Bed blocking in Hospitals

Simulation of the Transmural Care Chain

Paula van Brakel

UNIVERSITY OF TWENTE.

Reinier de Graaf Groep

UNIVERSITY OF TWENTE. Reinier de Graaf Groep

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MSc Graduation Thesis

Author

Paula van Brakel

Student Industrial Engineering and Management, University of Twente

Production and Logistics Management

p.vanbrakel@student.utwente.nl

Committee

John Verver

Manager of Innovation

Reinier de Graaf Groep, Delft

Anja van der Eijk

Manager team transfer nurses

Reinier de Graaf Groep, Delft

Erwin Hans

Associate Professor University of Twente

Peter Hulshof

PhD Candidate University of Twente

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Preface

I wrote this report commissioned by Reinier de Graaf Groep (RdGG), a Dutch hospital, to obtain my graduation as Master of Science in Production and Logistics Management. It was a great experience to get a sneak preview behind the scenes of a hospital, which is an interesting environment.

The subject of this thesis, bed blocking, is something where we all may deal with. My experience was with my grandmother who had to wait over a week in the hospital for a nursing home bed, after having a stroke. My aunt just became a member of a revalidation home to get preference in case she needs it one day. But we are not only confronted with it by our direct environment: we all pay the costs of the healthcare system, while the government attempts to cut costs.

I thank all who gave (in)direct support in writing this thesis. My special thanks go to Peter Hulshof, Erwin Hans, John Verver, Anja van der Eijk, and Kees Broekman. Peter Hulshof always took the time to thoroughly review my work and helped to deal with problems in a constructive way. Erwin Hans made me enthusiastic about the healthcare sector in the first place, and gave me support and feedback within his busy schedule. I thank John Verver for the opportunity to do this research and for sharing his expertise in the area of process improvement. Anja van der Eijk and her team of transfer nurses helped me out in the understanding of problem and process. Finally my acknowledgement goes to Kees Broekman, who has started to involve different parties in the chain to this project; without support and cooperation of all people involved, the road to success is rough.

This thesis is for everybody interested in the Healthcare sector and/or flow optimization. While reading this report let your mind spin; with various areas of knowledge and by reshaping existing approaches, flow between multiple health care institutions will become more efficient. We get there step by step.

Paula van Brakel
June 2010

Management Summary

Problem description

This research is done in the general hospital Reinier de Graaf Groep (RdGG). RdGG, just like many hospitals, has to deal with the problem of bed blocking: patients who need no further medical treatment are waiting in the hospital for aftercare.

The congestion of departments by bed blocking has a negative impact on both costs and service level of the provided care. Contradicting financial objectives of nursing homes and hospitals make this a continuous problem. Nursing homes aim at maximising bed occupation, while hospitals aim for maximum bed availability at nursing homes. Increased availability of nursing home beds allows patients who do not require further medical care to go to a nursing home, so it becomes possible to admit new patients in the hospital. The impact of every extra day spent in the hospital increases with the trend of decreasing lengths of stay in hospital care.

Bed blocking can be caused by lack of transparency and bad communication processes between the hospital and cooperating nursing homes. On the other hand, lack of available nursing home beds causes bed blocking. Fluctuations in demand and patient preferences for specific nursing homes, in turn, hinder balancing occupation. In the literature, little research is available on how to integrate care needs that span over different care providers. We study the dynamics of a smooth and timely flow of patients from a hospital towards nursing homes.

Objective

To design a tool that allows analysis of various configurations of transmural networks, in order to minimise bed blocking.

The study explores interventions of bed reservation by hospitals and of (temporary) reallocating capacity to other patient categories. The main performance indicators we use are waiting time (bed blocking days), occupation of nursing home departments and throughput of nursing homes.

Approach

Existing models in the literature lack detail and do not allow general distributions. We develop a discrete-event simulation model as an analysis tool for various interventions and scenarios. We take into account the main patient and information flows. The process starts with the patient’s arrival at the policlinic and ends with the patient’s dismissal from the nursing home.

Results

The results of the discrete-event simulation are at this point intended to be indicative of general patterns rather than descriptive of exact behaviour. These preliminary results can be used to enthuse involved care providers to collect more data. We use a base scenario to analyse results from three interventions:

- *Advance communication process*
  In this intervention, the process of communication from the hospital to the nursing home starts earlier. The expected duration of the communication process remains 4 days. The earlier communication results in a reduction of average waiting time in the hospital of 3.3 days.
- *Transfer beds*
  The intervention entails the introduction of an extra department that serves as temporary stay for patients who wait for nursing home care in wards of the hospital. The simulation results show that, for example, a small transfer department of 5 beds halves the bed blocking days in wards, while the occupation of this transfer department is 90 percent. The simulation model can be used to find a balance between the reduction in waiting time on wards and the occupation of the transfer department.
- *Reservation of nursing home beds*
  The intervention holds that the hospital reserves beds of nursing home departments, such that only patients from the hospital are admitted on these departments. The other, non-reserved, nursing home departments accept all patient types. The simulation results show that bed reservations starts to have impact when the expected occupation of the reserved nursing home beds approaches or exceeds occupation of the remaining nursing home beds. The waiting time of patients at home increases with bed reservation; the simulation model can be used to find a balance between waiting times of the various patient groups and occupation of the various departments.

These preliminary results show the possibilities of system improvement. The model gives the opportunity to quantify the expected results for a range of interventions and scenarios concerning patient flow.

Conclusions and recommendations

The tool we developed allows analysis of various configurations of transmural networks. At this moment we obtained various general insights concerning these configurations.

Reservation of a small number of beds seems an interesting option, since the waiting time in the hospital (bed blocking) drops, as well as overall waiting time for nursing home beds. This is influenced by the property of giving priority to patients that come from another nursing home department. To further reduce bed blocking in hospitals with bed reservation, the reservation should be such that nearly all hospital patients can be admitted on the reserved beds.

The research subject should not only be about how to reduce bed blocking, but to seek opportunities to cope with the phenomena in a more efficient way. An example is the use of a transfer department to reduce the waiting time in the, more expensive, wards. Transfer beds are especially interesting if beds available on other departments can be used when these are vacant for a longer time period. Adapted personnel planning is then important to obtain most benefit.

The context analysis shows that registration, communication and forecasting allow for improvement in RdGG. We recommend RdGG to pay attention to the following aspects:

- Set clear definitions of processes and concepts. This includes taking care of correct internal registration.
- Generate and monitor information of outflow and bed blocking using the current systems available.
- Improve the cooperation with nursing homes by earlier communication. The nursing homes should have insight in patient arrivals at the hospital and the hospital should have insight in bed availability at nursing homes. This allows for improved planning and forecasting of patient streams in the future.
- Collect data and make forecasts of patient demand in nursing homes. This allows balancing demand of the hospital and supply of nursing homes.

The involvement of the stakeholder groups for further analysis and improvement is the next step towards the reduction of bed blocking. When more and accurate data is collected, a more accurate analysis of system behavior can be achieved.

We recommend further research in the influence of the hospital planning process on bed blocking and forecasting using a patient's profile at hospital arrivals. Another interesting extension is research from the perspective of a nursing home. The simulation model is less applicable for capacity allocation, since this analysis is very time consuming. Analytical approaches can be used here, using simulation as validation and for final improvement iterations.

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Glossary

Abbreviation (if relevant)	***Full text English***	***Full text Dutch (if relevant)***	***Description (if necessary)***
RdGG		Reinier de Graaf Groep	
PvF		Pieter van Foreest	
CIZ	Centre for indication required care	Centrum Indicatiestelling zorg	Institution that indicates what nursing home care a patient requires by means of ZZPs.
ZZP	Weight of Care	Zorg Zwaarte Pakketten	Package that indicates the aftercare intensity a patient needs. Financial compensation is coupled to each of the packages.
DRG	Diagnosis Related Group	Diagnosebehande-lingcombinatie	Contain the financial compensation for the treatment of a patient with a certain clinical picture.
MDO	Multi disciplinary meeting	Multidisciplinair overleg	Meeting in the hospital with multiple involved disciplines (nurse, doctor, etc.) to discuss individual patients.
NH	Nursing home	Verpleeghuis	
SS	Short stay	Kortdurend verblijf	Nursing home care for patients with a need for revalidation (somatic) or screening of their care needs (cognitive).
LS	Long stay	Langdurend verblijf	Nursing home care for patients with a long term care need.
POINT		**P**unt voor **O**verdracht, **I**nformatie, **N**aslag en **T**ransfers	Computer program used for communication related to patient transferring.
AWBZ		Algemene Wet Bijzondere Ziektekosten	
ChipSoft			Computer program in RdGG used for registration of admissions and patient information.
	Transfer department	Transferpunt	
	Home for the elderly	Verzorgingshuis	
	Ward	Verpleegafdeling	
	Intermediate department	Schakelafdeling	
	Recovery unit	Herstelunit	
	Length of stay	Ligduur	
	Medically ready	Medisch klaar	A patient needs no hospital care anymore.
		Zorgkantoor	Institution that is responsible for the execution of the AWBZ. It strives to balance nursing home supply and demand in a particular region.

Table 1 Glossary; abbreviations and translations

1 Introduction

The population of the Netherlands is greying; the past twenty years the share of people older than 80 years has increased with more than one third. Elderly recover slower from medical injuries than younger people, and often cannot take care of themselves anymore when they leave the hospital. To take care of these people, many types of aftercare institutions exist. The transition of a patient from one institution to another is often delayed: a patient stays longer in the hospital than necessary, blocking a bed for other patients. This phenomenon is referred to as 'bed blocking'. The impact of every extra day spent in the hospital increases with the trend of decreasing lengths of stay in hospital care. More patients could be treated on this day. These developments require synchronization of hospitals and aftercare institutions.

Bed blocking has a negative impact on a patient's well-being and it increases the cost of care. Many hospitals in the Netherlands cope with this problem. The complexity of the problem is mainly due to the different institutions involved, what requires integration of the care chain. Research in healthcare logistics increased in recent years, but is still relatively new on the subject of integration through the care chain.

This research project concerns the development of a model that analyses the dynamics and interventions in patient flows from hospitals to nursing homes. Paragraph 1.1 starts with general information about 'Reinier de Graaf Groep', the hospital where this research is done. Paragraph 1.2 gives the problem description of bed blocking. The research design in Paragraph 1.3 describes the objective and research questions. Paragraph 1.4 gives an outline of the remainder of this report.

1.1 Research context

1.1.1 *Reinier de Graaf Groep*

This research is done at 'Reinier de Graaf Groep' (RdGG), a hospital that focuses on quality and process improvements. RdGG is a generic hospital situated in Delft, the Netherlands. Table 2 gives key figures regarding the size of the hospital.

Key figure	***Amount***
Acknowledged beds	881
Admissions	26,431
Days of inpatient treatment	134,520
1st outpatient visits	161,715
Days of Day-care treatment	23,352
Members medical staff	200
Employees	3,114
FTEs	1,983
Turnover	161 million euro

Table 2 Key figures RdGG (RdGG, 2008)

RdGG's mission is 'to offer quality in specialist medical care'. The quality of care is defined in six dimensions, based on the American quality program 'Pursuing Perfection' (Table 3).

Dimension of quality	***Clarification***
Patient centred	Care meets needs, wishes and values of the patient
Safety	Avoid risks and errors that can damage patients and employees
Effectiveness	Provide reliable, evidence-based care
Efficiency	Avoid care that does not contribute to patient demand and avoid waste
Timeliness	Provide care on the right moment and avoid waiting time for patient and employee
Equality	Provide equal care to all patient groups

Table 3 RdGG's six dimensions of quality based on Pursuing Perfection, 2009

RdGG supports this mission with projects on process improvements throughout the hospital. They use the method 'Lean Six Sigma': a combination of quality improvement methods 'Lean' and 'Six Sigma' (George et al., 2003). One of these projects investigated the length of stay of patients in a ward. Bed blocking came up as an important cause for the long length of stay (Pelle and Haverkamp, 2009).

1.1.2 *Transmural care chain*

RdGG is part of a transmural care chain; the hospital is a link in the beginning of the chain of a patient's flow to multiple care institutions. Various organisations in the region of RdGG supply aftercare with one or more institutions in the categories: home care, nursing home, care for elderly, and palliative care. Approximately 80 percent of the outflow from RdGG to nursing homes is to a specific organization, called Pieter van Foreest (PvF).

The inflow in nursing homes finds its source in hospitals as well as patients who come directly from their own homes. To which nursing home a patient goes, does not exclusively depend on the required care. Other factors are involved, like the patient's preference. A hospital department with so-called transfer nurses arranges the outplacement of patients who need aftercare. They communicate with the parties involved. Paragraph 2.1 will explain the details of the process of outplacement.

1.2 Problem description

Patients wait in a hospital bed for aftercare, while they need no hospital treatment anymore. The Innovation Coordinator of RdGG requires that the amount of bed blocking days is minimised. There are two main reasons why RdGG wants to minimise bed blocking:

- *Cost perspective*
    - The care the patients receive in the hospital is more expensive than in nursing homes.
    - Patients are literally 'blocking' the beds meaning the hospital cannot admit another patient in the bed.
- *Service perspective*
    - A patient receives the wrong level of care, also called 'Alternate Level of Care' (Rock et al., 1995). Several studies showed that this has a negative influence on the well-being of the patient (Jasinarachchi et al., 2009).

We estimate in Paragraph 2.5 that bed blockers cause 2.3 percent of the ward occupation in RdGG (ChipSoft, 2008), which causes a financial loss of €880,000 per year. To improve patient flow through the care chain, the hospital recently introduced a transfer department and a recovery unit. The effect of these organisational interventions is unknown, nevertheless RdGG desires research in possibilities for further improvement.

The problem of bed blocking occurs mainly with patients going to nursing homes. Bed blocking days are influenced by the moment of establishment a patient needs aftercare, the work process (internal) and the waiting time of a patient for an available bed in an aftercare institution (external). Approximately 10 percent of the patients that are admitted to RdGG need aftercare when leaving the hospital. As Paragraph 2.1 will describe, only 30 percent goes to nursing homes, but this group causes 80 percent of the bed blocking days.

RdGG wants to improve the synchronisation with the nursing homes, which must lead to a reduction of bed blocking days. This requires alignment of all logistical processes within the hospital, with the nursing homes and of the care chain. Six aspects that may lead to reduction of bed blocking are:

1. The capacity of both the hospital and the nursing homes
2. The flow of patients (e.g., admission at an intermediate department)
3. The communication of the hospital with nursing homes
4. The transparency of capacity and demand availability
5. The reward system of hospitals and of nursing homes
6. The moment of indication of care for a patient

The literature acknowledges that bed blocking is a problem, but research in this area is emerging only recently. "*The importance of well-integrated care is increasing, by the more complex medical picture of elderly and the issue of bed blocking, which are likely to intensify as the population ages*." (Travers et al., 2008)

RdGG wants to minimise bed blocking; a patient should immediately leave the hospital after medical treatment. Bed blocking days negatively affect the hospital, both from a financial and service perspective.

1.3 Research design

This paragraph outlines the research objective and how this research is done.

1.3.1 *Research objective*

The objective of this research is:

To design a tool that allows analysis of various configurations of transmural networks, in order to minimise bed blocking.

We define bed blocking as *the number of days a patient is waiting in the hospital, while the patient is "medically ready"*. The interventions can be both at RdGG and nursing homes.

1.3.2 *Scope*

In this research we analyse the problem of bed blocking in RdGG caused by nursing homes. Further analysis of the internal communication process in the hospital, between transfer nurses and nursing departments, is outside the scope of this research.

We design a model to explore possibilities and impact of organisational interventions and scenarios. We focus on the development of the model and use raw data for analysis of interventions. The obtained results are intended to be indicative of general patterns rather than descriptive of exact behaviour. The model can be used in a more descriptive way when there is high quality data available. The preliminary results can be used to enthuse involved care providers to collect more data. We will not give concrete recommendations concerning an intervention, nor implement an intervention.

1.3.3 *Research questions*

We divide the research problem into five research questions.

1. *What is the current situation of bed blocking at RdGG?*
    a. What are the consequences of bed blocking from the viewpoint of the different stakeholders involved? (Paragraph 2.2)
    b. Which information flows can be identified in the process of outplacement of a patient? (Paragraph 2.3)
    c. What flows of patients to nursing home departments can be identified? (Paragraph 2.1.2)
        i. What is the length of stay in the nursing home departments?
        ii. Which number of patients goes to which institution?
    d. What is the performance of the current situation? (Paragraph 2.5)
2. *What causes bed blocking in RdGG?* (Paragraph 3.2 and Paragraph 2.5.2)
3. *What interventions may reduce bed blocking by nursing homes?*
    a. Which solutions have been tried in the past by this and other hospitals? (Chapter 2.3)
    b. Which solutions can be found in the literature? (Chapter 3)
    c. What are the restrictions concerning solution alternatives for RdGG? (Paragraph 2.4)
    d. What interventions can be designed for RdGG? (Paragraph 4.1)
4. *How can we model the current situation and the designed interventions?*
    a. What decision model can we use to balance stakeholder interest while minimising bed blocking days? (Paragraph 3.3 and Paragraph 4.2.3)

b. What performance indicators should be used for the involved stakeholder groups? (Paragraph 4.2.6)

5. *What is the performance of the interventions?*

a. What is the performance of selected interventions in comparison to the base situation? (Paragraph 5.4)

b. How could the model be used in further analysis of interventions? (Chapter 6)

1.3.4 *Project framework*

This research project is structured in four phases: orientation, analysis, design and performance. Figure 1 shows the project framework with the actions involved and corresponding chapters.

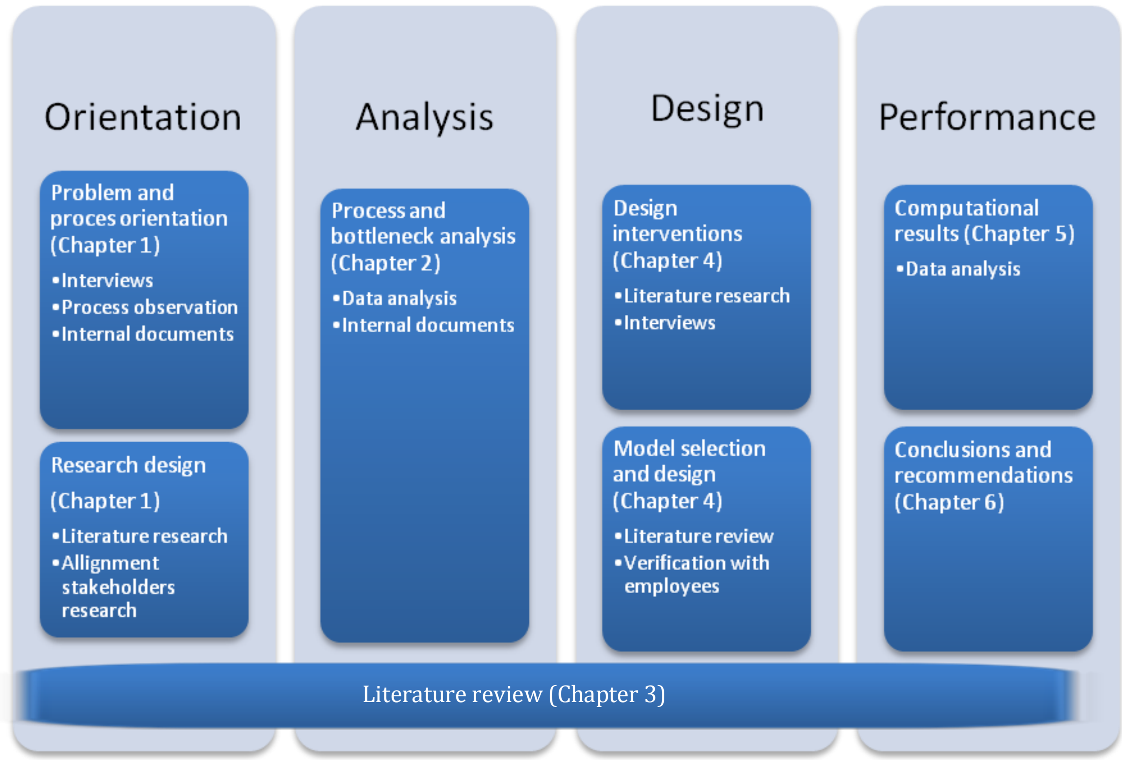


Figure 1 Project framework

1.4 Report outline

This report is structured in six chapters:

- **Chapter 1 Introduction** – *outlines the structure of the research by defining the problem and research questions*
- **Chapter 2 Problem analysis –** *describes the processes related to the bed blocking problem, the current performance and establishes bottle necks*
- **Chapter 3 Literature review –** *describes relevant literature for this study*
- **Chapter 4 Simulation model –** *contains a description of the conceptual model and intervention design*
- **Chapter 5 Computational results –** *contains the computational results and sensitivity analysis*
- **Chapter 6 Conclusions and recommendations –** describes recommendations for *organisational implementation and further research*

2 Context analysis

This chapter describes the context of the problem of bed blocking in RdGG. Paragraph 2.1 shows that the problem of bed blocking occurs mainly with patients that transfer to nursing homes. Paragraph 2.2 explains elements of the Dutch care system that are relevant for our study and describes the interests of the various involved stakeholders. Paragraph 2.3 describes the process from admission to aftercare as well as nursing home policy. Paragraph 2.4 outlines what influence hospitals and nursing homes have on patient flow. Paragraph 2.5 gives the current performance. Paragraph 2.6 summarises the fundamental observations for the literature review and the model design in respectively Chapter 3 and Chapter 4.

2.1 Bed blocking

2.1.1 *Definition bed blocking day*

When a patient needs no hospital care anymore, we call the patient 'medically ready'; the patient can then leave the hospital. In an ideal situation, a patient immediately leaves the hospital when the patient is medically ready. Every day a patient is still in the hospital, while having the status 'medically ready', is a bed blocking day.

RdGG distinguishes two kinds of bed blocking days that differ in the way they are financed. When a patient should go to a nursing home, the patient's status is 'V'. 'Algemene Wet Bijzondere Ziektekosten' (AWBZ) finances patients of type 'V', and a patient pays a personal contribution that is income dependent. For all other patients (not nursing home), the patient's status is 'W'. Health insurances fully finances patients of type 'W'. The hospital gets 162 euro per day for every bed blocker that the care administration registers.

2.1.2 *Demand for aftercare and bed blocking*

Approximately 10 percent of the admitted patients in RdGG need aftercare after their stay in the hospital. Various organisations in the region supply aftercare with one or more institutions in the categories: home care, nursing home, care for elderly, and palliative care. Appendix B gives a short description of all categories. Figure 2 shows the outflow of patients to the different categories of aftercare institutions. We use the patient streams in the period July 2008 to July 2009, because the system that registers this data was not in use before that period. We indicate nursing home departments with 'NH'. 2150 patients required aftercare that year, of which approximately 30 percent in a nursing home.

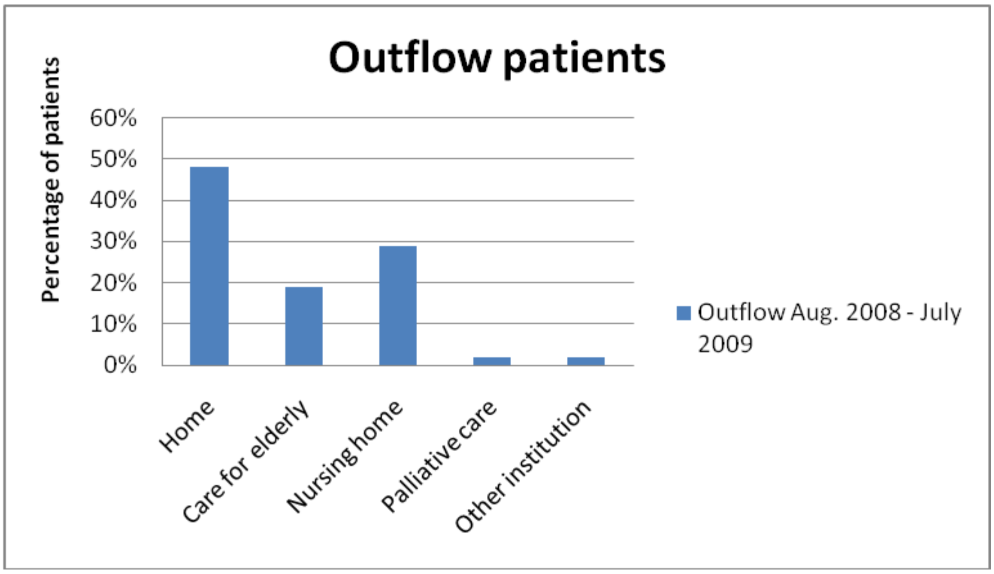


Figure 2 Outflow patients to after care institutions, N=2150, Aug.08 - Jul.09, POINT RdGG

Approximately 10 percent of the patients who need aftercare is recorded as bed blocker for 1 or more days. Figure 3 shows the destination of these patients differed in the main categories: home, nursing home and home for the elderly (ChipSoft, Jan. – July 2008 and Jan. – July 2009).

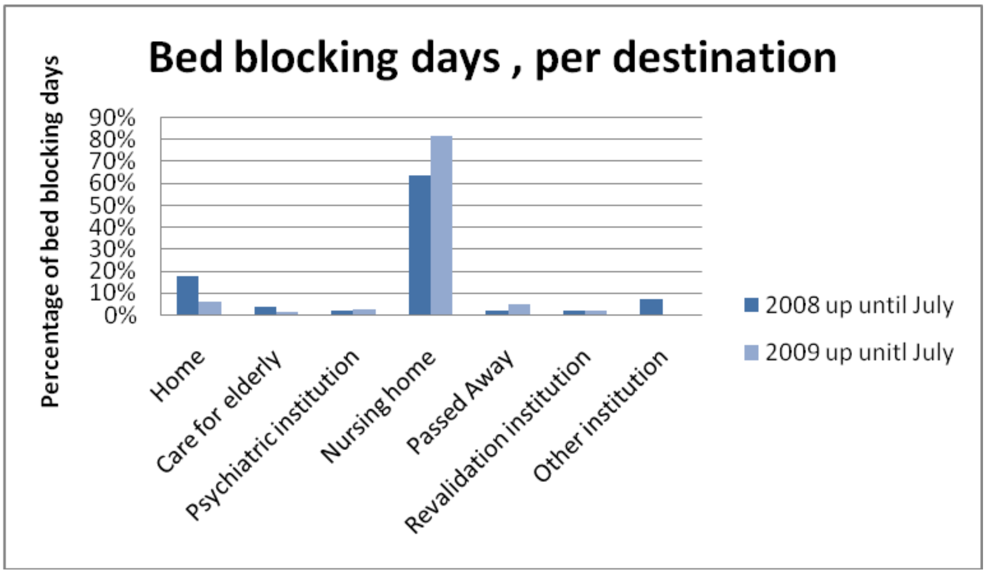


Figure 3 Destination of patients causing bed blocking days, 08/09, ChipSoft RdGG

In 2009, approximately 80 percent of the bed blocking days are caused by patients going to nursing homes, while only 30 percent of the complete patient group goes to a nursing home. The process of outplacement Paragraph 2.2 describes, is similar for all those patient groups, what suggests that specifically the nursing homes are of influence in this problem.

2.1.3 *Registration bed blocking days*

When a patient is medically ready, but cannot immediately leave the hospital, the patient should be registered as a bed blocker. Administrative reasons require the registration, but more important are the financial reasons. If the hospital does not register a bed blocker, they do not receive any compensation.

The experience of (transfer) nurses is that it rarely happens that a patient instantly leaves the hospital to an aftercare institution when medically ready. This implies that every patient who goes to an aftercare institution is a bed blocker for at least one day. Of the patients who need aftercare, approximately 52 percent need aftercare in an institution (ChipSoft, 2008/2009); the others go home (with homecare). Only 12 percent of the patients who need aftercare are registered as a bed blocker (POINT 2008). In addition, the way patients are registered seems often incorrect. More than 20 percent of the patients who wait for a nursing home according to the hospital system ChipSoft (bed blocking type 'V'), go home eventually (POINT and ChipSoft, 2008). We doubt all these patients first needed care in a nursing home, but could go home after all. They might have waited for home care, what requires registration of type 'W'. We asked several nurses what the different bed blocking types are, but they were not aware of the different types. We doubt the definition of bed blockers is clear within the hospital.

Once a patient is recorded as bed blocking in ChipSoft, care administration can declare the bed blocking days for every whole day. Care administration could not tell us when the financial day of possible declaration starts and/or ends. The registration of bed blocking days in RdGG does not seem reliable. We expect the problem of bed blocking to be larger than Paragraph 2.3 describes.

2.2 Dutch healthcare system

The way care is financed influences objectives of institutions. For those not familiar with the care system in the Netherlands, we outline the aspects relevant for our study in Paragraph 2.2.1 and 2.2.2. Paragraph 2.2.3 gives the objective of the involved stakeholders.

2.2.1 *ZZPs – classification system nursing home*

People who are no longer able to live independently, need a protected environment with ongoing supervision, and/or a therapeutic social climate can receive a complete package of AWBZ-care: a 'zorgzwaartepakket' (ZZP). The sector knows 10 different ZZPs that indicate the required care. The intensity of care increases with the number of the ZZP from 1 to 8. The last two packages are for specific target groups: ZZP 9 is a package for short term revalidation, ZZP 10 for palliative patients. Appendix A displays the intensity of the different ZZPs. In general, a minimum of ZZP 4 is required to go to a nursing home. In the remaining chapters we use the term ZZP to refer to specific groups of patients (Zorgzwaartepakketten sector V&V, 2009).

The 'Centrum Indicatiestelling Zorg' (CIZ) indicates the required care for a patient through ZZPs. Each ZZP encloses an amount of money per week of which the nursing homes receive to deliver the required care. The ZZP indication counts for a certain period of time and depends on the patient's needs. The indication is a condition for the nursing homes to receive money from the AWBZ. The 'Zorgkantoor' is responsible for the execution of the AWBZ. This institution strives to balance supply and demand in a particular region as good as possible. Nursing homes have to establish their supply (number of beds) in dialogue with Zorgkantoor. For the reader that is interested in a more detailed description of the AWBZ care system, we refer to the website of CIZ (www.ciz.nl) or the website of Zorgkantoor (www.zorgkantoor-zorgenzekerheid.nl). Through the ZZP-system, the nursing home revenue depends on the occupation of departments.

2.2.2 *DRGs – classification system hospital*

The financial system of hospitals also works through packages of care: Diagnosis Related Groups (DRGs, or in Dutch DBCs). DRGs contain the financial compensation for the treatment of a patient with a certain clinical picture. The main difference with ZZPs is that DRGs work with fixed prices per package of treatment, whereas prices of ZZPs are fully variable in time. DRGs are divided in two types 'A segment' and 'B segment'. Prices of A-segment are domestic and contain in addition to the fixed part, a variable part of 50 euro per day. Prices of B-segment differ per hospital; hospital and care insurer negotiate about these prices. The prices of B-segment are fully fixed. With the DRGs, the hospital revenue mainly depends on the number of admissions in the hospital. Because the (majority of the) price is fixed, the hospital should minimise the length of stay of the patient. Every extra day of treatment is loss for the hospital.

2.2.3 *Stakeholders*

The process of patient overflow from hospital to nursing home involves stakeholders of the hospital, nursing home and patient. Table 4 gives the objectives of the involved stakeholders.

