3 months in advance) the number of OR sessions can be altered. When admission times get too high for the OR, extra ORs can be asked. Seasonal effects that are foreseen can be taken into account during the request for ORs. Holidays of healthcare professional can also be adapted to peaks demand in care if known in advance. On the short term (2 months till 2 weeks in advance) the number of consultation hours can be altered. Optional consultation hours should be planned that can be used to see revisit patients, if the access time to the OD gets too high. Delay of the patient's treatment can be prevented. In case of a shortage of new patients in the OR, optional consultation are used to a specific type of new patients that can be treated in the OR on a short term, to prevent unused OR capacity. High access times to the OD can also be reduced by using optional consultation hours, although admitting new patients to the extra consultation hours should be done cautiously. Extra OR and future OD capacity should be available to prevent a shortage of capacity and an increase of the waiting list in the future.

With the current capacity, an increase of new patients is possible for Orthopaedics in DZ. The possible increase in DTC production is between 11% and 20% based on the production figures, working methods and capacity needs of 2006. An increase of 19% is possible if the total number of ORs increases to 412 OR-days a year (about 3300 hours). As a result, there is more variation of the MS time between working in the OD and OR, and all 2-yearly revisit patients are seen by the nurse practitioner.

**Recommendations**

Based on our findings we have the following recommendations for Orthopaedics in DZ:

- Schedule optional consultation hours and use these to:
    - See more (2-yearly) revisit patients, to reduce the access time and to prevent or reduce a further delay of the treatment;
    - See more new patients, to reduce the access time to the OD. Enough future capacity should be available to see these patients in the OR and OD;
    - See more new potential OR patients, to prevent a shortage of OR patients, with the aim to increase OR utilisation;
- Make a planning for a period of at least 6 months, for which the production targets are leading for making the monthly working schedules for the healthcare professionals;
- Make a more uniform protocol for the planning of surgeries of each medical specialist;

- Communicate in an early stage with the admission planning about the OR program and the problems encountered during the planning of OR sessions;
- Register more accurately the DTCs, if they are used for planning purposes;
- Build up larger waiting lists before or during the partial OR closure in the summer, with patients that want to be treated after the holiday period;
- Register the moment at which a patient asks for an appointment, to get more insight into the arrival of new patients through time;
- Use a waiting list with patients that want to be treated immediately instead of the current registration, to get insight into the real number of patients waiting.

High admission times for revisit patients result in overbooking of consultation hours and delay of treatments. Not all available day-parts of the medical specialist are currently used. It is also possible to reschedule consultation hours to busy periods. This offers possibilities to provide extra consultation hours to reduce overbooking of consultation hours and delay of treatments.

The OR is allocated more than 2 months in advance. This makes it difficult to adjust the OR capacity to the OR demand by new patients. To be able to fill the OR-time and have a high utilisation rate it is important to adjust the consultation hours (and the number of new patients) to the available OR-time.

Insight into the future demand for care should be obtained to foresee increasing access times. Currently the specialty reacts in a late stage to resolve problems, instead of preventing problems caused by increasing access times for the OD and OR. On the short term frequent communication with the admission planning is important to foresee shortages of OR capacity. The admission planning has a lot of insight and knowledge on the progress of the OR planning. In a future state, detailed logistical information on patient process should give the possibility to foresee shortages based on a mathematical model. In addition, more uniform protocols for planning surgeries create more flexibility for the admission planning to schedule surgeries.

It is important that the registration of DTCs is done more accurate and detailed. For example the registration of 2-yearly revisit patients should be separated (split up DTC code 2150) to offer a more accurate predication of capacity demand. Currently there is no information available on the number of types of 2-yearly revisit patients (hip, shoulder or knee) within the DTC registration.

The results of our mathematical model show a gradually decrease of new patients before the summer holiday and increase after the holiday. The specialty currently plans a maximum number of OR and consultation hours before and after the holiday. This is mainly based on preferences of the healthcare professionals and partly because of an increase of patient demand. If the specialty wants to maintain this high production period before and after the holiday period, attention should be paid to a shortage of OR patients after the holiday. By seeing more new patients before and during the holiday (creating a longer waiting list) a shortage of new OR patients can be prevented several weeks after the summer holiday period. Another option is to reduce the requested number of ORs.

To adjust the provision of care to the patient demand (patient centred care), the specialty should get more insight into the patient arrival in the OD. With our research we provided only insight into the patient demand for care after a first visit at the outpatient department. Currently there is no insight in when and how many patients want to get an appointment with a medical specialist for the first time.

**Further research**

Our research describes a mathematical model for the planning of patients and to balance the workload for the healthcare professionals and getting more insight into the demand for care. The initial patient demand (the arrival of new patients) is not yet known. A study on the arrival of new patients offers useful insight into the patient demand and is important for adjusting the Orthopaedics capacity to the patient demand. Offering patient-centred care is also offering timely care to patients. More research should be done in the Orthopaedics department to be able to react to and foresee growing access times for new patients.

# Terminology & Abbreviations

*Access time* — Time between the moment a patient makes an appointment and the moment the patient is actually seen by the medical specialist.

*Aging* — Proportional over-representation of elderly people (increase in over 65- and 80-year yearly revisits).

*AIOS* — Medical assistant in training.

*Service area* — The extent to which a population makes use of clinical care, and outpatient treatment of a hospital.

*Case-mix* — Number of different patients and categories within the patient population.

*Consultation room* — In Dutch “spreekkamer”. Room without an examination table, where only a consultation takes place and no examination.

*Consultation hour* — (in Dutch “spreekuur”). Time available for seeing and treating patients in the outpatient department.

*Dejuvenation* — Proportional under-representation of younger generation (decline in the number of people which are under 35-year yearly revisit).

*DTC* — Diagnosis Treatment Combination (in Dutch “Diagnose Behandel Combinatie” or “DBC”). Codes the specialist uses in a hospital to administratively handle the care process. A cost price will be available for each code, which can be used during negotiations and during benchmarking with other hospitals. The DTC-system consists of:

- *A-segment*: determined prices and covers 90% of the DTCs. Covers hospital care in which (at this moment) the financing is based on parameters like admissions, days of hospitalisations, outpatient treatments and FOVs (90% of the hospital budget). Producing more will not lead to extra revenue.

- *B-segment*: consists of negotiable prices in which insurance companies, hospitals and medical specialists negotiate. Covers the other 10% of the DTCs. Within this segment there is market competition.

- *C-segment*: not part of the Health Insurance Law (in Dutch “Zorgverzekeringswet”) and represents the remaining hospital care.

A DTC consist of a care process for a certain patient having a certain disease. A DTC can cover a maximum period of twelve months. After that the DTC will be closed automatically. A new initial DTC will be opened / started if a patient has a first visit with a gate specialty with a new disease. At the same time an FOV will be registered if there has not been a DTC opened in the last twelve months for that specialty. Otherwise a RV will be registered. Opening a DTC not leading to an FOV has not influence on the hospital budget. If a patient visits a specialty within twelve months with the same disease and the initial DTC has already been closed, a follow-up DTC will be opened. After twelve months a new initial DTC will be opened. A DTC does not have to be in parallel with an FOV.

*DZ* Deventer Ziekenhuis (in English “Deventer Hospital”).

*Elective care* Refers to care which is pre-arranged. Elective care is care that, in the opinion of the treating clinician, is necessary and admission for which can be delayed for at least 24 hours.

*FOV* First outpatient visit (in Dutch “eerste polikliniekbezoek” or “EPB”). In the case of an FOV a patient visits a medical specialist of a certain gate specialty in the hospital for the first time that year. An FOV may be registered and declared if in the twelve months preceding this visit no FOV has already been registered at that gate specialty. In case of an FOV, the following aspects must been met:

- Face-to-face contact between patient and medical specialist or medical assistant.
- "Help by, or due to the hospital ", The location (outpatient department inside or outside the hospital, or a nursery home) will be taken along.

Medical checks, inter-collegial consultations, co-treatment of clinical patients and handing over of clinical patients are not seen as FOV.

*Gate specialty* (in Dutch “Poortspecialisme”). In hospitals a distinction is made in gate specialties and supporting specialties. Gate specialties are specialties that the patient visits first (‘at the gate’) after being referred by a general practitioner. They are specialties who generate the hospitalisation, days of hospitalisation, etcetera. By this they influence the external budget that is determined by production parameters. Examples of gate specialties are internal medicine, cardiology, obstetrics, orthopaedics, paediatrics, surgery, etcetera. Examples of supporting specialties are radiology, anaesthesiology, medical microbiology, etcetera.

*HTB / HA* Healthcare Tariff Board / Healthcare Authority (in Dutch “College Tarieven Gezondheidszorg / ZorgAutoriteit in oprichting” or “CTG/ZAio”) in the Netherlands for determining the tariff of surgical procedures.

*OR* Operating Room.

| | |
|---|---|
| *Outpatient* | A patient who is admitted to a hospital or clinic for treatment that does not require an overnight stay. |
| *Outpatient department* | Area in a hospital with grouped consultation rooms and a front office desk. |
| *RV* | Repeat Visit (in Dutch “herhaalconsult” or ”HC”). In case of a RV a patient visits a medical specialist of a certain gate specialty and an FOV has already been registered. If an RV takes place after twelve months a new DTC will be opened and the RV will be converted into that DTC. |
| *Secondary needs* | Capacity needs of a specialty outside its own specialty. |
| *Specialty* | Science part that is separately practised. |
| *Treeknormen* | Defines the maximum acceptable access time for a treatment and a FOV. Within “Treeknormen”, a distinction is made in: |

- Access time first outpatient visit (FOV): the maximum access time for an outpatient consultation should not be more than 3 weeks in 80% of the cases and 4 weeks maximum;
- Waiting time clinical treatment: the maximum waiting time for a clinical treatment should not be more than 5 weeks in 80% of the cases and 7 weeks maximum;
- Waiting time outpatient treatment: the maximum waiting time for an outpatient treatment should not be more than 4 weeks in 80% of the cases and 6 weeks maximum;
- Waiting time day treatment: the maximum waiting time for a day treatment should not be more than 4 weeks in 80% of the cases and 6 weeks maximum.

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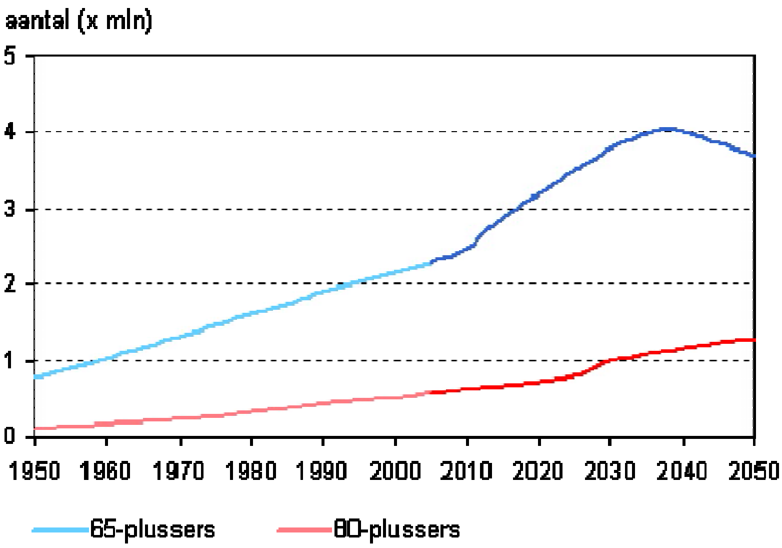
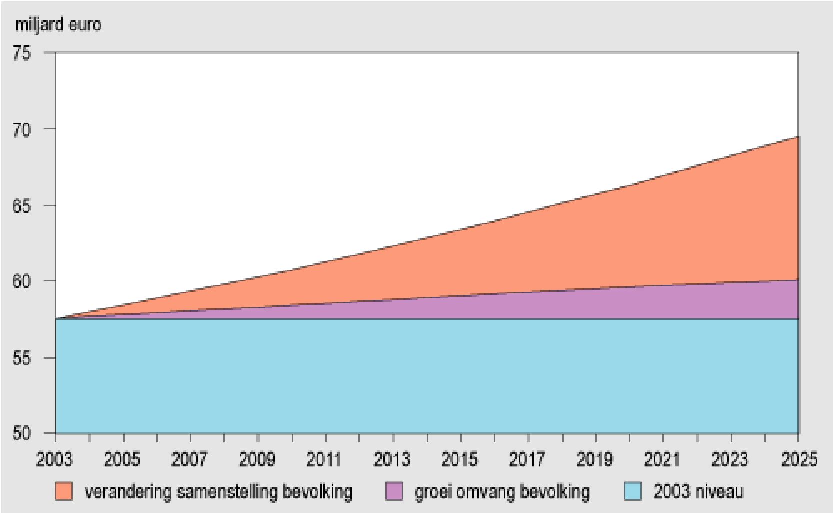
# Appendix I: Aging

The baby boom after World War II will result in an increase in the proportion of people of 65 years and older from 2010 with respect to the total population. It results in a maximum of 24% in 2040. At the moment this percentage is 14%. After 2025 the proportion of people of 80 years and older will increase to nearly 8% in 2050; at the moment this percentage is 3% (De Jong, 2005). Appendix I - Figure 1.1 shows this aging. Beside that the life expectancy also increases. The life expectancy at birth was in 2005 for men 77,2 years and 81,6 years of women. In the period 2006-2050 this life expectancy will further increase to 81,5 years for men and 84,2 years for women (CBS, 2006).




Appendix I - Figure 1.1: Number of 65+ and 80+ [De Beer en Verweij, 2005]

This means that the elderly, generally needing more healthcare demand, put a higher pressure on healthcare (Van den Berg Jeths et al., 2004). In the next 20 years this, but also because of the current lifestyle and obesitas, leads to more (40%) chronic diseases. Statistics Netherlands (in Dutch “Centraal Bureau voor de Statistiek” or “CBS”) expects an enormously increase in the number of elderly diseases in the upcoming years based op prevalence for important chronic disorders and population prognoses. This leads to aging. Because of the relative dejuvenation of the population disorders like asthma will decrease. This leads also to an increase of healthcare expenditure of 57 billion in 2003 to nearly 70 billion in 2025 as can be seen in Appendix I - Figure 1.2 (De Jong, 2005).

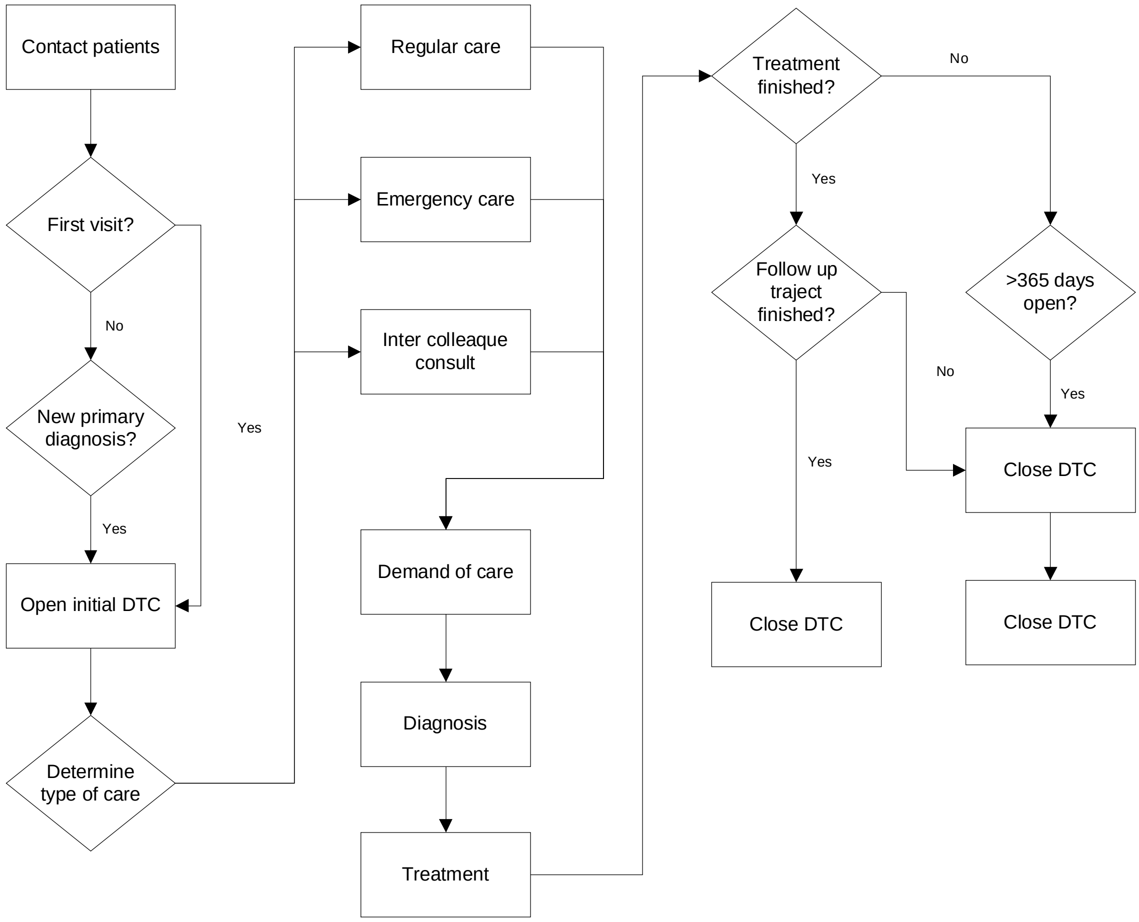



Appendix I - Figure 1.2: Development of healthcare expenditure based on demography [De Jong, 2005]

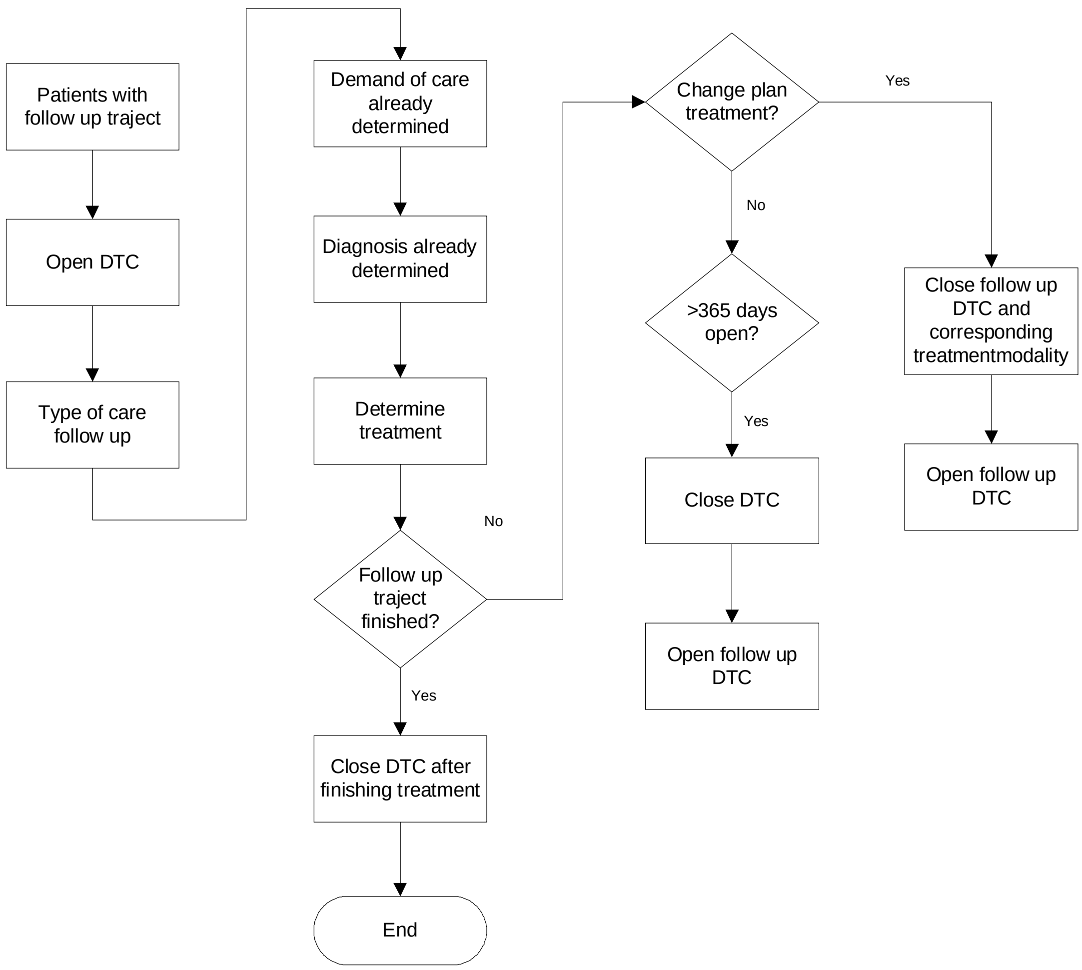
# Appendix II: DTC-codes for Orthopaedics

| ***Element*** | ***Division*** | ***DTC-code*** |
| --- | --- | --- |
| *Specialty* | Orthopaedics | 05 |
| *Type of care* | Regular / Initial care | 11 |
| | Inter colleague consult | 13 |
| | Revisit / Follow-up | 21 |
| | Route internal support | 51 |
| *Demand of care* | n/a | n/a |
| *Diagnosis* | | 1010 – 4103 (range) |
| *Treatment* | Conservative outpatient | 111 |
| | Conservative with one day(s) clinic | 112 |
| | Conservative with clinical episode(s) | 113 |
| | Singular outpatient conservative | 114 |
| | Surgical outpatient | 211 |
| | Surgical one day clinic | 212 |
| | Surgical clinical episode(s) | 213 |
| | Singular outpatient with treatment | 214 |
| | Clinical without days (in Dutch “KZD”) surgical with clinical episode(s) | 216 |
| | Surgical with clinical episode(s) with prosthesis | 223 |
| | Clinical without days (in Dutch “KZD”) surgical with clinical episode(s) with prosthesis | 226 |

# Appendix III: Open and closure of an initial DTC



# Appendix IV: Open and close of a follow-up DTC



# Appendix V: Overview model notations

| ***Notation*** | ***Description*** |
|---|---|
| T | Weeks |
| Q | Quartile |
| H | Healthcare professionals |
| $H_i$ | Healthcare professionals of type *i* |
| S | Diagnosis |
| B | Treatments |
| C | Healthcare demand |
| $v_i$ | Availability per year for a healthcare professional of type *i* |
| $w_i$ | Availability per week for a healthcare professional of type *i* |
| $vp_i$ | Time per week that healthcare professionals of type *i* has visiting activities |
| $f_i$ | Productivity factor healthcare professional type *i* with respect to an MS |
| $NP_t$ | Total number of new patients in week *t* |
| $np_{sb}$ | Part of the case-mix that has diagnosis *s* and treatment *b* |
| $NP_{sbt}$ | Number of new patients of patient type *s* with treatment *b* in week *t* |
| $hd_{sbct}$ | Probability of needing healthcare demand *c* after *t* weeks for patient type *s* with treatment *b* |
| $d_{sbct}$ | Duration of healthcare demand *c* after *t* weeks for patient type *s* with treatment *b* |
| $rd_c$ | Expected duration for yearly revisit patients for needing healthcare demand *c* |
| $\varepsilon$ | Mortality factor |
| $W_{sbct}$ | Workload for patients of type *s* with treatment b that need healthcare demand *c* in week *t* |
| $TW_{ct}$ | Total workload for healthcare demand *c* in week *t* |

| | |
|---|---|
| $YP_{ct}$ | Number of yearly revisit patients that need healthcare demand *c* in week *t* |
| $TOR_{q}$ | Expected number of yearly revisit patients in the outpatient department in week *t* |
| dch | Duration of a consultation hour |
| bch | Buffer during a consultation hour |
| $CH_{ct}$ | Needed consultation hours in week *t* for healthcare demand *c* |
| $npc_{c}$ | Maximum number of new patients during a consultation hour for healthcare demand *c* |
| dos | Duration of an OR-block |
| eor | OR-time that reserved per week for emergency patients |
| $mos_{t}$ | Maximum number of OR-blocks in week *t* |
| orc | Maximum OR-time available per year |

# Appendix VI: Synthesis of the proposed model

Taken the constraints together yield the following (mixed) integer linear programming (*ILP*) formulation of the strategic planning problem of patients in a hospital department:

$$ILP : z_{ILP} = \max(\alpha \times \min\{NP_t\} + \beta \times \min\{TW_{1t}\} + \gamma \times \min\{TW_{2t}\} + \delta \times \min\{TW_{3t}\}).$$

subject to:

$$\sum_t NP_t \geq \zeta \times mnp,$$

$$NP_t - Min\{NP_t\} \geq 0 \; (\forall_t),$$

$$Min\{NP_t\} \geq Min\{Min(NP_t)^{step2}\} \; (\forall_t),$$

$$\sum_s \sum_b \sum_{j=0}^{j=103} (NP_{(t-j)} \times np_{sb} \times hd_{sb1(t=j)} \times d_{sb1(t=j)})$$

$$Min\{\sum_s \sum_b \sum_{j=0}^{j=103} (NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)})\} \geq 0 \; (\forall_t),$$

$$Min\{\sum_s \sum_b \sum_{j=0}^{j=103} (NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)})\} \geq Min\{MinTW_{1t}^{step2}\} \; (\forall_t),$$

$$(\sum_s \sum_b \sum_{j=0}^{j=103} (NP_{(t-j)} \times np_{sb} \times hd_{sb2(t-j)} \times d_{sb2(t-j)}) + (YP_{2t} \times rd_2)) \times (1 - \frac{bch}{dch})$$

$$-$$

$$Min\{(\sum_s \sum_b \sum_{j=0}^{j=103} (NP_{(t-j)} \times np_{sb} \times hd_{sb2(t=j)} \times d_{sb2(t=j)}) + (YP_{2t} \times rd_2)\} \times (1 - \frac{bch}{dch}))$$

$$\geq 0 \; (\forall_t),$$

$$Min\{(\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb2(t-j)} \times d_{sb2(t-j)}) - (YP_{2t} \times rd_2)\} \times (1 - \frac{bch}{dch})) \geq Min\{MinTW_{2t}^{step2}\}$$

$$\frac{\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb3(t-j)} \times d_{sb3(t-j)})}{Min\{\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb3(t-j)} \times d_{sb3(t-j)})\}} \geq 0 \ (\forall_t),$$

$$Min\{\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb3(t-j)} \times d_{sb3(t-j)})\} \geq Min\{MinTW_{3t}^{step2}\}$$

$$\frac{\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)})}{(\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb2(t-j)} \times d_{sb2(t-j)}) + (YP_{2t} \times rd_2)) \times (1 - \frac{bch}{dch})} \leq \sum_{i=1}^{2} (|H_i| \times w_i \times f_i \quad vp_i) \quad eor \ (\forall_t),$$

$$\sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb3(t-j)} \times d_{sb3(t-j)}) \quad (YP_{3t} \times rd_3) \leq \frac{(|H_3| \times w_3 \quad vp_3)}{(1 - \frac{bch}{dch})} \ (\forall_t),$$

$$\frac{\sum_{t \in T_k} \sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)})}{(\sum_{t \in T_k} \sum_s \sum_b \sum_{j=0}^{103} (NP_{(t-j)} \times np_{sb} \times hd_{sb2(t-j)} \times d_{sb2(t-j)}) + (YP_{2t} \times rd_2)) \times (1 + \frac{bch}{dch})} \leq \sum_{i=1}^{2} (|H_i| \times w_i \times v_i \times f_i \quad vp_i \times 52) \quad eor \times 52 \ (\forall_k),$$

$$\sum_{t\in T_k}\sum_{s}\sum_{b}\sum_{j=0}^{103}(NP_{(t-j)} \times np_{sb} \times hd_{sb3(t-j)} \times d_{sb3(t-j)}) - (YP_{3t} \times rd_3) \le \frac{(|H_3| \times w_3 \times v_3 - vp_3 \times 52)}{(1 + \frac{bch}{dch})} \quad (\forall_k),$$

$$\sum_{t\in q}\sum_{c=1} YP_{ct} - \sum_{t\in q}\sum_{s} NP_t \times np_{s10} \times \left(\frac{\varepsilon}{1-\varepsilon}\right) - 0 \quad (\forall_q),$$

$$\sum_{t\in T_k}\sum_{s}\sum_{b}\sum_{j=0}^{103}(NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)}) \le orc \quad eor \times 52 \quad (\forall_k),$$

$$mos_t \times dos - \sum_{s}\sum_{b}\sum_{j=0}^{103}(NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)}) \ge 0 \quad (\forall_t),$$

$$\sum_{s}\sum_{b}\sum_{j=0}^{103}(NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)}) \le |H_1| \times w_1 - vp_1 \quad (\forall_t),$$

$$\sum_{t\in T_k}\sum_{s}\sum_{b}\sum_{j=0}^{103}(NP_{(t-j)} \times np_{sb} \times hd_{sb1(t-j)} \times d_{sb1(t-j)}) \le |H_1| \times w_1 \times v_1 - vp_1 \times 52 \quad (\forall_k),$$