Stakeholder group		Objective
Patient		- Minimal length of stay in hospital - Highest quality of care or treatment
Hospital	Management RdGG	- Maximum profit → minimal length of stay - Patient satisfaction
	Doctor/department nurse	- Best possible medical treatment patient - Bed availability to admit new patients
	Transfer nurses	- Patient satisfaction with the transfer
Nursing home		- Maximum occupation and throughput (in days) - Satisfaction patient (best possible care)
Government		- Patient at appropriate level of care, minimising the costs of the required care

Table 4 Stakeholders and their objectives (Interviews RdGG and PvF, 2009)

Hospital and nursing home have contradicting financial goals, caused by the differences in financial system as Paragraph 2.1.3 describes. Nursing homes aim at maximum occupation and throughput (in days) whereas hospitals aim at a maximum number of admissions, meaning a minimal length of stay. A high patient turnover in nursing homes would likely lead to a decreased occupation, which may lead to financial difficulties since nursing homes have tight financial restrictions. On the other hand every bed blocking day in the hospital is lost turnover for the nursing home. Hospital and nursing home have common goals concerning patient satisfaction, concerning transparency, and financial cooperation can lead towards mutual benefits.

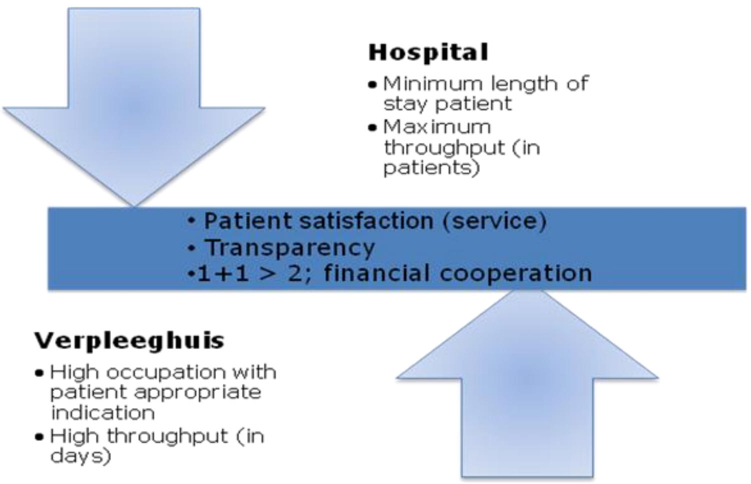


Figure 4 Interests hospital versus nursing home: shared or opposite?

2.3 Process description

Both the hospital and the nursing home have a department dedicated to the arrangement of patient logistics between the institutions. Figure 5 visualises these connective departments of transfer nurses and customer service. The institutions have a shared responsibility for the patient flow. In order to transfer the patient in a satisfying way, the pieces of the puzzle should fit together. This paragraph describes the transfer process and the stakeholders involved.

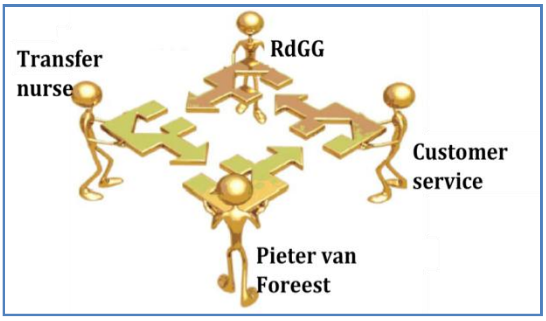


Figure 5 Hospital and nursing home

2.3.1 *Hospital process – from treatment to aftercare institution*

A department with so-called transfer nurses in the hospital arranges the outplacement of patients who need aftercare. They communicate with the nursing homes and CIZ through the software of computer program 'POINT' (Punt voor Overdracht, Informatie, Naslag en Transfers). The transfer nurses create a digital request when the requirement for aftercare of a patient is known. There are four stages in the process, and in each stage, a different actor is responsible. Figure 6 shows the four stages. We use these stages to unreveal the causes of bed blocking.

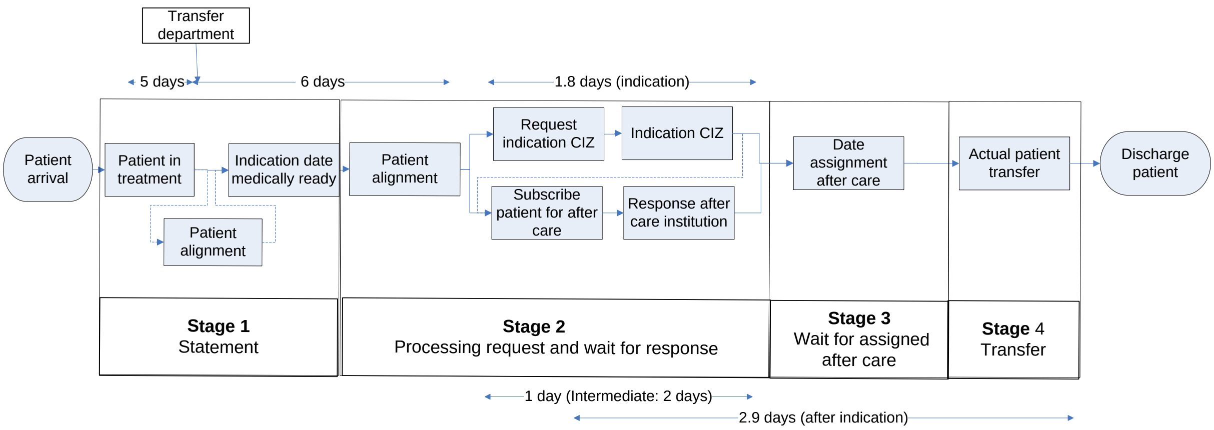


Figure 6 Process of patient outplacement in the hospital

Stage 1 – Statement

Arrival of the patient until the communication of the date that the patient is medically ready

The transfer process starts with the admission of a patient in the hospital. Identification of a patient's need for aftercare takes place at the patient's intake or in a multidisciplinary meeting (MDO). The moment of identification depends on the patient's nature: in general, identification can be earlier in the process for planned than for unplanned care. A department nurse is responsible for the statement of a patient's aftercare need and to report it to the transfer department. The department nurse makes an account for this patient in POINT. Now the patient is 'in process' at the transfer department. The transfer nurse is responsible for the contact with the patient (and the patient's family) to inventorise his needs and wishes. Not until the indication is given of the date the patient is medically ready, the transfer nurse starts the process of outplacement. Conversation(s) with patient and family might already take place before the patient is medically ready, since that can speed up the alignment with the patient later on. RdGG has no standard for these conversations, it depends on the transfer nurse to see the patient already in this stage or not. Transfer nurses indicate that it is case dependent whether an appointment is useful before the patient is medically ready.

Currently the 'trigger' of the process of the transfer nurse is the date a patient is medically ready. Before this date is known the transfer nurse cannot request CIZ indication or enrol the patient to an aftercare institution. Ideally the transfer process starts several days before the patient is medically ready, implying that the departments have to communicate the date earlier to the transfer nurses. The drawback of an early indication is that the reliability of the indicated date decreases; the date the patient can leave the hospital differs from the indicated date.

Stage 2 – Processing

Communication of the date the patient is medically ready until response of CIZ and nursing home

When a doctor indicates the date that a patient is medically ready, the transfer nurse requests an indication of care requirement at CIZ, and enrols the patient for an aftercare institution in agreement with patient, family and department nurse. The preference for a location of a patient is also considered, the patient has to accept a bed within one of the nursing homes the hospital has arrangements with.

The date the patient can leave is known. This can be today, but also within a few days; the required operations are similar. We divide this stage in two sub stages.

- *2a – Application*

  The transfer nurse applies a patient to the required institution and requests an indication of CIZ. Both indications are requested through the program POINT. A bed in an institution cannot be assigned to a patient though, before the CIZ indication is available. In general, the nursing home will wait for the CIZ indication to be available to be sure the patient has the required indication.

- *2b – Pending for response CIZ and nursing home*

  CIZ has 48 hours to set an indication for a patient and correspond this to the hospital. The duration of indication by CIZ depends on the type of care the patient requires. By experience, transfer nurses know this is longer for PG patients, while for home care this is on average shorter. By agreements, this process should take no longer than 48 hours.

  The nursing home of preference responds whether there is a bed available for the specific patient. If no bed is available, the transfer nurse will contact another institution via POINT. When there is no bed available in one of the contacted nursing homes, the patient is put on a waiting list, and remains in the hospital. The communication of availability takes place on patient level for a single nursing home, for every request. Transfer nurses, and as a consequence all RdGG, have no insight in the availability of beds in nursing homes.

<u>Stage 3 – Pending for assigned aftercare</u>
Response of CIZ until bed available for aftercare

The indication of CIZ is now known and the patient can be transferred if an appropriate bed becomes available. During this stage the patient is on a waiting list. The aftercare institution will communicate through POINT to the transfer nurse on what date there is a bed available for the patient.

<u>Stage 4 – Transmission of patient</u>
The patient can be admitted to the institution. The transfer nurse arranges, if necessary, alignment with family and transportation.

We do not have the data to distinguish between the moment a patient could be transferred to an available bed in an aftercare institution and the actual transmission of the patient. Therefore, we will merge stage 3 and 4 for now. These stages represent the waiting time that is related to the aftercare institution (communication, transparency, capacity).

Table 5 summarises the four stages with the responsible actor, the norm according to the transfer department of RdGG, and the indicator we use to determine the duration of each stage.

Stage	Actor	Norm	Indicator
1. Statement	Department nurse	3 days before medically ready	-
2a. Processing	Transfer nurse	Within 3 days	Number of days between notification medically ready and subscription CIZ (and: number of days before medically ready (bed blocking) contact with institution)
2b. Wait for response	CIZ versus Nursing home		Number of days between contact subscription CIZ and confirmation
3. Wait for assigned aftercare	Nursing home	As short as possible	Number of days between confirmation CIZ and transmission of patient.
4. Transfer	Transfer nurse	0 days	

Table 5 Stages process patient outplacement

2.3.2 *Nursing home policy – to what bed does a patient go*

The trigger for a nursing home to process the intake of a patient is the request from the hospital or general practitioner. The allocation of patients to beds is waiting list driven.

Pieter van Foreest (PvF) is the main partner of RdGG regarding aftercare; almost 80 percent of the patients who require after care in an institution go to one of their institutions. PvF has one client service that is responsible for the allocation of patients to all three nursing homes of their organisation.

PvF labels the beds; only specific patients groups are accepted for these specific beds. This has two reasons: to match facilities and personnel to the care needs of specific patient groups and to deliver more specialized care. There are specific departments for each patient group, divided in three main categories:

1. **Crisis** – for patients who come from a no longer sustainable home situation. The maximum stay is five days.
2. **Short Stay** – for patients with a need for revalidation (somatic) or screening of their care needs (cognitive). These patients will likely come from the hospital, e.g., because they just had surgery.

3. **Long Stay** – for patients with a long term care need, in general this need is permanent.

The nursing homes distinguish three main streams of patients: somatic, cognitive and Psycho-Geriatric (PG). Table 6 shows the categories of nursing home departments of PvF.

Category	Nature	Department type	Intended maximum length of stay (days)
Crisis	Somatic		5
	Cognitive	—	5
Short Stay	Somatic	Stroke	56
		Orthopaedics/ Surgery	100
		Recovery unit	28
		Remaining	100
	Cognitive		100
Long Stay	Somatic		-
	PG		-

Table 6 Categories of nursing home departments

The intended maximum length of stay represents the number of days within which the nursing homes strive to treat the patient. Patients might stay longer in a nursing home department for various reasons, like required follow-up care or specific patient requirements. This intended maximum length of stay results in a high peak of patients with a service time equal to this length of stay.

Approximately 90 percent of the patients that leave RdGG and go to a nursing home, go to a short stay department. We will shortly elaborate on the category of short stay departments, also referred to as intermediate departments.

In the beginning of 2005, PvF started a concept of nursing home departments for temporary stay. Patients who need nursing home care could then go to one of these departments for at most 100 days. The temporary departments are on two different locations and have a capacity of 118 beds, of which beds are assigned to orthopaedics/surgery, stroke, remaining somatic, PG and crisis beds. These beds are primarily meant for patients leaving a hospital, but patients from other sources (e.g., home) are also accepted, to prevent vacancy. RdGG has an informal commitment with the nursing home institution about these beds. A study in 2007 showed that approximately 65 percent of the inflow in the temporary departments is from RdGG (G. den Boer et al., 2007).

Separate PG departments are required because of protection of the patients with a mental illness. The admission of a patient is only allowed when the patient's screening shows the need for PG care. This screening takes place on a short stay cognitive department. The departments for various somatic revalidation needs have recently been introduced; patients who revalidate from a stroke and from orthopaedic/chirurgic operations are on separated departments. Paragraph 2.3.3 discusses the other department type, the Recovery unit. The main reason for the separation of patient groups is creation and allocation of expertise. The same holds for the separation of short stay and long stay departments. This separation might be strengthened by the way nursing homes steer the discharge of patients. Patients stay on short stay departments for diagnosis or recovery, while most patients remain in long stay departments until they are deceased.

In case no bed is available on a department that matches the patient's care need, but there is a bed available on another department, the patient has to wait. The client service of PvF can decide to accept patients on other departments when many patients are waiting and the complexity of the patient's care allows it.

Patients may need care in a department downstream of their current stay: short stay or long stay after crisis, and long stay after short stay. The order of admitting patients to long stay departments in PvF alternates: one patient from an internal department or from the hospital, then one patient from the home situation, etc. This policy of allocating patients to a nursing home bed is not similar for all regions within the Netherlands. In the region of Gorinchem the order is by day of admission, but most important is the extent a patient's profile fits the care provided on the department. The allocation policy of the nursing home affects the waiting time of patients in the hospital.

2.3.3 *Recovery unit*

To improve patient flow through the care chain, RdGG and PvF introduced a recovery unit in 2007. The recovery unit consists of 17 beds for patients who need intensive revalidation. The organizations presumed this number of beds to be the best workable size. PvF pays personnel and receives revenues for the patients based on ZZPs. RdGG pays overhead costs and can profit from increased patient flow. PvF and RdGG want to offer this product to their patients to increase patient service.

Transfer nurses determine whether a patient can go to the recovery unit. The patient has to fulfil three main criteria.

- The expected recovery time is less than 4 weeks
- The patient has no cognitive problems
- The patient has an indication of "ZZP 6" or "ZZP 9"

The criteria for the acceptance of a patient were relaxed in 2009, because the occupation was not high enough, patients with other ZZP indications (3 or 4) are now accepted as well. The recovery unit is still not running as desired for both RdGG and PvF. The occupation is too low for PvF, while patients have to wait too long for RdGG.

2.4 Control span

Hospitals and nursing homes are limited in their span of influence on patient flow. Table 7 outlines the hospital control and nursing home control span on six categories.

Category	Hospital control	Nursing home control
Arrivals	- Admissions of patient groups in the hospital	
Capacity		- Influence on bed capacity, in agreement with Zorgkantoor - Allocation of capacity to various patient categories
Planning	- Different allocation of slots for patient types in operating rooms - Cancel operations	- Flexibility in admissions of patients
Acceptance	- Policy on when a patient is obligatory to accept a nursing home bed (or go home)	- Restrictions of when a patient is accepted (CIZ indication, medical condition)
Communication	- Policy of discharge from the hospital (duration of the process) - Information of expected patient flow communicated to nursing homes	- Information of expected bed occupation to hospitals
Finance	- Financial compensation to nursing homes	

Table 7 Span of control of hospital and nursing home on patient flow

Hospital and nursing home may influence bed blocking by changing these factors. These factors describe the scope of possible interventions. We use the positioning framework for hospital planning & control by Van Houdenhoven et al. (2007) to specify control variables in the different hierarchical levels of resource capacity planning in Table 8.

The framework helps to structure intervention analysis. Chapter 4 uses the content of the framework in selection of interventions and model design.

Level	Resource capacity planning	Model objectives	Input	Output	Current situation	Possible interventions and scenarios
Strategic	Case mix planning, layout planning, capacity dimensioning	• Capacity dimensioning; reservation of beds by hospital, flexible capacity nursing home • Analyse the effect of 'enlarging' the system • Effect of including a buffer department	• **Demand** of beds for nursing home type Z of patient from location Y (**case mix,** probability that patient type X needs aftercare type Z) • **Number of beds** for patient type X in nursing home Z • **Length of stay** patient type X • Capacity **reservation** for hospital Y of nursing home type Z for patients X	• Bed **occupation rate** in nursing homes • **Number of patients** waiting to enter each type of facility in the system and the associated **waiting time** for patients in: hospital, nursing home facility, home		
Tactical	Allocation of time and resources to specialities, rostering	• Acceptance of patients on different departments • Determine allocation rules of patients to beds • Influence of utilisation recovery unit: what people do we allow on this department? • Effect of temporary increase in demand	• Moment patient X could be **admitted** on a nursing home department • **Allocation** rules; of a bed to patient X and of a patient X to a bed • **Maximum length of stay** at nursing home department Y • **Forecast** patients flows			
Operational offline	Patient scheduling workforce planning	• Influence of restricting rules and requests in the process	• **Request care** nursing home • **Need** for aftercare becomes **known** • Number of days before patient medically ready **indication** given by doctor • Moment final consult with doctor • Moment **request CIZ** indication • **Alignment** with doctor and patient by transfer nurse • Duration **CIZ indication**	• **Effect in number of bed blocking days of:** earlier request, alignment, etc.		
Operational online	Monitoring, emergency coordination	• Monitor and observe when problems occur • Decision to what bed patient X is allocated	• Patients needing aftercare, real time (demand, length of stay, etc.)			

Table 8 Span of control in hierarchical levels, after Van Houdenhoven et. al (2007)

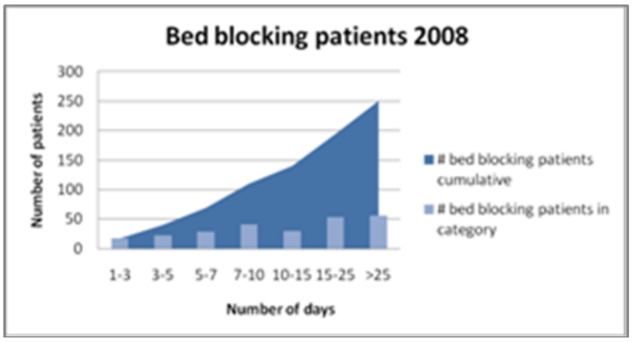
2.5 Performance

The bed blocking days are unwanted in the hospital. To what extent is bed blocking a problem and what are the consequences?

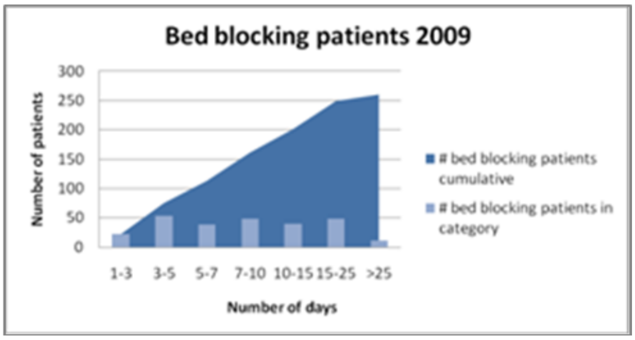
2.5.1 *Current situation in RdGG*

RdGG registers bed blocking for financial reasons. The policy of declaration is unclear and we expect the situation we outline here is only part of the problem. We have discussed the registration in Paragraph 2.2.2.

When a doctor declares a patient is medically ready, and therefore becomes a bed blocker, then nurses indicate this status in the hospital system ChipSoft. We use the information of this system for our analysis of bed blocking. We assume the amount of bed blocking days of a patient to be the difference of when the state of a patient changes into 'bed blocking', until discharge of the patient from the hospital. This means the bed blocking days are not counted as integers here, while they are when declared. The reason is that the main financial losses are the lost sales caused by a bed blocker, which is not integer either. In other words, the main loss is every time period a bed blocker is occupying the bed where a new patient could be admitted.



4.1 N=250, 2008



4.2 N=125, 2009

Figure 7 Deviation of the number of days patients are bed blockers, ChipSoft RdGG

In 2008, 4319 days where used by bed blockers, according to ChipSoft registration. That is 2.3 percent of available ward capacity and 12 of 519 beds. The number of bed blocking days in 2009 is remarkably lower than the amount in 2008. In 2009 this number is 2483, that is a little more than half of the amount in 2008. Figure 7 shows that this difference can be mainly explained by the patients who are bed blockers in the hospital for a long period. While the patients staying longer than 15 days were responsible for 41 percent of the bed blocking days in 2008; in 2009 this is only 15 percent.

Per department

Some departments cope with a relatively high amount of bed blockers, while others have nearly none. Table 9 shows the deviation of bed blocking days between departments.

Department	# Patients	# Days	% available bed capacity (2009)*
Internal medicine	67	1362	11,3%
Surgery	57	900	6,7%
Neurology	49	853	5,8%
Orthopaedics	50	641	7,0%
Cardiology	17	313	2,7%
MDL	10	109	1,9%
Lung diseases	9	103	0,9%
Plastic surgery	1	21	
Dermatology	1	7	
Urology	1	6	
Gynaecology	3	4	
Total	265	4319	2,28%
* % based on capacity 2009: 519 beds and 365 days			

Table 9 Bed blocking days, N=265, Jan. – Dec. 2008, ChipSoft RdGG

From Table 9 we conclude from that the department Internal Medicine is most affected by the problem of bed blocking days. According to nurses, the most important reason is the high average age (almost 80 years) and the complex clinical picture of these patients.

Figure 8 compares the developments among departments and shows remarkable differences in reduction of bed blocking days within some departments. Orthopaedics, cardiology and lungs all decreased these days by approximately 80 percent, while surgery is still on the same level.

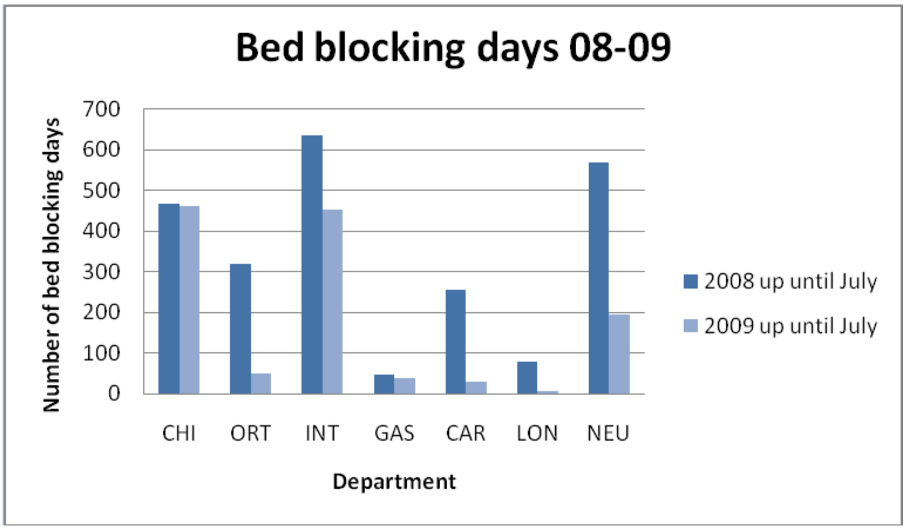


Figure 8 Bed blocking days 2008 versus 2009 per department, N=390, ChipSoft RdGG

Transfer nurses and department nurses expect the decrease in bed blocking days to be caused by the increasing availability of beds in nursing homes. Causes for the difference in development are unclear; the extreme decrease at orthopaedics may be related to a recently finished project that increased standardisation of patient's care paths for the department. Already on the policlinic the home situation of a patient is considered and a patient's possible need for aftercare.

Fluctuation through time

Figure 9 shows the development of bed blocking days in the past few years. In 2007 there was a large increase and until 2009 the level of bed blocking decreased again. Note that these are bed blocking days recorded by the departments, so an improved registration might appear as an increase of the problem and vice versa. The data used here is based on financial registration.

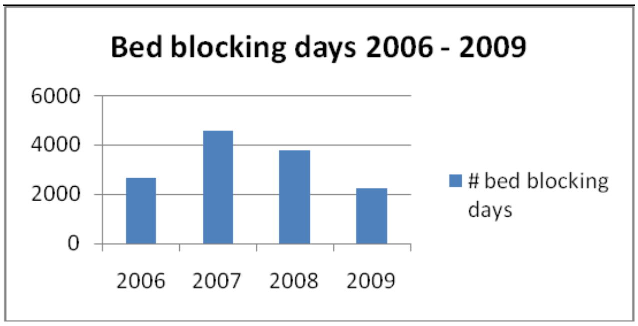


Figure 9 Development bed blocking days from 2006 until 2009 (2009 based on expectation), ChipSoft RdGG

The problem fluctuates during the year. Factors that could influence bed blocking are holidays, as more employees are absent what slows down the process, or winter, where more elderly get sick. Figure 10 shows the bed blocking days in RdGG for the past 19 months.

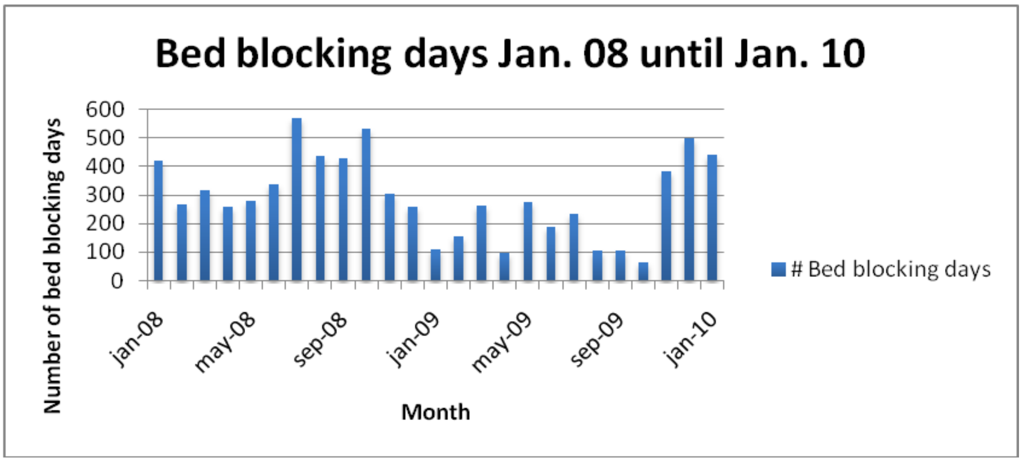


Figure 10 Development bed blocking days per month, N= 558, Jan.08 – Jan. 10, ChipSoft RdGG

It is difficult to draw conclusions for this short period of time, though we cannot observe any direct relation with summer or winter months. Remarkable is the collapse on September 2009; that month PvF opened 30 extra nursing home beds.

Bed blocking days may also be caused by variation in demand. Figure 11 shows this deviation in demand for nursing home care.

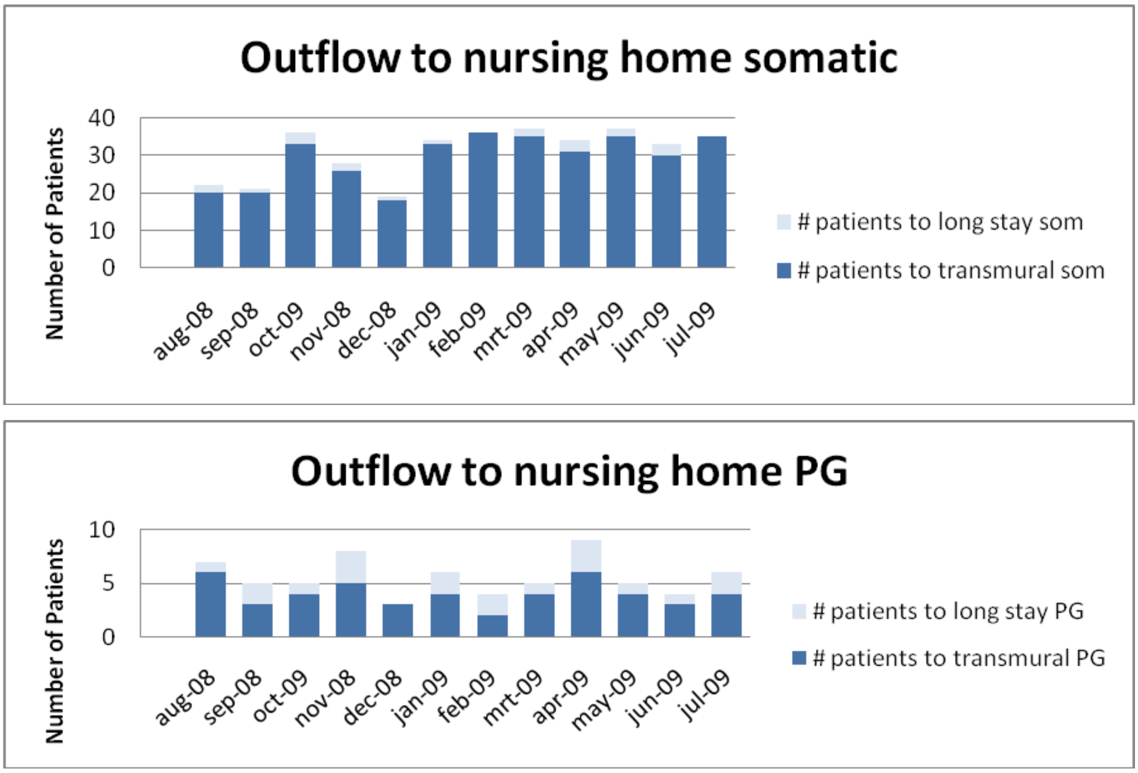


Figure 11 Number of patients to nursing homes for somatic and PG patients

RdGG depends on the availability of beds in the departments of nursing homes but the nursing homes on the other hand depends on the supply of patients of RdGG. Fluctuating supply will likely influence the occupation rates in nursing homes and bed blocking days in the hospital.

Figure 12 shows on what day of the week patients where registered as bed blocker. Registration decreases during the week, with an increase on Thursday for 2009, while we expect that the number of patients medically ready is similar every day of the week. We expect that this relation is due to moment the status of the bed blocker is noticed: during doctor's rounds and MDOs (first on Mondays, recently they started on Thursdays as well on several departments).

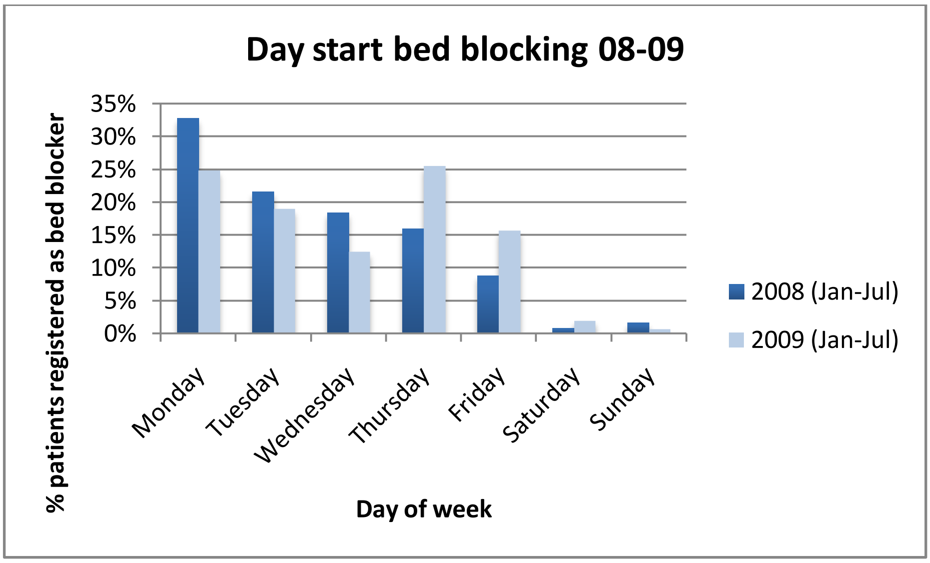


Figure 12 Patient registered as bed blocker starting on day, N_{2008}=154 N_{2009}=125, Jan.08 - July 08 and Jan.09 - July 09, ChipSoft RdGG

2.5.2 *Bed blocking days; where do they come from?*

The bed blocking days seem to be caused mainly by patients going to nursing homes. But what are the delaying factors in the process?