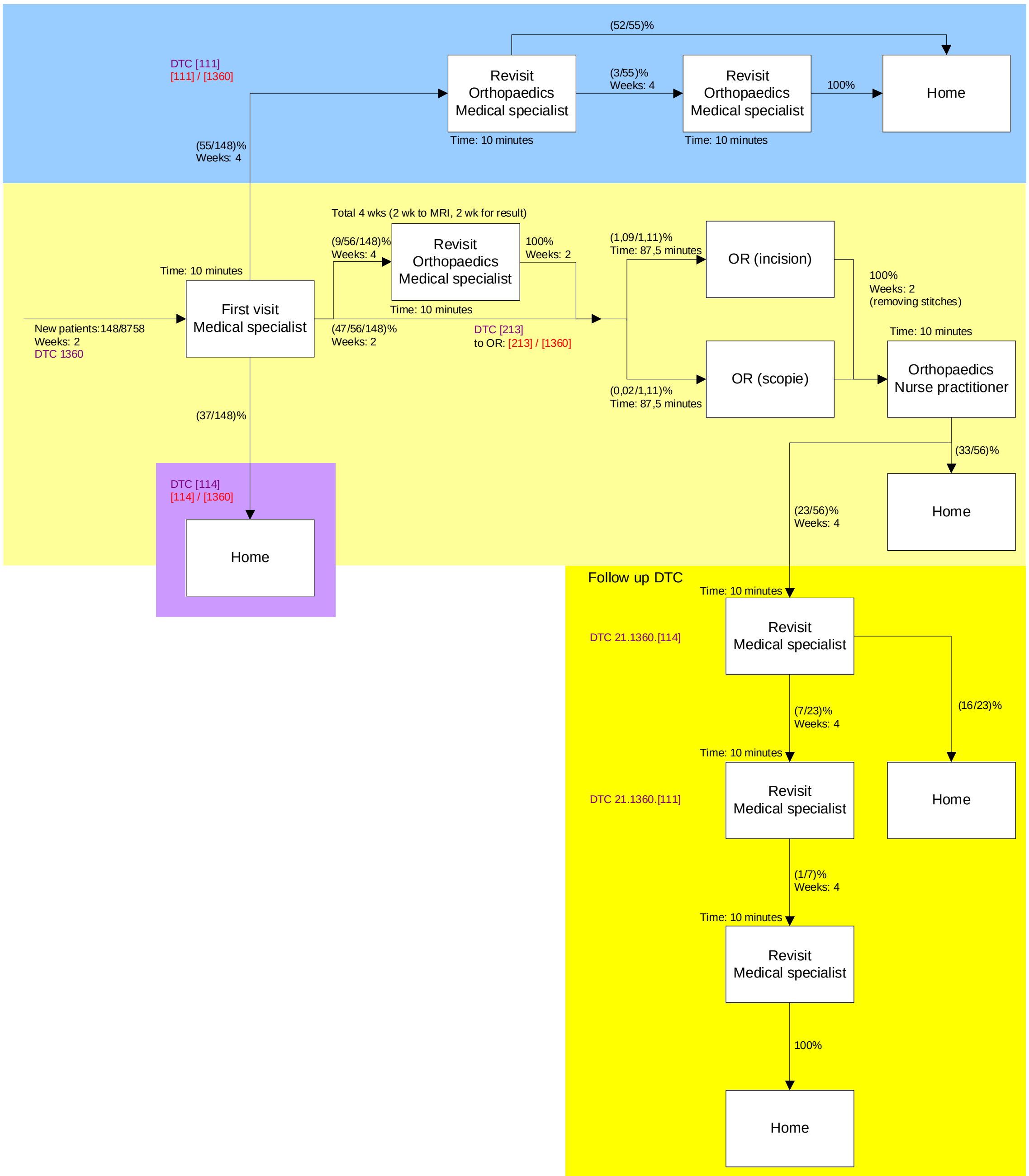
$$\frac{(\sum_{s}\sum_{b}\sum_{j=0}^{103}(NP_{(t-j)} \times np_{sb} \times hd_{sb2(t-j)} \times d_{sb2(t-j)})) \times npc_2 - NP_t}{dch} \ge 0 \quad (\forall_t),$$

all variables $\ge 0$,

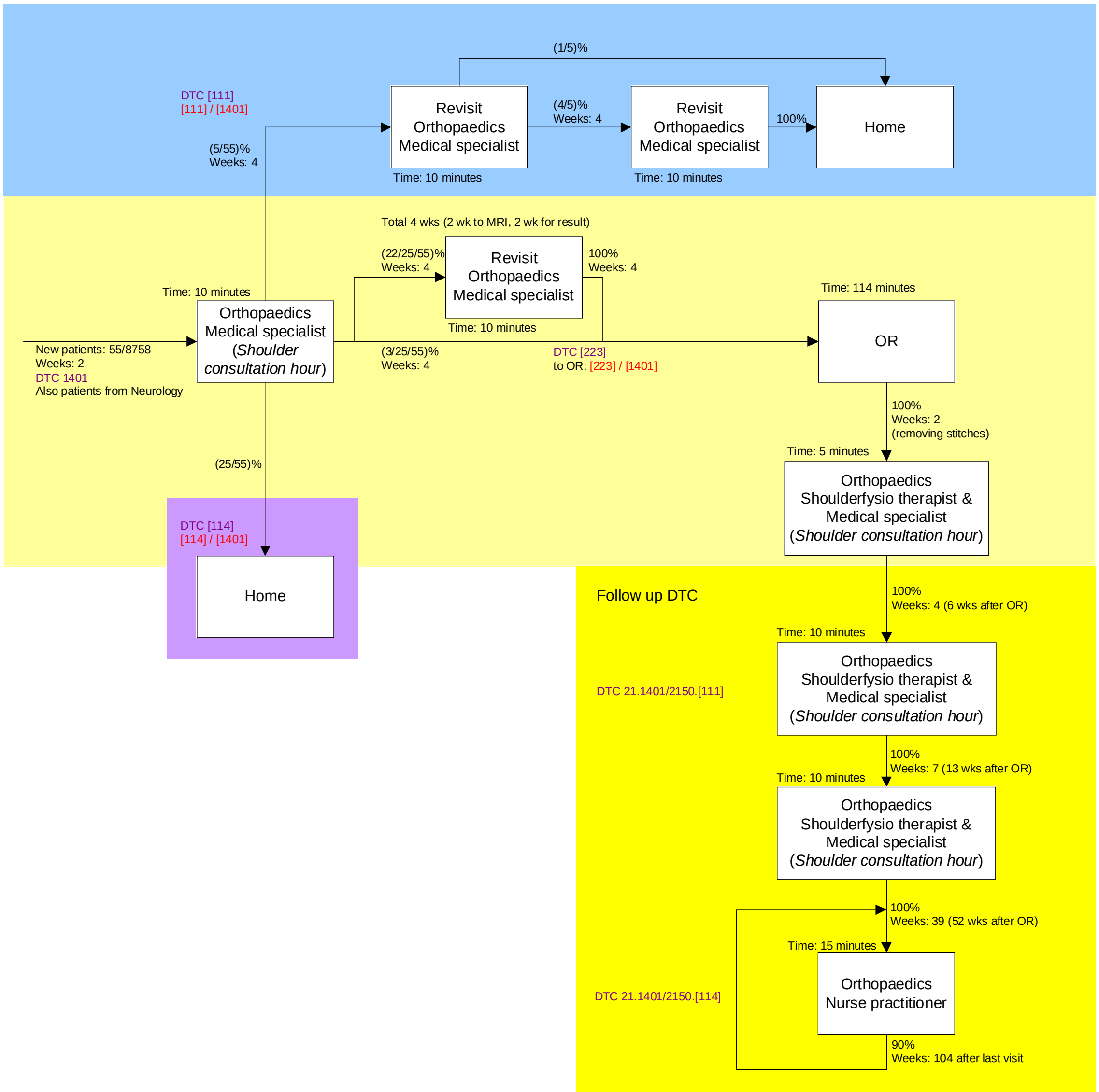
$NP_t$ integer.

# Appendix VII: Clinical pathways of Orthopaedic patient groups in DZ

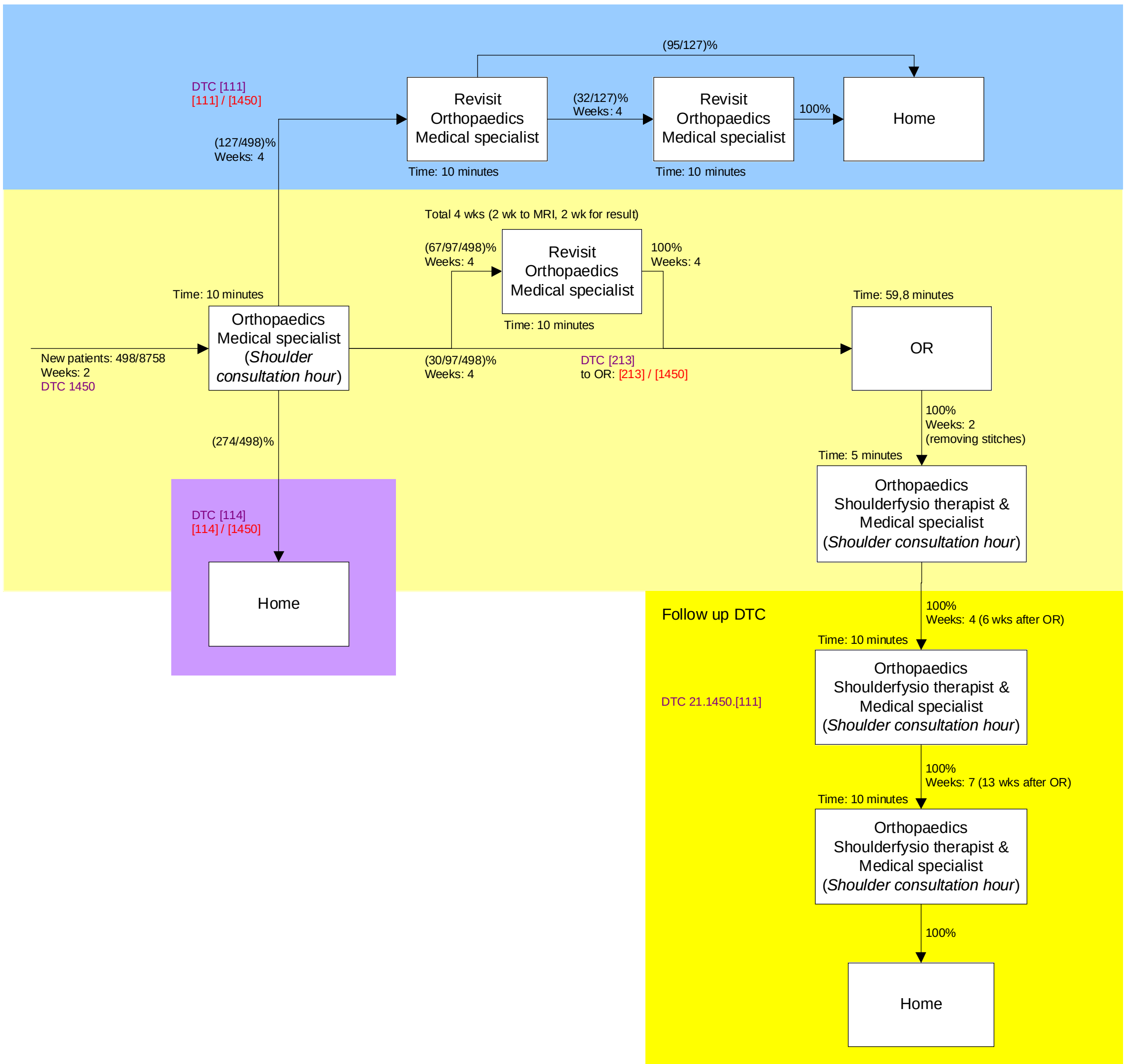
## 1. Hernia patients - 1360 H.N.P: Thoracic / lumbar spinal column