If the date a patient is medically ready is known, the transfer nurse can start the process arranging the outplacement of a patient. From that moment one part of the process concerns CIZ and another from the indication of CIZ until dismissal (stage 2b and stage 3 from Paragraph 2.2.1). Table 10 shows the duration of these parts. The number of measurements we can use is quite low, between 30 and 40 percent of the patients registered until July 2009; many dates are not registered in POINT. This is partly due to early breakdowns of the process, but the reason for this high percentage is unknown.

	Indication CIZ until dismissal	Response time CIZ
Measurements	2601	
Useful	968	975
Average	2.86	1.76
St.dev.	5.57	2.16

Table 10 Duration stages, Jan. 2009 – July 2009, POINT RdGG

The indication of CIZ takes in 26 percent of the cases more than 2 days. Now the indication of medically ready is often given at the moment a patient can leave the hospital, which means that the patient is blocking a bed during the process of CIZ indication. When the date a patient is established earlier, the length of stay of many patients might be decreased by a few days. This way the indication of CIZ can be demanded a few days earlier, while the patient is still in medical treatment (thus not blocking the bed).

Most bed blocking days seem to be caused when the indication of CIZ is known until the true dismissal of the patient to aftercare institutions. In this part of the process the only operations required are the assignment of a patient to a bed in an aftercare institution and the true transmission.

2.5.3 *Financial implications for RdGG*

Bed blocking has negative financial consequences for the hospital. The hospital receives compensation, but this does not cover the costs of bed blockers. More importantly, the time a patient is blocking a bed, no new patient can be admitted. This means lost sales for the hospital.

In principal, the wards have high occupation rates, especially on those departments having many bed blockers. Taking the average occupation rate of just those departments to establish lost sales will not be representative. We use the average of all occupation rates to make the assumptions that if a patient would not be blocking a bed, the occupation rate of this bed would be 95 percent. For that reason we establish the costs of a bed blocking day by the difference in lost revenue because no new patient can be admitted, corrected by its occupation rate, and the net revenue of a bed blocker.

A new admission yields approximately 270 euro per day in RdGG. This amount is established based on the average revenue of a patient using Diagnosis Related Groups (DRGs), accounting for the extra costs a new admission brings about. When a patient is labelled as a bed blocker, the hospital receives 162 euro as compensation from the AWBZ. The hospital should partly cover this with a budget they get on a yearly basis, resulting in net revenue of 53 euro per bed blocker per day. This gives us an amount of 203.50 euro that is lost per bed blocking day. Table 11 shows that this means a financial loss of almost €880,000 in 2008. In 2009 this is almost €300,000 up until July; with the same relative development as in 2008, the total loss is expected to be €460,000 in 2009.

Financial consequences bed blocking days			
Lost sale	- € 270	*per day*	
Revenue	€ 53	*per day*	
Loss	€ 203.50	*per day*	
Assumed occupation	95%		
	2008	**2009**	
		Jan. - July	*Expectation*
Number of days	4319	1239	2246
Total loss	€ 878,917	€ 252,137	**€ 457,061**

Table 11 Financial consequences bed blocking days 2008/2009

2.5.4 *Current situation PvF*

Financial incentives for a nursing home are maximum occupation and maximum throughput (days of treatment). This paragraph shows only little information about occupation of departments of PvF, due to lack of data availability.

Approximately 60 percent of the patients from RdGG who need nursing home care, go to a department of 'De Bieslandhof' (POINT, 08/09). Table 12 indicates the occupation of crisis and short stay departments, based on data of patient demand for care types accepted on these departments and their length of stay. Length of stays for long stay departments are not available.

Category	Nature	Department type	Occupation	% RdGG
Crisis	Somatic		53%	-
	Cognitive	—	59 %	-
Short Stay	Somatic	Stroke	48 %	100 %
		Revalidation	80 %	58 %
		Recovery unit		100 %
	Cognitive		47 %	80 %

Table 12 Bieslandhof, PvF, N = 942, Aug. 2008 to July 2009

Real occupation of nursing home departments is higher. Patients wait for care on a long stay department (blocking). We do not know real occupation rates, but snapshots show occupation rates between 90 and 100 percent. PvF states the occupation rates are in general that high, which is required due to tight financial restrictions. The occupation on somatic departments is in general lower than on Cognitive and PG departments. In recent months they cope with vacancy on somatic departments.

Paragraph 2.3.3 stated that the occupation of the recovery unit was too low due to tight restrictions. Figure 13 shows the development of the recovery unit's occupation.

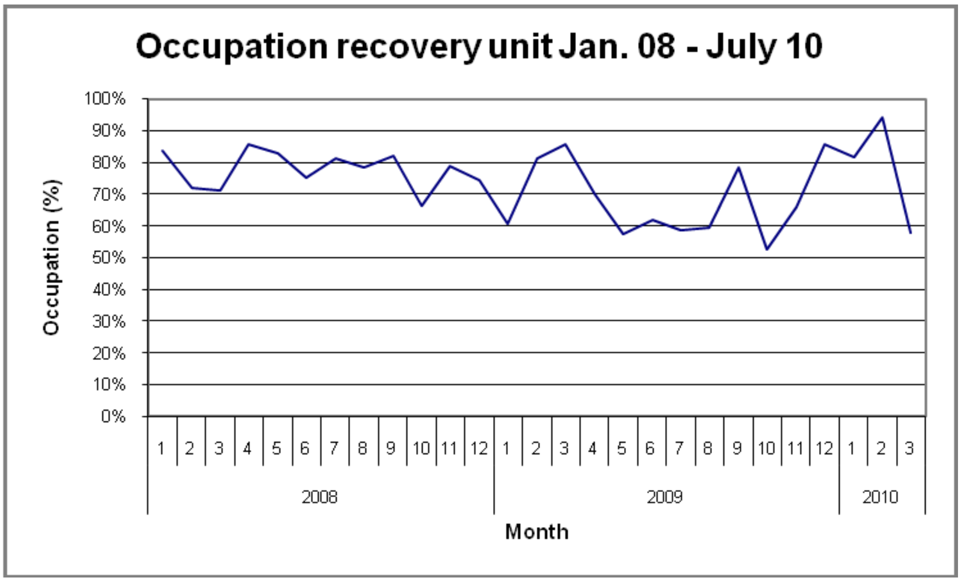


Figure 13 Occupation recovery unit, N=1649, Jan. 08 - July 10, Chipsoft RdGG

Although PvF relaxed admission criteria in 2009, the occupation of the recovery unit is still not high enough to achieve break even. The recovery unit made a loss of €200,000 in 2009.

2.5.5 *Patient service*

The bed blocking days do not only have unfavourable financial consequences, it has a negative influence on the quality of care as well. The patients do not get the treatment they need, the probability of infections is higher, and in general recovering patients experience the hospital not as a stimulating environment. Since this variable is hard to quantify and differs per patient, we will not use this as an indicator for analysis.

2.6 Conclusions

Bed blocking in RdGG is in the first place a financial problem; each bed blocking day costs the hospital approximately 200 euro. In 2008, 265 patients caused 4319 bed blocking days, that is 2.3 percent of total ward occupation. These patients go to several aftercare institutions, but patients who require care in nursing homes cause 80 percent of the bed blocking days. The main conclusions relevant for the following chapters are:

- Hospital and nursing home have contradicting financial goals, caused by the differences in financial systems. The hospital revenue mainly depends on the number of admissions in the hospital. The nursing home revenue depends on the occupation of the nursing home departments.
- Medically ready is sometimes too late, thereby causing some bed blocking days.
- Most bed blocking days are caused by waiting 'ready to go' to a nursing home. The only operations required are the assignment of a patient to a bed in an in a nursing home and the true transmission.
- Registration of bed blocking days is incomplete, costing a lot of money.
- The recovery unit is not utilised well due to strong restrictions in patient acceptance.
- There is no communication between the hospital and the nursing home about available capacity expected in the future in nursing homes, nor communication about expected patient demand for nursing home care.

3 Literature review

Healthcare logistics becomes increasingly popular in the literature. Healthcare models that concern multiple departments are starting to become part of this. Vanberkel et al. (2009), reviewed 88 articles describing models which encompass multiple hospital departments. Only few of these models describe the system of care and not only single departments in the care chain; the view on the whole chain is new in this context.

This chapter analyses the literature on patient flow through multiple departments. We use the concepts of bed blocking, capacity planning, transitional care, modelling patient flows and waiting time reduction as a starting point for this literature review. For the reader that is merely interested in the main insights, a summary is given in Paragraph 3.5. We refer to Appendix C for a summary of the articles discussed in this chapter.

Paragraph 3.1 gives a general introduction of the integration of care. To get an idea of the issues involved in bed blocking, Paragraph 3.2 gives an overview of factors that influence bed blocking the literature describes. Paragraph 3.3 describes modelling approaches in solving problems concerning capacity planning and analysis of patient flow. We will end this chapter with common performance indicators in this context in Paragraph 3.4.

3.1 Integrated care

To improve patient flow between hospital and nursing home the actors should work together to integrate their care to meet patient demand. Before we discuss the optimisation problem, we first need to define integrated care and the interests of actors.

The main actors in the care chain are hospital and nursing home, but the patient and his family, the government, care insurers and the care administration office are also involved. The suppliers should 'integrate' their care to meet patient demand. The National Council for Public Health in the Netherlands stated a widely accepted definition of transitional care; 'care, attuned to the needs of the patient, provided on the basis of co-operation and co-ordination between primary and specialised caregivers, with shared overall responsibility and the specification of delegated responsibilities' (Linden et al., 2000). Linden et al. (2000), conducted a national survey to determine the extent of the development of transitional care. Major causes of the gap between links in the care chain are separate organisational and financing systems.

The impact for patients of interruption in flow between care facilities is often that of receiving care in an inappropriate facility. Cohen et al. (2008), note that due to the nature of health care delivery, queues generally do not form when a particular unit is fully utilised. Instead, one of three actions is taken:

- The patient may be assigned to an inappropriate unit, at either a 'higher' or a 'lower' level of care than is necessary for the patient's condition.
- Other patients may be relocated to accommodate the patient.
- The patient may be directed to another hospital or sent home. (Cohen et al., 2000)

The importance of well-integrated care is increasing; the population ages and the medical picture of elderly becomes more complex (Travers et al., 2008). This need for integration may be intensified by the shift from a service oriented health care system to a patient central system. (M. van Swinderen, 2009).

Coleman and Boult (2003) argue that to advance the understanding and practice of high quality transitional care, research is needed to better understand how to empower persons with complex care needs and their caregivers to express their preferences and manage their care needs across healthcare settings. In addition, they argue that systems to optimise transitional care need to be developed and tested. Interventions should be patient centred and be designed to facilitate external adoptions in different delivery systems and under different payment mechanisms.

The creation of an integrated care chain seems to be a complex problem due to many actors involved with different interests. The increasing importance of well-integrated care urges the need for optimisation modelling in this area.

3.2 Causes of bed blocking

Bed blocking can have multiple causes related to different actors. To understand the phenomenon and to design interventions, we require insight in these causes. This paragraph gives an overview of what causes of bed blocking the literature describes.

Schwanhaueser et al. (2002), performed an audit of bed blocking in surgery. The purpose of this audit was to identify the causes of bed blocking and to determine what non-clinical or organisational factors were involved. They found that considerable delays in patient events are due to non-clinical reasons: 26% of patients experienced such delays. The major non-clinical delays in emergency patients were due to waiting for radiology and arranging care for elderly.

Rubin and Davies (1975) investigated 48 elderly in a long-stay hospital bed. They found that there is a lack of a multidisciplinary approach and that the problem of waiting lists is compounded by the lower priority given to patients already in the hospital.

Panton et al. (2004), distinguish three other main categories of reasons for delayed discharge:

- Lack of specialist staff resources for placement of returning home (including a place not being found)
- Lack of money to finance placement
- Lack of an alternative acute ward when the patient no longer needs acute care

They found that for 46% of the patients the discharge was delayed of which almost half was caused by insufficient specialist staff resources.

Koizumi et al. (2004) point out that, in contrast to popular perception, system congestion is not always a simple cumulative effect of shortages across all facility types. Their study suggests that system-wide congestion is primarily due to shortages in one specific facility type. Removal of such facility specific bottlenecks may often be the most cost-efficient way to reduce congestion in the system as a whole.

Benson et al. (2006), found that most reports highlight the lack of intermediate care as being a major cause of delayed discharge. They conclude that due to problems in defining delayed discharge, government figures probably underestimate the true numbers. Lack of intermediate care and social service provision are a major cause of bed blocking. As in other studies, they found that 'bed blockers' were older patients and more likely to have admitted as an emergency. Finally, the authors state the need for clarification of definitions to obtain accurate and reproducible figures.

Travers et al. (2008), conclude that access-block within the acute public hospital system stems from a mismatch between demand and supply, and cannot be understood by viewing the hospital system in isolation from other sectors that support the health and well-being of older Australians.

We conclude that bed blocking is often found to be due to a mismatch between supply and demand instead of capacity shortage in the whole system. System-wide congestion is then caused by shortages in one specific facility type. In addition, the arrangement of care and the lack of a multidisciplinary approach result in waiting patients.

3.3 Modelling

Different modelling approaches are used to analyse capacity planning in health care and to analyse patient flows. Models for resource planning described in the literature can be broadly categorised as analytical or simulation based. We discuss both model categories in the context of transitional care, to decide on the balance of the effort for model detail and reliable outcomes.

Analytical models specify a stochastic process that describes both the flow of patients through the system and the utilisation of resources. A growing number of researchers use queueing theory instead of simulation, because of its ease of calculation, minimal data requirements, and ability to be delivered in spread sheets (Cochran and Roche, 2008).

To estimate the effect of system changes and the potential impact of the ageing population Travers et al. (2008), developed a conceptual model of the dynamics at the acute-age care interface. The key aim of this model is to better understand why older patients with high care needs, often wait in acute public hospitals for entry into permanent Residential Aged Care (RAC). Figure 14 shows their conceptual framework for entering and waiting in different facilities.

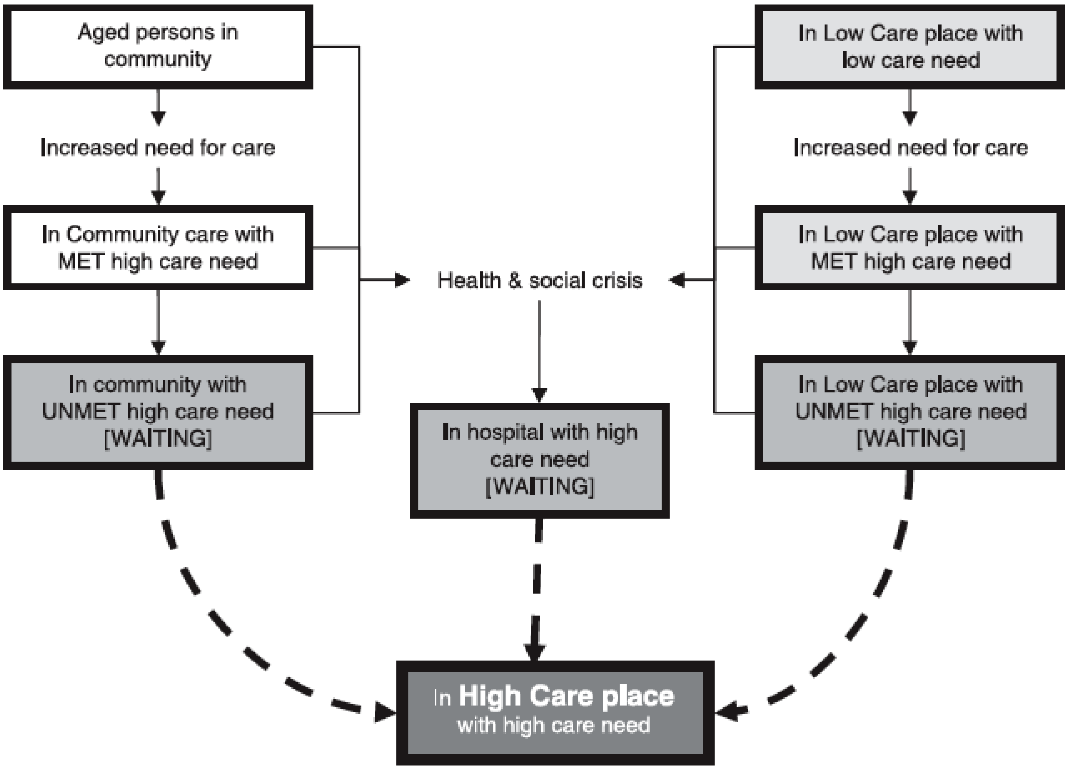


Figure 14 Conceptual framework for entry into permanent high-care Residential Aged Care, Travers et al. (2008)

The model conceptualises the pathway into permanent high-care RAC as a series of competing queues for available places by applicants from three sources: the hospital, internal RAC applicants in low-care places and community applicants. The time spent waiting in hospital depends on several factors, including hospital occupancy rates, the rate at which permanent high-care RAC vacancies occur and the number of applicants.

Koizumi et al. (2004), apply a queueing network system with blocking to analyse congestion processes between stations. Figure 15 shows the framework, which is an "arbitrary-linked" system where patients can skip stations.

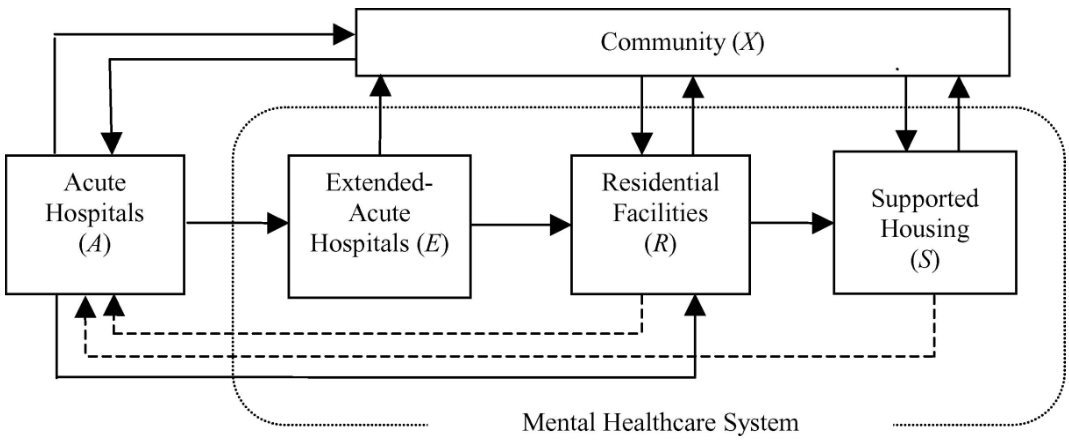


Figure 15 In-flows and out-flows between stations, Koizumi et al. (2004)

Koizumi et al., point out that for mathematical convenience, total arrival rates are often assumed to follow a Poisson distribution. Similarly, mean service times are typically assumed to follow an exponential distribution. Koizumi et al., modify the definition of "service time", in order to incorporate blocking into the model, by introducing the concept of "effective service time". The effective service time consists of two types of service times: "treatment time" and "blocked time". The model assumes that extra days in the upstream facilities do not reduce the length of stay at any downstream facility. The analysis treats the waiting space to enter a particular station as infinite when analysing the steady state of that station. Figure 16 shows their interpretation of effective service time in a tandem two-station system with no buffer.

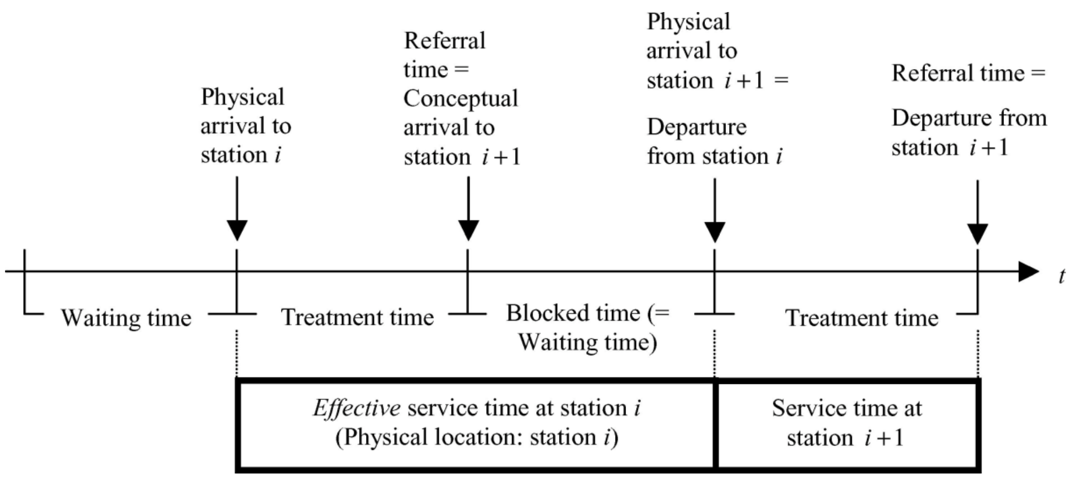


Figure 16 Tandem Two-Station system with no buffer, Koizumi et al. (2004)

Gorunescu et al., (2002), present another queueing technique for optimising the number of beds in order to maintain a delay probability at a sufficiently low level. They use an

M/PH/c queueing model; patient arrivals are described by a Poisson process, hospital beds are the servers and lengths of stay are modelled using phase-type distributions. The advantage of using the phase-type model for length of stay distribution is that it provides a useful description of the data and a convenient way of estimating arrival rates.

Harper and Shahani (2002) state that reducing the complexity of a problem to make solution methods tractable is less than ideal. The literature recommends simulations over analytical and deterministic approaches.

El-Darzi et al. (1998), consider the problem of bed blocking in geriatric departments. The flow of patients through geriatric hospitals is described in terms of acute, rehabilitation and long-stay states. They use a flow model and discrete-event simulation to allow a greater understanding of bed requirements and effective utilisation of resources. They conclude that further work is needed to determine the necessary emptiness in the acute beds to prevent admission queues forming, as it is clearly an unrealistic option to minimise admission queues by providing significant emptiness in long-stay. “In supermarkets separate server units are set aside for customers with baskets and less than eight items. Also extra server units are opened when queues increase. Similar concepts may need to be introduced into hospitals. Further work needs to be done on the simulation model to experiment with different arrival and admission methods and/or with data from other hospitals. Also seasonal variations as well as weekends and public holidays may need to be considered as they have been proved to influence referral and admission.”

The study of Cochran and Bharti (2006) aims to balance bed unit utilisation across an obstetrics hospital and minimise bed blocking from upstream units within given constraints on bed reallocation. The methodology includes the assessment and effect of time-dependent patterns of monthly, daily, and hourly demand. Queueing networks first assess the flows between units, establish target utilisations of bed units, and involve stakeholders in a flow characterisation that they understand. Discrete-event simulation then maximises the flow through the balanced system including non-homogeneous effects, non-exponential lengths of stay and blocking behaviour. The article concludes that another important area of future work is developing methodology for analysing the flow balance of patients and bed balancing across a network of hospitals instead of within a single hospital.

Cohen et al. (1980), describe a simulation model that can handle different policies to deal with blocked transfers. They conclude that the acceptance rule does significantly affect the results of the simulation study. It is therefore important to model the transfer policy that is to be used in the facility under study.

Haraden and Resar (2004) suggest making nursing home reservations. Most hospitals use a "push system" to discharge a patient to a nursing home facility; once a patient is determined to need a nursing home bed, a search is started by the hospital's social services staff. "A better, more efficient system might be to synchronise hospital and nursing home needs by establishing a reservation system whereby hospitals can reserve beds in nursing homes once a patient in need is identified, and vice versa. The nursing home or the hospital still receives payment if the reservation is, much like the system used in the hotel-industry."

In the literature, modelling related to the problem of transitional care, mainly concerns queueing models. Most models distinguish stations of short-stay and long-stay, some with a third station for acute care. The models analyse effects of capacity allocation on waiting times and bed occupation. The authors rely on the need to take into account other distributions and more detailed modelling by using simulation. Simulation studies within single hospitals show the significant effect of acceptance rules on patient flow. Suggestions to improve flow are flexible capacity, like in supermarkets, and reservation of beds, like in the hotel-industry.

3.4 Performance indicators

Inherent to performance of bed blocking is the patient's waiting time for admission. To reflect the interests of all actors in performance indicators, we study the literature on other performance indicators.

Koizumi et al. (2004) use two performance indicators, the number of patients waiting to enter each type of facility in the system and the associated waiting time at the steady state, in their queueing network model with blocking.

Cohen et al. (1980) introduced a new measure as an expression for the quality of care: the fraction of patient days spent inappropriately at a unit. This is an indicator for the quality of care. The other performance measures they use for their simulated model are the utilisation of each unit in the hospital and the faction of transfers blocked in each unit. These two measures are used in most of the literature.

3.5 Queueing notation

A standard notation to describe a simulation model does not exist, due to complexity and enormous variation in different simulation models. To develop a standard notation to distinguish interventions in our simulation model we explore the notation for queueing models.

To describe a queueing system, Kendall (1951) devised a general notation. The notation consists of six characteristics:

- The nature of the arrival process
- The nature of the service times
- The number of parallel servers
- The queue discipline
- Maximum allowable number of customers in the system
- Size of the population from which customers are drawn

An example of such a notation is M/M/1/FCFS/∞/∞; exponential interarrival and service times, one server with queue discipline First Come First Serve which an infinite customer allowance and population. This notation is used to describe a queueing system in which all arrivals wait in a single line until one of s identical parallel servers is free.

Extending this system to a k-stage series queueing system, where customers need treatment in more than one server, the notation for the number of parallel servers becomes depended of the stage j (s_j) (e.g., $M/M/s_j/GD/\infty/\infty$). When modelling a priority queueing model, a subscript should also be added to the first two characteristics, to indicate multiple customer types (e.g., $M_i/G_i/1/NPRP/\infty/\infty$); (Winston, 2004).

The elements of the queueing notation are typical for our simulation model as well. We can use the first four characteristics in our simulation model.

3.6 Conclusions

Modelling in health care is an emerging field, but the current work mainly concerns optimising a specific department. Little work is done in how to integrate care between departments or even in how to integrate the care need between different actors. We draw the following conclusions from the literature review:

- Many actors are involved in the creation of an integrated care chain. The increasing importance of well/integrated care urges the need for optimisation modelling in this area.
- Bed blocking is often found to be due to a mismatch between supply and demand.
- Modelling related to the problem of transitional care, mainly concerns queueing models. The models analyse effects of capacity allocation on waiting times and bed occupation. The authors rely on the need to take into account other distributions and more detailed modelling by using simulation.
- Most models distinguish stations of short-stay and long-stay, some with a third station for acute care.
- Simulation studies within single hospitals show the significant effect of acceptance rules on patient flow.
- Suggestions to improve flow are flexible capacity, like in supermarkets, and reservation of beds, like in the hotel-industry.
- Most models use two performance indicators: the number of patients waiting to enter each type of facility in the system and the associated waiting time (or fraction of time).

4 Simulation model

Chapter 1 describes the objective of this research: to design a tool that allows analysis of various configurations of transmural networks, in order to minimise bed blocking. This chapter outlines the model requirements and the model design. Paragraph 4.1 describes the design of interventions and makes a selection of interventions we will focus on. Paragraph 4.2 describes the conceptual model, which includes why we choose a simulation study. Paragraph 4.3 defines a standard model notation to recognise the difference in simulation settings between interventions.

4.1 Design of interventions

We focus in this study on an understanding of the system in an explorative way, by giving more insight in the effects of changing input factors and create a playground for analysis of interventions. This contributes to the question *what organisational interventions could reduce bed blocking by nursing homes?*

4.1.1 *Interventions*

To determine promising interventions we use the current system, suggestions by stakeholders and suggestions in the literature (Chapter 3) as a point of reference. We first simulate the situation 'as-is', as far as possible with the given data. Then by changing components one by one we quantify the effect of interventions on performance indicators. Here we give intervention concepts, in Paragraph 4.1.3 we make a selection of interventions we investigate in this research.

1. **Add (temporary) bed capacity** - when to add (or reallocate) capacity in nursing homes and when to remove it? We could add capacity if x patients are waiting or reallocate capacity if x beds are vacant for y days.

2. **Transfer beds for hospital patients** - what is the effect on bed blocking of introducing transfer beds (buffer) for hospital patients who require nursing home care and how many transfer beds should we have?

3. **Reservation of beds** - what is the effect on bed blocking if the hospital reserves beds at nursing homes, and how many should the hospital reserve against what costs? The hospital reserves beds where only patients from the hospital can be admitted and takes financial responsibility in case of vacancy.

4. **Priorities** – how do different priorities for the admission of various patient categories in nursing homes influence the waiting time for each of the

categories? Patients from the hospital, another nursing home bed, and home, get a different priority for admission in case of a waiting list.

5. **Merge departments** – what is the effect of department mergers on bed blocking? The number of labels for beds then decreases and the flexibility of bed usage increases.

6. **Enlarge the system** – how does an increase of the region, with multiple hospitals and nursing homes, affect bed blocking?

7. **Transparency patient flow–** what if nursing homes know hospital demand earlier in the process? This can be the admission of individual patients or predictions of arrivals of certain patient groups.

8. **Spread outpatient visits and operations –** what is the effect on bed blocking if the hospital increases the spread of outpatient visits and/or operation room scheduling? A smoother planning in the hospital could decrease the variation in the outflow of patients what might affect the waiting time of patients in the hospital.

4.1.2 *Model objectives*

The model requires to give insight in the effects of changing input parameters and create a playground for analysis of interventions of transmural networks. Input parameters and interventions can be analysed on different hierarchical levels. Paragraph 2.4 described the span of control amongst these different hierarchical levels. Considering the designed interventions and the process description of Paragraph 2.3, our study and model focuses on the elements described in the strategic and tactical levels. We will restrict ourselves to interventions concerning these levels, but take elements of the operational offline level into account in our model. Paragraph 4.2.2 describes the model's level of detail.

4.1.3 *Selection of interventions*

Due to time limitations, we only study a selection of the interventions Paragraph 4.1.1 describes. In the selection of these interventions we consider data availability, stakeholder interests and control, and contribution to give insight in model possibilities. We focus on three interventions:

1. **Advance communication process**

   As we mentioned in Paragraph 2.3.2, nursing homes search for alternatives when waiting lists are getting out of control, but forecasting could accelerate that. The situation:

- The communication process starts with the arrival of a patient in the hospital.

2. **Transfer beds for hospital patients**

   Instead of waiting in a hospital bed, we transfer all patients who wait for aftercare on a separate nursing home department. The situation:

   - All bed blockers wait in a nursing home department until a compatible nursing home bed comes available
   - Balance the occupation, costs for admission and revenue of reduced bed blocking.

3. **Reservation of beds**

   The hospital reserves beds where only patients from the hospital can be admitted and takes financial responsibility in case of vacancy. We compare two variants.

   Situation variant A

   - A selected group of patients can be admitted on the department
   - The hospital guarantees an occupation of 90 percent for the department

   Situation variant B

   - Hospital patients get preference on the department, other patients are also accepted

4.2 Conceptual model

We aim to create a model that allows investigating various interventions under various system complexities. We use Law and Kelton (2000) as a guideline for developing the conceptual model. The description of the conceptual model contains scope and detail, description of each subsystem, simplifying assumptions, and performance measures. Paragraph 4.2.1 describes the model requirements given the interventions defined in Paragraph 4.1. Paragraph 4.2.2 describes the level of detail of the model. Paragraph 4.2.3 outlines why we choose discrete-event simulation. The input the model requires is given in Paragraph 4.2.4 and Paragraph 4.2.5 gives the model description. Paragraph 4.2.6 describes the performance indicators we use for evaluation. Paragraph 4.2.7 outlines assumptions and simplifications of the model.

4.2.1 *Model requirements*

The model objective is to *analyse the effects of interventions and scenarios on system performance.* We specify this objective in a list of model requirements, where we use the interventions Paragraph 4.1 describes. The model is able to:

- Analyse how the system performs in the current situation with complete information transparency
- Analyse consequences for bed blocking and occupation in nursing homes by varying
    - Capacity dimensioning: reservation of beds by the hospital and flexible capacity in nursing homes
    - Acceptance of patient types on different nursing home departments
    - Allocation rules of patients to nursing home beds
    - Buffers for hospital patients (transfer beds)
    - Maximum lengths of stay to admit a patient (based on expectations)
    - Moment request care nursing home
    - Maximum number of nursing home admissions per day
- Analyse the effect of 'enlarging' the system
- Give insight when a predetermined objective will be violated (e.g. when x patients are waiting for a certain bed type, alternative solutions should be considered).
- Be applicable in other settings than our case study, with similar model objectives in patient flow from hospitals to aftercare institutions

Section 4.2.6 describes what we mean by system performance. We use these requirements to determine the level of detail the model requires.

4.2.2 *Level of detail*

We take into account the main patient and information flows. The process starts with the patient's arrival at the policlinic and ends with the patient's dismissal at the nursing home.

The model's goals are in the area of resource capacity planning. On the one hand, the model quantifies effects of capacity dimensioning; a problem on strategic level. On the other hand, the model quantifies effects of 'the rules of the game' (e.g., patient' allocation rules, time of requests), which is a problem on tactical level: how to assign time and resources to specialties. The model supports both of these aspects. The model cannot be used for decisions on operational level and is not a decision support tool. The nature of the problem requires assumptions for a longer time period, what makes results indicative of general patterns rather than descriptive of exact behaviour.

4.2.3 Model selection

Chapter 3 categorises resource planning models in analytical or simulation based models. We use discrete-event simulation for the following reasons:

- *System complexity* **-** analytical models do not allow general distributions and lack detail in relation to information flows. The literature acknowledges the importance to take these into account. Simulation studies within single hospitals show the significant effect of acceptance rules on patient flow.
- *Designed interventions* - we want to explore effects of various interventions; a simulation model is more flexible in modelling possibilities. Interventions with flexible capacity and/or different patient types are hard to describe analytically.

A simulation is a simplification or abstraction of reality. In simulation, we use a computer to evaluate a model numerically, and data are gathered to estimate the characteristics of the model (Law & Kelton, 2000). We develop the model using the simulation software Technomatix Plant Simulation version 8.1 (Siemens, 2008).

4.2.4 Model input

This paragraph describes the model's input parameters. Appendix D gives an overview of all sets and parameters of the simulation model.

Patient nature and care types

An arriving patient at a nursing home can be a hospital patient, elective or emergency, or a patient coming from home. We call this the patient nature p. This is a fixed set in the model. The arrival rate $\lambda_{d,w,p}$ of patients depends on the patient nature and may differ per day of the week d and/or per week of the year w .

In addition to the patient's nature, the patient requires a certain type of care in the resource, the care type c. The care type is divided in subsets: one for the hospital and one for each resource in the nursing homes. In the hospital this is for example a hip surgery in the department orthopaedics, whereas on a short stay nursing home department this can be intensive revalidation.

Resources and departments

The resource i is a fixed set and consists of Policlinic, Operating room, Ward, Crisis, Short stay, Long Stay and Community. Except the community, every resource consists of multiple departments. A department dep belongs to a certain location l, where a location can contain departments of various resources. We define five parameters related to department or resource.

- *Capacity* - department dep is at resource i on location l has $C_{dep,l,i}$ beds
- *Service time* - a patient with patient nature p at resource i has service time distribution $dist(\mu_c, \sigma_c)_{p,i}$ where the input parameters μ and σ depend on the patient's care type c.
- *Overflow probability* – a patient with patient nature p in resource i with care type c needs care type m in resource j downstream of i with probability $P_{i,j,p,c,m}$. If all care types are part of only one subset i (so $c \in i \text{ and } c \notin j \text{ if } i \neq j$) we use the notation $P_{p,c,m}$.
- *Preference* – a fraction of patients $preference_{l,m}$ with care type m have preference for location l.
- *Acceptance* – whether department dep accepts patients with care type c is indicated by $acceptance_{d,c}$

Information events

The sets and parameters described so far, concern the flow of the patient through the system. This process requires communication, which happens in parallel with the patient flow and what we call the information flow. Information events restrict admissions to a resource, e.g., for the nursing home a patient cannot be admitted before CIZ indication. Each information event e is a prerequisite for another patient event and/or information event f. The information event starts when the predecessors have been completed. The events and durations are variable. We use the parameters of information flow in addition to the parameters of patient flow as input for the simulation model.

4.2.5 *Model description*

The simulation model imitates real system behaviour of patient flows from hospital to nursing homes. We first give a general description of the model and then elaborate on the processes.

Figure 17 visualises the path that a patient follows from arrival in the hospital, via a nursing home, back to the community. This forms the basis of the simulation model.

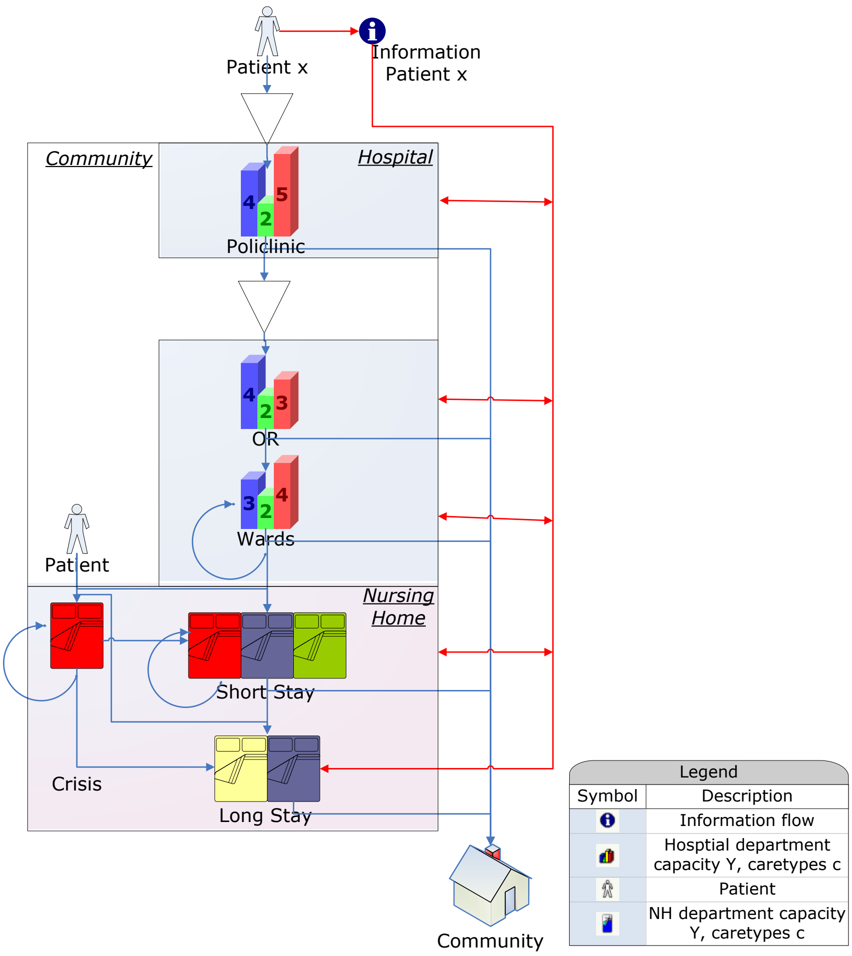


Figure 17 System description patient flow

An arriving patient at a nursing home can be a hospital patient, elective or emergency, or a patient coming from home. Additional to the patient's nature, the patient requires a certain type of care in the resource. In the hospital this is for example a hip surgery in the department orthopaedics, whereas on a short stay nursing home department this can be intensive revalidation. All departments are arranged for a certain group of care types; the department accepts only these care types. In addition information events are required before admission to a resource is possible, for example, the nursing home cannot admit a patient before CIZ indication. The model uses a matrix with events that restrict patient flow. Figure 18 shows the model with different resource capacities, care types accepted on departments, different locations (orange) and possibility of outflow.

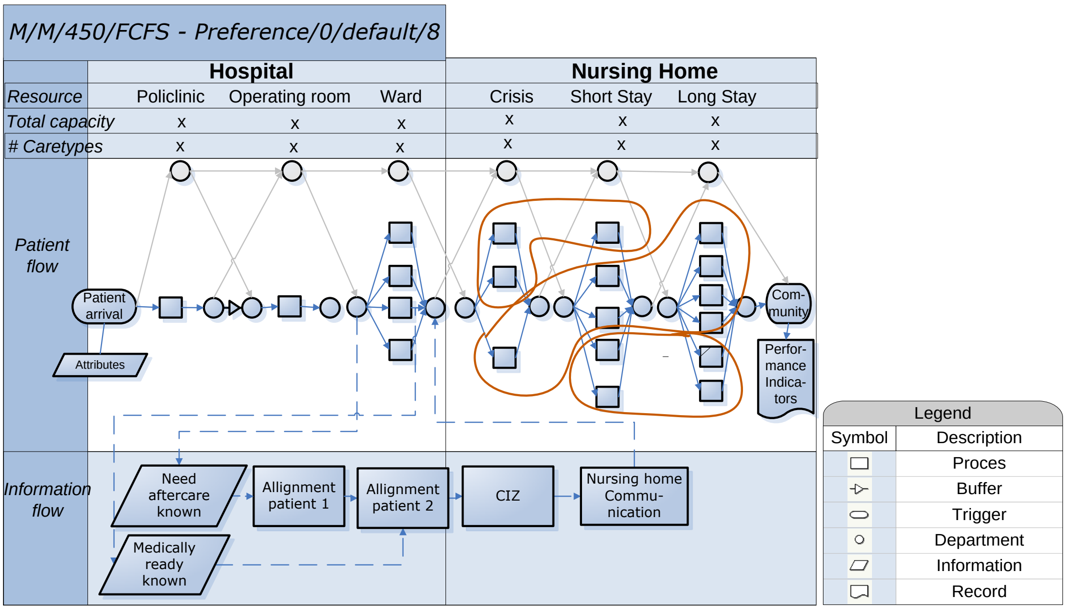


Figure 18 Example system description patient flow

Events trigger certain actions in a discrete event simulation. Figure 19 shows the basic events of the simulation. A patient arrives at a certain resource, enters the resource and leaves again. All resources are composed in the same way. Appendix F describes flow charts for each event.

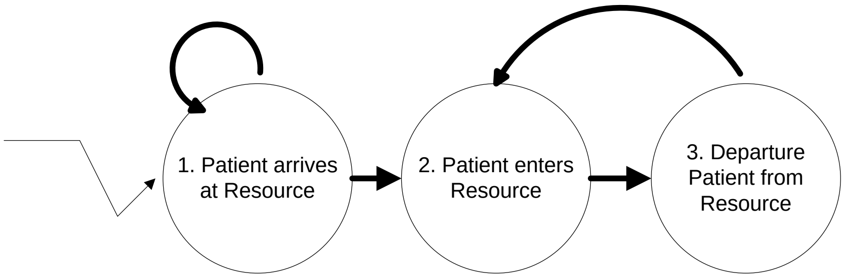


Figure 19 Event graph

The patient follows a path through the care chain that fulfils the patient's and department's restrictions as quick as possible.

4.2.6 *Performance indicators*

To measure the system performance we establish performance indicators, based on stakeholder-interests and the literature review. Primary indicators are our main interests for the analysis. We monitor and/or restrict the secondary indicators.

Primary

- The (relative) number of patients waiting to enter resource i and the associated waiting time for resource i
- Occupation rate of resource i (percentage)

- Fraction of time spent in inappropriate resource i

Secondary

- Average number of moves before patient on bed of required care
- Fraction of patients that is admitted to the nursing home location of preference

4.2.7 Assumptions and simplifications

We make the following simplifying assumptions:

- *Assumptions 1 - patient flows are only in downstream direction*
 A patient does not need more than one treatment in a resource and, for example, does not go to a short stay department when the patient is already in a long stay department.

- *Assumption 2 - x patients per day accepted for Policlinic and Operating Room*
 A patient belongs to a certain care group (for policlinic and for operating room) of which a maximum number of patients is accepted per day.

- *Assumption 3 - patient acceptance in nursing homes according to general rules*
 A nursing home department accepts a predetermined set of patients according to one characteristic at a time.

- *Assumption 4 - the number of beds determines capacity*
 Personnel and other facilities are not accounted for. These can be coupled to the number of beds later on.

- *Assumption 5 - service times*
 Service time distributions do not depend on the department where a patient receives treatment within a resource (it does depend on the care type).

- *Assumption 6 - waiting time affects service time*
 The following relation for the expected sojourn time E(S) holds:

$$E(S_{c,p,i}) = \frac{1}{\mu_{c,p,i}} + P_{p,m,c} * E(W_{i+1}) \;\; \forall c, p, i \neq NH_{Longstay}$$

$$E(S_{c,p,i}) = \frac{1}{\mu_{c,p,i}} - E(W_i) \;\; \forall c, p, i = NH_{Longstay}$$

 Where i+1 refers to the resource where the patient needs follow-up care subsequent to the care in resource i.

If a patient waits for care in a crisis department or short stay department, this does not affect the required service time on this department, independently of the location where the patient waits. We assume the indication of care the patient needs (crisis) or the revalidation of the patient (short stay) does not decrease or increase while waiting for care. If a patient waits for care in a long stay department, the required service time decreases with the time the patients wait at the downstream resource. We make this assumption since patients who require care in a long stay department in general remain in this department.

The model covers the main patient and communication streams of the transmural process. The communication process consists of consecutive events, where for example real-life complexity of specific patients or noice in knowledge of capacity, cannot be captured. One could approach such situations by creating separate care types for these groups and including communication events to represent the noice.

4.3 Model notation

This paragraph describes a standard notation for experiments of the simulation model. The objective of the notation is to recognise what model is considered. We set two requirements for this notation:

1. The notation contains the main characteristics of the simulation model
    a. Arrival distribution
    b. Service time distribution
    c. Other restrictions related to communication
    d. Allocation rule to pick a patient (queue discipline)
    e. Allocation rule to pick a bed
2. The notation visualises the difference between interventions under consideration
    a. Reservations or not
    b. Type of communication requirements
    c. Total nursing home bed capacity
    d. Number of different patient care types
    e. Number of different nursing home departments

We take the queueing notation that Paragraph 3.5 describes as a starting point. In queueing it becomes harder to achieve a clear overview of model characteristics when adding priorities or when dealing with a network (Winston, 2004). This problem increases with the additional complexity of a simulation model. Since the aim of the notation is to recognise the settings for an intervention and distinguish between interventions, we only add the characteristics that differ from the interventions under consideration. Table 13 gives the additional requirements.

Related queueing characteristic	***Requirement simulation not captured by queueing notation***	***Characteristic notation simulation***
Priority of customer	Not only priorities in customers, also selective acceptance	If customer not accepted in department, call the priority of the customer type '0'
Number of servers (capacity)	Not possible to see whether the hospital reserves beds	Add a characteristic with the number of beds reserved in the hospital
Number of servers (capacity)	Not possible to see the number of different nursing home departments	Add a characteristic to define the number of different nursing home departments
-	Only a queue discipline, not an allocation rule to pick a bed	Add a characteristic to define the allocation rule to pick a bed
-	Communication stream is not taken into account	Add a characteristic and define communication disciplines
-	Not possible to see the number of different care types	Add a subscript to first letter (arrival process) with the number of care types

Table 13 Additional requirements to queueing notation for standard notation simulation

A combination of the queueing notation and the additional requirements gives the following notation for each simulation intervention:

1/2/3/4 – I/II/III/IV

1. The nature of the arrival process
2. The nature of the service times
3. Total nursing home bed capacity
4. The queue discipline

I. Allocation rule to pick a bed
II. Number of beds reserved by the hospital (FixedNR or FlexNR or 0)
III. Type of communication requirements
IV. Number of different nursing home departments

Appendix G gives an explication of the meaning of several signs. The notation can be extended, if required, by adding disciplines for an existing characteristic and/or adding characteristics. An example of the notation we use is M_3*/M/100/FCFS - Location/Fixed10/Default/5.* This is not a complete description of the model settings. The notation helps us to compare different settings of the model.

4.4 Summary

We develop a model that gives insight in the effects of changing input parameters and create a playground for analysis of interventions of transmural networks. Our study and model focuses on elements within the span of control of hospital and nursing home on strategic and tactical levels. Of various intervention concepts the model can cope with, this research explores the following selection:

- Advance communication process
- Transfer beds for hospital patients
- Reservation of beds

We use discrete-event simulation due to system complexity and the designed interventions. The simulation model covers the main patient and information flows. The process starts with the patient’s arrival at the policlinic and ends with the patient’s dismissal at the nursing home. To recognise the intervention under consideration, every intervention of the simulation model is indicated by a notation of eight characteristics.

5 Computational results

This chapter contains preliminary results obtained from the simulation model Chapter 4 describes. For the analysis we use the RdGG case study as starting point, but it does not directly reflect the current situation in RdGG. We use only data of a fraction of the system and use rough estimates and assumptions, due to data availability during this study. This chapter explores impact of interventions and sensitivity of performance indicators to parameters.

Paragraph 5.1 clarifies input data and assumptions in the experimental design. The model verification and validation are discussed in Paragraph 5.2. Paragraph 5.3 shows the computational results in the base scenario and two variants on this scenario. We use these outcomes for analysis of intervention performance in Paragraph 5.4. Paragraph 5.5 analyses the sensitivity on model performance of changing some of the parameters in the base scenario. Finally, Paragraph 5.6 outlines conclusions from the experiments.

5.1 Experimental design

To compare interventions, the simulation model requires the input parameters described in Paragraph 4.2.4. To be able to analyse the influence of interventions, we define a 'base scenario'. This paragraph gives an overview of the input parameters used for the base scenario and clarifies the construction. Paragraph 5.1.1 outlines the input data of the base scenario, and then Paragraph 5.1.2 describes additional assumptions related to the input parameters.

5.1.1 *Input data base scenario*

The construction of the base scenario is a combination of assumptions of most likely values and data of Bieslandhof, one nursing home of PvF. The system under consideration is therefore smaller than in real life.

Care types

Care types are categories of care that patients require. The care types c are divided in subsets; those for hospital care and for nursing home care. We only distinguish one type of hospital care, since our interventions focus on process part to nursing homes. Distinguishment of multiple care types in the hospital is important in, for example, analysis of the effect of operating room scheduling on bed blocking. Table 14 shows the various nursing home care types introduced in Chapter 2.

Locations

The base scenario only distinguishes one location type, 'Bieslandhof'.

Departments and acceptance

Nursing homes may use several departments, providing the same care, providing the same care, based on workability. We call units only different departments if either the location or provided care differs, since these are of relevance for our model. Table 15 shows these various departments and the care types the department accepts, based on nursing home Bieslandhof.

Communication events

The model distinguishes communication events with and without processing times. The events, from Chapter 2, in the base scenario are:

a. After care need
b. Medically ready known
c. Alignment patient
d. CIZ
e. Nursing home
f. Medically ready

Three of these events have a processing time larger than zero, the completion of the other events is only related to the patient's course through the process. Figure 20 shows their relation. The expected duration of the communication process is 4.

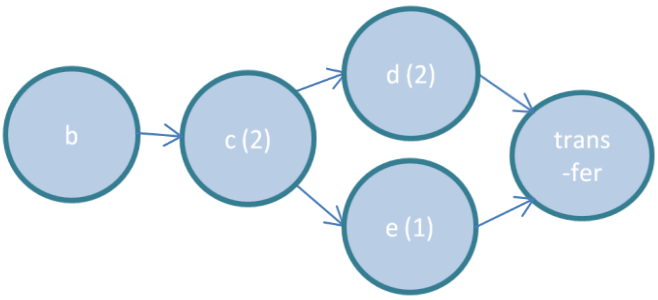


Figure 20 Relation communication events base scenario

Arrival rates

Arrival rates are exponentially distributed. The arrival rate is estimated from available data of PvF's Bieslandhof and therefore is the rate of arrival at one nursing home location. We combine this data with patient outflow of the same period in POINT to establish the fraction of arrivals of hospital patients and the fraction of other arrivals. Appendix I outlines computation of these values.

Service time distributions

We estimate service times for the various care types from data of PvF from a period of 1.5 years. Since the data is not fully transparent concerning the various care types, this is a rough approximation of service times. We use the statistical program MathWave EasyFit (MathWave Technologies, 2010) to analyse best fit distributions on the available data, see Appendix I. Since the typical pattern that a large group of patients has the same service time, for most care types no good fit could be found. The service times for the base scenario will therefore be derived from empirical distributions, based on available service times. Paragraph 5.5 discusses the influence on performance indicators when using different distributions.

For the long stay departments no data on service times is available. The long stay departments achieve high occupations; occupation snapshots of nursing home departments of PvF show department occupations from 90, but often a 100 percent. We use the assumption of 95 percent occupation to establish average service times of the long stay department. The long stay departments are assumed to follow exponential distributions, since this is the most common assumption in the literature.

Overflow probabilities

An approximation of flow probabilities from hospital and from home to the various care types are estimated from the same data as arrival rates. The overflow probabilities within nursing home resources are rough estimates of experts.
Table 16 shows all overflow probabilities.

Capacities

The capacities of all i resources are divided amongst the departments. We first allocate capacities to the three resources, where:

$$\sum_i C_i = \left(1 + \frac{1}{a} + \frac{1}{b}\right) C_i \quad for \;\; i = NH_{Longstay}$$

$$where \quad C_i = \sum_l \sum_{dep} C_{dep,l,i}$$

$$a = effective\ occupation\ NH_{Crisis}\ as\ fraction\ of\ occupation\ NH_{Longstay}$$

$$b = effective\ occupation\ NH_{Shortstay}\ as\ fraction\ of\ occupation\ NH_{Longstay}$$

[1] The explanation of symbols can be found in Paragraph 4.2.4 and an overview in Appendix D

The bed occupation of crisis departments is intended to be 1/a times lower than of long stay departments and the occupation of short stay departments to be 1/b times lower than of long stay departments. In the case study the situation is such that:

$$\sum_i C_i \quad = 310$$

$$a = 0.5$$

$$b = 0.8$$

These capacities of the resources should now be divided amongst the various departments. We cannot use the capacity allocation of our case study, since some departments will then be overloaded, while others have unrealistically low bed occupations. We expect that reasons are: poor data, a slight difference in bed allocation in practice and actual disbalance of capacities. To analyze interventions it is important the system is balanced. To balance capacities we tend to linearly divide capacity within a resource based on expected required demand.

Balance capacities amongst departments

For the capacity *C* of department dep at location l of resource i holds that:

$$C_{dep,l,i} = \frac{\delta_{dep,l,i}}{\sum_{dep,l} \delta_{dep,l,i}} \qquad \forall dep, l, i$$

Where $\delta_{dep,l,i}$ is the weighted demand that is accepted on department dep within resource i, such that:

$$\delta_{dep,l,i} = \sum_m \left(\frac{Acceptance_{dep,m}}{\sum_{dep} Acceptance_{dep,m}} * \sum_p \left(D_{m,p} * \hat{E}\left(S_{c,p,i}\right)\right)\right)$$

$$\forall dep, l, i$$

Where D_m is the total demand of patients with care type *m*, from:

$$D_{m,p} = \sum_{c,o} \left(\hat{\lambda}_p * P_{p,c,m} + \hat{\lambda}_p * P_{p,c,n} * P_{p,n,m} + \hat{\lambda}_p * P_{p,c,n+} * P_{p,n,o} * P_{p,o,m} \right) \qquad \forall m$$

$$\hat{\lambda}_p = \frac{\sum_w \sum_d \lambda_{d,w,p}}{d * w} \qquad \forall p$$

$\hat{E}(S_{c,p,i})$ is an approximation of the expected sojourn time in resource i. From assumption 6 in Paragraph 4.2.7 we need an estimate for the waiting time $\hat{E}(W_{i+1})$ in a resource upstream of i. We approximate $\hat{E}(W_{i+1})$ by using queueing theory, where resource i is a M/M/C queue with capacity $\sum_l \sum_{dep} C_{dep,l,i+1}$ (Adan and Resing, 2002). The expected waiting time is computed from:

$$E(W) = \Pi_W \cdot \frac{\rho}{1-\rho} \cdot \frac{1}{c\mu}$$

Where Π_W is the probability that a patient has to wait, from:

$$\Pi_W = \frac{(c\rho)^c}{c!}\left((1-\rho)\sum_{n=0}^{c-1}\frac{(c\rho)^n}{n!} + \frac{(c\rho)^c}{c!}\right)^{-1}$$

The assumption used in this approach, that the resource consists of one department where all patients are accepted, underestimates expected waiting time. On the other hand, waiting time is overestimated, since occupation of long stay departments decreases with waiting times. Table 15 shows the resulting capacities of each department.

Transfers and location preference

In the base scenario we do not restrict the number of transfers or location preferences of patients. Paragraph 5.5 describes the effect of adding either of these restrictions.

Parameter		
$\lambda_{d,w,elective}$	1.2877	$\forall d,w$
$\lambda_{d,w,home}$	0.9766	$\forall d,w$
$Duration_{CIZ}$	2	
$Duration_{CIZ}$	1	
$Duration_{PatientAllignment}$	2	
$Preference_{l,m}$	0	$\forall m, l \neq NoPreference$

Care type	Resource	Nature	Origin of the patient	ZZPs	Distribution length of stay $dist(\mu_c)_{p,i}$
Hospital	Ward	-	Hospital		Expon(17)
Cr-Som.	Crisis	Somatic	Home		Expon(8.7)
Cr-Cog.	Crisis	Cognitive	Home		Exp(17.9)
CVA-6/9	Short stay	Somatic	CVA	ZZP 6/9	Emp(41.9)
Ort./Chi.-3/4	Short stay	Somatic	Orthopaedic or Chirurgic	ZZP 3/4	Emp(75.6)
Ort./Chi.-6/9	Short stay	Somatic	Orthopaedic or Chirurgic	ZZP 6/9	Emp(45.4)
Rem.-3/4	Short stay	Somatic	Remaining; not CVA or Ort/Chi	ZZP 3/4	Emp(75.6)
Rem.-6/9	Short stay	Somatic	Remaining; not CVA or Ort/Chi	ZZP 6/9	Emp(44.1)
SS-Cog.	Short stay	Cognitive	All		Emp(45.4)
LS-Som.	Long stay	Somatic	All		Expon(315.7)
LS-PG	Long stay	Cognitive	All		Expon(380.6)

Table 14 Nursing home care types for Simulation

Department	Recourse	Location	Capacity $C_{dep,l,i}$	Accepts $Acceptance_{d,c}$
Policlinic	H_Policlinic	Hospital	-	Hospital
OperatingRoom	H_OperatingRoom	Hospital	-	Hospital
OrtChi	H_Ward	Hospital	15	Hospital
CVA	H_Ward	Hospital	15	Hospital
Ward_Rem	H_Ward	Hospital	15	Hospital
Cr_Som	NH_Crisis	Bieslandhof	2	Cr-Som.
Cr_Cog	NH_Crisis	Bieslandhof	2	Cr-Cog.
SS_Som_OrtChi	NH_ShortStay	Bieslandhof	26	Ort/Chi-3/4, SS-Ort/Chi-6/9
SS_Som_Rem	NH_ShortStay	Bieslandhof	47	Rem-3/4, Rem-6/9
SS_Som_Herstel	NH_ShortStay	Bieslandhof	9	Rem-6/9, Ort/Chi-6/9[1]
SS_Som_CVA	NH_ShortStay	Bieslandhof	17	CVA-3/4, CVA-6/9
SS_Cog	NH_ShortStay	Bieslandhof	11	SS-Cog
LS_Som	NH_LongStay	Bieslandhof	61	LS-Som
LS_PG	NH_LongStay	Bieslandhof	135	LS-PG

[1] Additional conditions: $\mu \leq 28$ and $p = elective\ or\ emergency$

Table 15 Departments and capacities for simulation

Patient Nature	CareType	Ort/Chi-3/4	Rem-3/4	CVA-6/9	Ort/Chi-6/9	Rem-6/9	SS_Cog	LS_PG	LS_Som	Cr_Som	Cr_Cog	No
Elective	Hospital	0.019	0.012	0.257	0.367	0.225	0.094	0.004	0.021			
	Ort/Chi-3/4											1
	Rem-3/4											1
	CVA-6/9								0.05			0.95
	Ort/Chi-6/9								0.05			0.95
	Rem-6/9								0.05			0.95
	SS_Cog							0.95				0.05
	LS_PG											1
	LS_Som											1
	Cr_Som					0.5						0.5
	Cr_Cog						0.5					0.5
	No											
Home	Hospital											
	Ort/Chi-3/4											1
	Rem-3/4											1
	CVA-6/9								0.05			0.95
	Ort/Chi-6/9								0.05			0.95
	Rem-6/9								0.05			0.95
	SS_Cog							0.95				0.05
	LS_PG											1
	LS_Som											1
	Cr_Som					0.5						0.5
	Cr_Cog						0.5					0.5
	No		0.027			0.520		0.193	0.075	0.123	0.062	

Table 16 Overflow probabilities for simulation

This input data of the base scenario is used to analyse interventions. The next paragraph describes additional settings and assumptions related to the input parameters.

5.1.2 *Model settings and assumptions*

Paragraph 4.2.7 describes simplifying assumptions that concern the model design. This paragraph describes assumptions related to input parameters for the experiments.

- *Assumption 1 – allocation rules*

  When a bed becomes available, nursing homes give preference to patients that are waiting in nursing home beds (internal patients) over external patients. Furthermore patient selection is based on First Come First Serve (FCFS).

  If a patient arrives and beds are available on more than one appropriate department, the department is selected randomly. An exception is if a department exists especially for patients from hospitals, then a patient will be first allocated to this department.

- *Assumption 2 – capacity allocation*

  To balance capacity amongst resources, we use different fractions (a,b) of required occupation (waiting times excluded). We assume that the following always holds in the division of capacities amongst resources:

  $$\rho_{NH_{crisis}} \leq \rho_{NH\_Shortstay} \leq \rho_{NH\_Longstay}$$

  For division of capacities amongst resources for the base scenario (average case) we use the available data of our case study.

5.2 Validation and verification of the simulation model

To assure that the simulation model works as intended, one should use verify the correctness of the model. Model validation deals with building the right model; to what extend the model corresponds with the objectives. In our simulation study few data is available and rough assumptions have to be made. Results are preliminary and validation with real performance is hardly possible; the verification part is of main importance now and a better validation in a later stage. We verify the model by a structured walk through and comparison to steady state behaviour of a comparable queueing network.