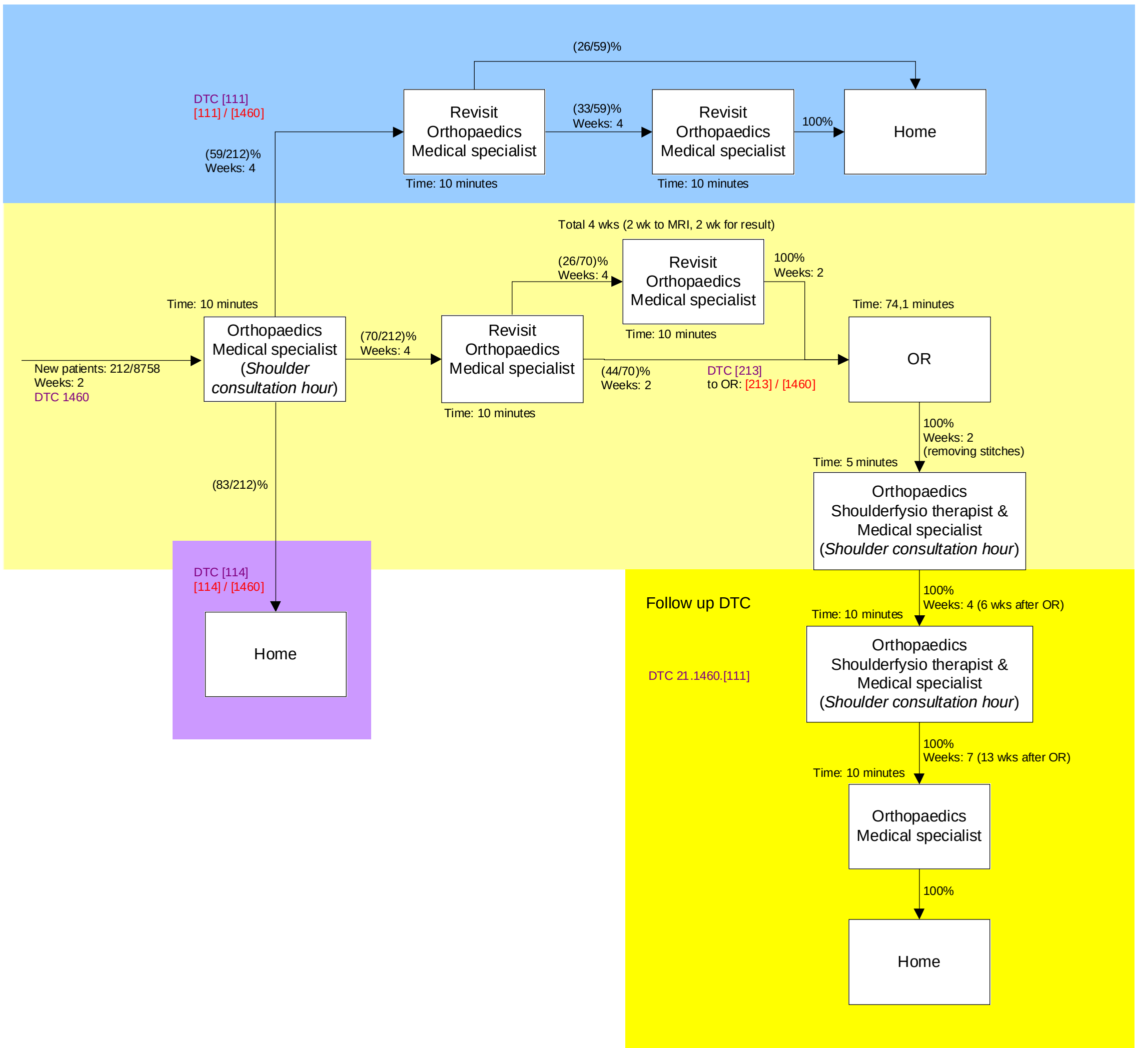
## 2. Shoulder prosthesis – 1401 Arthrosis: Shoulder belt / upper arm



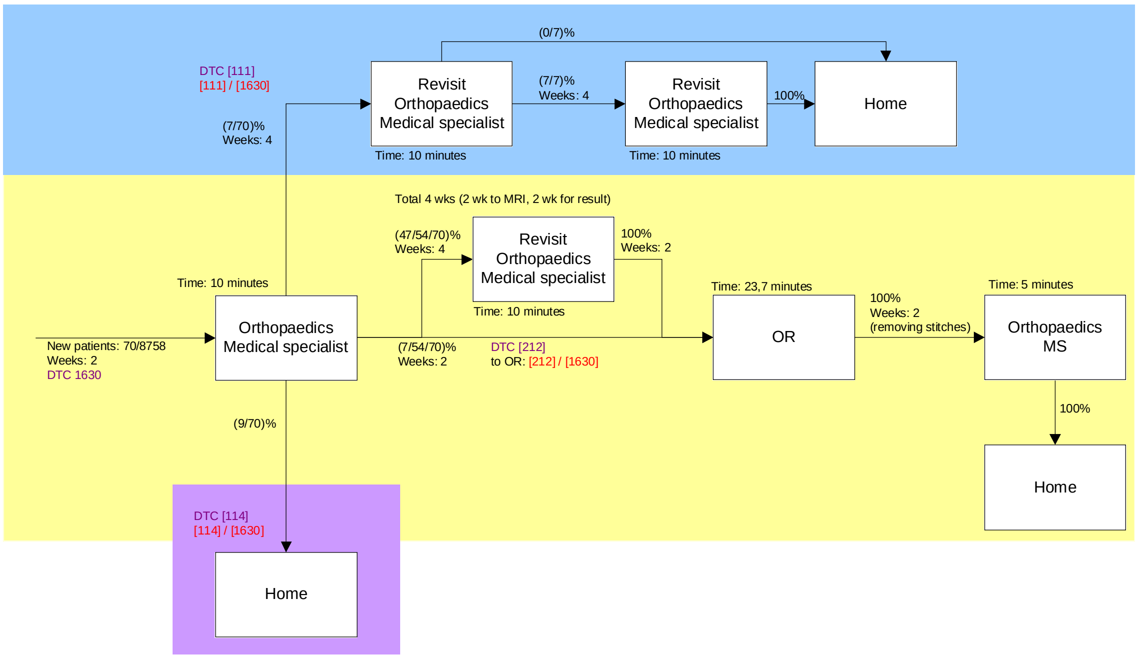
### 3. Shoulder scopy – 1450 Tendinitis supraspinatus/biceps



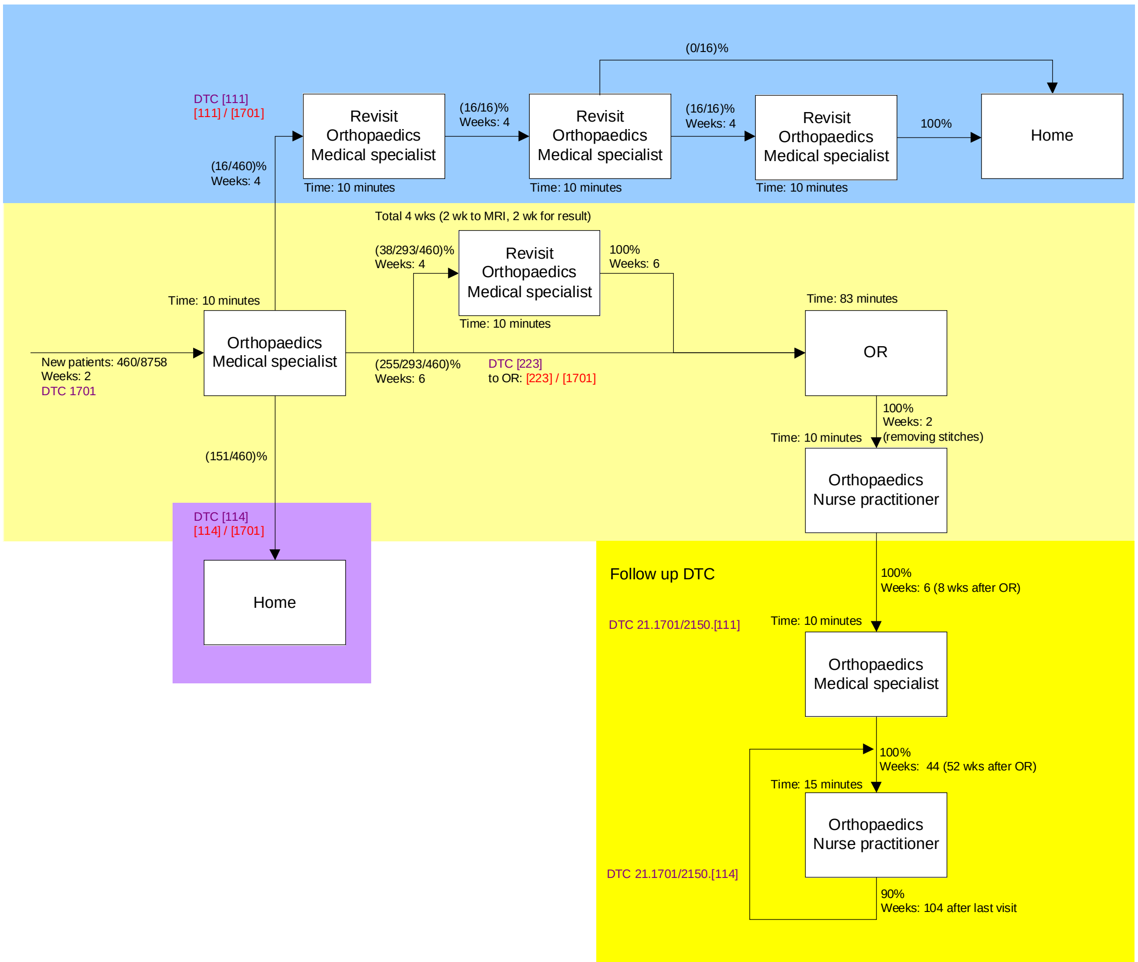
**4. Shoulder (stitching muscles) – 1460 Rupture rotator cuff/biceps tendon**



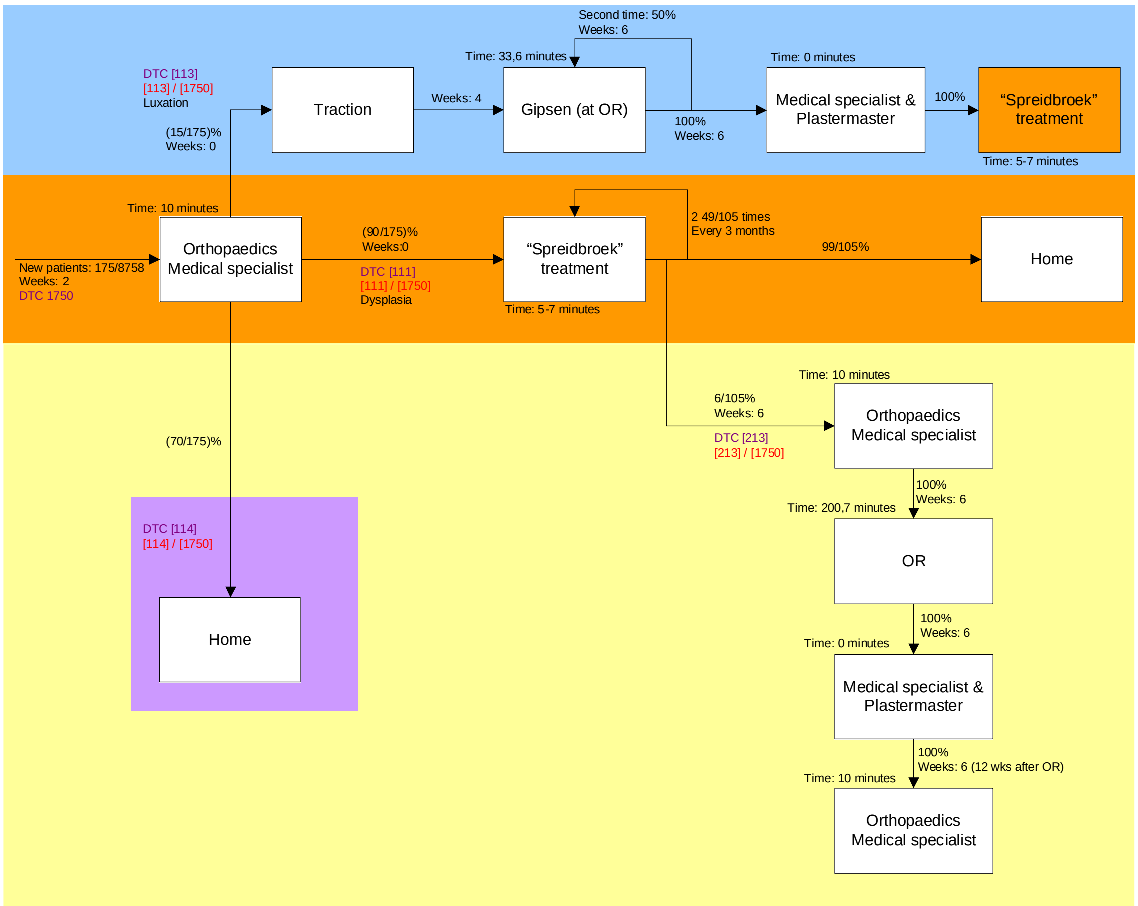
### 5. Carpal tunnel release – 1630 Carpal tunnel syndrome



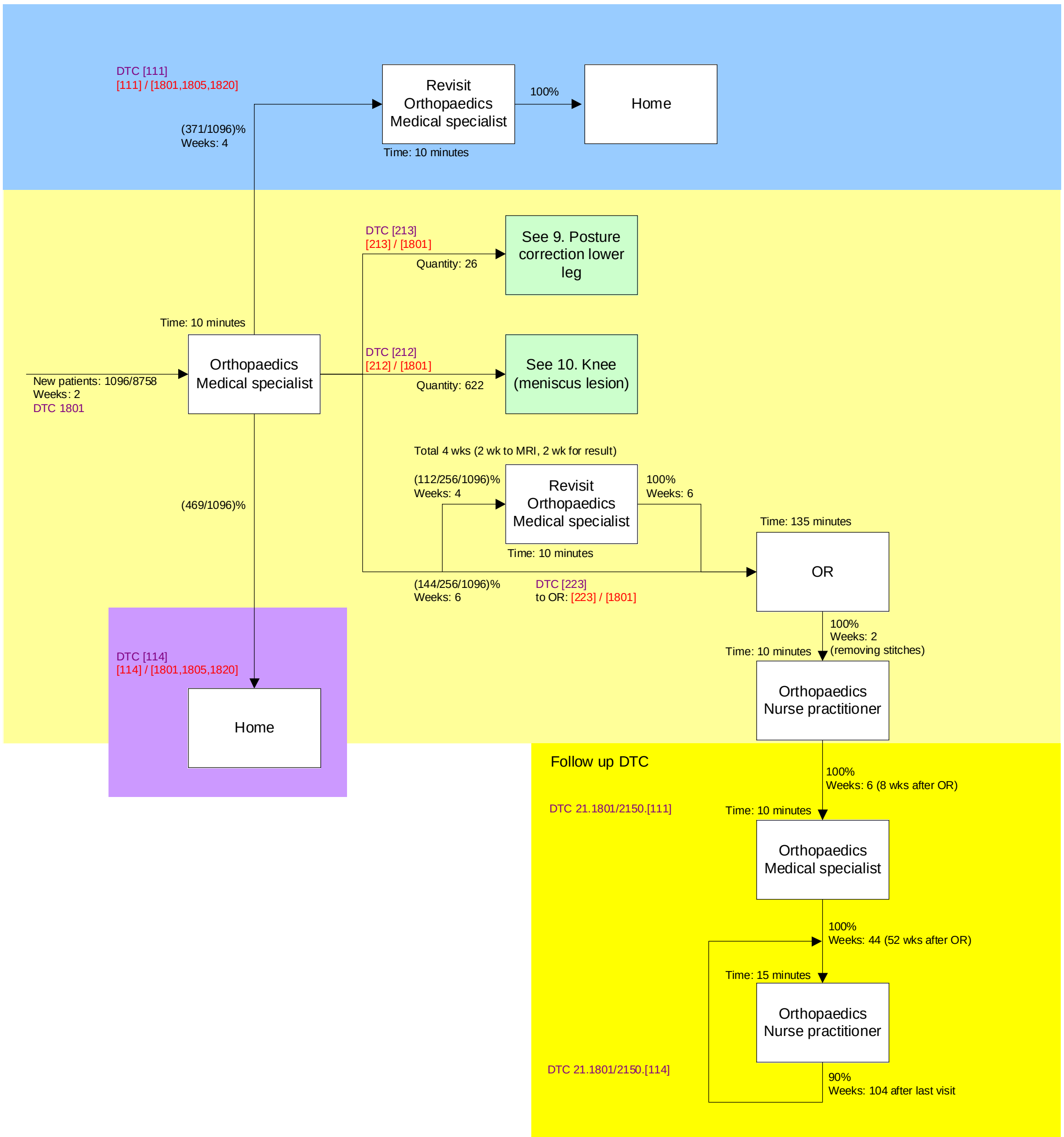
### 6. Hip (new) – 1701 Arthrosis: Pelvis / hip / upper leg



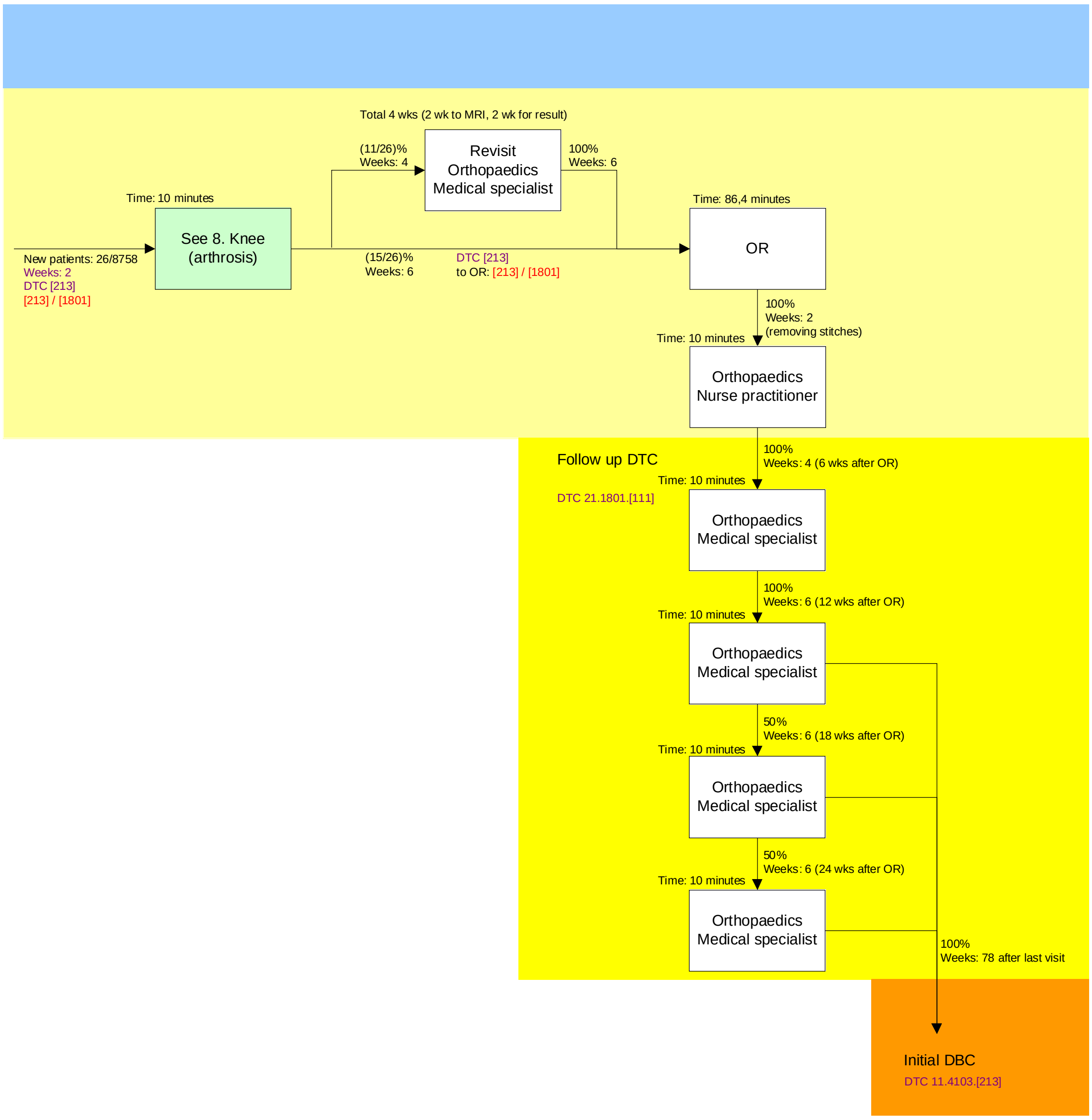
**7. Congenital hipsdysplasia – 1750 Congenital dysplasia/luxation**



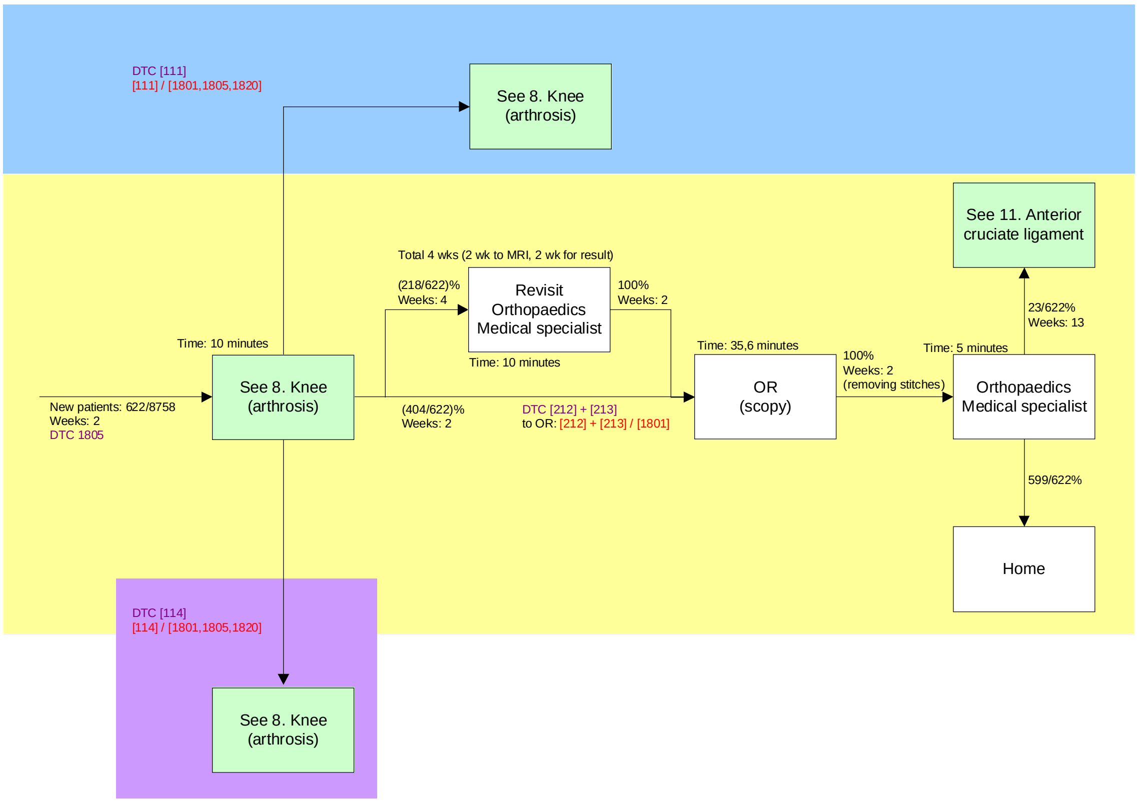
**8. Knee (new) - 1801 Arthrosis**



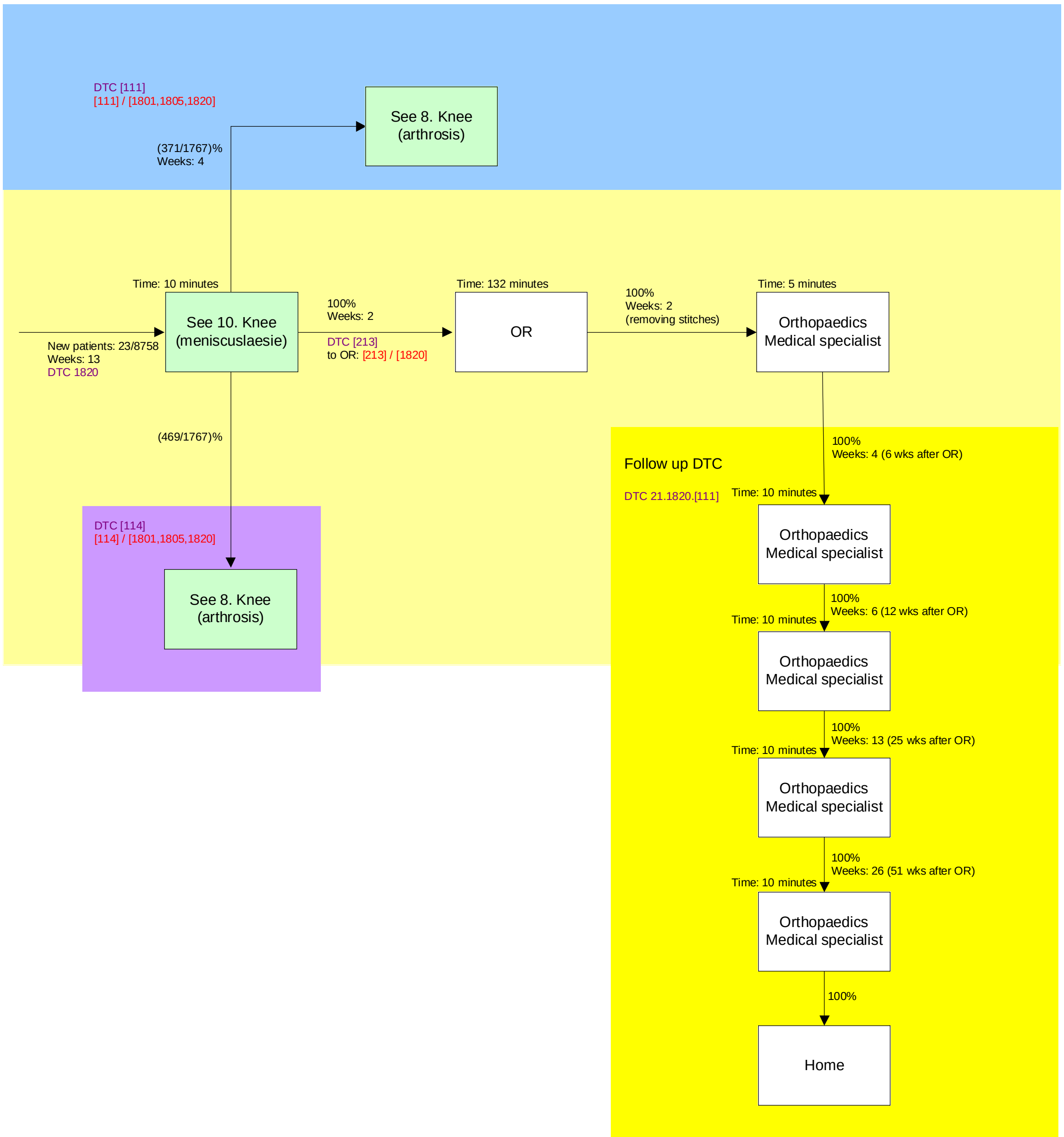
### 9. Arthrosis – 1801.213 Posture correction lower leg



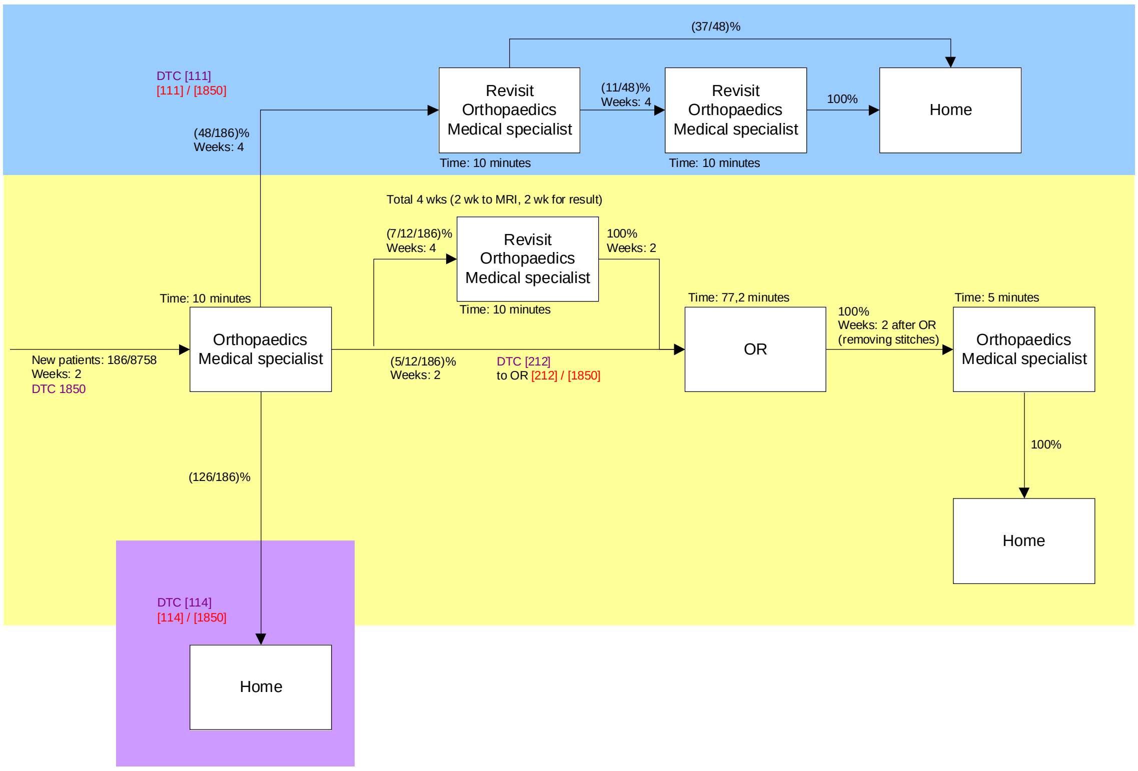
**10. Knee scopy – 1805 Meniscus lesion**