5.2.1 *Structured walk-through*

To verify correct programming of the model we checked step by step all methods of the simulation model. We ran the model in various settings and monitor the system's actions. Checks to see whether the output data is reasonable were performed next. An analytical queueing model is used to verify these outputs measures.

5.2.2 *Queueing*

Our simulation model, as Chapter 4.2 describes, consists of a network of queues. The base structure resembles a queueing network.

We use a Jackson network to verify the outcomes of our simulation model. Each resource, that is a bed facility, represents one node, which gives a network of four nodes. To establish the input parameters, we use weighted parameters over all departments. For verification purposes we use simulation settings that correspond to the Jackson network. The outcomes of both occupation and waiting times are supposed to be similar to the simulation outcomes if we:

- Exclude communication events
- Use exponential distributions for service times
- Allow all care types on the various departments within a resource
- Acceptance on departments according to queueing principle FCFS
- Same arrival rate for all days

- No restrictions concerning locations
- No limit to number of transfers per day

We expect the occupation rates to be similar; we expect that the waiting times of the simulation model are comparable to the Jackson network. However we expect the waiting time of the simulation model somewhat higher, since the queueing model uses exponential distributions for the service time of each resource instead of hyper exponential distributions, as it is modelled in the simulation (whose coefficient of variation is higher than of the exponential distribution). Furthermore the blocking manipulates the system, which makes the system different than the Jackson network. To compute outcomes of the Jackson network we use the Excel queueing software QtsPlus (D. Gross and C.M. Harris, 1998). Table 17 shows 95 % intervals of the simulation run and the steady state situation of the Jackson network. We compute the total occupation of the queueing network by the sum of the effective occupation and expected occupation due to patients waiting for a higher level resource.

Occupation	Simulation			Queueing		
	Average Occupation	Interval Max	Min	Effective Occupation	Waiting Occupation	Total Occupation
Crisis	53.03%	52.60%	53.45%	53.19%	0.13%	53.31%
SS	78.31%	77.84%	78.79%	76.47%	1.48%	77.94%
LS	94.75%	94.37%	95.13%	95.00%	0.00%	95.00%

Waiting time	Simulation			Queueing
	Average W(q)	Interval Max	Min	W(q)
Crisis	1.543	1.449	1.637	1.31
SS	0.077	0.043	0.110	0.014
LS	10.30	8.24	12.36	13.48

Table 17 Verification of simulation outcomes by Jackson network

For the occupation rates, all queueing outcomes are within the 95% confidence interval of the simulation outcomes. The waiting times are close to, but not in the 95% confidence intervals. We expect that is due to the system manipulation by blocking in simulation model.

5.2.3 *Warm- up period, run length and number of replications*

Each simulation starts with initial conditions, for example an empty system. The performance then depends on these initial conditions; also called transient system behaviour. The real world situation is in steady state and the performance does not depend on initial conditions anymore. This problem is called the problem of the initial transient or the start-up problem in the simulation literature. The technique most often suggested for dealing with this problem is called *warming up the model* or *initial-data deletion*. We determine the warm-up period by using Welch's method, based on plotting moving averages (Law and Kelton, 2000).

Since the long stay department requires most time to convert to steady state behaviour, we use the occupation of the long stay departments to determine the required warm-up period. Appendix H shows that after 10 years occupation occurs to be stable. To make sure we reduce the impact of the initial state as much as possible, we take a warm-up period of 15 years.

To ensure that enough output data have been obtained from the simulation in order to estimate the model performance with sufficient accuracy, we select an appropriate run-length and determine the number of replications. We first used the *fixed-sample-size procedure* (Law and Kelton, 2000) with approximate 95% confidence interval to estimate sample size. Then we used the replication/deletion approach for means, where we make n independent runs and ignore observations from warm-up period such that our relative error is 10% on the 95% confidence interval. We choose to run all interventions for a period of 50 years (where a warm up period of 15 years is already excluded) with 30 replications. We use this number for all interventions since we consider this sufficient for the comparison of preliminary results.

5.3 Experiments of the base scenario

This paragraph shows the performance of the base (initial) scenario from analysis with the simulation model. The purpose is to use the performance of this scenario to evaluate the impact of interventions, not to evaluate or compare current performance.

Table 18 shows performance measures on two levels: overall key figures and figures per resource/patient nature.

Base Scenario A	Notation Emp$_9$/Emp/310$_{0.5,0.8}$/FCFS&Internal – Department/0/Default/11		
Overall W_{avg}	Hospital [1]	8.8	
	Home	4.8	
	Overall	7.4	
Overall Occupation		88.4%	

		Occupation [2]		W [3]		W_{max} [4]	%Wait [5]	$Frac_{LOS}$ [6]	Through-put [7]
		Avg	St.dev.	Avg	St.dev.				
Resource	NH_Crisis	55.7%	1.1%	5.0	0.22	161.1	92%	63%	779
	NH_ShortStay	78.3%	0.3%	5.8	0.04	486.2	90%	33%	30191
	NH_LongStay	94.7%	0.1%	14.6	0.20	245.4	83%	8%	67763
Patient nature	Hosptial			9.3	0.07	266.5	98%	43%	46094
	Home			5.0	0.08	158.8	77%	14%	52640

[1] The location where the patient is waiting; overall means all location are included
[2] The average occupation over all simulation runs, with the corresponding standard deviation
[3] The average waiting time of patients over all simulation runs, with the corresponding standard deviation
[4] The maximum waiting time: the average of maxima of all simulation runs
[5] The percentage of patients with a waiting time larger than zero
[6] The waiting time of a patient relative to the required service time the patient is waiting for
[7] The number of days per year that patients are in the nursing home

Table 18 Performance from simulation of Base Scenario (A)

Remarkable is that the average waiting time for hospital patients is 8.8 days versus 4.8 days for home patients. The waiting time is higher because the communication process in the hospital is taken into account, while for home patients only the waiting time due to capacity availability is considered. Figure 21 and Figure 22 show performance measures per department and per care type. This way various performance measures can be compared in more detail. For the interventions in the next paragraph we compare overall key figures and figures per resource and patient nature.

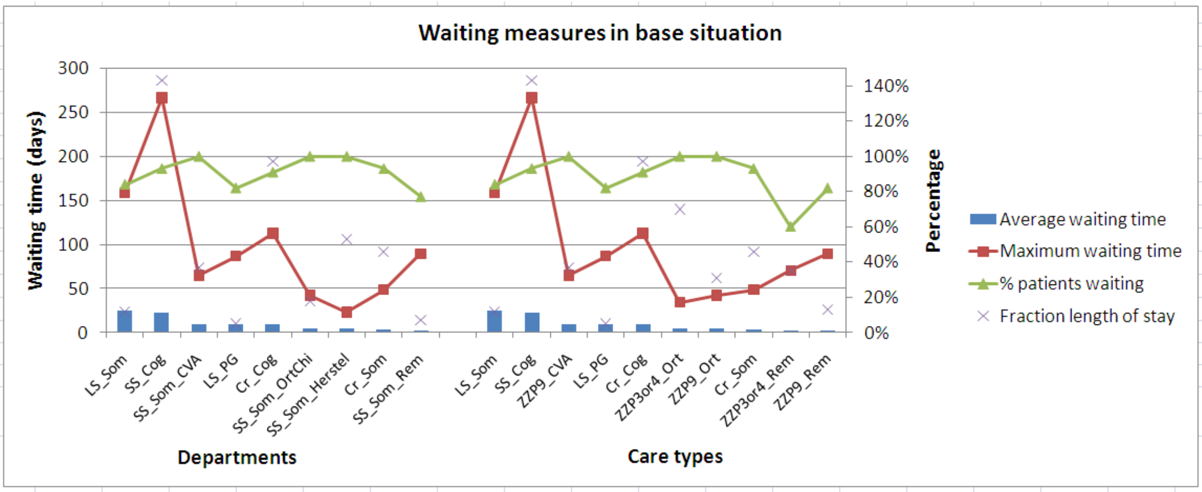


Figure 21 Waiting time measures per department and per care type of Base Scenario

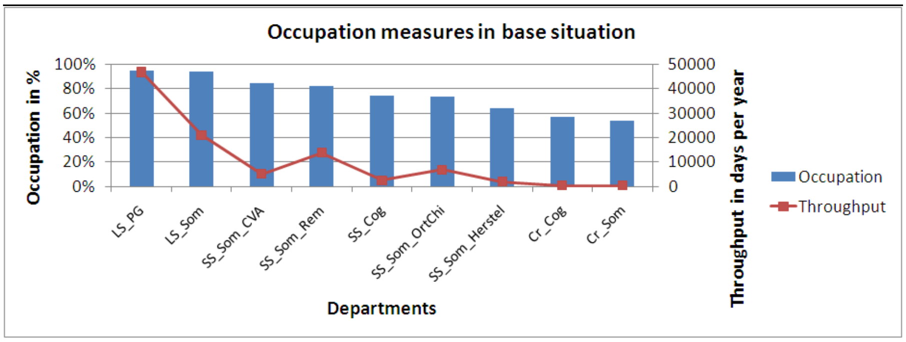


Figure 22 Occupation measures per department and per care type of Base Scenario

The average waiting time for cognitive ('SS_Cog') departments is high, while the department does not have the highest occupation. It is a relatively small department, which requires more capacity to achieve a similar waiting time as larger departments. The same holds for the long stay somatic ('LS_Som') department.

The effect of interventions might differ for other scenarios. Therefore we compare intervention performance to the two alternative scenarios Appendix K defines.

5.3.1 *Experiments alternative scenarios*

This paragraph shows the performance of two alternative scenarios (B and C) from analysis with the simulation model. The purpose is to use the performance of these scenarios to evaluate the impact of different initial settings on an intervention's performance. The performance should not directly be compared to the base scenario

Base Scenario B	**Notation** $Emp_9/Emp/341_{0.6,0.68}/FCFS$**– Department/0/Default/11**		
Overall W_{avg}	Hospital [1]	6,26	
	Home	16,43	
	Overall	9,62	
Overall Occupation		79,7%	

		Occupation [2]		W [3]		W_{max} [4]	%Wait [5]	$Frac_{LOS}$ [6]	Through – put [7]
		Avg	St.dev.	Avg	St.dev.				
Resource	NH_Crisis	68,4%	1,0%	68,0	1,04	795,7	95%	994%	670
	NH_ShortStay	64,3%	0,5%	4,7	0,06	281,7	78%	30%	36739
	NH_LongStay	93,9%	0,1%	14,2	0,21	249,0	81%	8%	60637
Patient nature	Hospital			6,9	0,07	186,3	98%	35%	55685
	Home			15,6	0,20	512,8	39%	173%	42361

[1] The location where the patient is waiting; overall means all location are included
[2] The average occupation over all simulation runs, with the corresponding standard deviation
[3] The average waiting time of patients over all simulation runs, with the corresponding standard deviation
[4] The maximum waiting time: the average of maxima of all simulation runs
[5] The percentage of patients with a waiting time larger than zero
[6] The waiting time of a patient relative to the required service time the patient is waiting for
[7] The number of days per year that patients are in the nursing home

Table 19 Performance from simulation of alternative Base Scenario B

Table 19 shows that the average waiting time for Crisis departments in this scenario is 68 days. This unrealistically high waiting time is caused by the relatively high (effective) occupation for this small department and that patients from crisis beds get no preference on Short Stay departments. The values are only used to compare intervention effect, so this does not make the situation less useful.

Scenario variant C	Notation Emp$_9$/Emp/295$_{0.6.0.68}$/FCFS&Internal– Department/0/Default/11		
Overall W_{avg}	Hospital [1]	30,20	
	Home	4,96	
	Overall	15,46	
Overall Occupation		92,5%	

		$Occupation$ [2]		W [3]		W_{max} [4]	$\%Wait$ [5]	$Frac_{LOS}$ [6]	$Through-put$ [7]
		Avg	$St.dev.$	Avg	$St.dev.$				
Resource	NH_Crisis	46,6%	1,2%	1,9	0,09	114,0	83%	24%	891
	NH_ShortStay	89,2%	0,2%	17,6	0,16	1154,8	96%	90%	26487
	NH_LongStay	95,2%	0,1%	14,2	0,21	242,5	84%	8%	70848
Patient nature	Hospital			28,0	0,25	514,2	98%	132%	35042
	Home			5,4	0,07	156,7	88%	14%	63185
		46,6%	1,2%	1,9	0,09	114,0	83%	24%	891

[1] The location where the patient is waiting; overall means all location are included
[2] The average occupation over all simulation runs, with the corresponding standard deviation
[3] The average waiting time of patients over all simulation runs, with the corresponding standard deviation
[4] The maximum waiting time: the average of maxima of all simulation runs
[5] The percentage of patients with a waiting time larger than zero
[6] The waiting time of a patient relative to the required service time the patient is waiting for
[7] The number of days per year that patients are in the nursing home

Table 20 Performance from simulation of alternative Scenario C

In scenario C, the waiting time for ('SS_Cog') departments is again high, due to its relative small size. The occupation rate of short stay departments is arbitrarily higher in this scenario than base scenario A, what results in higher waiting times.

5.4 Experiments of interventions

This paragraph describes the experiments of the selection of interventions from Paragraph 4.1.3. The interventions are compared to the base scenario. For each intervention we define the difference in input from the base scenario, results from the simulation, and observations. Here we focus on the visualization of waiting times if occupations remain similar. Of course, the impact on waiting time can be translated to a change of capacity, and with that occupation, to remain similar waiting times.

5.4.1 Advance communication process

To analyse the effect of an earlier trigger of the communication process we compare the base scenario Paragraph 5.3 describes, to a situation where the hospital knows and anticipates on a patient's nursing home care need with the arrival in the hospital. Figure 23 shows the difference in input of this intervention with the base scenario.

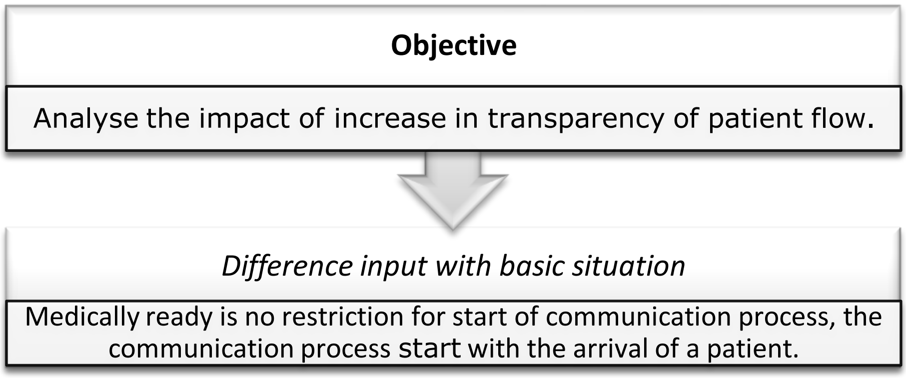


Figure 23 Intervention 'Advance communication process'

The intervention affects the waiting time of patients in the hospital. The patient's communication process will cause less waiting time. The maximum waiting time reduction of this intervention is the expected duration of the communication process. From our base scenario the waiting time of a patient can then be reduced by 4 days. Table 21 shows the performance per resource and patient nature of the intervention.

Advance communi-cation	**Notation – $Emp_9/Emp/310_{0.5,0.8}$/FCFS&Internal – Department/0/Arrival/11**	
Overall W_{avg}	Hospital [1]	5.5
	Home	4.6
	Overall	5.7
Overall Occupation		88.2%

		$Occupation$ [2]		W [3]		W_{max} [4]	$\%Wait$ [5]	$Frac_{LOS}$ [6]	$Throughput$ [7]
		Avg	$St.dev.$	Avg	$St.dev.$				
Resource	NH_Crisis	55.6%	1.1%	5.1	0.27	162.3	92%	63%	780
	NH_ShortStay	78.2%	0.3%	3.7	0.03	480.7	87%	20%	30242
	NH_LongStay	94.5%	0.1%	13.5	0.09	244.5	81%	7%	67631
Patient nature	Hospital			6.3	0.04	268.7	94%	25%	46131
	Home			4.8	0.05	162.9	76%	14%	52523

[1] The location where the patient is waiting; overall means all location are included
[2] The average occupation over all simulation runs, with the corresponding standard deviation
[3] The average waiting time of patients over all simulation runs, with the corresponding standard deviation
[4] The maximum waiting time: the average of maxima of all simulation runs
[5] The percentage of patients with a waiting time larger than zero
[6] The waiting time of a patient relative to the required service time the patient is waiting for
[7] The number of days per year that patients are in the nursing home

Table 21 Performance from simulation – Advance communication

Conform our expectations no significant differences occur (on 95% confidence intervals) in variables other than waiting time for hospital patients. Figure 24 shows the average waiting time of the patients in the hospital and the impact on the overall average waiting time for nursing home departments.

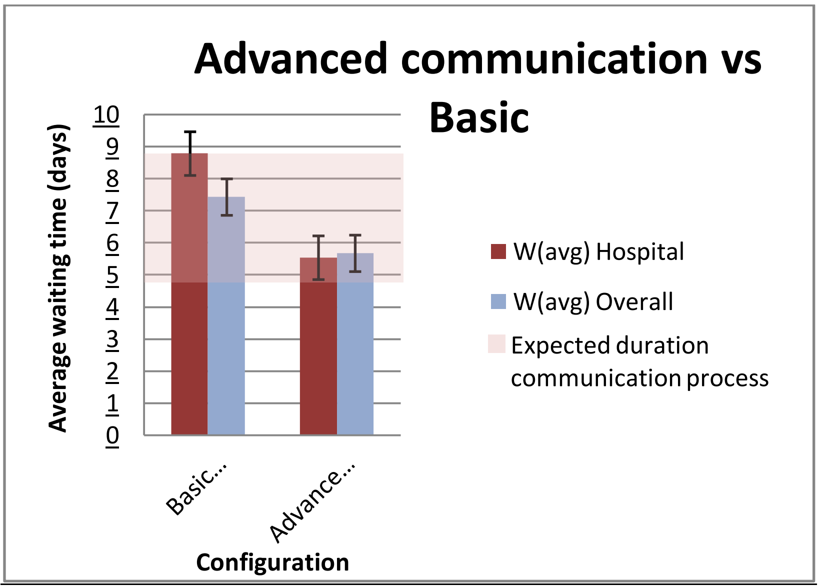


Figure 24 Performance Advance communication process versus Base scenario

Compared to the base scenario, the intervention gives a reduction of the average waiting time in the hospital of 3.3 days. The relative impact of the transparency is higher than we expected. The impact of the intervention depends on the service time distribution in the wards of patients, since the intervention assumes the communication process to start with the patient's arrival. That is an extreme situation, but the model could also analyse a situation in between.

5.4.2 *Transfer beds for hospital patients*

Admission of a patient, who is waiting for nursing home care, on a lower care department can reduce the costs of bed blocking. To simulate this situation we introduce a transfer department that only admits bed blocking patients from the hospital. Figure 25 shows the difference in input of this intervention with the base scenario.

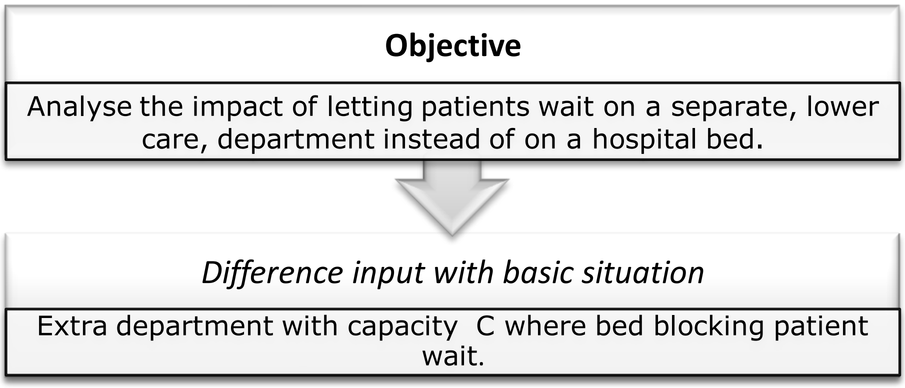


Figure 25 Intervention 'Transfer beds'

We investigate the situation where the capacity of the transfer department $0 \leq C_{EMS} \leq 16$ with intervals of 4 beds. Figure 26 shows respectively the percentage of patients that is admitted on the transfer department, the occupation of the transfer department and the resulting reduction of waiting time in the wards.

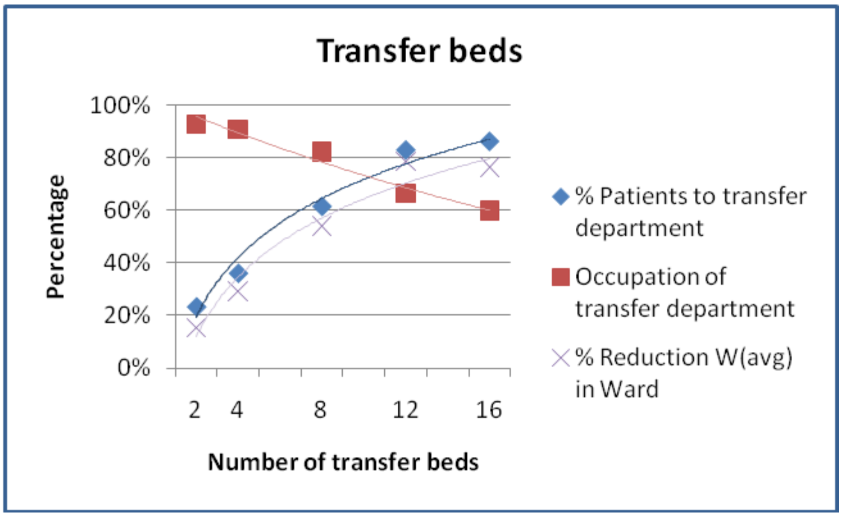


Figure 26 Performance with transfer beds

The occupation of transfer beds is comparable to short stay departments, when half of the bed blocking days is captured by the transfer department, e.g., 6 beds with a nearly 90% occupation rate reduces bed blocking days on wards with 50%. The occupation rate reduces while the increase of reduction in waiting time declines. A balance should be found between the reduction in waiting time on wards and the occupation of the transfer department. Since the transfer department delivers lower (cheaper) level care, occupation requirements may be lower.

A drawback is that many patients are transferred to the transfer department, slightly more than the percentage reduction of waiting time, what means that lots of patients have an extra transfer to a new environment. To prevent this, a restriction could be included such that a patient only goes to the transfer department if the expected waiting time will be more than x days.

5.4.3 *Reservation of beds*

We compare the situation with two kinds of short stay departments. One is allocated to all patients and the other only patients from the hospital are accepted, we call these beds 'Reserved'. Figure 27 shows the difference in input of this intervention with the base scenario.

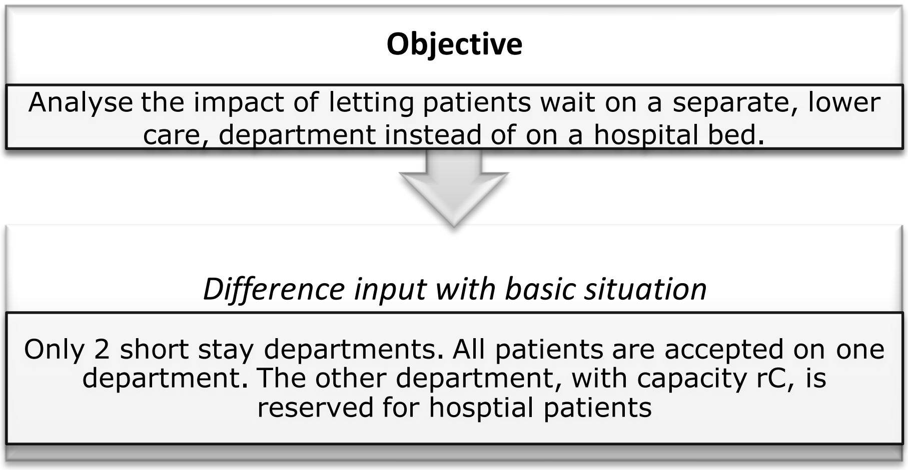


Figure 27 Intervention 'Reservation of beds'

We investigate the situation where different fractions of capacity are reserved, such that external demand (other than hospital demand), can still be met. The reserved capacity varies $C_{reserved} \leq 0.77\,C$ with intervals of 0.1 C. If a bed on the reserved department is available, hospital patients will be first admitted to these beds (assumption 2, Paragraph 4.2.7). Figure 28 shows the average waiting time of patients in respectively the hospital, at home and an overall average.

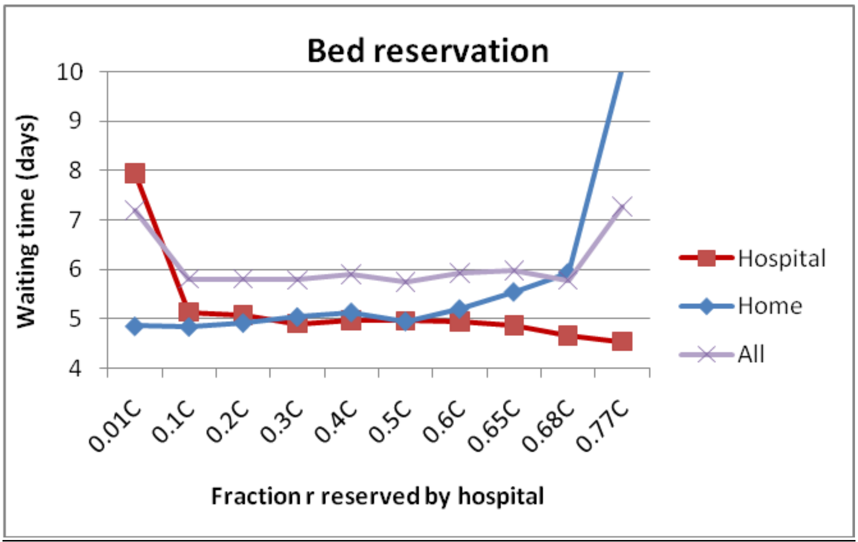


Figure 28 Performance with bed reservation, waiting times

Only for the crisis department a significant difference in occupation occurs for the different fractions of reservation. The higher occupation results from longer waiting times on the crisis departments for patients who require follow-up care in a short stay department.

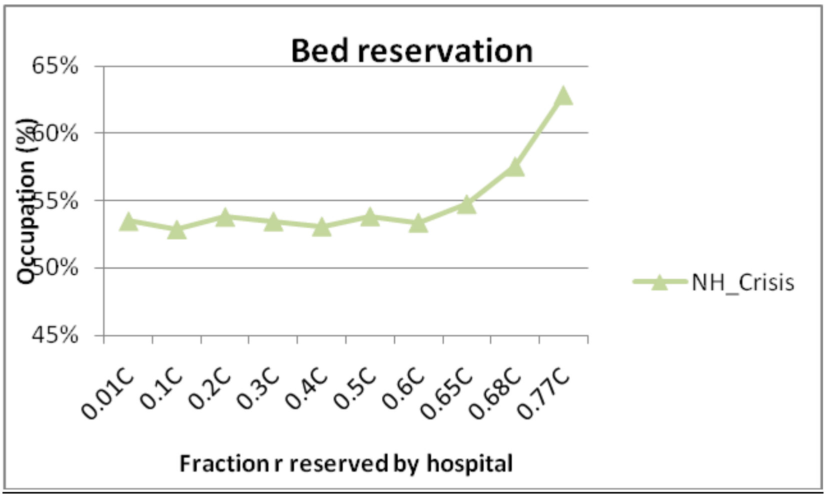


Figure 29 Performance with bed reservation, occupation

The allocation of all beds for all patients does not result in much lower waiting times than base scenario; the average waiting time for patients in the hospital only decreases from 8.8 to 7.9 days. This decrease is lower than we expected and probably due to the preference of internal patient on the short stay departments. A moderate bed reservation for hospital patients, where the expected occupation is significantly higher than the expected occupation where all patients are accepted ($E(\rho_{SS\_reserved}) >> E(\rho_{SS\_all})$), does not result in significant differences in average waiting time. Bed reservation starts to have impact when the expected occupation of the reserved beds approaches or exceeds occupation of the department where all patients are accepted. The overall waiting time then increases due to waiting times of patient at home.

Finally we compare a situation of soft bed reservation, where patients only get preference on all departments. The other settings remain such as the base scenario (A). Figure 30 shows the average waiting times and bed occupation of this intervention in comparison to the base scenario.

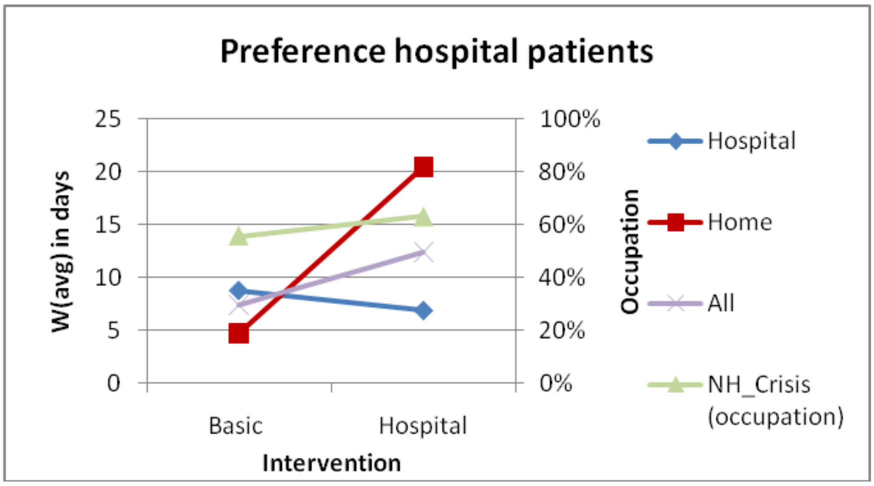


Figure 30 Performance preference hospital patients

The graph shows a similar pattern as for bed reservation: although waiting times of patients in the hospital decrease, overall waiting times increase due to the increase of waiting times at home.

On the one hand, the waiting time of home patients increases more than the decrease in waiting time of hospital patients. On the other hand, the strong increase of waiting time for patients at home could be softened by an (slight) increase of capacity, since the reservation causes incomes for nursing homes as well. In addition, the increase of waiting time for patient at home might be less severe and to a certain level not a problem.

5.5 Sensitivity analysis

Sensitivity analysis should be performed to determine the robustness of the outcomes of the analysis. This can be the robustness of a specific solution for changes over time or for assumptions made. This paragraph focusses on the robustness of intervention effects under various scenarios. The parameters to focus on depend on the intervention under analysis. In general, we expect that five main factors influence the model's performance indicators. These are used to construct alternative scenarios.

5.5.1 *Alternative scenarios*

The base scenario requires assumptions to be made of various factors. Different values from the base scenario may influence results from interventions. The main factors that we expect to influence the model's performance indicators are:

- *Allocation of resource capacity*
  The relative capacity allocated to crisis (a) and short stay (b).
- *Capacity available*
  The total nursing home capacity that is available and with that the average occupation rate of nursing home departments.
- *Fraction demand of hospital*
  The fraction of demand that comes from the hospital under consideration compared to total demand.
- *Overflow probabilities*
  The fraction of patients who require care in an upstream resource.
- *Acceptance rules*
  In the base scenario internal patients (who are already in a nursing home department) get preference for admission over external patients. This rule can be relaxed.