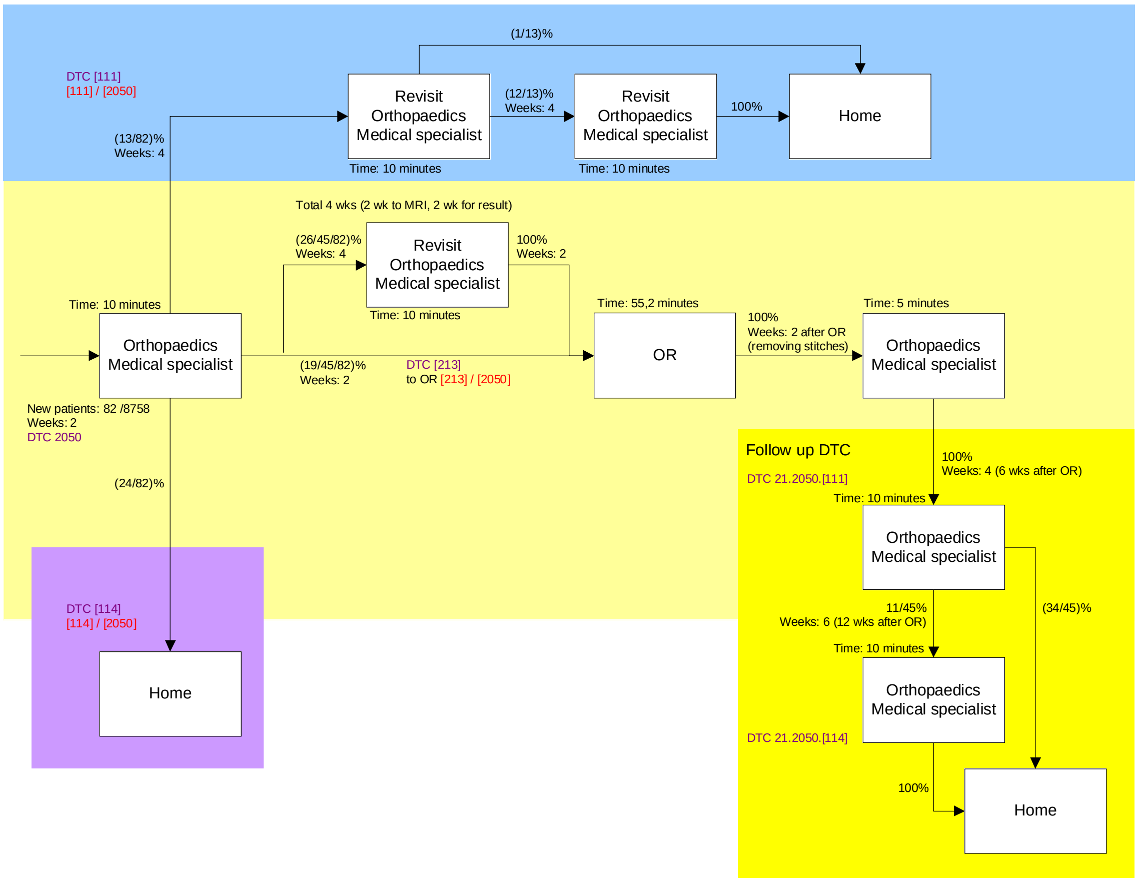
## 11. Anterior cruciate ligament reconstruction – 1820 Anterior cruciate ligament lesion



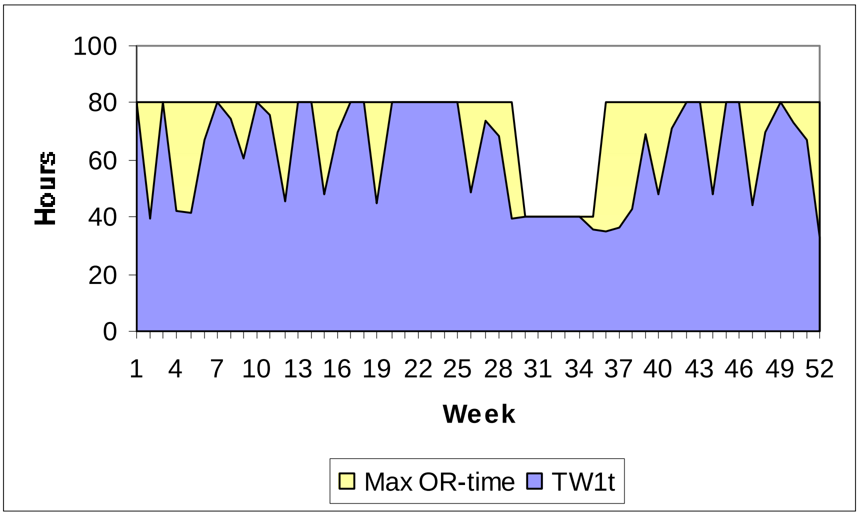
**12. Patellofemoral pain syndrome – 1850 Patellofemoral pain syndrome**



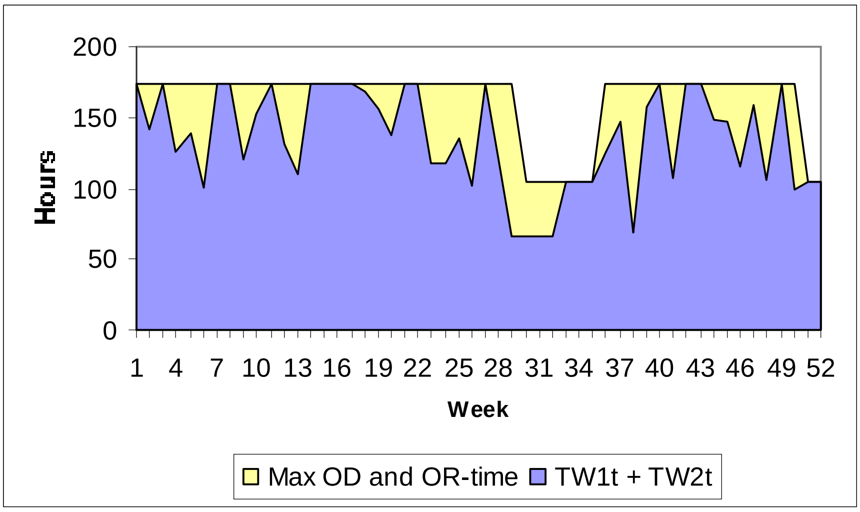
## 13. Hallux valgus – 2050 Hallux valgus



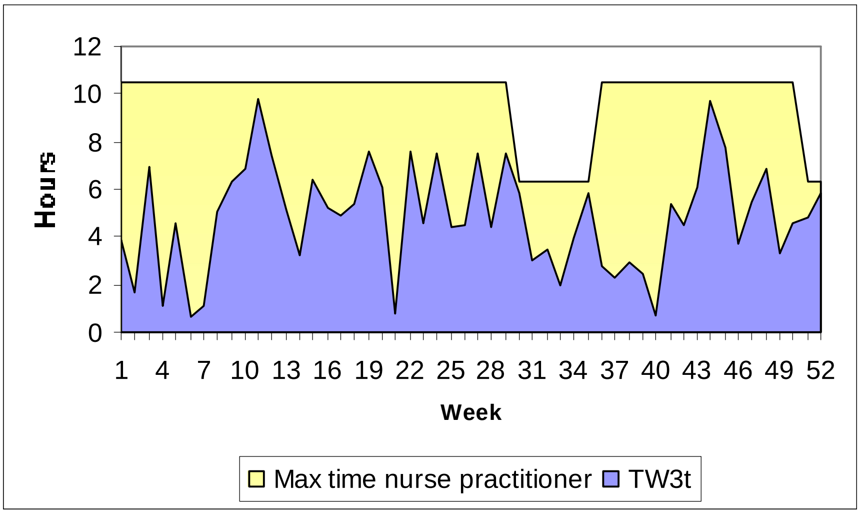
# Appendix VIII: Results step 1 of the model for Orthopaedics in DZ



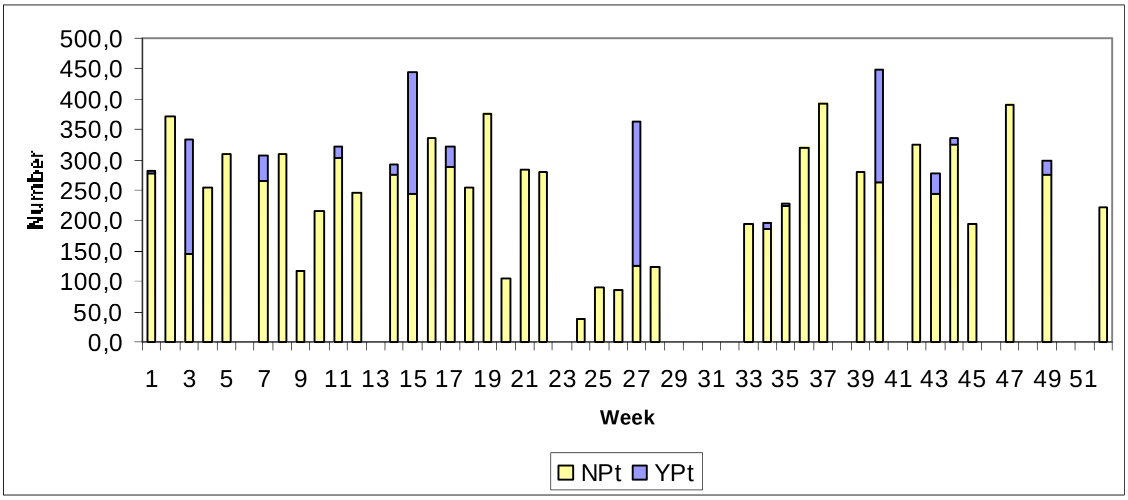

Appendix VIII - Figure 1: $TW_{1t}$ with respect to its maximum after step 1




Appendix VIII - Figure 2: $TW_{1t}$ and $TW_{2t}$ with respect to its maximum after step 1




Appendix VIII - Figure 3: $TW_{3t}$ with respect to its maximum after step 1




Appendix VIII - Figure 4: $NP_t$ and $YP_t$ with respect to its maximum after step 1

# Appendix IX: Results step 2 of the model for Orthopaedics in DZ

Below the results op the second step of the model applied for Orthopaedics. Each of the optimisation criteria is shown.

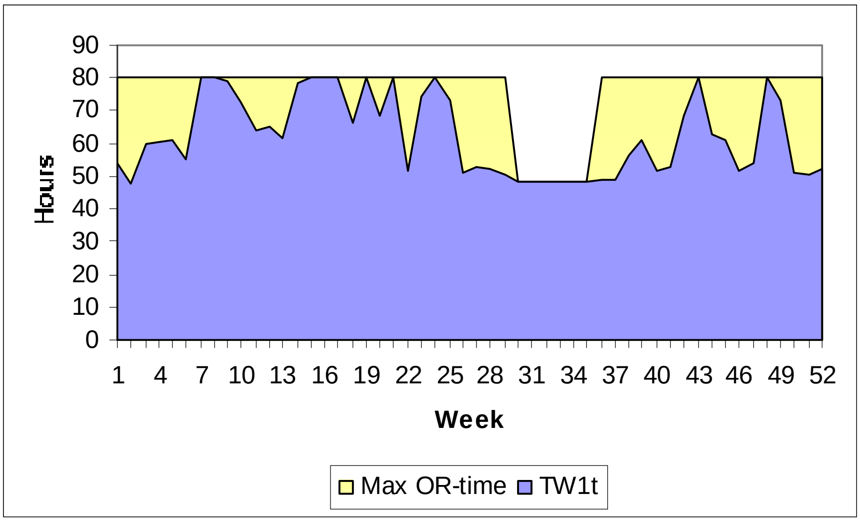
***Maximise the minimum number of new patients per week ($NP_t$)***

The results for the different minimum values are given in Appendix IX - Table 1. Appendix IX - Figure 1 until Appendix IX - Figure 3 illustrates the weekly capacity demand for each separate capacity compared with the maximum weekly available capacity (including day-offs). Finally Appendix IX - Figure 4 shows the number of new patients per week and the total number of 2-yearly revisit patients.