To incorporate the effect of other values for these factors in our intervention analysis, we create two alternative scenarios that represent extreme scenarios. Appendix J therefore describes the expected effect on sensitivity of the performance indicators under each of the interventions when increasing the factors. For example, when we increase total capacity available we expect the effect of transfer beds to decrease (-), since occupation rates will decrease and thereby the need for transfer beds.

Category		**Advance communication process**	**Transfer beds hospital patients**	**Reservation of beds**	**Scenario variant B**	**Scenario variant C**
Allocation capacities resources	a	-	+	+	Low	High
	b	+	-	-	High	Low
Total capacity available		+	-	-	High	Low
Relative hospital demand		+/-	+/-	-	High	Low
Overflow probabilities		-	+	+	Low	High
Preference internal patients		-	+	+	Low	High

Table 22 Score of main influence factors on interventions to construct altnernative scenarios

We take fictive values for these two variants on the base scenario, such that we expect to observe a significant difference in sensitivity to the various interventions but the values still seem realistic. Appendix K shows the values.

5.5.2 *Sensitivity of interventions with alternative scenarios*

The main patterns of interventions are similar for the alternative scenarios as for our base scenario. Appendix L shows the results of the three interventions under both alternative scenario B and C.

The absolute waiting time reduction from earlier communication is similar for all scenarios, but the relative impact of this intervention differs. In other words, the priority this part of the process should have, depends on its context.

The same trend on the impact of a transfer department on performance indicators occurs for all scenarios. The number of transfer beds required, to reduce the waiting time on wards with a given factor, differs based on the scenarios. As a result of the lower waiting times in scenario B, more patients have to be transferred to the department to achieve the same waiting time reduction on wards, which makes the transfer department slightly less attractive. The occupation of the transfer department, when capturing a given fraction of bed blocking days, is lower in scenario C.

Reservation of beds shows the most significant differences under the various scenarios. In scenario B the allocation rule for all short stay departments is FCFS, in contrast with the other scenarios internal patients do not get preference. This takes away the positive effect of the reservation of a small fraction of short stay bed capacity. Reservation of a large fraction of short stay capacity (again such that the expected occupation of the reserved nursing home beds approaches or exceeds occupation of the remaining nursing home beds) shows similar trends for all scenarios.

Remarkably is the difference in waiting time for scenario C of merging departments, when analysing the effect of bed reservation. The analysis of bed reservation is with only two short stay departments, one with reserved beds and one where all short stay patients are accepted. The waiting time under scenario C reduces by 60 percent (from 30 to 12), when short stay nursing home departments are merged to a department where all patients are accepted.

5.5.3 *Sensitivity on capacity allocation*

The available capacity and how this capacity is allocated amongst resource strongly effects the model's performance indicators. This is an important consideration in real system design.

Appendix L shows the simulation results of six scenarios with changes in nursing home bed capacity and capacity allocation. We conclude that although most hospital patients go to short stay departments afther their hospital treatment, this patient group benefits from sufficient capacity allocated to the long stay departments. The importance of a sufficient fraction of long stay beds for the waiting time of hospital patients is higher than we expected. The overall occupation of nursing home departments is also for this scenario, because the nursing home 'loses' fewer days due to waiting time of patients. In addition, we conclude that a relatively small increase in capacity, may cause a strong decrease in waiting time.

5.6 Conclusions

This chapter contains preliminary results obtained from the simulation with the RdGG case study as starting point. It does not directly reflect the current situation in RdGG, since we only use data of some parts of the system and we use rough estimates and assumptions. We explore the impact of three model interventions:

- *Advance communication process*
  In this intervention, the process of communication from the hospital to the nursing home starts earlier. The expected duration of the communication process remains 4 days. The earlier communication results in a reduction of average waiting time in the hospital of 3.3 days.

- *Transfer beds*
  The intervention entails the introduction of an extra department that serves as temporary stay for patients who wait for nursing home care in wards of the hospital. The simulation results show that, for example, a small transfer department of 5 beds halves the bed blocking days in wards, while the occupation of this transfer department is 90 percent. The simulation model can be used to find a balance between the reduction in waiting time on wards and the occupation of the transfer department.

- *Reservation of nursing home beds*
  The intervention holds that the hospital reserves beds of nursing home departments, such that only patients from the hospital are admitted on these departments. The other, non-reserved, nursing home departments accept all patient types. The simulation results show that bed reservations starts to have impact when the expected occupation of the reserved nursing home beds approaches or exceeds occupation of the remaining nursing home beds. The waiting time of patients at home increases with bed reservation; the simulation model can be used to find a balance between waiting times of the various patient groups and occupation of the various departments.

6 Conclusions and recommendations

This research explores the dynamics and interventions in patient flows from hospitals to nursing homes. The research objective was *to design a tool that allows analysis of various configurations of transmural networks, in order to minimise bed blocking.* Paragraph 6.1 discusses conclusions of the research content and preliminary results. Paragraph 6.2 discusses recommendations related to RdGG, the hospital of our case study. Suggestions for further research are discussed in Paragraph 6.3.

6.1 Conclusions

Bed blocking in RdGG is in the first place a financial problem; each bed blocking day costs the hospital approximately 200 euro. Patients go to several aftercare institutions, but patients who require care in nursing homes cause 80 percent of the bed blocking days. These bed blocking days are partly caused by the communication process, but most are caused by waiting for a nursing home bed. Hospital and nursing home have contradicting financial goals, caused by the differences in financial systems. The hospital revenue mainly depends on the number of admissions in the hospital. The nursing home revenue depends on the total number of days that patients stay in the nursing home.

The tool we developed allows analysis of various configurations of transmural networks. At this moment we obtained some general insights concerning these configurations.

The case study allows viewing the overall process, but not much data is available, and we have limited knowledge of nursing home control span. The situation does not directly reflect the current situation in RdGG, but explores the impact of interventions and the sensitivity of performance indicators to the parameters. These preliminary results can be used to enthuse involved care providers to collect more and accurate data. We analyse the results of three interventions:

- *Advance communication process*
  In this intervention, the process of communication from the hospital to the nursing home starts earlier. In the base scenario this process starts when the patient needs no medical treatment in the hospital anymore. If the process would start when a patient arrives in the hospital, then the waiting time (bed blocking days) due to communication can be reduced significantly. Early communication decreases the reliability of care demand, since demand may change. The simulation model can be used to find a balance between the uncertainty of the care demand and the advantage of the reduction of bed blocking.

- *Transfer beds*
  The intervention entails the introduction of an extra department that serves as temporary stay for patients who wait for nursing home care in wards of the hospital. The costs of care on the transfer department are lower than costs of care on wards. The simulation results show that, for example, a small transfer department of 5 beds halves the bed blocking days in wards, while the occupation of this transfer department is 90 percent. The simulation model can be used to find a balance between the reduction in waiting time on wards and the occupation of the transfer department.

- *Reservation of nursing home beds*
  The intervention entails that the hospital reserves beds of nursing home departments, such that only patients from the hospital are admitted on these departments. Reservation of beds seems an interesting option for a small number of beds, since the waiting time in the hospital (bed blocking) drops, as well as overall waiting time for nursing home beds. This is influenced by the property of giving priority to internal patients. To further reduce bed blocking in hospitals with bed reservation, the reservation should be such that nearly all hospital patients can be admitted on the reserved beds. The simulation model can be used to find a balance between waiting times of the various patient groups and occupation of the various departments.

These results show possibilities for system improvement. The model gives the opportunity to quantify the expected results for a range of interventions and scenarios concerning patient flow. A qualitative study to consider quality and safety aspects of patients should always be part of the analysis.

The research subject should not only be about how to reduce bed blocking but to seek opportunities to cope with the phenomena in a more efficient way. An earlier knowledge of the date a patient is medically ready reduces bed blocking and so will an increase in bed availability. Still bed blocking days occur, where for example transfer beds can contribute.

6.2 Recommendations RdGG

This paragraph describes recommendations for RdGG from our process analysis and results of our simulation.

6.2.1 *Transparency and planning*

Hospital and nursing home objectives seem contradicting, but their main objective is the same: patient satisfaction. Common benefits, also in operations and financially, can be created by cooperation.

RdGG has an intensive relation with its main nursing home partner, PvF, on a patient level. Since most patient transfers are to one of PvF's institutions, planning teams of both institutions are frequently in contact. Extending this relationship by earlier communication and forecasting improves patient flow: earlier communication of patient arrivals and bed availability in order to increase predictability, planning and forecasting on a tactical level in order to balance supply and demand. The communication makes reactive actions to changes possible whereas the tactical planning enables acting proactively. The nursing home can better balance its supply and predictability of patient arrivals increases, which speeds up the patient's outplacement from the hospital. This results in less bed blocking days.

An easy start of increasing transparency is digital information sharing, between hospital and nursing home, the way it already happens in the Health Care sector from hospital to patient. The software system POINT is a good starting point, but PvF and RdGG could use this system more extensively. Transparency improvement can be realised by using the following steps:

1. *Set clear definitions of processes and concepts within RdGG*
   - Improve registration of bed blocking days, with notification of the various bed blocking types (type 'V' and type 'W').
   - Make it obligatory to fill in the prediction of the date a patient will be medically ready within RdGG.

2. *Monitor outflow bed blocking*
   Use the output from POINT to visualise everyday performance. Make the outflow and present bed blockers visible for all wards and transfer nurses on a daily basis (for example with a bulletin board). Appendix M describes and visualises what information we recommend to generate from POINT and how this information can be used.

3. *Transparency on patient level*
   Improve the cooperation with nursing homes by earlier communication in a transparent environment. The nursing homes should have insight in patient arrivals at the hospital and the hospital should have insight in bed availability at nursing homes. The current possibilities of the computer system POINT can be used. PvF can establish expected arrivals from POINT. For this purpose RdGG has to record information as complete as possible.

4. *Make predictions on a tactical level*
   Collect data and set targets of patient demand in nursing homes. This allows balancing demand of the hospital and supply of nursing homes. In addition, when compare the patient outflow and bed blocking days of RdGG with the occupation of involved nursing homes on a regular basis. This allows discovering patterns, making predictions and determining opportunities for improvement.

The involvement of the stakeholder groups for further analysis and improvement, is the next step towards the reduction of bed blocking. When more and accurate data is collected, a more accurate analysis of system behavior can be done. Supply and demand should be mapped first. Critical factors to do that are, except data availability, to set the decision space (what variables do we want to change?) and to make predictions of developments of patient arrivals. Concrete objectives should be formulated by the involved parties.

6.2.2 *Recovery unit*

The recovery unit is a further fragmentation of nursing home bed supply. In general, such fragmentation deteriorates flow of patients, given the assumption that the capacity is not additional to existing capacity and the service time is independent of the department within a resource, where a patient receives treatment. Though, since only patients from the hospital are accepted on these beds, this is already a form of bed reservation for a specific patient group. The reservation could result in waiting time reduction for hospital patients. However, on the current recovery unit all compatible patients are accepted, what will only result in this reduction if the occupation of the department is significantly lower (what results in higher occupation and waiting times on other departments). We think that to supply this service, under before mentioned assumptions, either or both of the following should be true:

- **The possibility to use part of the recovery unit as transfer department**. The capacity of the recovery unit is flexible, such that in periods of low occupation a number of beds can function as transfer beds for patients waiting for other care. Flexibility of staffing should be incorporated.
- **Capacity << demand, rest of demand to other departments**. The capacity of the recovery unit is sufficiently lower than demand for the service; patients are only accepted if a bed is available or is expected to be available on short term. Otherwise the patient will be treated on a department, which is compatible, other than the recovery unit. This way a high occupation can be achieved, without causing long waiting lists.

In conclusion, the road to reduce bed blocking in RdGG starts with information gathering and monitoring.

6.3 Discussion and suggestions further research

Modelling in health care is an emerging field, but the current work mainly concerns optimisation of a specific department. Little work is done in how to integrate care between departments or even in how to integrate the care need between different actors. Figure 31 visualises the scope of this research in the problem of bed blocking in hospitals. We construct the scope in 3 dimensions: 'organisational level', 'span of control of stake holders' and 'stage of development'. Our research focuses on a broad part of the chain in an explorative way, and mainly on a tactical level.

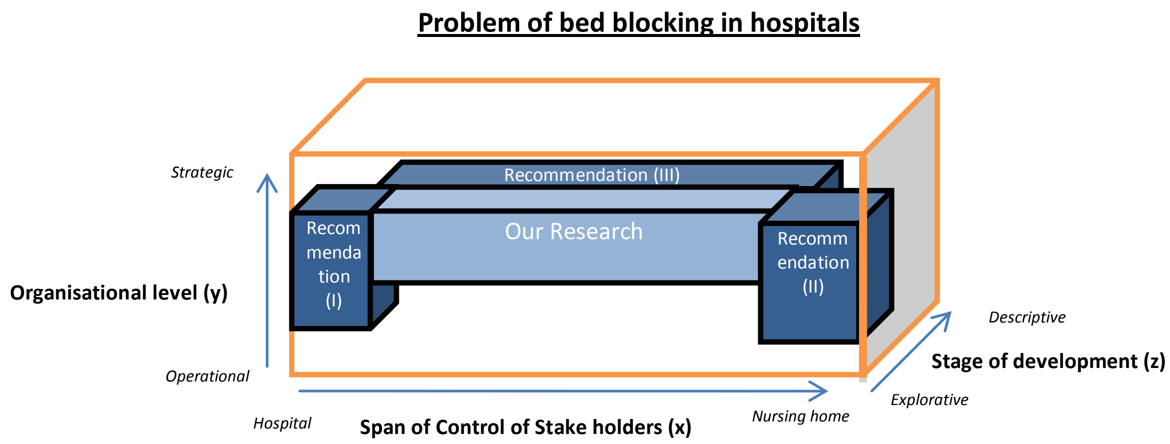


Figure 31 Research scope, problem of bed blocking in hospitals

We recommend further research in the influence of the hospital planning process on bed blocking and forecasting using a patient's profile at hospital arrivals (recommendation I). Another interesting extension is research from the perspective of nursing homes (recommendation II).

Further research is required in the organisational interventions defined in Paragraph 4.1.1, by modelling other situations, and by more detailed analysis (recommendation III). This requires mapping of costs, including personnel costs. The analysis can include extensions of the interventions considered in this research. An interesting extension on information transparency would be, that the bed is 'reserved' when a bed becomes available x days before, or after the request. No other patients can then be admitted on the bed. An extension on the transfer beds could be that the transfer department is not a separate unit. A slot of beds of a department with overcapacity can temporary serve as transfer department.

When there is reliable data, the foundation of model assumptions should be explored. For the optimization problem it is, among others, important to know more about the behaviour of a patient's length of stay in nursing homes. To what extend influences occupation length of stay of patients? How does residence in an inappropriate unit influence the patient's length of stay? If a patient's length of stay is not affected when waiting in a lower level unit, we should allocate a penalty to this phenomenon in some way, if we want to discourage long waiting times within nursing home resources to increase occupation and throughput times. To bring research a step further in the *stage of development,* close cooperation between the hospital and nursing home is important.

The simulation model is less applicable for capacity allocation, since it is very time consuming. Analytical approaches can be used here, using simulation as validation and for final improvement iterations.

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8 Appendices

Appendix A Zorg Zwaarte Pakketten (ZZPs)

ZZP	***Definition***	***Average number of hours per week (BG/PV/VP)****
VV 1	Sheltered stay with some guidance	4.5
VV 2	Sheltered stay with guidance and provision	6.5
VV 3	Sheltered stay with guidance and intensive provision	9
VV 4	Sheltered stay with intensive guidance and extensive provision	10
VV 5	Protected stay with intensive care for dementia	16
VV 6	Protected stay with intensive provision and nursing	16
VV 7	Protected stay with very intensive care, for specific ailments, with focus on guidance	19
VV 8	Protected stay with very intensive care, for specific ailments, with focus on provision/nursing	24
VV 9	Revalidation focused nursing and provision	16
VV 10	Protected stay with intensive palliative care	27

Figure 32 Clarification ZZPs, CIZ 2009

* Guidance (BG, begeleiding), provision (PV, persoonlijke verzorging), and nursing (VP, verpleging)

Appendix B Description aftercare categories

1. <u>Home care</u>

   There is a lot of competition in home care in the region. RdGG mainly allocates its patients to one organisation, Careyn, but if they cannot supply the needed care RdGG has contact with many other organisations in home care. The hours a patient requires home care differs, but this has no consequences for the organisation that should deliver the care.

2. <u>Nursing home</u>

   The nursing homes distinguish three main streams of patients: somatic, cognitive and Psycho-Geriatric (PG). There are specific departments for these patients. Nursing homes have both long stay departments and temporary departments. We will shortly elaborate on the temporary formula.

   In the beginning of 2005 a concept started in the region of RdGG where patients who are medically ready go to one of the temporary departments of a nursing home of aftercare institution Pieter van Foreest (PvF). In these departments a patient can stay for at most 100 days. The temporary departments are on two different locations and have a capacity of 118 beds of which beds are assigned to orthopaedics/surgery, stroke, remaining somatic, PG and crisis beds. These beds are primarily meant for patients leaving a hospital, but patients form other environments are inflow for these departments (e.g., home) as well, to prevent vacancy. RdGG has an informal commitment with the nursing home institution about these beds. A study in 2007 showed that approximately 65 percent of the inflow in the temporary departments is from RdGG. Furthermore the maximum length of stay is exceeded in 28 percent of the cases. The nursing homes do not have the aim of minimising this period; they will not benefit financially. Patients require an indication of ZZP 5 or higher to be allowed in a nursing home.

3. <u>Recovery unit</u>

   Patients who require aftercare after having a hip operation for example, can recover in a special 'recovery unit' as well. Patients get intensive care for a short period (about four weeks) to recover quickly. This is a product RdGG wants to offer. In the recovery unit 17 beds are available; this number of beds is based on the workability. The recovery unit opened in 2007, but is not running as desired. The criteria for a patient to enter the recovery unit are very strict and the current occupation is not enough to run breakeven.

   Patients require an indication of ZZP 6 or 9 to be allowed in the recovery unit.

4. Care for elderly

   In a home for elderly a patient can be admitted for a long stay either extramural or intramural long. Furthermore a patient can go to the home for the elderly on a short-term basis, for which specific beds are available. Patients require an indication of ZZP 1 or higher to be allowed in a nursing home.

5. Palliative care

   Terminal patients can go to a hospice or to a palliative department within a nursing home.

Appendix C Articles

This appendix summarises the articles discussed in chapter 3. The summaries focus on what is relevant for our research and not on give a complete view on the articles content.

Paper	Relevant aspects
S.G. Rubin and G.H. Davies, 1975	Rubin and Davies describe that bed blocking implies that regular patient or client through-put with regard to that particular bed has stopped. They investigated 48 elderly in a long-stay- hospital bed. Important conclusions drawn from this research are: - there is a lack of a multidisciplinary approach - the problem of waiting lists is compounded by the lower priority given to patients already in hospital
C. Joan and G.H. Davies, 1979	• shortage of beds in many geriatric units • better support from social welfare and housing departments would facilitate bed availability in both short and long stay units
Koizumi et al., 2004	Congestion in facilities caused many patients to unnecessarily spend extra days in intensive facilities. This study applies a queueing network system with blocking to analyse such congestion processes. Two performance indicators, the number of patients waiting to enter each type of facility in the system and the associated waiting time at the steady state, are derived in the steady-state analysis. Koizumi et al., made a model framework as a "arbitrary-linked" system where patients can skip stations. For mathematical convenience, total arrival rates are often assumed to follow a Poisson distribution with mean λ. Similarly, mean service times are typically assumed to follow an exponential distribution with mean $1/\mu$. The definition of "service time" and its distribution need to be modified in order to incorporate blocking into the model. Koizumi et al., do this by introducing the concept of "effective service time". The effective service time is comprised of two types of service times, namely "treatment time" and "blocked time". The model assumes that extra days in the upstream facilities do not reduce the length of stay at any downstream facilities. The analysis treats the waiting space to enter a particular station as infinite when analysing the steady state of that station. The model from the study suggests that system-wide congestion is due primarily to shortages in one specific facility type, namely supported

	housing. Removal of such facility specific bottlenecks may often be the most cost-efficient way to reduce congestion in the system as a whole. In contrast to popular perception, system congestion is not always a simple cumulative effect of shortages across all facility types. An important direction for extending the present model would be to allow parameters such as arrival rates to change over time. While such interaction effects are often difficult to model formally, they are easily introduced into simulation models. N.B.: Burke's theorem assures that internal and total arrival rates follow a Poisson distribution as long as the external arrival are assumed to follow a Poisson distribution and there are no feedback flows in the system. Generally effective service time can be modelled using an Erlang distribution. However, as observed by Perros, it is common practice to approximate effective service time distributions by the simpler exponential model.
Panton et al., 2004	This study examined the possible role of intermediate care beds with British mental health trusts. It found that the prompt discharge of older patients from acute psychiatric care was a significant problem and that many of those patients may benefit from the therapeutic and rehabilitative process afforded by intermediate care. Intermediate care (IC) is defined as 'a range of integrated services to promote faster recovery from illness, prevent unnecessary acute hospital admission, support timely discharge and maximize independent living.' The article argues that if the only problem preventing appropriate discharge is funding by the cash-strapped social care system, it is important that patients are not left in an intermediate care bed instead of a permanent home. The reasons of delayed discharge where recoded into four categories: - lack of specialist staff resources for placement of returning home (including a place not being found) - lack of money to finance placement - lack of an alternative acute ward when the patient no longer needs acute care - miscellaneous For 46% of the patients the discharge was delayed of which almost half was caused by insufficient specialist staff resources. The possibility of new funding for intermediate care is an opportunity to turn the problem of

	delayed discharge around. Intermediate care should help the development of seamless service provision.
E.A. Coleman and C. Boult, 2003	The article discusses several positions concerning transitional care. One of the positions is that research should be conducted to improve the process of transitional care. Coleman and Boult argue that to advance the understanding and practice of high quality transitional care, research is needed to better understand how to empower persons with complex care needs and their caregivers to express their preferences and manage their care needs across healthcare settings. In addition, systems of care designed to optimise transitional care need to be developed and tested. Such interventions should be patient centred and be designed to facilitate external adoptions in different delivery systems and under different payment mechanisms. Furthermore they argue that performance indicators and quality-improvement technologies that focus on the quality of transitional care need to be developed and tested.
Benson et al., 2006	The paper analyses patients who were unable to be discharged from a surgical ward despite being surgically fit to leave. Benson et al., found that most reports highlight the lack of intermediate care as being a major cause of delayed discharge. They conclude that due to problems in defining delayed discharge, government figures probably underestimate the true numbers. Lack of intermediate care and social service provision are a major cause of bed blocking. They remark that, as in other studies, they found that patients who were 'bed blockers' were older and more likely to have admitted as an emergency. Finally the article states that urgent clarification of definitions is needed so that accurate and reproducible figures can be obtained.
C. Vasilakis and E. El-Darzi, 2001	The winter bed crisis is a cyclical phenomenon which appears in British hospitals every year, two or three weeks after Christmas. Vasilakis and El-Darzi consider this problem as a queueing system and evaluate the model numerically with discrete event simulation. During the Christmas and New Year period surgeons are not operating on routine cases. After Christmas, when the surgeons return, the surgical beds are occupied by medical patients. As the surgeons commence their work there are insufficient beds for medical emergencies and therefore, queues form. They analyse the number of admissions and discharges over several years and show that the reason behind the crisis is not the rise in the admissions but the delays in hospital discharge during and in the

	period immediately after Christmas. Key concepts of their simulation are exponentials distributions of acute, rehabilitative and long-stay departments and that acute beds are blocked when no beds are available. The paper shows that if discharges run smoothly then an extreme bed crisis could be avoided.
Linden et al., 2000	A bottom-up facilitating approach was chosen to stimulate development of 'transmural-care' between traditionally separate sectors in the Netherlands. Linden et al., conducted a national survey to determine the success of the bottom-up policy and the extent of the development of transmural care. One identified problem area is the major gap between primary and hospital care, which had emerged as a result of separate organisational and financing systems. The National Council for Public Health in the Netherlands stated a widely accepted definition of transmural care; ' care, attuned to the needs of the patient, provided on the basis of co-operation and co-ordination between primary and specialised caregivers, with shared overall responsibility and the specification of delegated responsibilities.'
Cohen et al., 1980	The study provides a methodology for investigating the relationships between capacity decisions and selected performance measures for a progressive patient care facility. Due to the nature of health care deliver, queues generally do not form when a particular unit is fully utilised. Instead, one of three actions is taken: • The patient may be assigned to an inappropriate unit, at either a 'higher' or a 'lower' level of care than is necessary for the patient's condition. • Other patients may be relocated to accommodate the patient. • The patient may be directed to another hospital or sent home. The specific performance measures calculated by application of the model to the simulated flows include - the utilisation of each unit in the hospital - the fraction of transfers blocked in each unit - the proportion of each unit's patient-days that are due to inappropriate use Models of progressive patient care facilities can be classified into two categories: analytic models and simulation models. Cohen et al., describe a simulation model that can handle different policies to deal with blocked transfers. They conclude that the bumping rule does

	significantly affect the results of the simulation study. It is therefore important to model the transfer policy that is to be used in the facility under study.
P.T. Vanberkel and J.T. Blake, 2007	The paper describes the use of operational research techniques to analyse the wait list for a Division of General Surgery. [Blake et al. summarise the problems associated with prioritisation].
Schwanhaeuser et al., 2002	Schwanhaueser et al., perform an audit of bed blocking in surgery. The purpose of this audit was to identify the causes of bed blocking and to determine what non-clinical or organisational factors were involved. They found that the considerable delays in patient events owing to non-clinical reasons. From the study population, 26% of patients experienced such delays. The major non-clinical delays in emergency patients were related to radiology and social services events. This study demonstrates the need for adequate resourcing of our social services department to allow for prompt discharge of elderly patients from acute surgical beds.
Travers et al., 2008	This research tries to understand the dynamics underlying 'bed-blocking' in Australian public hospitals by analysing data of utilisation patterns in hospital and aged care services. The issue of bed blocking is likely to intensify as the Australian population ages. The authors distinguish between low care and high care. To estimate the effect of system changes and the potential impact of the ageing population Travers et al., developed a conceptual model of the dynamics at the acute-age care interface. The key aim of this model was to better understand why older patients with high care needs often wait in acute public hospitals for entry into permanent RAC. The model conceptualises the pathway into permanent high-care RAC as a series of competing queues for available places by applicants from three sources: the hospital, internal RAC applicants in low-care places and community applicants. The length of time spent waiting in hospital depends on several factors, including hospital occupancy rates, the rate at which permanent high-care RAC vacancies occur and the number of applicants. Travers et al., conclude that access-block within the acute public hospital system stems from a mismatch between demand and supply, and cannot be understood by viewing the hospital system in isolation from other sectors that support the health and well-being of older Australians.
El-Darzi et al., 1998	The paper considers the problem of bed-blocking as a queueing system to assess the effect of blockage on the flow of patients in geriatric departments. What- if analysis is used to allow a greater understanding of

	bed requirements and effective utilisation of resources. The results show that the flow model and the unconstrained simulation are equally viable tools to measure bed occupancy in a geriatric department. In the unconstrained model considerable fluctuations occurred in the levels of occupancy and emptiness in the acute, rehabilitative and long-stay beds, which are relevant from a clinical point of view. El-Darzi et al., conclude that further work is needed to determine the necessary emptiness in the acute beds to prevent admission queues forming, as it is clearly an unrealistic option to minimise admission queues by providing significant emptiness in long-stay. In supermarkets separate server units are set aside for customers with baskets and less than eight items. Also extra server units are opened when queues increase. Similar concepts may need to be introduced into hospitals. Further work needs to be done on the simulation model to experiment with different arrival and admission methods and/or with data from other hospitals. Also seasonal variations as well as weekends and public holidays may need to be considered as they have been proved to influence referral and admission.
Haraden and Resar, 2004	The institute of Healthcare Improvement has worked with more than 60 hospitals in the United States and the United Kingdom to evaluate what influences the smooth and timely flow of patient through hospital departments and to develop and implement methods for improving flow. One of the suggestions Haraden and Resar make is to make the nursing home “reservation”. Most hospitals use a “push system” to discharge a patient to a nursing home facility. Once a patient is determined to need a nursing home bed, a search is started by the hospital’s social services staff. A better, more efficient system might be to synchronise hospital and nursing home needs by establishing a “reservation” system whereby hospitals can reserve beds in nursing homes once a patient in need is identified, and vice versa. The nursing home or the hospital still receives payment if the reservation is cancelled and the bed goes unused, much like the system used in the hotel-industry.
Vanberkel et al., 2009	This survey reviews quantitative health care models to illustrate the extent to which they encompass multiple hospital departments. Vanberkel et al. (2009) reviewed 88 articles describing models which encompass multiple hospital departments. Only few of these models describe the system of care and not only single departments in the care chain.

Cochran and Bharti, 2006	The study of Cochran and Bharti aims to balance bed unit utilisations across an obstetrics hospital and minimise the blocking of beds from upstream units within given constraints on bed reallocation. The methodology includes the assessment and effect of time-dependent patterns of monthly, daily, and hourly demand. Queueing networks are first used to assess the flows between units, establish target utilisations of bed units, and involve stakeholders in a flow characterisation that they understand. Discrete-event simulation is then used to maximize the flow through the balanced system including non-homogeneous effects, non-exponential lengths of stay and blocking behaviour. The article concludes with that another important area of future work is developing methodology for analysing the flow balance of patients and bed balancing across a network of hospitals instead of within a single hospital.
Gorunescu et al. , 2002	In this paper Gorunescu et al., present a technique for optimising the number of beds in order to maintain an acceptable delay probability at a sufficiently low level. They use a M/PH/c queueing model; patient arrivals are described by a Poisson process, hospital beds are the servers and lengths of stay are modelled using phase-type distributions. The advantage of using the phase-type model for length of stay distribution is that it provides a useful description of the data and a convenient way of estimating arrival rates. The results are intended to be indicative of general patterns rather than descriptive of exact behaviour, in the interests of providing clarification of the issues involved.

Appendix D Data structure

In order to model the problem described, we outline the sets, parameters and events and performance indicators involved. The time horizon of one simulation is a year.

Sets

d	day of the week	[monday,…, sunday]
w	week number	[1,…,52]
i, j	the resource type a patient is staying [policlinic, Operating Room, ward, NH-crisis, NH-shortstay, NH-longstay, community]	
p	the patients nature, where a patient is either of type elective or emergency in the hospital or needs care in a nursing home directly from home [emergency, elective, home]	
$c \supseteq h, m, n, o$	the care type of a patient, consists of 4 subsets, where: h is the care type in hospital, m is the first care type the patient requires in a nursing home, n the is the second and o is the third. [1,…, number of hospital care types]	
l	locations of departments [1,..., number of locations]	
dep	departments of a certain resource [1,…, number of departments]	
e, f	events of the simulation [1,…, number of events]	

Relation: a resource consists of certain locations and a location consists of certain departments. A location can consist of departments of several resources.

Parameters

$\lambda_{d,w,p}$ $\forall d,w,p$

Real; the arrival rate of patients on day d in week w of patient nature p

$dist(\mu_c)_{p,i}$ $\forall p$

Real; one divided by length of stay of at resource i of patient with patientnature p and care type c, where resource i has service time distribution dist for patient with nature p

$C_{dep,l,i}$

Integer; capacity at department dep that is at location l at resource i

$P_{i,j,p,c,m}$ $\forall j > i, p, c \in h, m$

Real $\{0,1\}$*; probability a patient with patient nature p in resource i with care type c needs care type m in resource j downstream of i*

$Preference_{l,m}$

Real $\{0,1\}$*; fraction of patients needing nursinghome care type m with a preference for location l*

$Acceptance_{dep,c}$

Boolean; whether care type c is accepted on department dep

$Transfers_d$

Integer; maximum number of transfers (admissions) to a nursing home department on day d

$Allocation_{t,m}$

Integer; number of days required by nursing home for allocation of patient with care type m if request on day d

$Informationflow_{e,f}$

Completion of event e is required for the execution of event f

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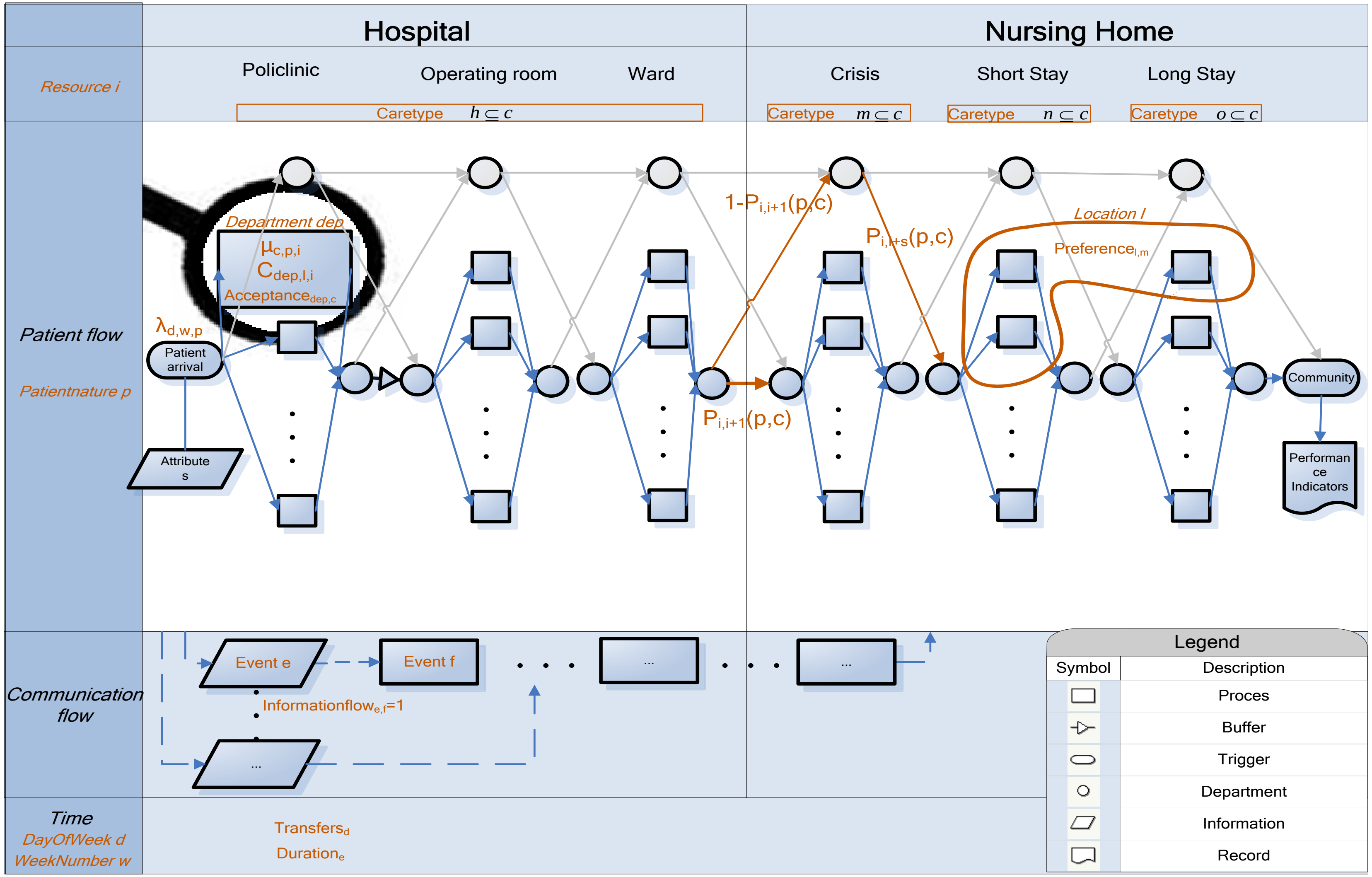
Appendix E Broad structure of the simulation model

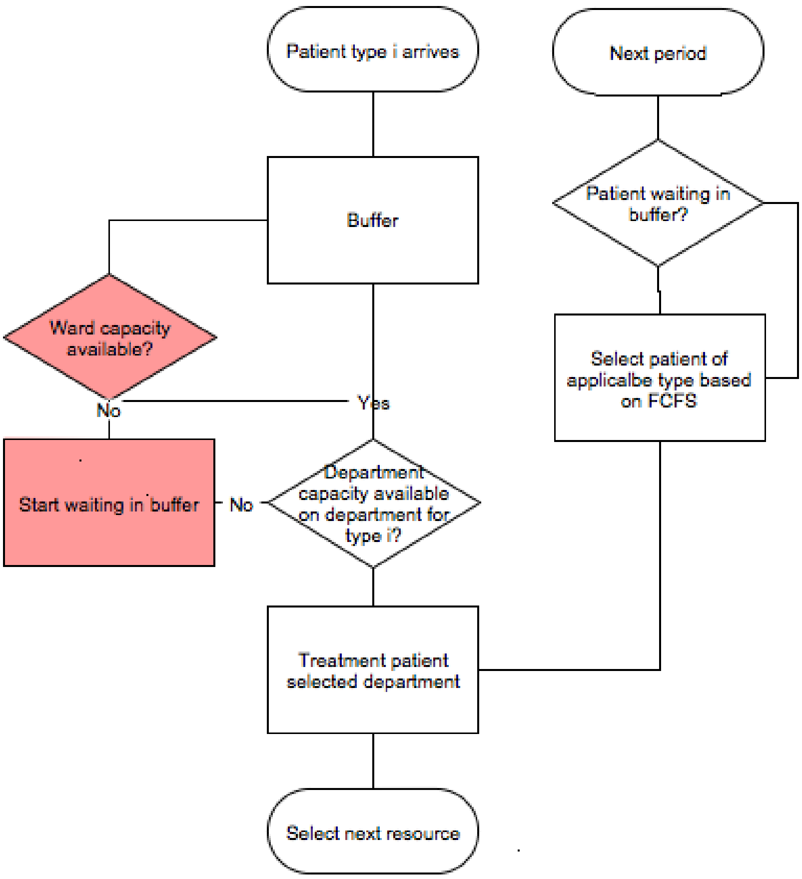


Appendix F Flowcharts – Conceptual model

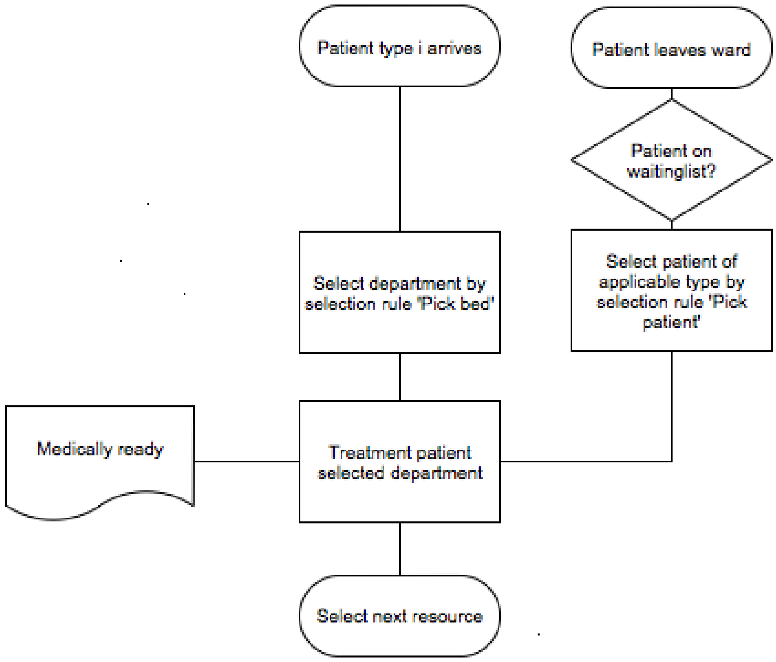
The simulation model consists of the Policlinic, Operating Room, Ward, Nursing Home and a communication stream. The flowcharts in in this appendix display what the simulation model does in each of these phases.

Policlinic – Operating room

The Figure below displays the model for both the policlinic and the operating room. The blocks in red only hold for the operating room.

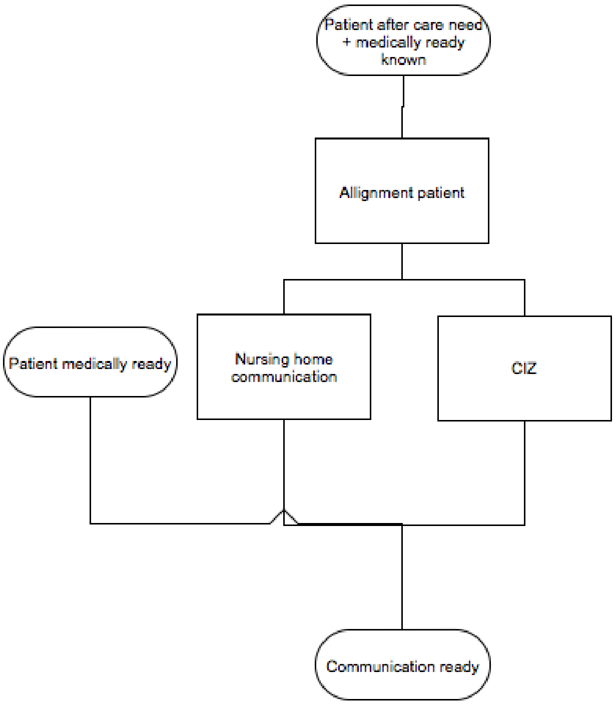


Ward

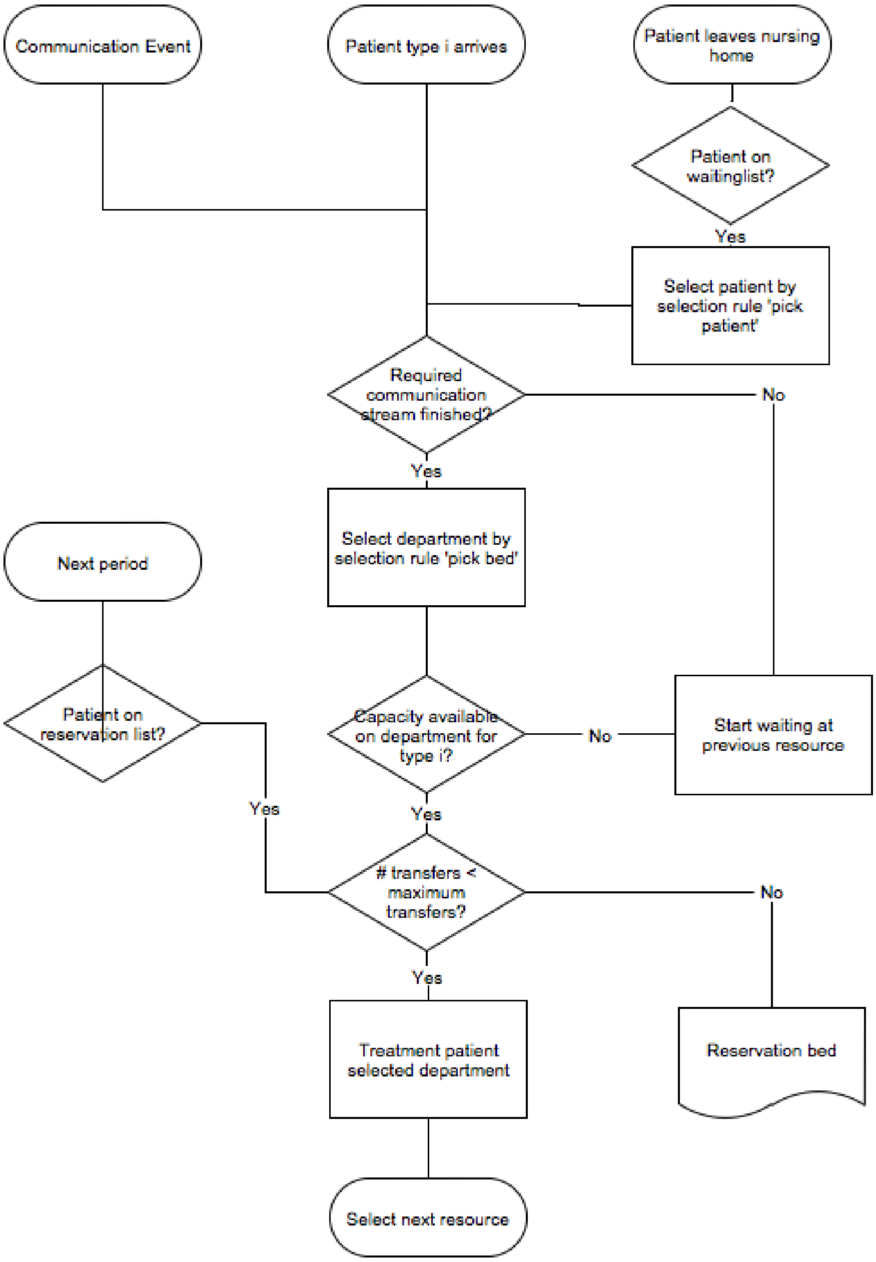


Communication

The communication stream in the simulation checks , for each event whether ithe required events are finished before it strats and whether it triggers other events to start. The figure below gives the communication stream as we model it for the current situation.



Nursing home department



Appendix G Model notation

Here we specify the disciplines used for all characteristics of the model notation as described in Paragraph 4.3.

Charac-teristic number	***Explanation characteristic***	***Discip-lines***	***Explanation discipline***
1	Nature of arrival process	***M***	Exponential
		D	Deterministic
		G	General
		E	Emperical
2	Nature of service times	***M***	Exponential
		D	Deterministic
		G	General
		E	Emperical
3	Total nursing home bed capacity	***<nr>***	Gives the sum of total capacity
4	Queue discipline	***FCFS***	First come first serve
		Care type	The care type that the department most preferably (highest priority) admits of all patients waiting
		Internal	A patient that is already in a nursing home departments gets preference over others
		Hospital	A patient that waits in the hospital gets preference over others
		Home	A patient that waits at home gets preference over others
		Random	A patient is picked randomly from the waitinglist
I	Allocation rule for a picking bed	***First Found***	The first department that is contacted and has a compatible bed available; the departments are contacted in the same order every time
		Depart-ment	The department where the patient is most preferable admitted (highest priority)
		Location	A department at the location where the patient is most preferably admitted (highest priority)
		Random	A department with available capacity is picked randomly
II	Number of reserved beds by hospital	***Fixed <nr>***	The fixed number of beds reserved by the hosptial
		Flex <nr>	The number of beds reserved by the hospital where hospital patients get preference: if no hospital patients are waiting, others are accepted
		0	No beds reserved
III	Type of communication requirements	***Default***	Setting as in current situation RdGG (Paragraph 5.1.1)
		Early	Same as 'Default', but now the communication process starts when the patients arrives in the hospital
IV	Number of different nursing home departments (types)	***<nr>***	Gives number of types

Appendix H Warm-up period, run length and number of replications

This appendix shows the outcomes of analysis concerning warm-up period, run length and number of replications for the simulation experiments.

Warm up period

When starting to run the simulation model, the experiment starts to run an empty system. This is not representative for steady-state behavriour and therefore pollutes results of the experiments. The problem is called the *problem of the initial transient* or the *startup problem* in the simulation literature. The technique most often suggested for dealing with this problem is called *warming up the model* or inital-data deletion (Law and Kelton, 2000). We use this technique for our simulation experiments.

Since the long stay department requires most time to convert to steady state behaviour, we use the occupation of the long stay departments to determine the required warm-up period. For 100 replications of 1 year we determine moving averages with a window *w=3*, since that is the smallest value of *w* for which the corresponding plot "reasonably smooth". Figure 33 shows the moving averages for the long stay PG department.

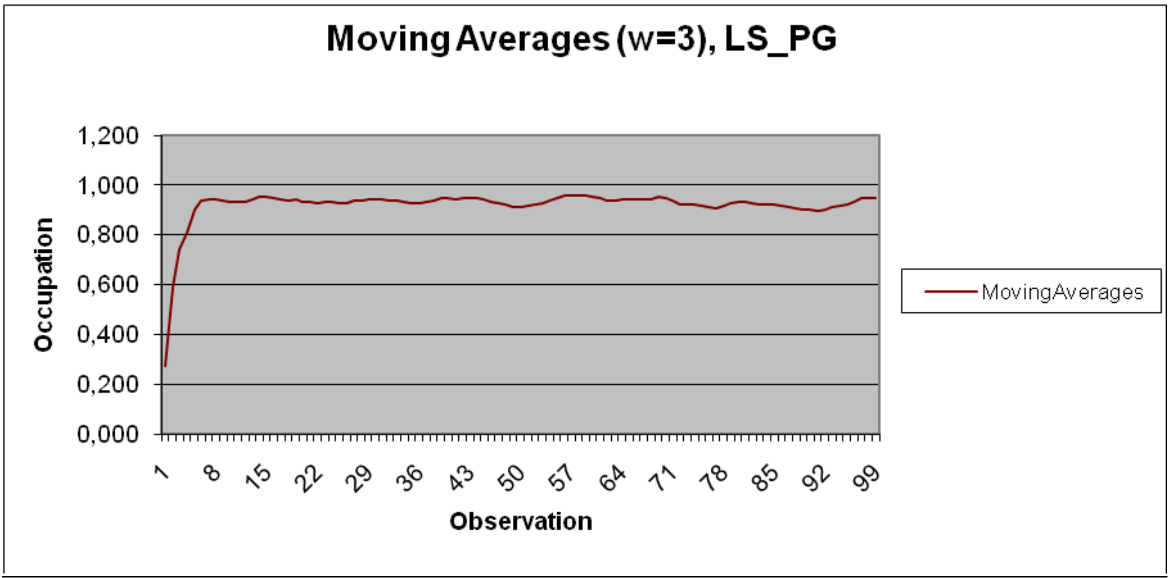


Figure 33 Moving average occupation of Long stay PG department, outcomes of simulation model with a run length of 100 years

After 10 years the graph occurs to be stable. To make sure we reduce the impact of the initial state as much as possible, we choose a warm up period of 15 years for the experiments.

Run length and replications

To ensure that enough output data have been obtained from the simulation in order to estimate the model performance with sufficient accuracy, we select an appropriate run-length and determine the number of replications. We first used the *fixed-sample-size procedure* (Law and Kelton, 2000) with approximate 95% confidence interval to estimate sample size. Then we used the replication/deletion approach for means, where we make n independent runs and ignore observations from warm-up period such that our relative error is no more than 10% on the 95% confidence interval.

Where the long stay departments require the longest warm up period, the crisis departments require most runs, since the variation of occupation in these departments is the highest. We choose to run all interventions for a period of 50 years (where a warm up period of 15 years is already excluded). Below the required number of runs for each of the departments is listed, while concidering the reliability of the occupation measure.

Alpha	0.05
Relative error	0.05
Department	**n***
Cr_Som	9
Cr_Cog	16
SS_Som_OrtChi	6
SS_Som_Rem	2
SS_Som_Herstel	3
SS_Som_CVA	11
SS_Cog	12
LS_Som	4
LS_PG	4

To achieve the same reliability for the waiting time, it takes more runs, since waiting time has a strong sensitivity for changes in occupation. We choose to do 30 replications for each run to achieve in the worst case a relative error of 10 percent on the 95 percent confidence interval, namely for the cognitive crisis department. We do 16 replications when only the performance measures per resource and per patient nature, not per care type or per department, are required results.

We use these numbers for all interventions since we consider this sufficient for the comparison of preliminary results.

Note that since we have multiple measures of performance, the probability that all k confidence intervals simultaneously contain their respective true measures satisfies:

$$P(all\ measures\ in\ reliability\ interval) \geq 1 - \sum_{dep} \alpha_{dep}$$

The confidence will therefore be lower than the 95% interval, but since the occupation of departments and waiting times are correlated, we expect the left hand side to be significantly larger than the right hand side.

When using service time distributions with variance > 1 (exponential distribution), it is necessary to recomputed the required number of replications.

Appendix I Input data

This appendix gives an overview on how input data of service times, arrival rates and overflow probabilities is obtained for the base scenario of our analysis.

Service time distributions

We use the statistical program MathWave EasyFit (MathWave Technologies, 2010) to analyse best fit distributions on the available data. Table 23 shows the parameters of the exponential distribution and the best fit distribution of various care types on crisis departments and short stay departments. For the long stay care no data on service times is available. We use the Kolmogorov Smirnov test to test the goodness of fit of distributions. We test the significance on a 95% confidence interval.

Department	N	Exponential distribution			Best fit distribution			
	Number of measurements	*Parameter*	*Goodness of fit statistic*	*Significant?*	*Distribution*	*Parameters*	*Goodness of fit statistic*	*Significant?*
Crisis somatic	75	0.1147	0.3153	No	Lognormal	σ=1.7882 μ=4.8763	0.1765	No
Crisis cognitive	32	0.0558	0.2433	No	Weibull	α=1.2897 β=17.945	0.2179	No
Short stay cognitive	73	0.0220	0.0781	No	Exponential	0.0220	0.0781	No
Short stay CVA	156	0.0239	0.2836	No	Lognormal	σ=0.6790 μ=3.5762	0.2287	No
Short stay Recovery Unit	289	0.0377	0.2292	No	Lognormal	σ=0.6805 μ=2.9914	0.0908	No
Short stay remaining 3/4	18	0.0132	0.4099	No	Weibull	α=0.6584 β=36.74	0.1677	No
Short stay remaining 6/9	392	0.0186	0.0723	No	Weibull	α=1.1023 β=55.7	0.0423	Yes

Table 23 Fit of service time distributions, Jan. 08 – June 09, Bieslandhof PvF

Nearly any of the distribution fits are rejected. Since the typical pattern that a large group of patients has the same service time, for most care types no good fit could be found. Figure 34 shows this pattern of service time for the short stay CVA patient group.

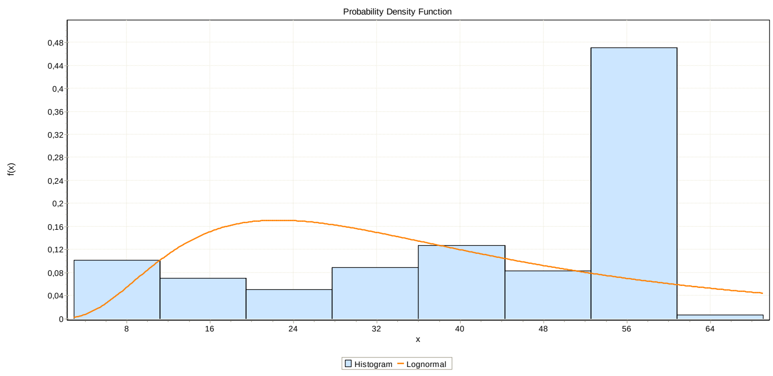


Figure 34 Service times of 'Short stay CVA' with best fit distribution, lognormal

The service times for the base scenario will therefore be derived from empirical distributions, based on available service times.

Arrival rates and overflow probabilities

Arrival rates are exponentially distributed. The arrival rate is estimated from available data of PvF's Bieslandhof and therefore is the rate of arrival at one nursing home location. We combine this data with patient outflow of the same period in POINT to establish the fraction of arrivals of hospital patients and the fraction of other arrivals to the various care types. Table 24 shows the arrivals of hospital patients for various nursing home care types.

Hospital arrivals

Care type	Total amount	Arrival probability (RdGG)
Crisis Som	0	0.0000
Crisis cog	0	0.0000
SS ort/chi[2]	182	0.3865
SS rem[2]	111	0.2369
SS CVA[1,2]	121	0.2574
SS cog	44	0.0936
LS som	10	0.0213
LS PG	2	0.0043
Hospital arrivals	**470**	*per year*
	1.2877	***per day***

[1] Estimate form POINT that about 32 percent of ´short stay somatic´ is CVA
[2] Of these categories 5% is in the category ZZP 3/4 and 95% is in the category ZZP 6/9

Table 24 Arrival rate and flow probabilities hosptial patients, POINT jul. 08 - june 09

The short stay somatic category consist for 5 percent of ZZP 3 and ZZP 4, whereas for 95% of ZZP 6 and ZZP 9 in demand for care. We use the knowledge of arrivals from RdGG and of total arrivals (though from another system), to establish the arrivals that are not from RdGG. The overflow probabilities within nursing home resources are rough estimates of experts. Table 25 shows the the arrivals of non RdGG, here called 'Home', patients for various nursing home care types.

Home arrivals

Care type	Total amount	Total amount not RdGG	P (not RdGG)	P (next internal resource)	Next resource	External arrivals not RdGG	Arrival probability (not RdGG)
Crisis Som	44	44	1.000	0.5	SS rem	44	0.1234
Crisis cog	22	22	1.000	0.5	SS cog	22	0.0617
SS rem[1]	510	217	0.425	0.0475[2]	LS som	195	0.5470
SS CVA[1]	121	0	0.000	0.05	LS som	0	0.0000
SS cog	55	11	0.200	0.95	LS PG	0	0.0000
LS som	67	57	0.851	0	-	27	0.0750
LS PG	123	121	0.984	0	-	69	0.1929
Total	942	472	0.501				
Home arrivals						***356***	*per year*
						0.9766	*der day*

[1] Of these categories 5% is in the category ZZP 3/4 and 95% is in the category ZZP 6/9
[2] For patients with ZZP 6/9 the overflow probability is 5%; for patients with ZZP ¾ the overflow probability is 0%

Table 25 Arrival rate and flow probabilities home patients, POINT jul. 08 - june 09 and PvF Bieslandhof jul. 08 - june 09

Appendix J Sensitivity on interventions

Allocation capacities resources

If 'a' increases, this means that the occupation rate of crisis departments increases. The relative occupation rates of short stay and long stay then decrease. An increase of 'b' means the occupation rate of short stay departments increases. The relative occupation rates of crisis and long stay then decrease.

1. *Transparency patient flow*
   - **a. +**

     The main patient flow from the hospital is to the short stay departments. The lower occupation rate increases the importance of timely communication, since a patient's waiting time for a bed decreases. The sensitivity on performance indicators will increase.
   - **b. -**

     The higher occupation rate of short stay departments decreases the importance of timely communication. The sensitivity on performance indicators will decrease.
2. *Transfer beds hospital patients*
   - **a. -**

     The lower occupation of short stay and long stay departments decreases the sensitivity for transfer beds for hospital patients, since less patients will have to wait.
   - **b. +**

     The higher occupation of short stay departments, the main patient flow from the hospital is to short stay departments, increases the sensitivity for transfer beds for hospital patients.
3. *Reservation of beds*
   - **a. -**

     The lower occupation of short stay and long stay departments decreases the sensitivity for bed reservation.
   - **b. +**

     The higher occupation of short stay departments increases the sensitivity for bed reservation.

Total capacity available (under same arrivals)

More capacity available with the same arrival rates means lower occupation rates. The lower occupation rates will have similar consequences for the sensitivity to the various interventions as discussed for an increase of the value 'a' above.

1. *Advance communication process* **+**
2. *Transfer beds hospital patients* **-**
3. *Reservation of beds* **-**

Relative hospital demand

1. *Advance communication process* **+/-**
   In general, a relatively lower hospital demand makes transparency for hospital waiting times more important, since there are more 'other' patients that can corner a bed. This does not affect the intervention under consideration here, since the bed is not reserved in any way.
2. *Transfer beds hospital patients* **+/-**
   The absolute amount of hospital outflow and its fluctuation is relevant for the sensitivity to the introduction of transfer beds. The stream of other patients does not directly influence this sensitivity.
3. *Reservation of beds* **-**
   The sensitivity to bed reservation decreases if relatively more demand if from the hospital (fewer 'external' demand).

Overflow probabilities

Higher overflow probabilities result in higher internal waiting times. In other words, residence of patients in crisis and in short stay departments increases, because part of the patients has to wait for follow-up care. Unlike for the crisis and short stay care, the service time of long stay care decreases with the waiting time for this care. The residence of patient in long stay departments therefore decreases. The increase in occupation rates for short stay departments will have similar consequences for the sensitivity to the various interventions as discussed for an increase of the value 'b' above.

1. *Advance communication process* **-**
2. *Transfer beds hospital patients* **+**
3. *Reservation of beds* **+**

Preference internal patients

No preference of internal patients might decrease hospital waiting time if arrivals from crisis departments on short stay department are relatively high compared to overflow probabilities of patients from short stay to long stay departments. The effect might be an increase of hospital waiting time if this is the other way around. Since the influence of this factor is related to the fraction of hospital patients and overflow probabilities, we couple this allocation rule to these factors. High overflow probabilities and relatively low hospital demand results in the highest sensitivity on bed reservation. We expect that this will be increased by preference for internal patients.

1. *Advance communication process* **-**
2. *Transfer beds hospital patients* **+**
3. *Reservation of beds* **+**

Category		**Advance communication process**	**Transfer beds hospital patients**	**Reservation of beds**	**Scenario variant B**	**Scenario variant C**
Allocation capacities resources	a	+	-	-	High	Low
	b	-	+	+	Low	High
Total capacity available		+	-	-	High	Low
Relative hospital demand		+/-	+/-	-	High	Low
Overflow probabilities		-	+	+	Low	High
Preference internal patients		-	+	+	Low	High

We take fictive values for these two variants on the base scenario, such that we expect to observe a significant difference in sensitivity to the various interventions but the values still seem realistic. We describe the differences compared to the base scenario as described above.

Appendix K Alternative scenarios

Scenario variant B

- Increase capacity with 10 percent. The overall occupation rate (excluding internal waiting) will then decrease from approximately 88 percent to 80 percent.

$$\sum_i \sum_l \sum_{dep} C_{dep,l,i} = 341$$

- Increase factor 'a' with 20 percent; decrease factor 'b' with 15 percent.

$$a = 0.6$$

$$b = 0.68$$

- Increase relative arrival rate hospital versus home, such that the proportion of hospital patients increases with 20 percent. This proportion then becomes approximately 0.683, which gives us arrival rates:

$$\lambda_{d,w,elective} = 1.6984 \ \forall d,w$$

$$\lambda_{d,w,home} = 0.7894 \ \forall d,w$$

- Decrease overflow probabilities with 30 percent. Since the overflow probabilities where chosen roughly, we choose a high reduction value.

Patient Nature	CareType	Ort/Chi-3/4	Rem-3/4	CVA-6/9	Ort/Chi-6/9	Rem-6/9	SS_Cog	LS_PG	LS_Som	Cr_Som	Cr_Cog	No
Elective	Hospital	0.019	0.012	0.257	0.367	0.225	0.094	0.004	0.021			
	Ort/Chi-3/4											1
	Rem-3/4											1
	CVA-6/9								0.035			0.965
	Ort/Chi-6/9								0.035			0.965
	Rem-6/9								0.035			0.965
	SS_Cog							0.665				0.335
	LS_PG											1
	LS_Som											1
	Cr_Som					0.35						0.65
	Cr_Cog						0.35					0.65
	No											
Home	Hospital											
	Ort/Chi-3/4											1
	Rem-3/4											1
	CVA-6/9								0.035			0.965
	Ort/Chi-6/9								0.035			0.965
	Rem-6/9								0.035			0.965
	SS_Cog							0.665				0.335
	LS_PG											1
	LS_Som											1
	Cr_Som					0.35						0.65
	Cr_Cog						0.35					0.65
	No		0.027			0.520		0.193	0.075	0.123	0.062	

Scenario variant C

- Decrease capacity with 5 percent (10 percent will give an unrealistically high occupation rate). The overall occupation rate (excluding internal waiting) will then increase from approximately 88 percent to 92 percent.