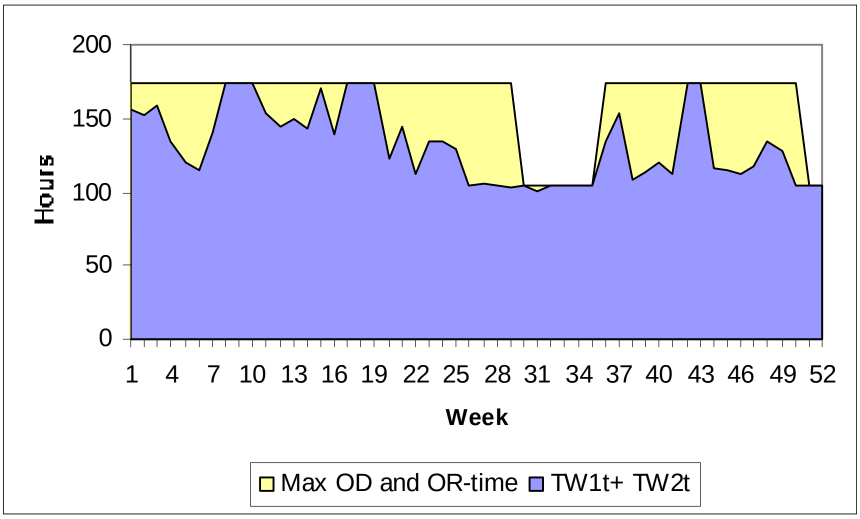
| ***Variable*** | ***Value*** |
|---|---|
| Minimum number of new patients ($NP_t$) | 117,7 |
| Minimum OR-time ($TW_{1t}$) | 2.787,7 |
| Minimum OD-time MS and AIOS ($TW_{2t}$) | 2.533,7 |
| Minimum OD-time nurse practitioner ($TW_{3t}$) | 222,2 |

Appendix IX - Table 1: Results minimum values by maximising the minimum value of $NP_t$

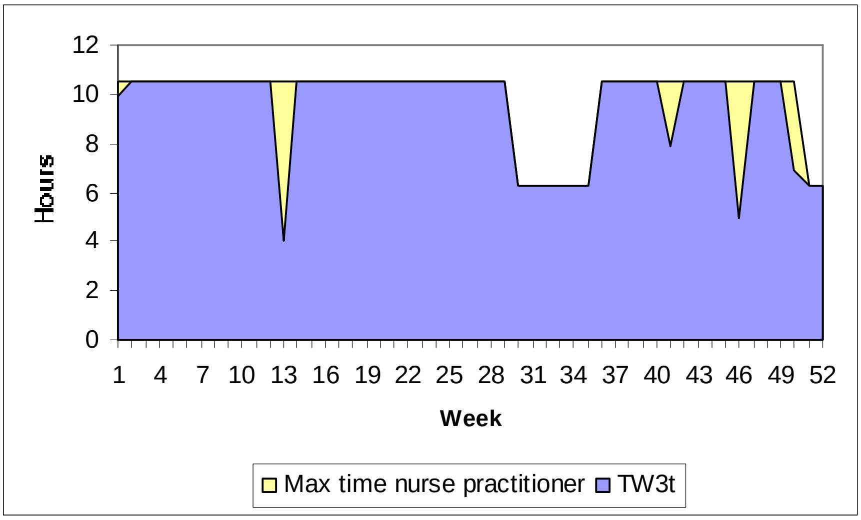
Although the optimisation criterion is to maximise the minimum number of new patients ($NP_t$), still high differences are seen in the number of new patients per week. The availability of the OR during the holiday limits the maximum value of the minimum number of new patients per week to increase.



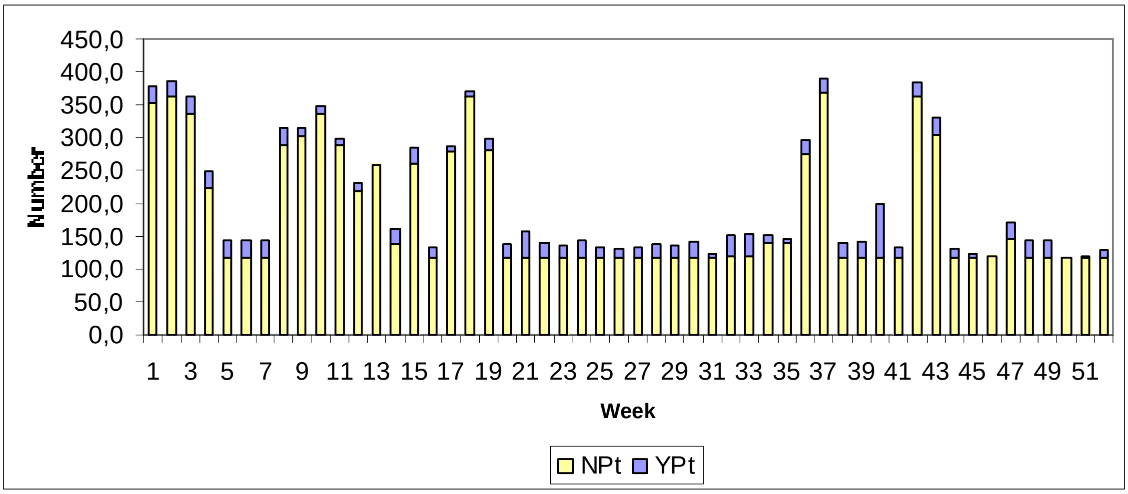

Appendix IX - Figure 1: $TW_{1t}$ with respect to its maximum after maximising the minimum value of $NP_t$




Appendix IX - Figure 2: $TW_{1t}$ and $TW_{2t}$ with respect to its maximum after maximising the minimum value of $NP_t$




Appendix IX - Figure 3: $TW_{3t}$ and $TW_{2t}$ with respect to its maximum after maximising the minimum value of $NP_t$




Appendix IX - Figure 4: $NP_t$ and $YP_t$ after maximising the minimum value of $NP_t$

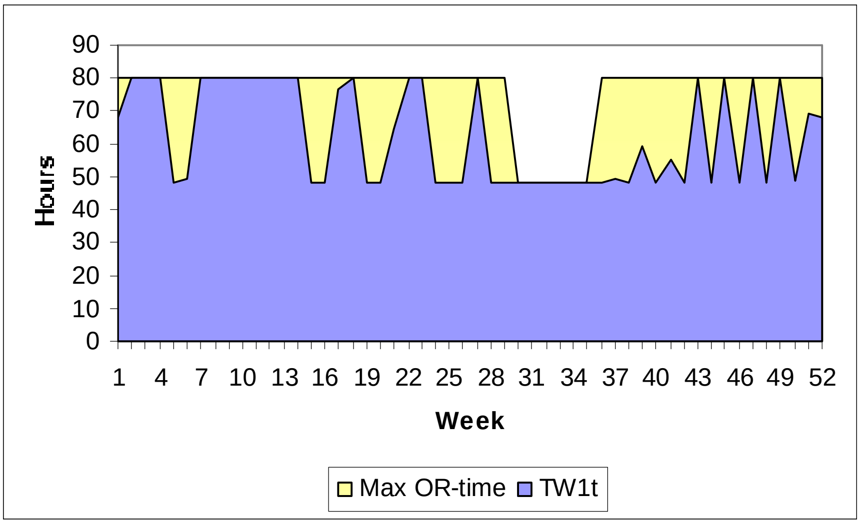
***Maximise the minimum OR-time per week ($TW_{1t}$)***

The results for the different minimum values are given in Appendix IX - Table 2. Appendix IX - Figure 5 until Appendix IX - Figure 7illustrates the weekly capacity demand for each separate capacity compared with the maximum weekly available capacity (including day-offs). Finally Appendix IX - Figure 8 shows the number of new patients per week and the total number of 2-yearly revisit patients.

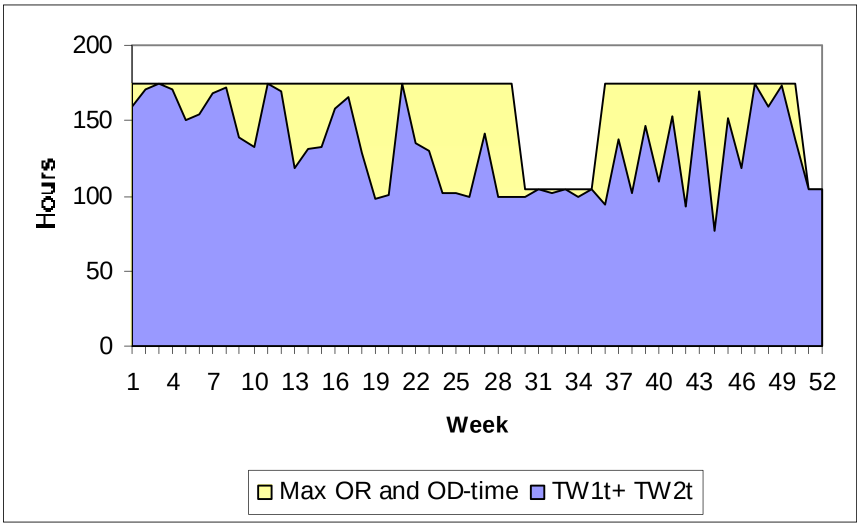
| ***Variable*** | ***Value*** |
|---|---|
| Minimum number of new patients ($NP_t$) | 0,0 |
| Minimum OR-time ($TW_{1t}$) | 2.820,0 |
| Minimum OD-time MS and AIOS ($TW_{2t}$) | 1.352,8 |
| Minimum OD-time nurse practitioner ($TW_{3t}$) | 249,1 |

Appendix IX - Table 2: Results minimum values by maximising the minimum value of $TW_{1t}$

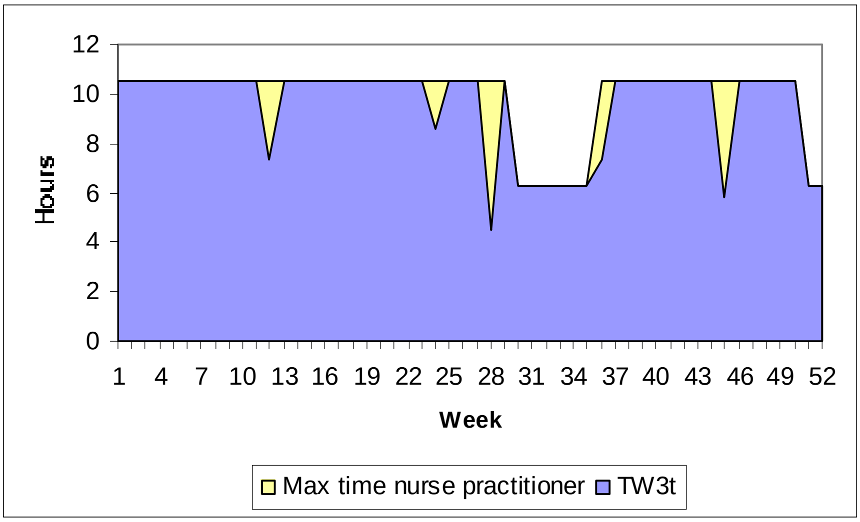
$TW_{1t}$ is better levelled over the week, but there are still peaks in OR demand. $TW_{3t}$ is also better levelled, but $TW_{1t}$ and $TW_{2t}$ together not. The same applies for $NP_t$ and $YP_t$.



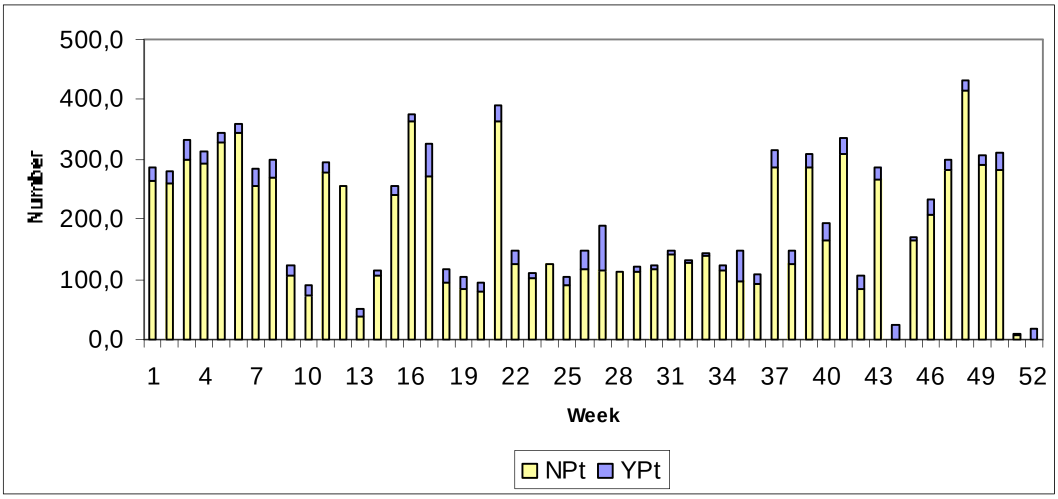

Appendix IX - Figure 5: $TW_{1t}$ with respect to its maximum after maximising the minimum value of $TW_{1t}$




Appendix IX - Figure 6: $TW_{1t}$ and $TW_{2t}$ with respect to its maximum after maximising the minimum value of $TW_{1t}$




Appendix IX - Figure 7: $TW_{3t}$ with respect to its maximum after maximising the minimum value of $TW_{1t}$




Appendix IX - Figure 8: $NP_t$ and $YP_t$ after maximising the minimum value of $TW_{1t}$

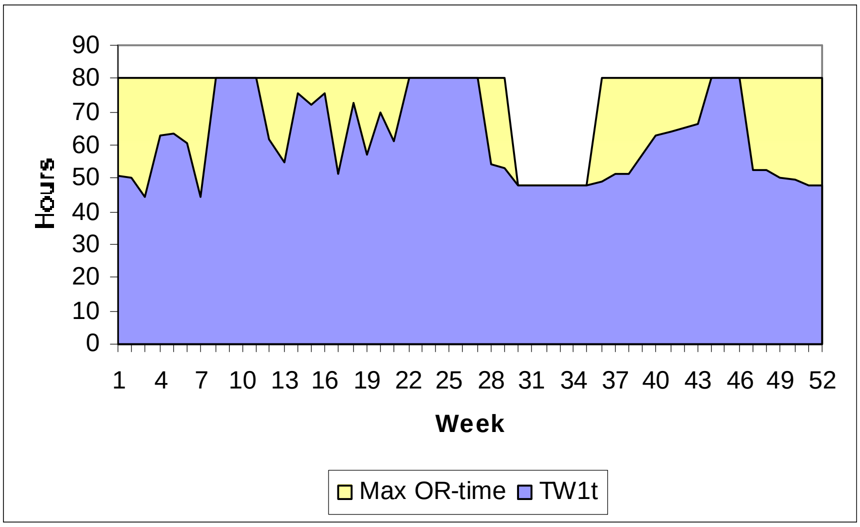
***Maximise the minimum OD time of MS and AIOS per week ($TW_{2t}$)***

The results for the different minimum values are given in Appendix IX - Table 3. Appendix IX - Figure 9 until Appendix IX - Figure 11 illustrates the weekly capacity demand for each separate capacity compared with the maximum weekly available capacity (including day-offs). Finally Appendix IX - Figure 12 shows the number of new patients per week and the total number of 2-yearly revisit patients.