  $\sum_i \sum_l \sum_{dep} C_{dep,l,i} = 295$

- Decrease factor 'a' with 20 percent; increase factor 'b' with 15 percent.

  $a = 0.4$

  $b = 0.92$

- Decrease relative arrival rate hospital versus home, such that the proportion of hospital patients decreases with 20 percent. This proportion then becomes approximately 0.455, which gives us arrival rates:

  $\lambda_{d,w,elective} = 1.031\ 0\ \forall d,w$

  $\lambda_{d,w,\square ome} = 1.2344\ \forall d,w$

- Increase overflow probabilities with 30 percent. Since the overflow probabilities where chosen roughly, we choose a high reduction value. Since the SS_Cog care type already had an overflow probability of 0.95 this probability now becomes 1.

Patient Nature	CareType	Ort/Chi-3/4	Rem-3/4	CVA-6/9	Ort/Chi-6/9	Rem-6/9	SS_Cog	LS_PG	LS_Som	Cr_Som	Cr_Cog	No
Elective	Hospital	0.019	0.012	0.257	0.367	0.225	0.094	0.004	0.021			
	Ort/Chi-3/4											1
	Rem-3/4											1
	CVA-6/9								0.065			0.935
	Ort/Chi-6/9								0.065			0.935
	Rem-6/9								0.065			0.935
	SS_Cog							1				0
	LS_PG											1
	LS_Som											1
	Cr_Som					0.65						0.35
	Cr_Cog						0.65					0.35
	No											
Home	Hospital											
	Ort/Chi-3/4											1
	Rem-3/4											1
	CVA-6/9								0.065			0.935
	Ort/Chi-6/9								0.065			0.935
	Rem-6/9								0.065			0.935
	SS_Cog							1				0
	LS_PG											1
	LS_Som											1
	Cr_Som					0.65						0.35
	Cr_Cog						0.65					0.35
	No		0.027			0.520		0.193	0.075	0.123	0.062	

Appendix L Computational Results Sensitivity Analysis

This appendix shows the results of the alternative scenarios from Appendix K on each of the interventions discussed in Chapter 5.

Sensitivity of interventions with alternative scenarios

Interventions Communication

Figure 35 shows the waiting time reduction for hospital patients as a result of an advanced communication process, both absolute and in terms of percentage, for the basic and alternative scenarios. The absolute waiting time reduction from earlier communication is similar for all scenarios, but the relative impact of this intervention differs.

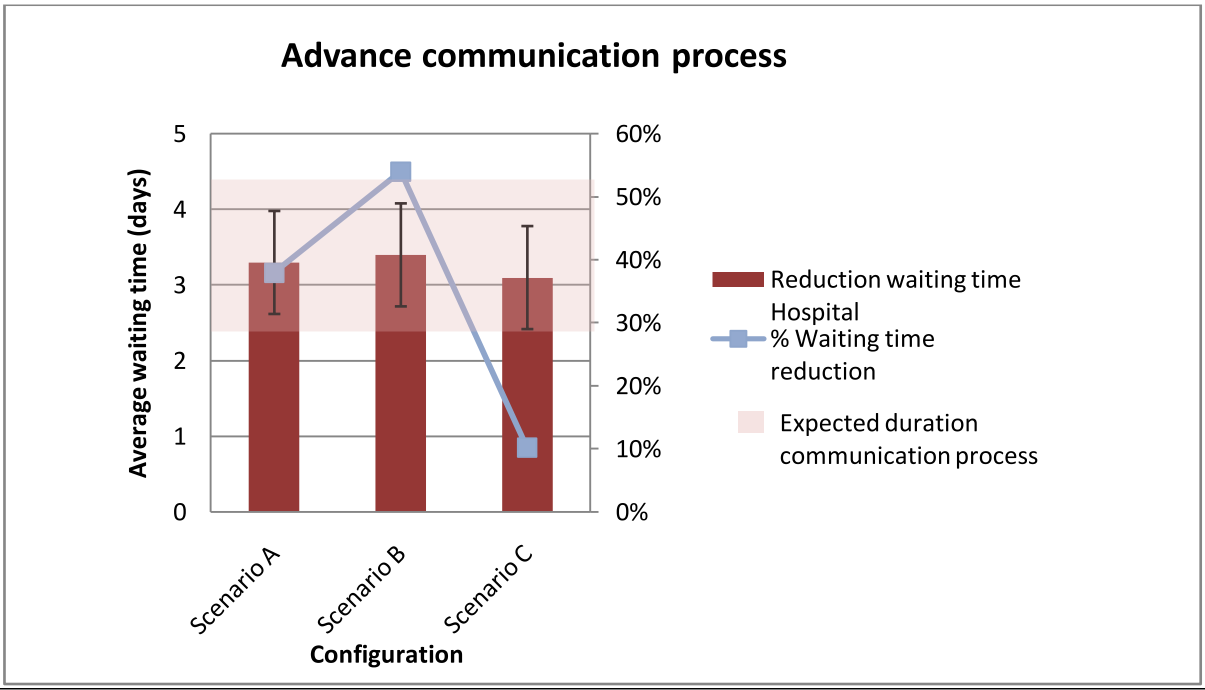


Figure 35 Performance Advance communication process of alternative scenarios

Intervention transfer beds

Figure 36 shows the simulation results of the introdcution of transfer beds for the basic and alternative scenarios. The number of transfer beds required, to reduce the waiting time on wards with a given factor, differs based on the scenarios.

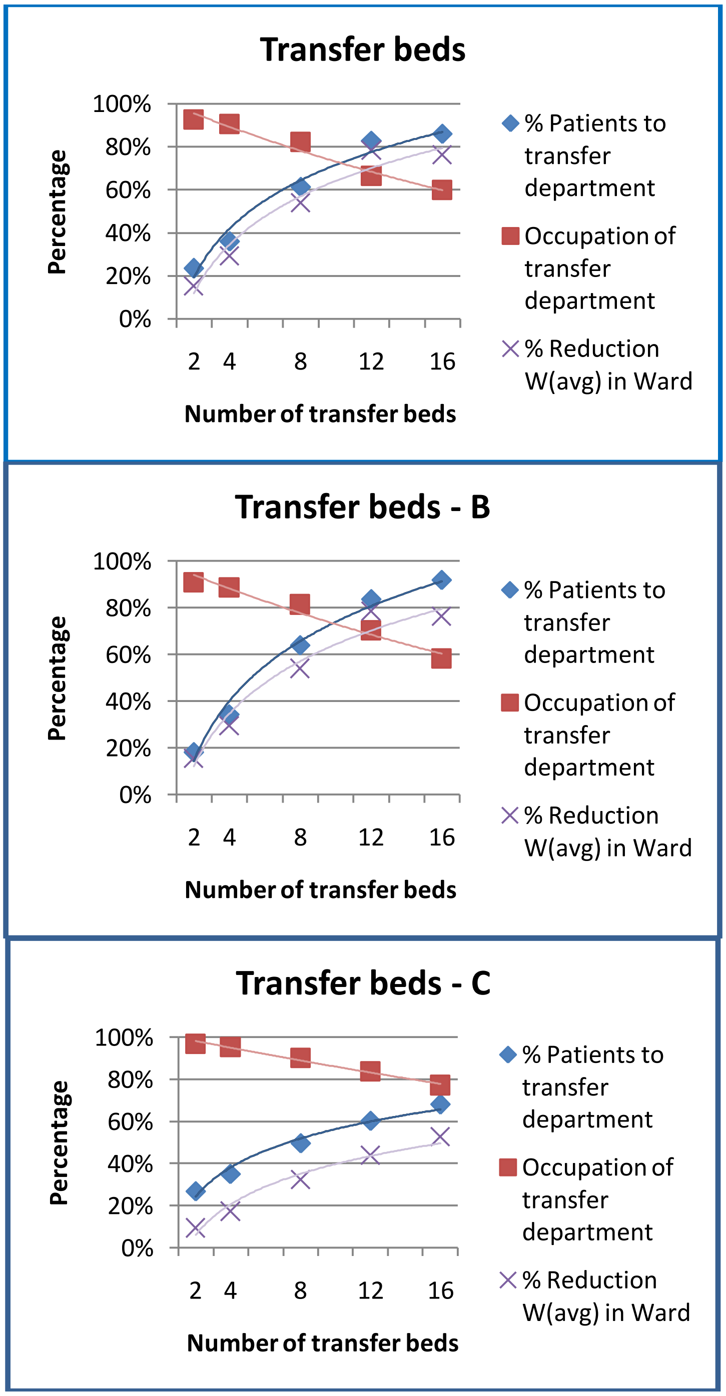


Figure 36 Performance Transfer beds of alternative scenarios

Intervention bed reservation

Figure 37 shows the simulation results of bed reservation for the basic and alternative scenarios. Reservation of beds shows the most significant differences under the various scenarios. Bed reservantion has not impact for a small number of beds in scenario B due to difference in allocation rules. Bed reservation for a small number of beds has less impact on scenario C than on the basic scenario.

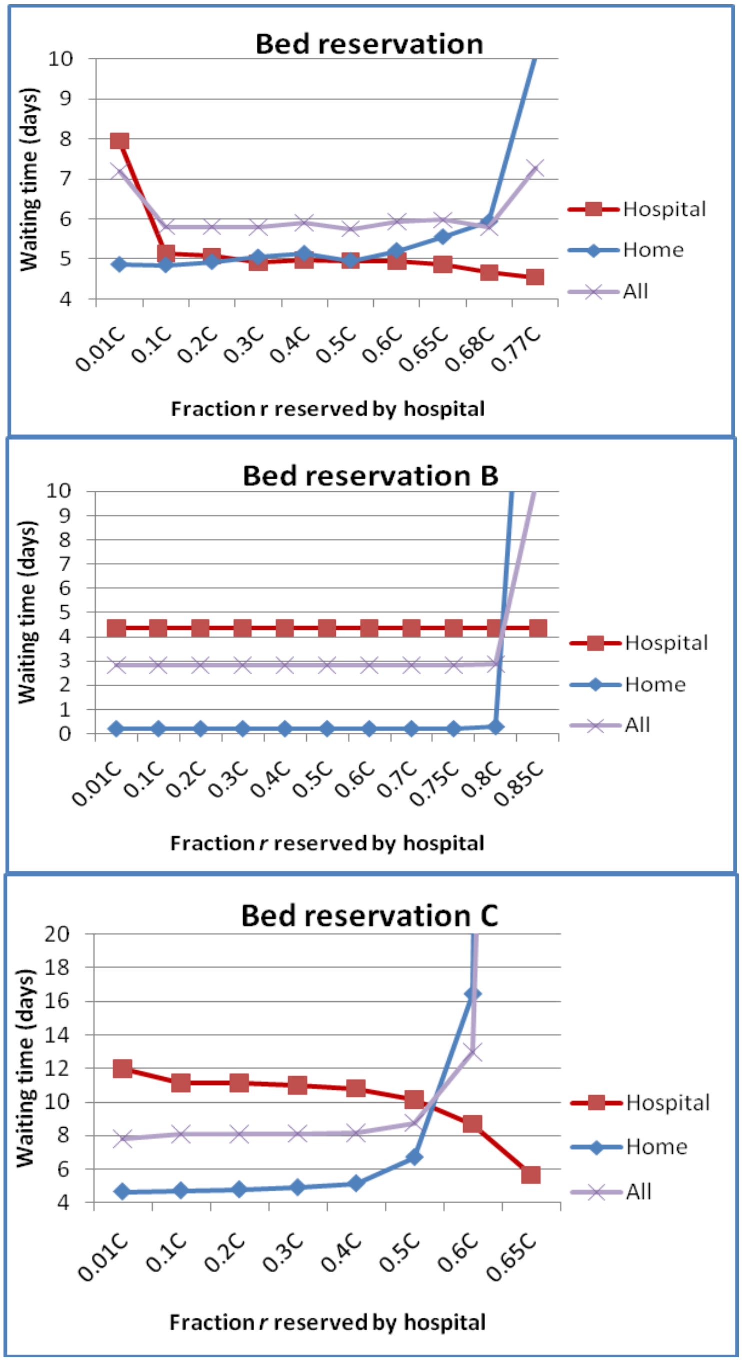
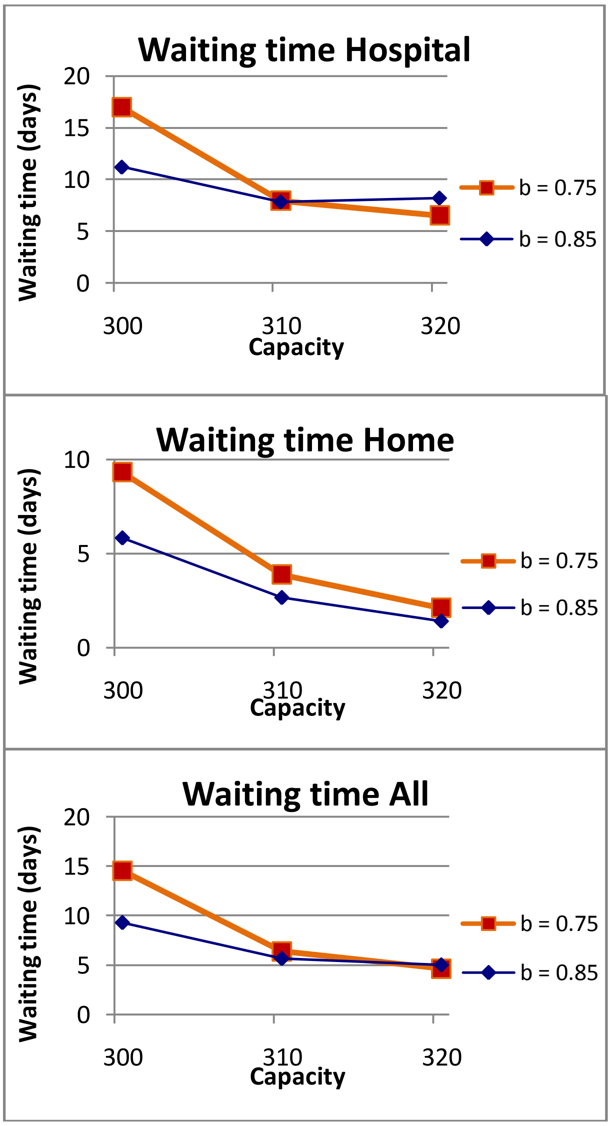


Figure 37 Performance Bed reservation of alternative scenarios[1]

[1] The analysis with bed reservation is again, for each scenario, with only two short stay departments. Therefore the results can not be compared to the outcomes discussed in Paragraph 5.3.1

Sensitivity on capacity allocation

Figure 38 shows the simulation results of six scenarios with changes in nursing home bed capacity and capacity allocation. Comparison of a higher capacity allocation to the short stay departments (b=0.75) to the short stay capacity allocation of our base situation (b=0.85), shows that the last seems more favorable. Although most hospital patients go to short stay departments after their hospital treatment, this patient group also benefits from sufficient capacity allocated to the long stay departments. The importance of that for the waiting time hospital patients is higher than we expected. The overall occupation of nursing home departments is also higher when b=0.85, because the nursing home 'loses' fewer days due to waiting time of patients. In addition, Figure 38 shows that a relatively small increase in capacity may cause a strong decrease in waiting time. For example, an increase of total bed capacity form 300 beds to 310 beds reduces bed blocking days more than 2 times (from 14.5 days to 6.5 days), while the occupation only decreases with less than 5 percent (from 92 to 88 percent).



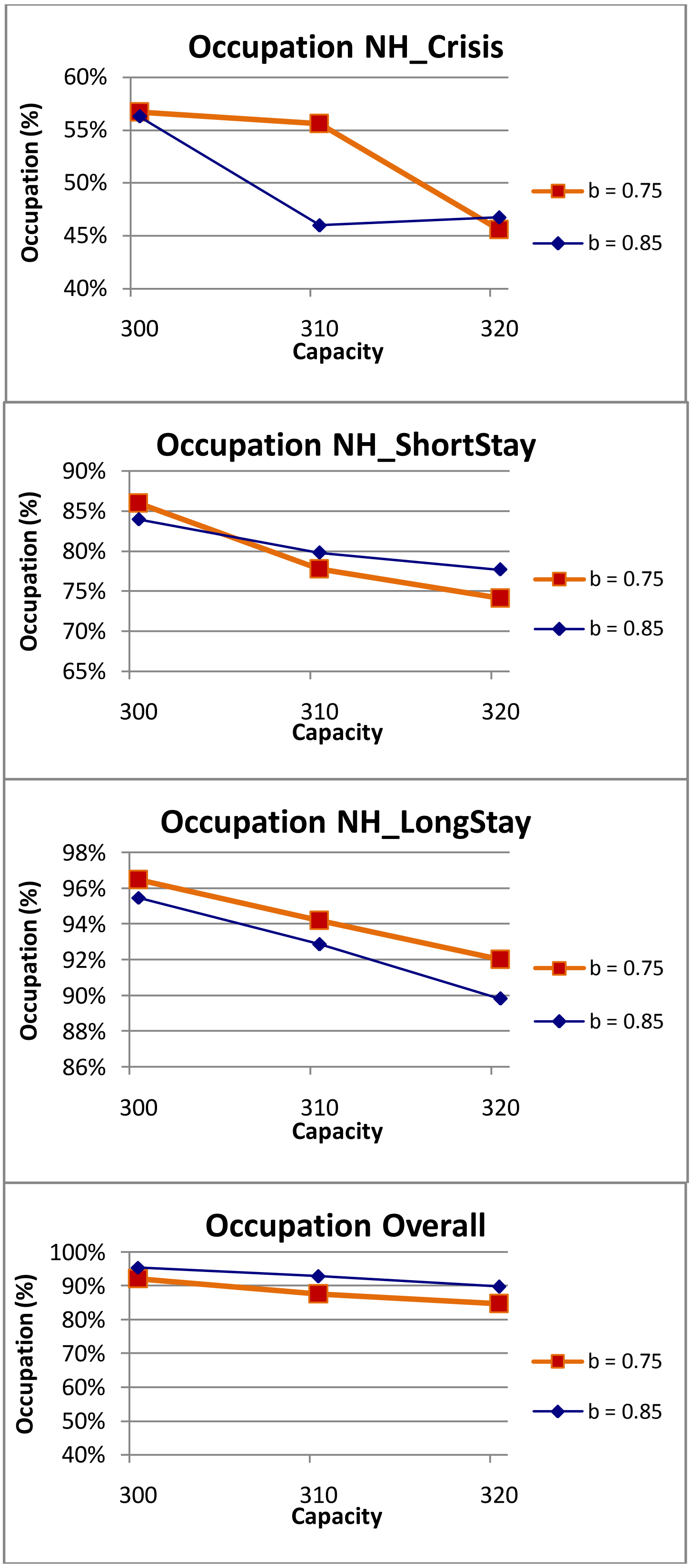


Figure 38 Effect of different capacity allocation on waiting time and nursing home bed occupation

[1] For all scenarios holds that a=0.5.

Appendix M Management information from POINT

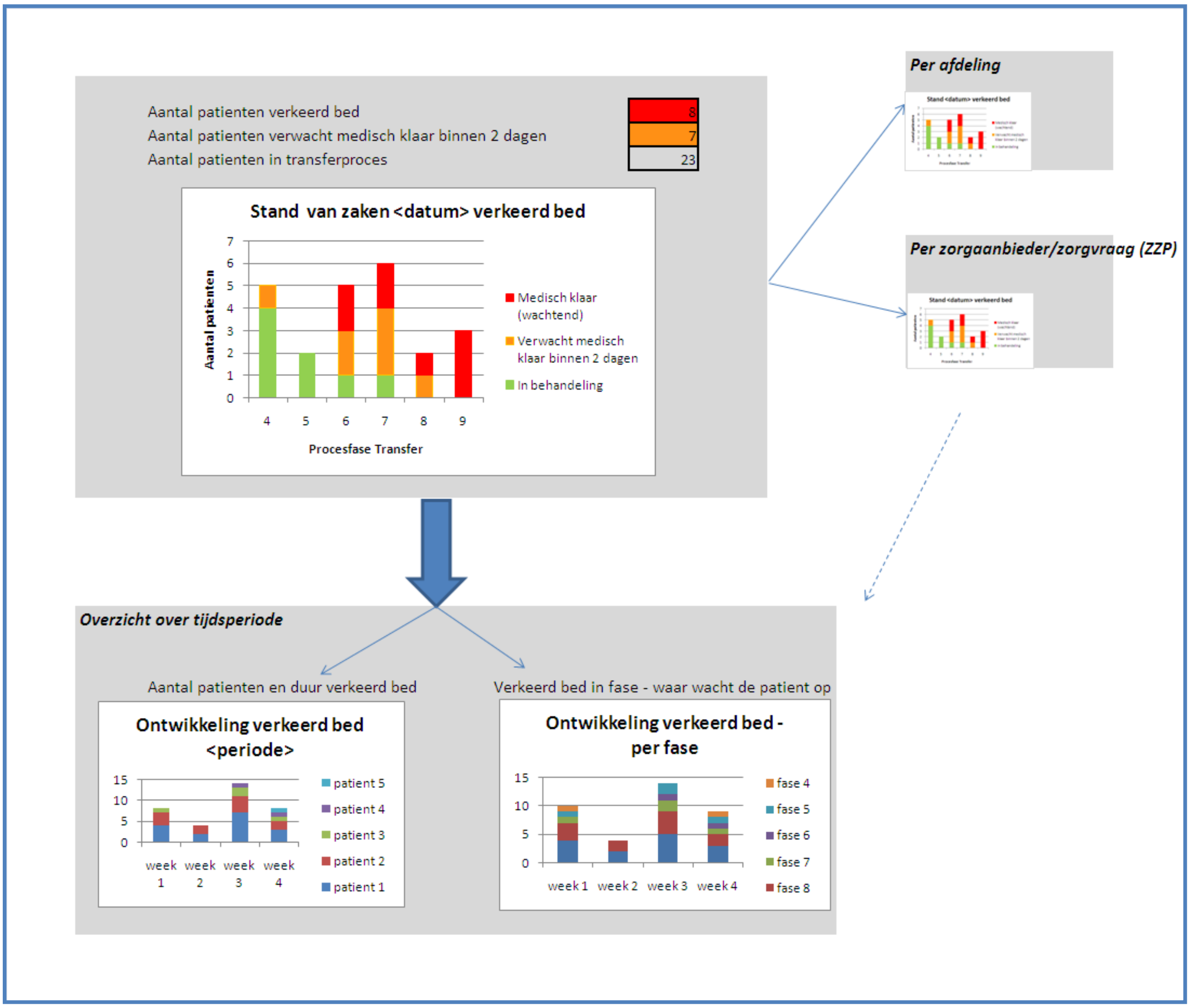
To monitor bed blocking in RdGG the current system ´POINT´ can be used. To start with, we recommend generating the information described below. This is in Dutch for practical reasons.

Zichtbaarheid verkeerde beddagen

Om de wachtende patiënten in het ziekenhuis te kunnen monitoren kunnen er dagelijkse of wekelijkse overzichten gegenereerd worden uit POINT. Een voorwaarde hiervoor is de registratie van de (verwachte) medisch klaardatum van patienten in POINT. Verder moeten de volgende gegevens automatisch gegenereerd kunnen worden:

- Geef in het rapport 'gewenste ontslagdatum gepasseerd', tevens de volgende informatie weer:
    1. De gewenste zorgaanbieder
    2. De verpleegafdeling waar de patient ligt
    3. De huidige proces fase weergeven van het transfer proces
- De mogelijkheid om deze informatie per verpleegafdeling te selecteren; deze informatie kan dan naar de afdelingen.

Figuur 1 geeft een illustratie van de overzichten die op deze wijze gegenereerd kunnen worden. Een overzicht van de stand van zaken per fase draagt er zorg voor dat we tijdig inzicht hebben in problemen. Om die reden zou ook niet alleen het aantal patiënten dat al medisch klaar is (rood) weergegeven moeten worden, maar ook het aantal patiënten dat naar verwachting binnen, bijvoorbeeld, 2 dagen medisch klaar is (oranje) en het aantal patiënten dat nog in behandeling is (groen). Hetzelfde overzicht voor de patiënten op een specifieke verpleegafdeling geeft de afdeling overzicht, zodat ook zij de situatie zelf kunnen monitoren. Een overzicht per zorgaanbieder/zorvraag (ZZP), geeft voor het ziekenhuis inzicht in de probleemgebieden met betrekking tot een specifieke zorgvraag dan wel zorgaanbieder. Voor het verpleeghuis is een dergelijk overzicht ook waardevol, omdat zij direct patiënten kunnen koppelen aan nog leegstaande bedden.



Figuur 1 Genereren uit POINT voor monitoren verkeerde beddagen

De momentopnamen zoals hierboven besproken, kunnen als basis dienen voor een overzicht van de ontwikkeling over een langere tijdsperiode, bijvoorbeeld per maand of per kwartaal. Enerzijds kan de ontwikkeling van het aantal verkeerd bed patiënten en het aantal verkeerd bed dagen per patiënt gemonitord worden. Anderzijds kan gemonitoord worden waar de patiënt op wacht, met andere woorden hoe lang een patiënt in een specifieke fase heeft verkeerd (bijvoorbeed wachten op CIZ indicatie), terwijl deze patiënt medisch klaar was. Tot slot kan deze informatie tevens als controle middel dienen voor de verkeerd bed registratie, waarvan op dit moment twijfel bestaat over de juistheid.

Momenteel wordt er een aparte schakellijst bijgehouden voor patiënten die verpleegzorg nodig hebben op een schakelafdeling. Dit zou echter ook in POINT verwerkt kunnen worden, zodat er geen aparte lijst voor nodig is en dat de informatie in POINT vollediger is.

Appendix N Collect data for analysis with simulation model

Input model

• **Case mix**
  • Probability patient type X needs aftercare type Z
  • Probability patient arrival of type X
  • Fraction of patients elective and emergency
  • Number of patient arrivals
 	
  • Fluctuation in flow per week of the year
  • Fluctuation in flow per day of the week
 	
  • Inflow of home patients at nursing home of type Z
 	
• **Capacity**
  • Capacity policlinic of a certain care type
  • Capacity Operating Rooms of a certain care type
  • Capacity wards of a certain care type
  • Capacity nursing homes crisis beds
  • Capacity nursing homes short stay
  • Capacity nursing homes long stay
 	
  • Scope of nursing homes in contact with hospital (number of locations hospital directs patients to)
 	
  • Maximum number of transfers to a nursing home per day
 	
• **Length of stay**
  • Length of stay at ward of certain care type
  • Length of stay at nursing home of certain department
 	
• **Acceptance**
  • Types of patients accepted on department I of hospital
  • Types of patients accepted on department I of nursing home
  • Allocation rules; of bed Y to patient X and of patient X to bed Y
  • Preference of patient for location
 	
• **Communication**
  • Moment **request care** nursing home
  • Number of days required for allocation of patient with type Z by nursing home
  • Moment **need** for aftercare **known**
  • Number of days before patient medically ready **indication** given by doctor
  • Frequency and moment of MDO ('multi disciplinair overleg')
  • Frequency and moment of doctors rounds
  • Moment **request CIZ** indication
  • Duration **CIZ indication**
  • **Alignment** with doctor and patient by transfer nurse
  • Communication requirements before next process step

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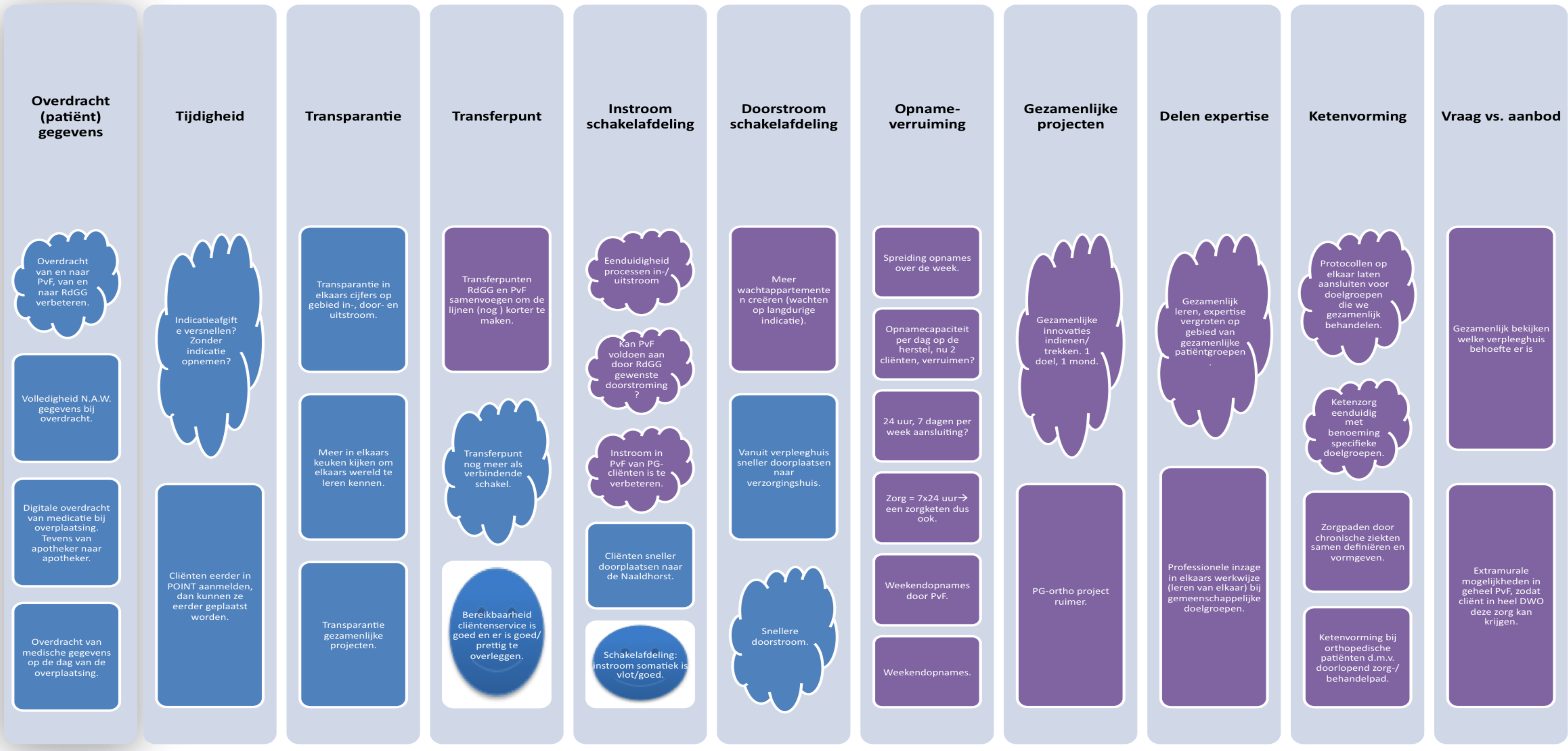
Appendix O Brainstorm RdGG en PvF – 1 maart 2010



Legenda

	Verbetervoorstel
	Constatering verbeterbehoefte
	Dat gaat goed!
	Tactisch niveau
	Operationeel niveau