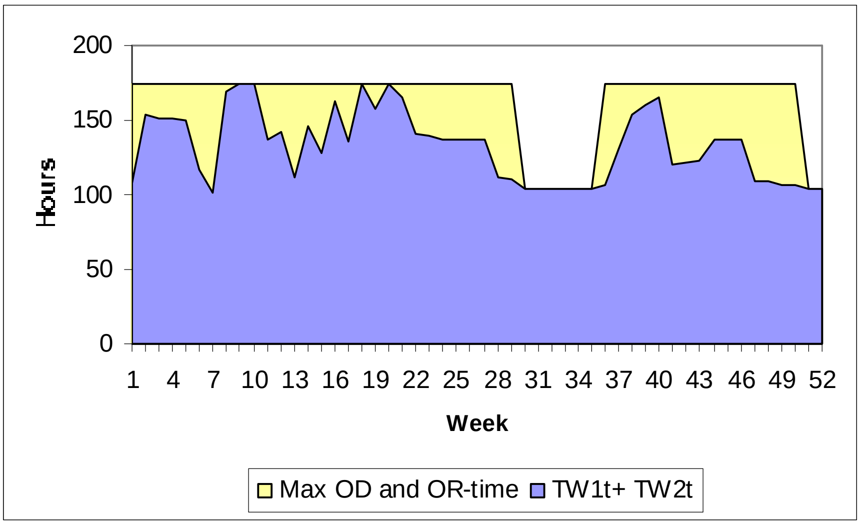
| *Variable* | *Value* |
|---|---|
| Minimum number of new patients ($NP_t$) | 0,0 |
| Minimum OR-time ($TW_{1t}$) | 2.605,0 |
| Minimum OD-time MS and AIOS ($TW_{2t}$) | 2.764,0 |
| Minimum OD-time nurse practitioner ($TW_{3t}$) | 109,0 |

Appendix IX - Table 3: Results minimum values by maximising the minimum value of $TW_{2t}$

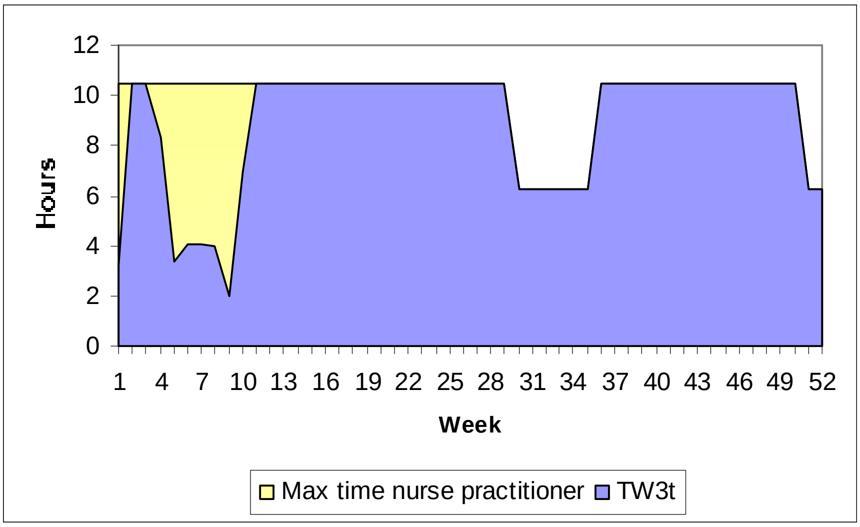
The maximum of the minimum value of $TW_{2t}$ increases and is better levelled over the weeks. Also $NP_t$ and $YP_t$ are better levelled. $TW_{3t}$ is not better levelled and $TW_{1t}$ shows no difference with respect when it comes to levelling.



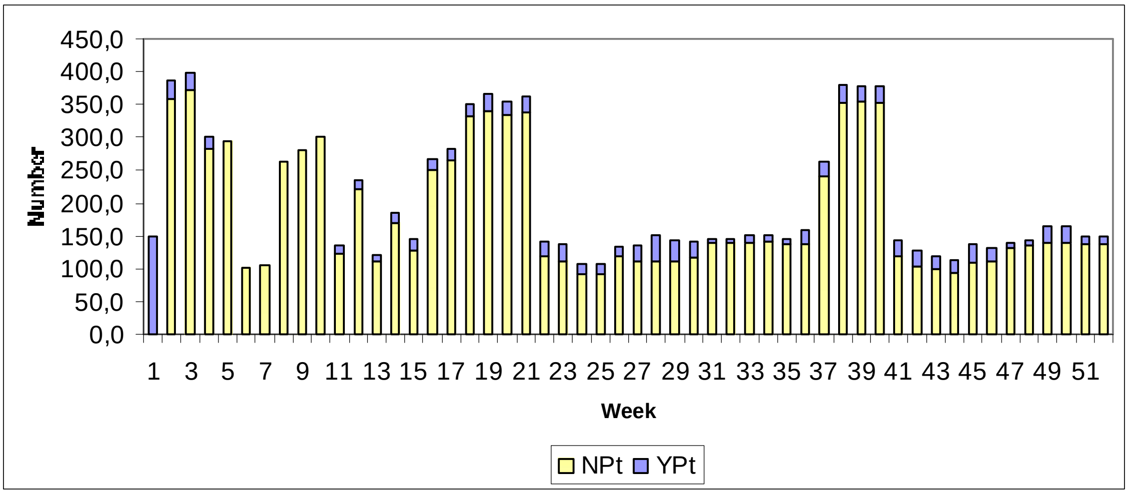

Appendix IX - Figure 9: $TW_{1t}$ with respect to its maximum after maximising the minimum value of $TW_{2t}$




Appendix IX - Figure 10: $TW_{1t}$ and $TW_{2t}$ with respect to its maximum after maximising the minimum value of $TW_{2t}$




Appendix IX - Figure 11: $TW_{3t}$ with respect to its maximum after maximising the minimum value of $TW_{2t}$




Appendix IX - Figure 12: $NP_t$ and $YP_t$ after maximising the minimum value of $TW_{2t}$

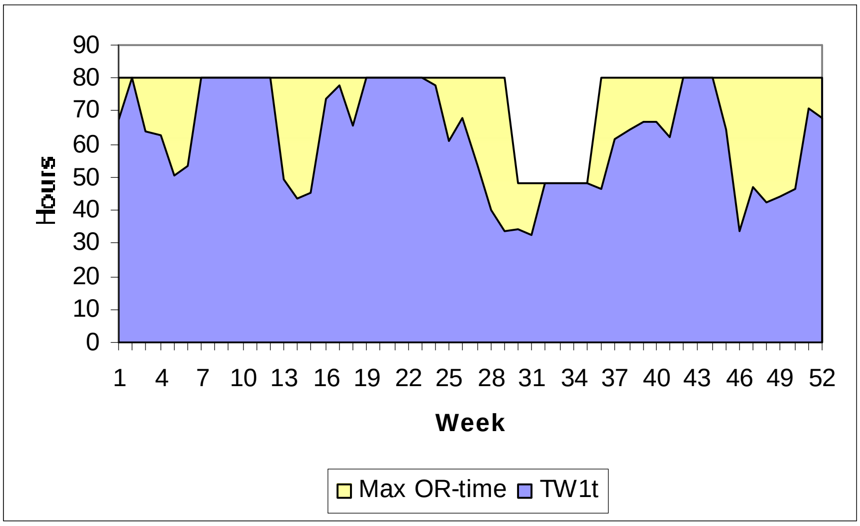
***Maximise the minimum OD time of the nurse practitioner per week ($TW_{3t}$)***

The results for the different minimum values are given in Appendix IX - Table 4. Appendix IX - Figure 13 until Appendix IX - Figure 15 illustrates the weekly capacity demand for each separate capacity compared with the maximum weekly available capacity (including day-offs). Finally Appendix IX - Figure 16 shows the number of new patients per week and the total number of 2-yearly revisit patients.

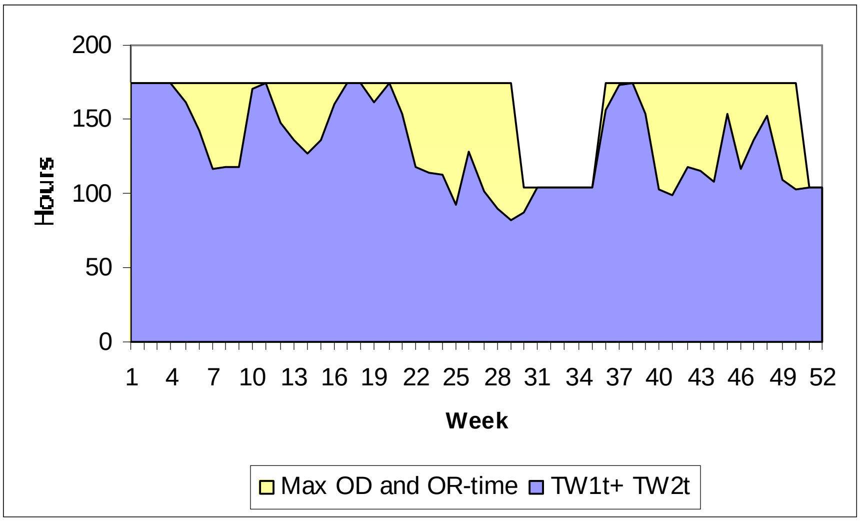
| ***Variable*** | ***Value*** |
|---|---|
| Minimum number of new patients ($NP_t$) | 0,0 |
| Minimum OR-time ($TW_{1t}$) | 1.891,8 |
| Minimum OD-time MS and AIOS ($TW_{2t}$) | 1.302,8 |
| Minimum OD-time nurse practitioner ($TW_{3t}$) | 351,0 |

Appendix IX - Table 4: Results minimum values by maximising the minimum value of $TW_{3t}$

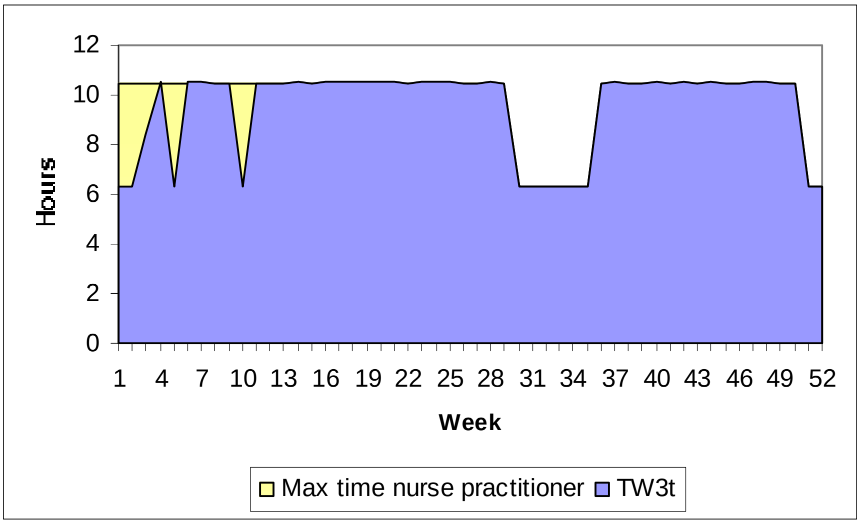
Maximising the minimum value of $TW_{3t}$ results in high variations in the number of new patients per week. The same hyearly revisits for $TW_{1t}$ and $TW_{2t}$. $NP_t$ and $YP_t$ are by far worse levelled over the weeks.



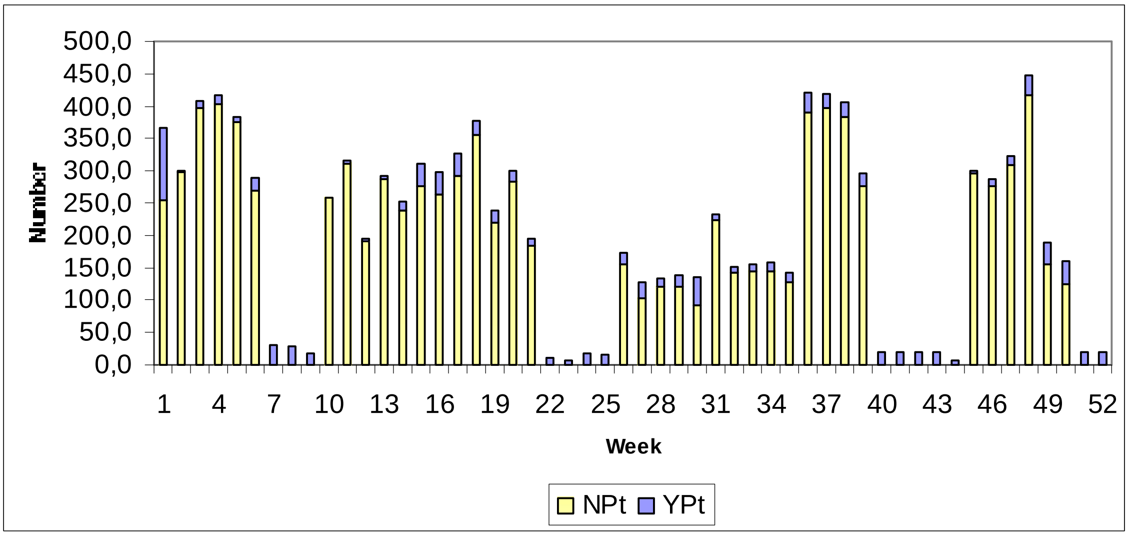

Appendix IX - Figure 13: $TW_{1t}$ with respect to its maximum after maximising the minimum value of $TW_{3t}$




Appendix IX - Figure 14: $TW_{1t}$ and $TW_{2t}$ with respect to its maximum after maximising the minimum value of $TW_{3t}$




Appendix IX - Figure 15: $TW_{3t}$ with respect to its maximum after maximising the minimum value of $TW_{3t}$




Appendix IX - Figure 16: $NP_t$ and $YP_t$ after maximising the minimum value of $TW_{3t}$